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Industry Study

Final Report
The Energy Industry

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ABSTRACT: The United States requires a holistic energy policy that guarantees a secure and sustainable supply of energy, modernizes infrastructure, incorporates emerging technologies, and mitigates the impact of consumption on the environment. Capitalizing on technological innovation, The U.S. now has an ample and diverse supply of energy but booming demand in the developing world and the specter of climate change pose global challenges which impact U.S. interests and which require U.S. leadership to solve. The greatest chance for success lies in limited government intervention to orient a global energy market to enable continued economic development with reduced negative environmental impacts. A coherent national energy policy that incorporates the following recommendations could secure America's energy future, place the United States in a leadership role in energy production and technology, and ensure a cleaner, healthier global environment by mid-century.

1) The Administration should recharter and empower the Department of Energy to create and lead the implementation of a national energy policy.
2) The United States should embrace the opportunity to become a net exporter of energy—including LNG—to satisfy the needs of China, the developing world, and energy-thirsty partners like Japan and the EU.
3) The U.S. must also stimulate export of energy design technologies key to manufacturing of solar panels, wind turbines, nuclear reactors, air scrubbers, and Smart Grid components.
4) Given the importance of the nation's energy infrastructure to its economy, health, and security, the national energy architecture must be modernized. The architecture of the future must enable distributed generation, Smart Grid operations, resilience against cyber and terrorist threats, and improved efficiencies.
5) Protection of the global environment must be an integral part of any energy policy through increased use of renewable energy, implementation of a carbon tax, increased R&D for carbon capture and sequestration technologies, and R&D on game-changing technologies such as nuclear fusion.
6) The U.S. government should support diversification of transportation fuels. Facilitating a national infrastructure of filling and charging stations will further reduce U.S. (and global) reliance on oil imports and exposure to oil price volatility.

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PLACES VISITED

Domestic:

- Congressional Research Service (Washington, D.C.)
- U.S. Department of Energy, Energy Information Administration (Washington, D.C.)
- U.S. Green Building Council (Washington, D.C.)
- Hong Kong Economic and Trade Office (Washington, D.C.)
- U.S. House Committee on Energy and Commerce (Washington, D.C.)
- U.S. House Committee on Science and Technology (Washington, D.C.)
- Embassy of Canada (Washington, DC)
- Embassy of Japan (Washington, DC)
- Three Mile Island Nuclear Station (Middletown, PA)
- Conowingo Hydroelectric Power Plant (Darlington, MD)
- CONSOL Energy Loveridge Coal Mine (Morgantown, WV)
- Cove Point LNG Facility (Cove Point, MD)
- Maryland Department of the Environment (Annapolis, MD)
- Dickerson Coal Plant (Dickerson, MD)
- Montgomery Resource Recovery Facility, Division of Solid Waste (Rockville, MD)
- Covanta Waste Incinerator Electricity Generation Plant (Dickerson, MD)
- Mt. Saint Mary's Solar Farm (Thurmont, MD)
- Kinder Morgan Pipeline Terminal (Vancouver, BC)
- Ford/Daimler-Benz Automotive Fuel Cell Cooperation (Vancouver, BC)
- British Petroleum Cherry Point Refinery (Cherry Point, WA)
- Snohomish Public Utility District (Snohomish, WA)
- U.S. Coast Guard Station (Seattle, WA)
- University of Washington (Seattle, WA)
- Washington State Department of Commerce (Olympia, WA)
- Chevron Corporation (San Ramon, CA)
- Lawrence Livermore National Laboratory (Livermore, CA)
- Stanford University (Palo Alto, CA)
- University of California (Berkley, CA)
- Wind Farms (Various, CA)

Introduction

Reliable and affordable supplies of energy support world economic productivity and provide the basis for capital investment and technological innovation. Energy is an economic and industrial enabler. Without a reliable supply, a nation cannot make the leap from agrarianism to an industrialized society. On its present trajectory, the growth rate of global energy consumption will rapidly eclipse current infrastructure with demand in developing nations rising 65 percent by 2040.[1] The challenge for the energy industries in developed and emerging nations alike is threefold: to successfully satisfy the rising global demand for energy; address efficiency standards to drive demand down; and to exploit technology opportunities to minimize environmental impact from activities related to energy production and use. To do this, the United States requires a holistic energy policy that guarantees a secure and sustainable, market-based supply of energy, modernizes infrastructure, incorporates emerging technologies, and mitigates the impact of production and consumption on the environment.

This is a complex task, partly because the energy industry spans a wide variety of markets. The industry includes companies involved in the exploration and development of oil, gas, and coal; private and public electricity generation, transmission, and distribution; as well as renewable energy technology development applicable in both the electrical generation and transportation sectors.

The purpose of this paper is to make recommendations that could be part of a broader energy policy to bolster U.S. national security in what promises to be a challenging energy environment looking out to 2050. To do this, the study group, comprised of military and civilian members from the Armed Services, the Department of Defense, the Department of State, and industry gathered and analyzed information from classroom and domestic field studies to assess the following: U.S. national interests in the energy industry, the current status of the industry, global trends that will impact it in the future, and what measures the U.S. could take to shape the environment by the 2050 timeframe.

U.S. Energy Interests

U.S. energy-related interests can be grouped into three major areas: guaranteeing energy security through a reliable supply and delivery infrastructure; enabling economic growth and development; and ensuring the sustainability of energy consumption by mitigating its negative impacts on the environment. The relative importance of these three interests has fluctuated over time, but all three must be balanced in designing forward-looking policies that address U.S. and global energy security concerns.

The security of U.S. energy supply has been the motive behind much of U.S. national security policy writ large for the past 40 years. The Arab oil embargoes of the 1970s shocked many Americans into the realization that the era of plentiful energy at cheap prices had passed and spawned a new belief that the U.S. needed to reduce—if not entirely eliminate—its dependence on foreign fuels. The termination of a U.S. strategic alliance with Iran, one of the world's most important oil suppliers, only intensified the rhetorical resolve from the White House and the halls of Congress vowing to wean America off of foreign oil.

However, the quest for complete energy independence is not realistic in an interconnected world in which countries strive to maximize their comparative advantages in energy just as they do in other types of markets. Cost and economic viability tend to govern decision-making, leaving a concept such as "energy independence" more a political slogan than a viable objective. Moreover, the fungible nature of today's global energy market largely obviates the former strategy of hoarding energy supplies for the purposes of achieving political advantage or diplomatic leverage. For these reasons, it is imperative that U.S. policymakers construct a realistic energy policy, focused on energy security rather than energy independence. Security seeks to bolster development of a diverse range of reasonably priced domestic energy resources, improve the resilience of infrastructure, minimize waste and consumption through improved efficiencies, and facilitate a steady supply of energy to and from the rest of the world.

Energy is a resource that underpins the U.S. economy and the industries that comprise it. It fuels American manufacturing, enables transportation, and facilitates the services that are the bedrock of our economy (ref Fig.1, App A). From cell phone batteries to gasoline, energy enables our way of life. Energy is also what helps us defend that way of life. The Department of Defense (DOD) is the single largest consumer of energy in the world. With this in mind, it is easy to see how the Federal Government plays an integral role both as a policymaker and as an energy consumer in creating an environment that stimulates economic development both at home and abroad.

Today, the globe is also confronted with the insidious problem of climate change. The consequences of a heating planet reinforce a strong U.S. national interest in maintaining a clean and livable environment. The dichotomy between energy and the environment continues to fuel a polarized debate within the American body politic. The phenomenon of global warming, which most scientists attribute in part to the increasing amount of carbon dioxide in the atmosphere, has segments of American society clamoring for energy and environmental policies designed to reduce the emissions from fossil fuels. Rebuilding infrastructure to facilitate a switch to renewable energy sources is prohibitively expensive and impractical given America's vast hydrocarbon resources. Conversely, failing to reduce the impact of energy use on the environment could have catastrophic effects globally, leading to rising ocean levels, species extinction, desertification, and mega-storms. These developments could lead to conflicts and mass migrations—crises that the U.S. would likely be forced to address.

Keeping these interests in mind, this brief evaluates the current status of the energy industry and the trends that will impact the United States' ability to secure reliable and affordable energy in the future. Advancing U.S. energy security, economic, and environmental interests will require not only smart, holistic, and long-term domestic policies but also U.S. leadership on the global stage because demand and consumption outside our borders will continue to impact these same interests on an international level.

Current Industry Analysis

Oil and Gas:

Petroleum represents the largest proportion of U.S. energy consumption at 36%. The majority of petroleum products are used for transportation (71%), with the rest being divided between industrial (23%), residential/commercial (5%), and electric power generation needs (1%).[2] The U.S. oil and gas industry grew an average of 3.1% a year from 2007-2012 and cleared over $159 billion in profits in 2012.[3] This rate is expected to increase to 3.5% per annum until 2017. The global oil and gas market, with an annual growth rate of 1.3% since 2008 and projected revenues of $4.5 trillion in 2013, has experienced heightened volatility since the economic slowdown in 2008.[4] China and India's industrialization and the purchase of cars by an emergent middle class have fed this growth.[5] Political turmoil in oil producing nations and the fluctuating value of the U.S. dollar and 10-year Treasury bill, have contributed to price volatility.

The shale gas "revolution" and the current economic viability of extracting unconventional oil through hydraulic fracturing and horizontal drilling are changing the energy landscape in North America and across the world. The full impact of this technology has yet to be felt, as nations such as China, which reportedly has more technically recoverable shale gas than any other country, are only beginning to implement it on a large scale.[6] Unconventional oil, like oil sands and tight oil, has likewise altered the industry.[7] The U.S. Energy Information Administration's (EIA) April 2013 outlook projects that by 2040 U.S. tight oil production will be 2 million barrels per day—33% of projected total U.S. oil production, and the International Energy Agency (IEA) forecasts that the U.S. will overtake Saudi Arabia by the mid-2020s as the world's largest producer of oil.[8] [9]

Growth in U.S. natural gas production has also enabled North American energy security. Although coal fuels nearly half of U.S. electricity generation, improving access to vast natural gas reserves, low natural gas prices, and increasing focus on reducing power plant greenhouse gas (GHG) emissions are increasing the share of natural gas in electricity generation. Advantages such as combined-cycle technology, which allows operators to minimize energy loss, and the ability to quickly expand plant capacity with minimal cost, make gas-powered plants both cost-effective and environmentally friendly when compared to coal.

From 2000-2010 U.S. shale gas production increased to 14 billion cubic feet per day[10], and natural gas reserves have risen 49% since 2005.[11] Because of this growth, net power generation by natural gas has increased from 639 million megawatt hours (MWh) in 2001 to over 1 billion MWh in 2011.[12] Most of this growth is attributable to the production of shale gas, which grew as a percentage of total natural gas from 10% in 2007 to 32% in 2010.[13] The EIA forecasts that this growth will continue, increasing the natural gas share of domestic electricity to 30% by 2040, as prices for the commodity remain comparatively low.[14] Furthermore, EIA projects that U.S. natural gas production will grow 28% by 2035, giving the U.S. 79 years of production at current levels.[15]

Coal:

One of the largest contributors to the global emissions of GHGs is burning coal for electricity generation. Thirty-four percent of all carbon dioxide (CO_2) emissions in the U.S. are a result of coal combustion.[16] Despite its harmful environmental effects, coal accounts for about 46% of U.S. electrical power generation.[17] Additionally, the IEA reports that coal meets 40% of the world's electricity needs and has been the fastest growing global energy source since the beginning of the 21st century.

One of the driving factors behind coal-intensive electricity generation is its global abundance. The U.S. holds the largest amount of coal reserves in the world and is estimated to have over 200 years' worth of domestic coal supply at current production levels. Russia has the second largest deposit of coal and China is third with 13 percent of the world's reserves (an estimated 45-year supply at current production levels).[18] Coal is an economically attractive option for many developing nations. Despite the high usage rates for coal, the IEA estimates that coal reserves can meet global demand for 130 years based on 2011 output rates.[19]

Ongoing advances in science and technology may prove to drastically reduce the many negative byproducts of coal. Most coal plants now use a variety of controls to either lower or capture emissions of carbon dioxide, sulfur oxides, nitrogen oxides, and other contaminants. The coal industry continues to develop technologies that make burning coal cleaner and more economical partly in response to existing and expected regulations. Some of the more promising technology advances include: various carbon capture and storage (CCS) technologies, integrated gasification combined cycle, chemical looping, supercritical systems, and ultra-supercritical systems. Other technologies are being researched and developed, but remain cost prohibitive and require large-scale demonstrations involving substantial capital investment and commitment from both government and industry. Developing nations may offer the greatest opportunity to test new technologies if aided by direct foreign investment to build new coal plants to meet the emerging demand for more power.

Nuclear:

Today, nuclear power produces approximately 13.5% of the world's electricity[20] and 21% of electricity in the U.S.[21] Over the course of the next 15-20 years, demand for electricity from nuclear energy is estimated to grow by 76%—double the rate of other energy sources.[22] Nuclear power provides zero-carbon, reliable base-load power to the electric grid, running at full capacity for up to two years between plant refueling operations. This is the advantage of nuclear power over all other sources of electricity. However, there are five key issues that cloud the future of the sector: safety, storage of radioactive waste, environmental impact, security, and nonproliferation.[23] Coherent national and international policies are required to overcome these concerns about nuclear power and realize its potential to help meet forecasted growth in demand for energy.

Currently, there are 104 nuclear reactors at 65 sites in the United States. The Nuclear Regulatory Commission (NRC) licenses reactors initially for 40 years, and 80% have applied for or received renewals to operate for a total of 60 years. "Under the current mixture of 40- and 60-year licenses, 36 reactors will have to shut down by 2030 and the rest by 2049."[24] Although five new nuclear plants are planned to begin operation by 2020, the projected cost of $11.7 billion to build a dual-unit 2,200 megawatt plant has dampened plans for additional growth. "Despite the cost, however, deployment of new nuclear capacity supports the long-term resource plans of many utilities, by allowing fuel diversification and providing a hedge in the future against potential GHG emission regulations or natural gas prices that are higher than expected."[25]

Perhaps more difficult to overcome than the cost of building nuclear plants are concerns about safety. Following the devastating tsunami-induced disaster at Tokyo Electric Power Company's Fukushima Dai-ichi plant, the international community is leveraging lessons learned to identify and recommend safety improvements. Different countries have responded differently: Germany announced plans to shut down all of its nuclear plants by 2022,[26] while France continues to embrace nuclear energy, which provides more than 75% of its electricity.[27] Failing to satisfy concerns about nuclear safety from regulators and the public could be the single greatest impediment to nuclear energy's contribution to meeting future demands for electricity.

Added to this is the issue of nuclear waste disposal. The U.S. continues to search for a solution to disposal of nuclear waste since the Obama Administration stopped the Yucca Mountain project in search of a solution with broader consent. Most protests against the Yucca Mountain project center on the hazards associated with the transportation of nuclear waste across the country and the impact of long-term consolidated storage on the environment. Nuclear energy has great potential to help provide a supply of energy that is abundant, diverse, resilient, and low-carbon. Policymakers must strike a balance between the inherent advantages of nuclear power and the various concerns that surround it if they are to achieve consensus on the viability and necessity of nuclear energy to satisfy future demand.

Renewables:

In the United States, use of renewable sources for electricity generation continues to grow thanks to the federal Renewable Electricity Production Tax Credit (PTC), which was extended until January 2014, and state-level Renewable Portfolio Standards (RPS), which are required quotas for electricity generated from renewable sources. Over half of power plants coming online in 2012-13 use renewable sources.[28,29,30] In 2011, renewables generated 13%, or 526 billion kilowatt hours (kWh) of U.S. electricity, 62% of it from hydro. Hydroelectric dams, nearly all of them built between the 1940s and 1980s, continue to be the most reliable and largest-scale renewable electricity source, with some upgrades providing marginal additional generation capacity.[31] However, other than pumped storage facilities, no new, large-scale hydro projects have come online recently nor are planned. The growth in renewable-sourced electricity has come mainly from wind and solar. Wind accounts for the lion's share of new renewable electricity capacity over the past decade. In 2012, it comprised 42% of all new U.S. electric generating capacity, with a 28% increase in installed capacity from 2011 and a record 6,600 wind turbines installed in a year, bringing the U.S. total to 45,100 wind turbines—enough to power 15.2 million homes.[32] The boom in the U.S. wind and solar electricity markets has attracted both domestic and foreign manufacturers.[33] Coupled with a global oversupply, advances in technology and low U.S. natural gas prices have driven prices for wind turbines and solar panels downward dramatically causing many firms to close.[34] These market pressures and the inherent intermittency of wind and solar have made subsidies, mandates, or a price on carbon dioxide a continuing necessity to make wind and solar energy economically competitive with other sources of electricity.[35,36]

Similarly, fuel blend and efficiency standards have continued to bolster the use of biofuels for transportation in the United States. In 2011, liquid biofuels accounted for 8% of total primary energy use.[37]

The rise of renewables is even more dramatic at the global level. Recognizing their importance to energy security, development, and climate goals, UN Secretary General Ban Ki-Moon called for renewables to comprise 30% of the world's total energy mix by 2030.[38] Renewables accounted for over 20% of global electricity generation in 2011. The largest increment among renewable power sources was installed wind capacity (40 GW, bringing the total to 238 GW).[39] Developing countries possess over half of the world's current renewable capacity, and are investing heavily in renewable power industries.[40] Europe is the global leader in electricity produced from renewables while the United States lags behind the world average. Unlike in the United States, hydropower continues to grow globally. China is the world leader in adding hydroelectricity capacity, as well as wind and solar capacity.[41] Other growing economies, like India and Southeast Asia, have also embraced renewables. U.S. manufacturing of large hydro turbines has all but ceased, and manufacturers of wind turbines and photovoltaic cells have quickly fallen behind Asian and European competitors despite significant U.S. investment in research and development.[42,43,44,45]

Energy Storage and Fuel Cell Technology:

As the demand for renewable sources of energy grows, so will the demand for complementary energy storage technology. The intermittency of some renewables has made them expensive and sometimes unreliable investments because once the electrical energy is generated it must be used or it is lost unless it can be stored.

DOD learned this firsthand in its bid to reduce the operational energy supplied by fossil fuels in deployed locations. As of November 2012, the Army had installed ten 28-kilowatt solar generation systems in Afghanistan to provide "700 megawatt hours per year, saving approximately 460,000 gallons of fuel." Battery storage systems have allowed soldiers to fully realize the potential of renewable energy by making it available when it is needed rather than only when it is generated.

Battery storage has a variety of other applications as well. Today the industry is largely driven by automotive requirements for hybrid and electric vehicle technology. "With increasing environmental concerns and [rising] gasoline prices, hybrid electric vehicles will continue to grow in popularity. As a result, industry revenue is forecast to grow over the next five years at an average of 4.5% per year to $14.6 billion by 2018."[46] This number is up from 2.2% per year since 2008.[47]

Battery technology in hybrid vehicles translates well into more industrial applications. Today there are a variety of battery technologies capable of supplying industrial-level power to the grid. Each option provides varying degrees of energy density, power, and cost. As a component of the electrical grid, batteries demonstrate the feasibility of bulk power storage by providing "on-demand power for shaving peak loads."[48] These systems also allow power producers to participate in the market with stored supply when demand slips below a plant's minimum production threshold. Grid storage projects installed at the community level are reducing peak demand and helping utilities use more intermittent wind and solar power.[49] Continued implementation of distributed grid storage will improve grid congestion, open the door for greater renewable integration, and allow for a flatter peak-to-trough load in commercial power production. This last feature of distributed grid storage will likely reduce the need for expensive peak capacity generators as proliferation of storage increases.

Fuel cells are another leading green technology that has significant application in the automotive and power generation sectors. Fuel cells convert the chemical energy from a fuel like hydrogen, natural gas, or methane into electricity through a reaction with oxygen.[50] The advantage is that they emit water vapor, heat and low levels of CO_2. The U.S. is the leading patent holder for fuel cell technology and is well poised to participate in a global market that was up 39% from 2010 to 2011 and nearly tripled the number of units shipped in 2012.[51]

Electric Power Infrastructure:

Major blackouts in the Northeast in 2003, the 2011 Southwest blackout, and extensive power outages created by Hurricanes Katrina and Sandy present dramatic examples of the electric grid's fragility. However, these events represent a subset of a much larger problem associated with the grid. New infrastructure spending over the past several decades has been insufficient for maintaining a healthy grid and there has been little capital investment in refurbishing existing transmission components.[52] Current investment patterns do not appear likely to change this trajectory although the average age of transformers is already 42 years old and the majority of transmission lines are 25 years old.[53] The result is evident in America's patchwork system of power lines and transformers that vary widely in terms of age, performance, and capacity.[54] Failing infrastructure is a principle driver for why major power outages have increased 124 percent over the past two decades.[55]

Aging equipment and transmission bottlenecks prompted the American Society of Civil Engineers to award the U.S. electric grid a nearly failing grade in its most recent report on the state of the nation's energy infrastructure.[56] The Department of Energy (DOE) arrived at a similar conclusion, adding that the grid is "aging, inefficient, and congested, and incapable of meeting the future energy needs of the Information Economy without operational changes and substantial capital investment."[57]

These factors are a concern for the nation's economy and overall quality of life. They also create vulnerabilities that could facilitate large-scale disruptions. For example, insufficient transmission capacity reduces the system's margin of safety required to maintain stability during periods of peak loading. At the same time, more congestion subjects the system to heightened probabilities for cascading failures.[58] These shortcomings are only exacerbated by the balkanized nature of the electric grid, which inhibits a free flow of electricity from regions of excess supply to other regions straining to cope with peak demands.

Another source of grid fragility stems from dependence on key nodes such as control centers and substations that are not physically or digitally secured or hardened to withstand a coordinated attack to disrupt the electric grid. A number of critical components such as high voltage transformers and circuit breakers make the grid susceptible to long duration disruptions if attacked because of their unique construction and a lack of spare inventory.[59] Also, vulnerabilities associated with cyber warfare continue to expand as electric grid operators become more reliant on supervisory control and data automation (SCADA) systems. These design features led the National Academy of Sciences to warn that the entire electric grid is "inherently vulnerable to attack."[60] It also concluded that deliberately targeting even a small fraction of critical nodes could incur levels of failure across broad stretches of the electric grid that would require months or even years to repair.[61] The Department of Homeland Security (DHS) has found that attacks across all critical infrastructures including the electricity industry are on the rise and it "has been responding to intrusions on oil pipelines and electrical power organizations at an alarming rate." Backing up DHS's concerns is the fact that "[m]ore malware was detected on computer networks in 2011 than in all previous years combined, with critical infrastructure being a prime target."

Future Trends

Global Increase in Demand:

The world's population is projected to grow 25% from 2010 to 2040, reaching nearly 9 billion.[62] Of the world's population at that time, 7.9 billion will be living in developing nations. Nearly all of the growth will be in "sub-Saharan Africa, Asia, Oceania and Latin America."[63] At the same time, poverty rates will decrease as the global middle class doubles or even triples in size by 2030.[64]

Global population growth will drive a corresponding boost in energy consumption especially in Asia. The demand for energy in Asia will be fueled by three factors: a growing population, rapid urbanization, and the number of increasingly industrialized economies. By 2040, 75% of the planet's population will live in Asia—most of them in China and India.[65] China alone will contribute more than 20% of world GDP growth by 2040.[66] Thus, China's demand for electricity is forecasted to double, India's quadruple, and Africa's is expected to increase 335 percent.[67]

This means that China and India will lead the energy demand growth of Asia's developing nations—growth that is responsible for nearly 75% of the world's increased demand over the next ten years (ref Fig. 2 and Fig. 3, App A).[68] Despite increasing world energy capacity and efficiency-driven demand reductions in developed countries, it is difficult to overstate the geostrategic importance of Asia's growth-driven demand. These forces will continue to reshape world energy markets well into the future, creating ongoing strategic opportunities for further economic integration both regionally in Asia and across the globe. This trend is already underway with Asian nations procuring the majority of their oil and gas from Persian Gulf states through long-term contracts and equity stakes in oil and gas development projects. Nonetheless, Asian apprehension of supply disruption due to regional instability remains strong and creates a steady desire for energy supply diversification.

As an aggregate, the demand from developing countries for electricity generation will rise 50 percent by 2040 compared to 2010, reflecting an expansion of prosperity in the global middle class, economic growth, and access to electricity by more and more of their population.[69]

Environmental Trends:

The Intergovernmental Panel on Climate Change (IPCC) cites scientifically derived observations of increased average air and ocean temperatures across the globe as causal to the degrading polar ice pack, retreating glaciers, and rising sea levels.[70] Most agree that carbon dioxide and other GHGs are the leading cause of climate change and global warming. Although these gases occur naturally in the earth's atmosphere, industrial activity clearly produces higher concentrations. There is a great deal of uncertainty regarding how the rise in global temperatures will impact the planet. For the purposes of this discussion, this trend assumes a consensus position that "most impacts are expected to be adverse." It assumes that "the risks of abrupt, surprising climate changes…could push natural and socio-economic systems past key thresholds of tolerance."[71]

For these reasons, climate change is also broadly recognized as a current and future national security concern. DOD leadership has identified global climate change as an "accelerant of instability."[72] Rising sea levels and more intense weather events could cause eventual displacement of populations (particularly from island and coastal areas) since an estimated 80% of people worldwide live within 200 miles of a coast.[73] There could also be greater humanitarian requirements for public health, food security, and disaster response as a result of climate change.[74] These factors lead to geopolitical instability, competition for resources, and regional conflicts.

Competition of Energy, Water, Food, Land, and Minerals:

"The Resource Nexus" is a term used to describe the competition between energy, land, food, water, and minerals. Over the course of the next several decades, competition for resources within the nexus will intensify. The United States and other global energy leaders must decide how best to manage the nexus to avoid conflict. The Transatlantic Academy identified three main areas where the resource nexus is important. First, the market for resources will continue to operate at local, regional, and global levels in a variety of commodity chains.[75] At all levels, markets compete for increasingly scarce resources that often exhibit an inelasticity of demand. Foodstuffs like corn exist as dietary staples for millions. Corn is also a growing feedstock for biofuel production.[76] In the resource nexus, the food and biofuel markets compete for corn creating scarcity of supply and driving up commodity prices. Second, the resource nexus will have an enormous impact on the area of inter-state relations. This area is directly related to the location of natural resources close to international borders and the use or consumption of those resources by individual nations.[77] The competition for these resources could cause violent conflicts between neighboring countries. Tensions are already high as a result of "dam building by upstream states on major rivers threatening the livelihoods of populations in downstream states in South and Southeast Asia and along the Nile."[78] The third and final area pertains to local human security as it relates to access to energy, land, food, water, and minerals for daily consumption (ref Fig. 4, App A).[79] Insufficient resources will lead to civil unrest and instability as people take increasingly drastic measures to procure the resources they need to survive. Access to water is perhaps the clearest example, as growing mega-cities compete with agriculture and mining uses for a vital resource that will be increasingly affected by global climate change.[80]

Preferred Environment

These trends provide a basic a priori foundation for planning and forecasting a future energy environment. Even with these assumptions, the future of the energy industry will be dynamic and malleable. The United States and other major energy suppliers and consumers will have ample opportunity to shape the future energy situation. Most of the changes in the industry will come as a result of market forces. But there is significant room for government to create the right environment by orienting and enabling these forces. The following discussion outlines a vision of the preferred energy environment for the United States as the U.S. seeks to satisfy its three main energy interests. The focus of this vision deliberately avoids an insular view of the future U.S. domestic energy situation recognizing the global nature of the industry.

Energy Security:

The future of energy security relies on dynamically balancing a variety of factors. The satisfaction of growing demand through diverse and reliable supplies, attenuation of demand through efficiencies, and delivery of supply through a modernized and resilient infrastructure all contribute to the overall equation. Ultimately, it is important to realize that domestic energy security has an impact well beyond the U.S. borders.

Supply. The IEA predicts that the world's current oil reserves will provide enough supply for the next 40 years and enough natural gas for the next 120 years. The technological advent of hydraulic fracturing ups the natural gas reserve estimates to 250 years and sharpens the double-edged sword of fossil-fuel consumption.[81] On one hand, the projection of abundant, cheap, carbon-based fuel is welcome in view of a growing Asian demand. On the other, it brings with it deepening concerns over the planet's ability to absorb increased concentrations of GHGs. Both have an impact on security but in different ways. Greater supplies will ensure reliable sources of energy. But consuming or exporting those fuels will compromise security against environmental calamity. For this reason the global supply of renewable fuels for electricity generation and transportation will continue to grow, bolstered by technology improvements and government policies. Even so, the increased use of renewables will not be enough to meet the growth in global energy demand through 2050. Thus, to satisfy demand, the United States must shape the environment such that the market is inclined to invest in a variety of reliable fuel sources that strike a balance between the security and profitability of hydrocarbons and the promise of disruptive clean energy sources that reduce the drivers of climate change.

Portfolio Diversification. In the preferred environment unconventional fuels will play a greater role in energy demand based on technology improvements. By 2040 natural gas will surpass coal as the second largest demanded fuel behind oil. The move in domestic energy generation to combined cycle generation plants is already underway. Exxon Mobil's 2012 outlook predicts that oil, natural gas, and renewables will grow while coal experiences a decline. By using all major sources of energy, the United States will build in diversity, minimize risk, and eliminate single points of failure. Diversification will buffer the U.S. from the impacts of market volatility in any single fuel source.

Increasing Demand Efficiency. Countries belonging to the Organisation for Economic

Cooperation and Development (OECD) must continue to realize energy savings through efficiency gains to offset the tremendous growth expected by China and non-OECD countries through 2050. Efficiency gains by consumers and businesses globally could generate energy savings of 500 quadrillion Btu by 2040 (ref Fig. 5, App A).[82] These gains could keep global energy use essentially flat even as domestic and OECD economic output grows 80 percent through 2040.[83] Simply put, efficiencies extend our world's energy supplies, reduce greenhouse gas emissions, and contribute to domestic energy security.

Resilience and Robustness of Electrical Infrastructure. The U.S. must have a robust energy infrastructure in order to support a robust economy and satisfy a growing desire for uninterrupted supplies of electric power. Electric grid infrastructure must be capable of both delivering and accepting myriad distributed generation sources and supplying power throughout the country with a nation-wide interconnected transmission network. Ideally, federal, state, and local governments will collaborate on the construction and implementation of an electric grid capable of absorbing damage from a variety of high impact threats in ways that avoid long-term or widespread power outages.

Department of Defense (DOD) Operations. For years DOD has apportioned forces to maintain access to key waterways to ensure the flow of oil from the Middle East to the U.S. and other world markets. To this day, the Strait of Hormuz remains the most strategic access point for oil shipments. In the preferred environment, increased shale gas and oil production will allow the U.S. to temper its military commitment to the region, allowing regional allies to take on greater responsibility for maintaining stability while promoting the significance of unconventional oil producers around the world.

Economic Prosperity and Security:

Given the implications of current and future energy trends, the U.S. must set priorities now to maximize the potential of future economic prosperity. U.S. goals should include a reduction of energy price volatility, investment across a variety of energy subsectors, and an increase of U.S. technological as well as commodity exports.

Market Volatility. Growing world demand—especially from Asia—is reducing spare oil production capacity in key states like Saudi Arabia. This can induce market volatility. Oil's price spike to $147 per barrel in 2008 was not caused, as some have argued, by speculators. Instead world demand pushed the typical 5% Saudi spare capacity to its limits according to the Securities and Exchange Commission (SEC) and EIA, undermining OPEC's price control authority and leaving the markets to make the determination. Asia's growing energy appetite creates important strategic considerations for the U.S. economy, national security, and geopolitical posturing. Inclusive in these considerations is the reality that the world's energy markets are global and "increasingly dependent on [a] tight, fearful and spike-prone oil market whose supply is dominated by the Persian Gulf." As such, the U.S. will need to simultaneously pursue and exploit the benefits of its own growing energy security, while at the same time ensure that global energy considerations maintain a central role in its policy construction, especially within the Asia-Pacific region.

U.S. industrial and manufacturing sectors have benefited in recent years from low natural gas prices; however, low domestic commodity prices limit revenue within the gas industry, which discourages private investment in energy development. The *Financial Times* warned that natural gas prices "could be volatile at times"[84]—a consequence of abundant domestic supply and high international prices. This illustrates that the husbanding of domestic resources in an effort to keep prices artificially low may produce the negative consequence of aggravating price volatility. The preferred environment would therefore capture market certainty through the implementation of policy mechanisms that encourage long-term price stability while maintaining reasonable price levels for all fossil fuels.

Economic Growth. In the preferred energy environment of the future, the U.S. economy will benefit from all aspects of a diverse energy strategy. In addition to making all other economic activity possible, the energy industry will contribute directly to U.S. GDP and provide several million U.S. jobs. Energy expenditures totaled 8.3% of nominal GDP in 2010, and oil and gas extraction and related support activities alone accounted for about 465,000 jobs.[85] New manufacturing jobs in the U.S. could be as high as one million by 2025 as a direct result of the shale gas boom. In 2012, nearly 120,000 Americans worked in the solar energy industry. America's expertise and impressive safety records in the nuclear power industry make companies like General Electric and Westinghouse leading contenders to build new nuclear power plants here and overseas. These are just a few examples of how the American energy industry could greatly bolster the U.S. and world economies in the coming decades.

Exports. Looking forward, growing energy exports fueled by the shale gas and tight oil booms in the U.S. and Canada could make North America a net energy exporter by 2035.[86] Exports of liquefied natural gas (LNG), coal, and clean energy technologies will help reduce the nation's trade deficit, grow U.S. GDP, and help address the potentially destabilizing growth in global demand.

The U.S. has lagged behind other nations in exploiting its natural gas resources for export. Applications to export natural gas to the 18 countries with which the U.S. has a free trade agreement (FTA) have been quickly approved, but current laws and regulations inhibit exports to non-FTA countries.[87,88] As of March 2013, DOE had approved only one application to export domestically produced LNG to non-FTA countries and would not give a timeline for processing the 19 pending applications.[89] These delays are holding up private sector plans to build new gas liquefaction plants and terminals while others eagerly build infrastructure to meet the global market need.[90] In order to incentivize infrastructure development that would make the most of dry gas discoveries, the price for natural gas would need to rise to approximately $5 per thousand cubic feet.[91] Increasing exports and allowing market forces to act would diminish the overabundance of domestic supply and permit this increase to occur. Opponents argue that expanding exports will increase consumer prices at home and negatively impact the manufacturing and chemical sectors. But a 2012 report determined that the U.S. could experience net economic benefits from increased LNG exports. Exports could yield an increase of $10 billion to $30 billion in revenue as well as overall increases in general economic welfare and real household income (up to $47 billion by 2020).[92] A separate study assessed that LNG exports could add $4 billion annually to the U.S. economy, creating 8,000 jobs in export facility construction and 60,000 long-term jobs in the natural gas industry overall.[93] Moreover, exports could assist with achieving broader strategic objectives. Japan, for instance, serves as a critical U.S. ally in the Asia-Pacific and relies heavily on imports of natural gas to support domestic energy demands. Following the March 2011 Fukushima nuclear plant disaster, the Japanese government imposed a moratorium on nuclear energy, which increased Japan's dependency on imported natural gas and helped cause a meteoric increase in the price for natural gas to its current level of $15.09 per million British thermal units (Btu).[94] Despite this, the U.S. supplies less than 7% of Japan's LNG, hindering America's national military strategy of "building partner capacity."[95]

Coal exports are also important to the U.S. economy and U.S. jobs. The U.S. has reduced coal use for domestic electricity generation in recent years, but coal is the only energy source for which the U.S. has had a trade surplus (of $13 billion in 2011). The U.S. exported nearly a third more coal in 2011 than 2010, and 2012 exports shattered that record with approximately 13 million short tons exported in June alone. The value of U.S. coal exports increased from less than $4 billion in 2006 to nearly $17 billion in 2011, due mainly to increased exports to Asia and Europe. China doubled the volume of U.S. coal it imported from 2011 to 2012.[96]

For many of the same economic reasons, the preferred future also envisions the U.S. as a leading supplier of nuclear components, renewable energy generating equipment, fuel cells, electric vehicles, smart grid components, manufacturing processes, pollution controls, carbon capture techniques, and management know-how. These technologies will be critical to helping developing countries transition to a cleaner energy future by 2050.

The apparent win-win of American energy exports would both strengthen the U.S. economy and feed Asia's strong energy appetite. It would also assuage Asia's supply disruption concerns, allowing it to diversify supply, bolstering its energy security interests. Potential second-order implications quickly arise from further American-Asian economic integration in a market as critical as energy. Such linkage could provide leverage in American-Sino conversations on sensitive topics like territorialism, freedom of navigation, and trade relations—all-important elements of American regional economic interests. Indeed, "energy cooperation could be pursued as an 'objective,' where stable energy supply would be valued, and it could be used also as a 'means' through which other forms of political and economic cooperation could be achieved."[97]

Environment:

The move to invest in low-cost natural gas will do more than boost the economy. Part of the attraction is that it burns much cleaner than other fossil fuels used for electrical generation and transportation. Natural gas has 43% fewer carbon emissions than coal for each unit of energy delivered, and 30% fewer emissions than oil.[98] The attraction to lower-carbon fuel sources has made constraining carbon emissions a focal point for the preferred environment. There are three ways to do this.

First, U.S. markets for power generation must look for the right fuel mix to bring down carbon emissions (for global fuel mix projections, ref Fig. 6, App A). Natural gas combined-cycle power plants are an obvious investment and already underway. Natural gas can also play a role in fuel cell power generation. As the price for fuel cell technology comes down over the next several years, the popularity of stationary fuel cell power generation will continue to grow. Distributed fuel cell power generation that relies on natural gas or biogas allows for continual operation independent of the grid, and can serve an important role in providing power for emergency municipal services as well as government installations. The advantages to DOD are clear. The benefit from future defense large-scale purchases of this technology will promote environmentally conscious power production while facilitating greater penetration of emerging clean energy technology.

Second, the U.S. transportation market must make a similar assessment of its fuel mix. By 2050, the number of cars in the world is forecast to triple[99] with 80-88% of the transport sector still reliant on gasoline, diesel, fuel oil, and jet fuel.[100] Blending these fuels with biofuels is one way to reduce carbon dioxide emission. But problems with biofuel production emerge when looking at the competition for water and other resources. Even so, biofuel will help to satisfy demand, increasing fourfold by 2050 with electricity, hydrogen, and natural gas increasing six-to-seven-fold over the same period.[101]

Third, city, state, and local governments will look at ways to improve demand efficiencies through better building design and city planning. A recent initiative in New York City to improve building performance standards and enable buildings to "produce their own green energy" provides a model for future efforts.[102] It is an initiative that could "unlock as much as $800 million in potential annual energy savings for New Yorkers."[103] Other aspects of city planning will address zoning so that cities achieve a sustainable density that allows for sufficient and effective infrastructure and public transportation while limiting sprawl that increases transportation energy demand.

In a future preferred environment, carbon must be priced to account for the externalities it causes with the resultant distortion of the market moving the public to more environmentally conscious behavior. One manifestation will be a decrease in per capita demand for energy. To do this, policymakers must make a clear and compelling case to the global public about the dire consequences of a warming planet. If recent studies are any indication, the degree to which government intervention and regulation are successful will have a correlating effect on the environment.[104]

Energy Research and Development (R&D):

Historically, the ability of private sector investments to translate alternate energy R&D technologies to a sustained commercial profit model has not borne out. Energy research is extremely expensive, with a long-term return on investment that often requires large-scale deployments for market viability. No matter how innovative the technology used to produce the energy, the final product is a commodity to sell within highly regulated markets that compete with an extensive fossil fuel infrastructure. To successfully diversify the U.S. energy portfolio, the preferred energy R&D environment must support private investment in technologies and incentivize continued commercial commitment beyond applied research to ensure market penetration and acceptance. With an "all of the above" energy strategy, federal attempts to focus R&D on promising technologies will be difficult. More public/private partnerships will be necessary to ensure that the market forces of industry can inform the power of directed government research to ensure research goals and commercial applications are in synch..

Policy Recommendations

The very nature of the energy industry requires that any policy recommendation accommodate short-, mid-, and long-term time horizons. The capital intensity of the industry and the length of time required to see significant return on investment drive a fundamental need to forecast policy implications well beyond a two to six year electoral cycle.

Unfortunately, the political system in the United States is biased toward achieving short-term gain rather than mid- or long-term goals. With federal elections every two years, creating policy is often done with the next election in mind. Therefore, conveying the need to deal with wicked and long-term, slow-build problems is extremely challenging when competing with the immediate difficulties of unemployment and the housing collapse of 2008. Issues such as entitlement reform, debt, education, energy, and the environment have languished for decades as politicians have determined that they are either too challenging or not urgent enough. Ultimately, most leaders either abdicate or ignore these issues, leaving the task to the next generation of leaders again and again.

Energy policy is both complicated and long-term, making it an unlikely candidate for meaningful deliberation. Generally, the public and the elected officials who represent them focus only on one aspect of energy policy: keeping commodity prices low. The challenge for an energy policy recommendation is to communicate the need for prompt action by identifying the consequences of not addressing the long-term now. Within the energy industry several problems have emerged to retard the nation's progress in protecting its interests: a lack of unified, coordinated effort; an aging and insufficient electrical infrastructure; the consequences of long-term environmental inaction; and a lack of coherent federal oversight for R&D. The following recommendations for federal government policy attempt to balance the roles of the public; federal, state, and local governments; and private industry in the pursuit of a national energy policy that addresses these problems in the context of guaranteeing a secure and sustainable supply of energy, modernizing infrastructure, incorporating emerging technologies, and mitigating the impact of consumption on the environment.

Recommendation #1—Transform the Department of Energy

A consistent refrain over the last 40 years is that the United States lacks a comprehensive national energy policy. In addition to recent efforts from the White House and Congress to unify government efforts toward this goal, the new Secretary of Energy must be prepared to lead the U.S. energy industry through a revolutionary upheaval as technology introduces unprecedented challenges and opportunities to our infrastructure and the emergence of new energy supplies alter the sensitive dynamics of global trade.

The Administration should re-charter and empower DOE, transforming it into the lead agency for the coordination and integration of a national energy policy working hand-in-hand with the States and other government regulatory agencies to create consensus on how to posture the U.S. as a world-leader in clean energy supply, generation, and consumption. An expedient way to implement policy is through regulatory edict. The recommended approach avoids this, understanding that if done unilaterally, DOE may run afoul of state regulatory programs and market forces that may doom legitimate attempts to bring about needed change. A better approach is to bring unity of effort to the federal policymaking apparatus through strong leadership and a prompter response to Energy Advisory Committee (EAC) recommendations. The EAC incorporates input from both private and public entities in the industry. DOE could drive change by implementing EAC guidance through a more closely aligned relationship with the Federal Energy Regulatory Commission and socializing changes with state energy offices for implementation. The end result would be the establishment of new industry standards that modernize infrastructure and incorporate emerging technologies. This approach mimics the way in which the National Highway Traffic Safety Administration, as part of the Department of Transportation, writes and enforces the successful Corporate Average Fuel Economy (CAFE) standards.

In selecting Secretaries to lead this department over the coming crucial decades, the Executive should look for individuals who have strong credibility with the various industry sub-sectors and stakeholders, a healthy understanding of the electrical infrastructure, an ability to spur public and private R&D, and a long-term vision for how America can establish a low-carbon energy environment. Selecting the right person for the job does two things. It gives the United States strong leadership where it is desperately needed, and provides an advocate for energy security, economic strength, and environmental responsibility.

Recommendation #2—Incentivize Exports of Energy Fuels, Technology, and Equipment:

In the near to mid-term, the United States needs a diverse export strategy to bolster the energy industry and grow the U.S. economy. Rapid approval of LNG exports to non-FTA nations enables the U.S. to capitalize on its growing natural gas supply, growing global demand, and the large differential between domestic, Asian, and European gas prices. Moreover, approving the Keystone XL pipeline to bring Canadian oil to American refineries, where it can be turned into finished product for both export and domestic use, further strengthens the nation's most important energy partnership.

On the surface, these recommendations appear to hamper global GHG mitigation. But in a phased approach, a push to increase use of cleaner natural gas over coal is a plus. The world will continue to burn coal for the coming decades, so the U.S. government should also support U.S. exports of existing and emerging clean coal and carbon capture technologies.

Strong exports start with strong domestic industry. Congress should phase in a corporate income tax rate reduction by tying it to economic recovery. This will level the playing field between U.S. and foreign companies and encourage firms to move manufacturing jobs back to the United States. Congress should also stabilize temporary tax credits for renewables that have grown the U.S. market by extending them for at least ten years to provide the certainty necessary to spur private investment. The current one-to-two year extensions are not commensurate with the time and investment required to validate new technologies or implement large-scale projects. Credits and incentives should be expanded to include U.S. exports of renewable energy products and technologies. And, if a carbon tax or cap-and-trade system is implemented (see Recommendation 5 below), some of those proceeds could also go to making the U.S. renewable industry globally competitive.

To complement these efforts, U.S. national labs should feed promising technologies in the energy sphere to domestic companies that agree to turn basic R&D into manufactured products within the United States. A reduced corporate tax rate coupled with incentives to add manufacturing jobs in the U.S. could greatly stimulate manufacturing and exports of energy-related products to the developing world. Hybrid and electric cars, Smart Grid technologies, wind turbines, solar and fuel cells, nuclear reactors and plant components, turbines, and carbon capture and pollution mitigation techniques are just a few areas where the United States could be a world leader if proper government policies and tax structures incentivized them.

Taking these steps to export energy commodities as well as emerging renewable and clean energy technologies supports multiple U.S. interests. These initiatives would not only serve to improve U.S. energy security through diversification of reliable supplies, they would also enhance U.S. international security by promoting trade and mitigating energy scarcity in other parts of the world. A U.S. willingness to share its energy resources and technologies with the rest of the world at affordable prices could go a long way in fostering international stability and U.S. soft power. Increased U.S. exports directly contribute to U.S. economic growth and job creation.

Recommendation #3—Modernize the U.S. Energy Industry Architecture:

While the U.S. has funded Smart Grid and infrastructure projects via the American Recovery and Reinvestment Act of 2009, "there has not been a comprehensive effort to study the needs, set goals, and provide targeted federal funding for the modernization of the U.S. grid as part of a long-term national energy strategy."[105] An Energy Industry Architecture is an imperative—one that defines the "as is" environment, envisions the "to be" environment, and resources a transition plan for moving from one to the other. Efforts are underway to establish this Energy Architecture—the White House's March 2011 *Blueprint for a Secure Energy Future* and Senator Lisa Murkowski's February 2013 *Energy 20/20: A Vision for America's Energy Future* are notable examples. What is not entirely clear in the documents however, are specific "to be" visions for infrastructure, R&D investments, energy security, cybersecurity, and transportation infrastructure.

Electric Grid Infrastructure. The U.S. must modernize its aging energy generation and transmission grid infrastructure to function as a resilient system. An enhanced energy infrastructure with Smart Grid technology enables increased electricity capacity flows, better reliability during peak demand, increased survivability during large-scale disasters, and improved physical security. Furthermore, the envisioned energy infrastructure should be designed and built with standardized parts to ensure essential replacement components and spares are available and redistributed quickly through supply channels. Finally, the federal government must direct the siting and construction of a national backbone of high-voltage transmission lines to move power effectively and enable grid resiliency. The cost of construction should be born by utility companies and individual rate-payers, but will result in long-term savings due to vast improvements over our current patchwork system of loosely interconnected regional grids that are prone to bottlenecks and transmission shortages.

Emerging Technologies. Public and private funding for innovative projects will advance several promising energy-related initiatives—implementation of Smart Grid technology, energy storage, microgrids, and distributed generation technologies. The Smart Grid construct upgrades the electric power infrastructure with new information technology systems designed to improve efficiency, minimize waste, and integrate renewable energy sources. The Smart Grid hardware to integrate renewable systems is only part of the solution. Policies must encourage states and utilities to outline standards that rapidly approve interconnection of distributed grid generation (DG) and allow aggregated DG the ability to bid in the Day-ahead and Real-time power markets. Taking these steps will orient the market to incentivize the introduction of renewable resources while taking full advantage of current Smart Grid technology. This is the future of the U.S. energy infrastructure—better visibility, better management, faster response, and overall robustness of the system.

Cybersecurity. The current state of U.S. grid cybersecurity and information sharing is in disarray. Given political and infrastructure expense realities, cyber information sharing between industry participants is a path of least resistance towards a more secure grid. But to share information more effectively, the industry and government must accomplish four things:

- First, they must address the need for electricity industry culture change. Utility leadership must confront threat complacency, reluctance to share information, and, in partnership with the Department of Homeland Security's Infrastructure Protection organization, build stronger connections with other energy critical infrastructure sector companies.
- Second, they must introduce government incentives for better information sharing mechanisms to electricity and other critical infrastructure companies. Sharing information through third party security information clearinghouses puts a safe distance between the government and cagey companies, but still enables key classified threat information to flow to industry, and enables industry to disclose cyber intrusions without fear of government retribution.
- Third, Congress cannot continue to abdicate its cybersecurity role. It must renew efforts to pass a cyber bill that addresses private sector privacy concerns, while acknowledging the essential link between electricity (a critical infrastructure industry) and American safety, security, and economic prosperity.
- Fourth, the SEC must step up efforts to ensure companies, on a quarterly basis,

adequately disclose cyberattacks, cyber risks, and effective mitigation plans. These requirements should include cyberattack damage valuations combined with management discussion on clearly laid out company plans to address current and future cyberattacks.

Transportation Infrastructure. The transportation sector is the single largest consumer of imported oil, accounting for 70% of all imports.[106] Transportation fuel accounts for 14 million of the total 20 million barrels used per day in the United States.[107] By leveraging the natural gas renaissance here at home, the right policy could be the most important catalyst in the past 50 years to reduce dependence on oil and increase domestic energy security. Natural gas powered vehicles offer a proven economic model, but are constrained from rapid growth by a lack of fueling stations. Natural gas is currently cheaper than gasoline or diesel, costing the equivalent of just $2.10 a gallon (nearly half of standard fuels). However, there are fewer than 1,000 natural gas fueling stations around the country. Long-haul trucking conversions to natural gas make perfect economic sense, as heavy-duty trucks are driven more frequently than other vehicles and relatively inexpensive front-end conversion costs can be recouped in as little as 2-5 years. The EIA projects that if enough LNG filling stations are built, sales of heavy-duty natural gas vehicles could increase to 275,000 by 2035, equivalent to 34 percent of new vehicle sales.[108] Additionally, natural gas burns cheaper, making it easier to meet emissions standards, and as a domestic fuel provides insulation from volatile geopolitics that can drive up gasoline prices.[109] Congress should immediately include tax incentives for construction of alternative fueling stations to spur more rapid adoption of alternative fuel sources and proven economic models. These tax incentives can also be applied to electric charging stations or hydrogen refueling for fuel cell vehicles as those technologies continue to improve and achieve commercial viability. A transportation sector renaissance is being held back by a literal "chicken-or-the-egg" conundrum with demand and manufacturers limited by lack of fueling stations and vice versa. This policy could transform the long-haul trucking sector within two decades and simultaneously pass those benefits onto other consumer vehicles.

Recommendation #4—Research and Development and Rapid Adoption of Emerging and Renewable Technologies:

Inconsistent emphasis in the federal R&D priorities over time has complicated the U.S. ability to move beyond its fossil fuel dependence and modernize its energy portfolio. Critical components to strengthening the national energy portfolio include: sustained funding for focused R&D application; consistency of national energy policies and objectives; teaming with industry in public-private ventures; and statutes and policies to stimulate adoption of new energy supply and use methods. When compared to U.S. consumption of energy, the energy innovation market has not attracted much private investment in the U.S., largely due to its capital-intensive nature and regulatory challenges in many sectors. Because of the high cost of entry and the market structure within much of the energy industry, private investment in energy R&D tends to rely heavily on federal basic research, policies, and subsidies to create market momentum.

The ability to promote emerging technologies within the U.S. energy portfolio depends on a focused approach in three primary areas: 1) direct management and oversight of federal R&D funding for applied research in potentially disruptive energy technologies; 2) regulations (such as fuel, safety, or emissions standards) that give direction to research and help make a business case for private research; and 3) a U.S. R&D tax credit and market incentives that meaningfully contribute to the energy market playing field. The need for R&D direct management and oversight is due to the diversity of technologies and disparate projects related to energy. DOE's recently implemented Energy Innovation Hub model attempts to address this systemic issue by combining basic science research with applied science knowledge (or engineering), with the goal of transferring the technology to the private sector. Federal and state regulatory standards create technical goals that shape the energy portfolio capabilities and drive market adoption. A tax credit to support collaborative development efforts (industrial clusters) as well as individual corporate innovative efforts would also further stimulate U.S. energy R&D.

In addition to strengthening investment management, regulatory standards and market incentives, continuity and consistency of R&D energy policies will support U.S. domestic demand and promote U.S. global energy market competiveness. Consistent policies will promote innovations that stabilize domestic energy markets while minimizing environmental impact. "Disruptive innovations" are expected to transform traditional energy markets by creating "a new market and value network" that eventually "disrupts an existing market and value network, displacing an earlier technology."[110] Ongoing research at the Lawrence Livermore National Laboratory in California may produce nuclear fusion ignition in the near future—an event that would revolutionize power generation and life as we know it. A long-term view is critical to successful technology adoption and transformation within the U.S. energy portfolio.

Recommendation #5—Protection of the Environment:

Because the global demand for energy is forecast to increase, the ultimate fate of the environment is directly linked to the adoption of new and cleaner ways to generate and consume the energy required for economic growth. Fiscal policy has an important role in affecting energy security and economic growth while encouraging industry and consumer behavior to pursue environmental goals. Specifically, fiscal policy may be able to drive increases in energy efficiency, reduce national debt, contribute to U.S. leadership in energy technology development, and reduce GHG emissions.

The centerpiece of this recommendation is a carefully phased and targeted federal carbon tax. The tax should be structured to decrease negative impacts on the environment and produce a revenue source for further investment in a variety of energy related technologies. The targeted technology investments will further develop CO_2 reduction and capture, advance Smart Grid implementation, accelerate energy storage advances, foster microgrid development, and standardize alternative fuel transportation infrastructure. Additionally, the tax should reward increased efficiencies across the energy sector. This tax will likely increase costs to both consumers and producers of energy in the short term, and thus meet substantial political resistance. To enhance the political viability of this approach, a carbon tax may need to be packaged with offsets in existing labor, income, and investment taxes to U.S. individuals and corporations.

To improve the competitiveness of alternative energy solutions, federal oil and gas subsidies and tax breaks must cease. This elimination would contribute to the U.S. economy by reducing unnecessary government expenditure allowing some of the additional revenue for previously cited technology development to advance environmental goals and energy security as described in the preferred environment.

Finally, to improve efficiency, the Federal government should continue to promote Leadership in Energy and Environmental Design (LEED) and mandate a minimum LEED Silver certification for new federal buildings or major renovations.[111] Moreover, the government should extend tax incentives for technologies that promote efficient consumer products such as Energy Star compliant appliances; community, residential housing and commercial building improvements; and fuel-efficient hybrid or electric plug in vehicles and their supporting infrastructures.

Conclusion

Few analyzing the energy industry 37 years ago could have predicted the transformational changes that shaped the energy landscape of today—from new oil and gas supplies unlocked through deep sea drilling and hydraulic fracturing to advances around the world in affordable solar, wind, and electric vehicle technologies. This improved access to resources and their efficient use has proven that entrepreneurship paired with supportive government policies can succeed in meeting growing global demand. The energy landscape and new technologies of 2050 are just as difficult to predict. However, the challenges for both industrialized and emerging nations remain clear: to successfully satisfy the rising global demand for energy; address efficiency standards to drive demand down; and to exploit technology opportunities to minimize environmental impact from activities related to energy production and use.

The United States now has much better access to reliable, diverse supplies of energy, but booming demand in the developing world and the specter of climate change pose global challenges which directly impact U.S. interests and which require U.S. leadership to solve. To help shape our preferred environment, the United States must pursue a holistic energy policy that continues to guarantee a secure and sustainable supply of energy, modernizes infrastructure, incorporates emerging technologies, and mitigates the impact of consumption on the environment. These following five recommended short-to-long-term elements of such a policy will help achieve a reliable, cleaner energy industry that meets growing demand, enables development, and reduces the environmental impacts of energy use:

7) The Department of Energy must refocus, starting with strong leadership, to create and lead the implementation of a national energy policy.
8) The United States should embrace the opportunity to become a net exporter of energy (including LNG) to satisfy the immediate needs of Asia and the developing world and while stimulating manufacturing and export of energy technologies such as solar panels, wind turbines, nuclear reactors, CO_2 reducing technologies, and Smart Grid components.
9) Given the importance of the electric grid, oil and gas pipelines, and related infrastructure to America's economy, health, and security, the U.S. must improve the national energy architecture. The architecture of the future must enable distributed generation, Smart Grid operations, resilience against cyber and terrorist threats, as well as infrastructure that enables a diversity of transportation fuels.
10) The U.S. should focus federal R&D efforts through direct management and oversight of federally funded projects, provide regulatory direction to guide market-based research, and provide R&D tax credits to incentivize private R&D continuation of federal research.
11) The U.S. should demonstrate leadership in the protection of the global environment through: increased use of renewable energy, implementation of a carbon tax, increased R&D for carbon capture and sequestration technologies, and R&D on game-changing technologies like nuclear fusion.

Together, our recommendations offer ways and means to get to the preferred environment by 2050. Our vision is a global energy market that enables economic development while reducing environmental impacts—a market that enables access to energy in the developing world where access leads to jobs, education, healthcare, sanitation, clean water, and food. The U.S. has the potential to contribute to world energy demand and in doing so, champion its own economic recovery. Energy is the centerpiece of America's strength and prosperity. By protecting it we ensure our national security survival. By harnessing it we advance our world economic leadership. By redefining it we ensure its availability for future generations.

APPENDIX A

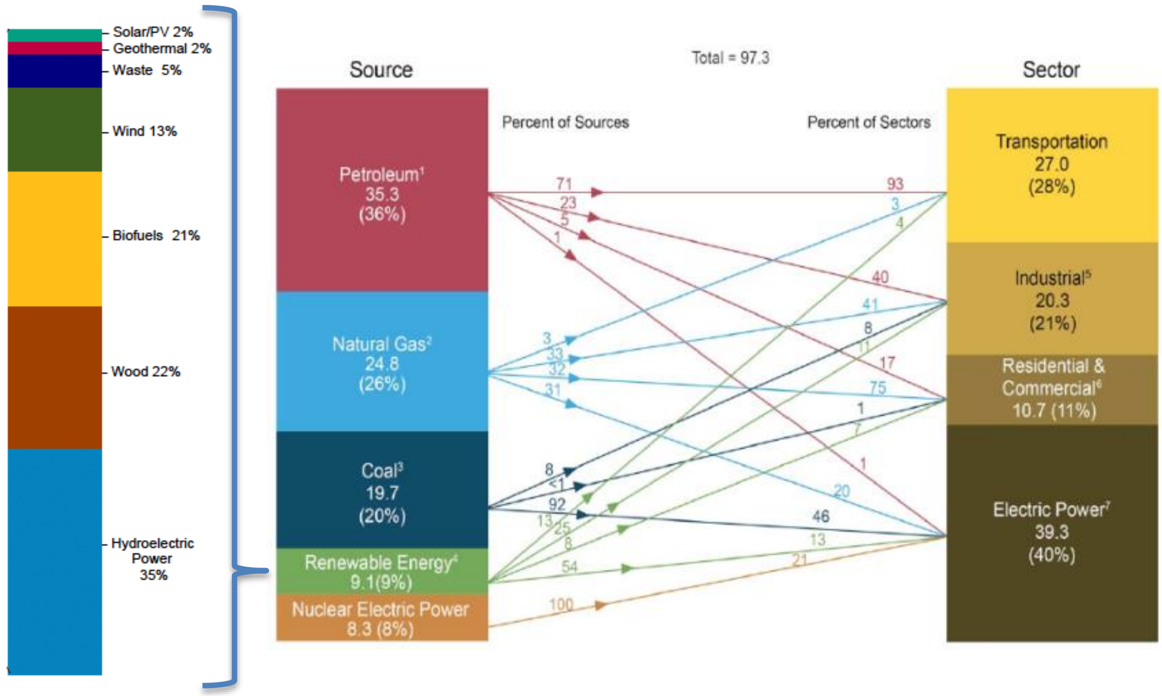

Figure 1. U.S. Primary Energy Consumption by Source and Sector, 2011 (in quadrillion Btu's). Source: EIA.

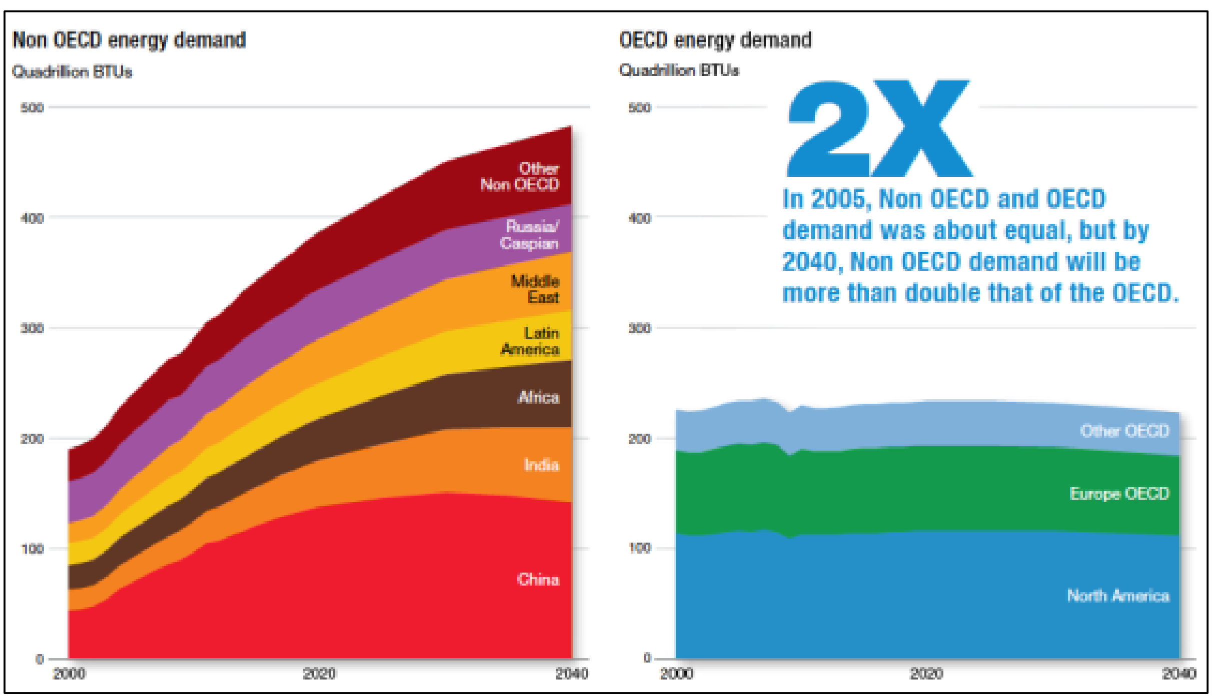

Figure 2. Global Energy Demand. Source ExxonMobil.

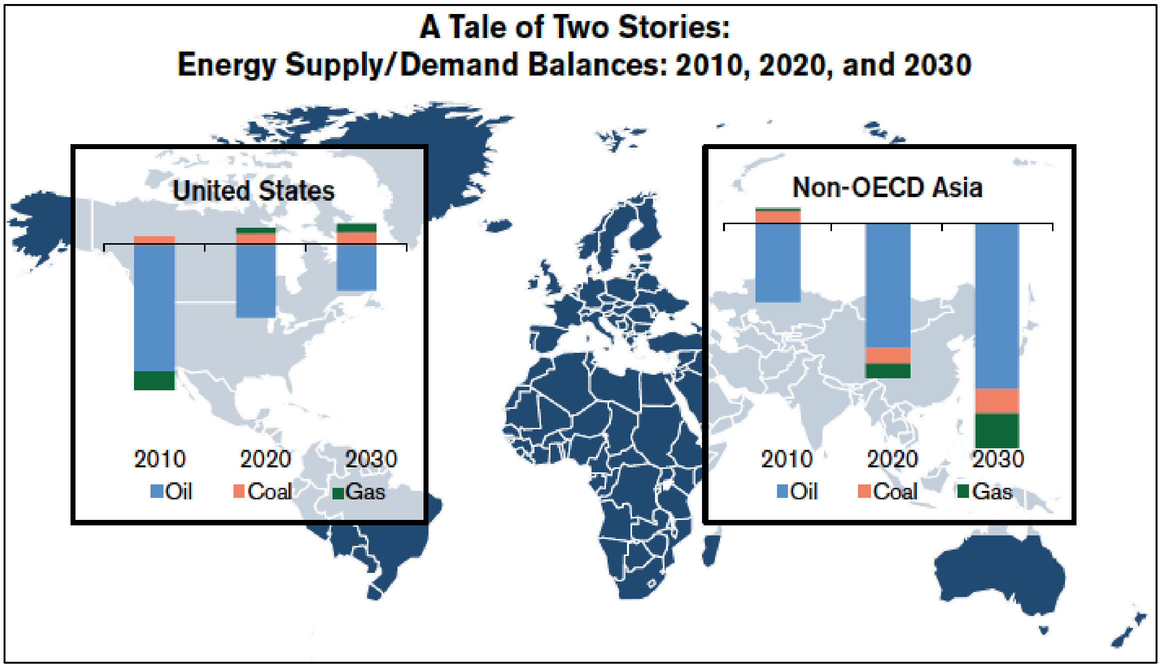

Figure 3. Future Trends in Energy Supply/Demand. Source: Brookings Institute.

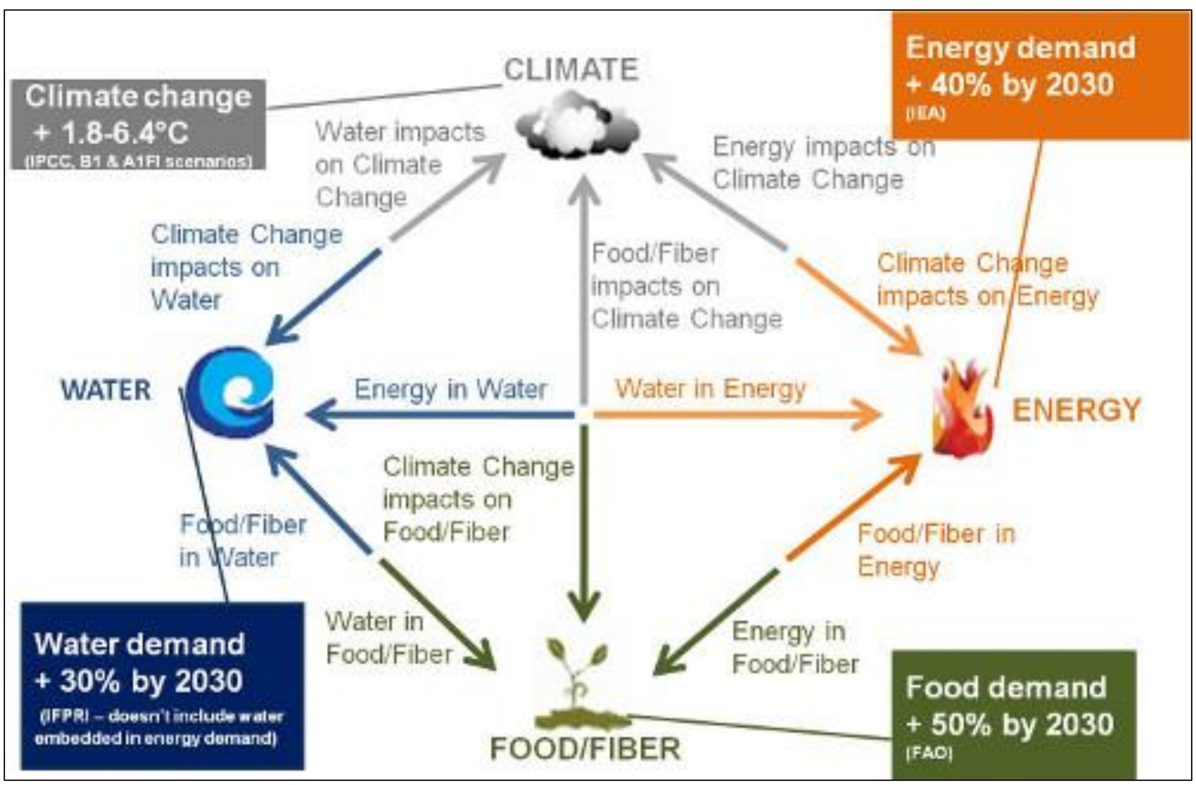

Figure 4. Resource Nexus. Source: World Business Council for Sustainable Development

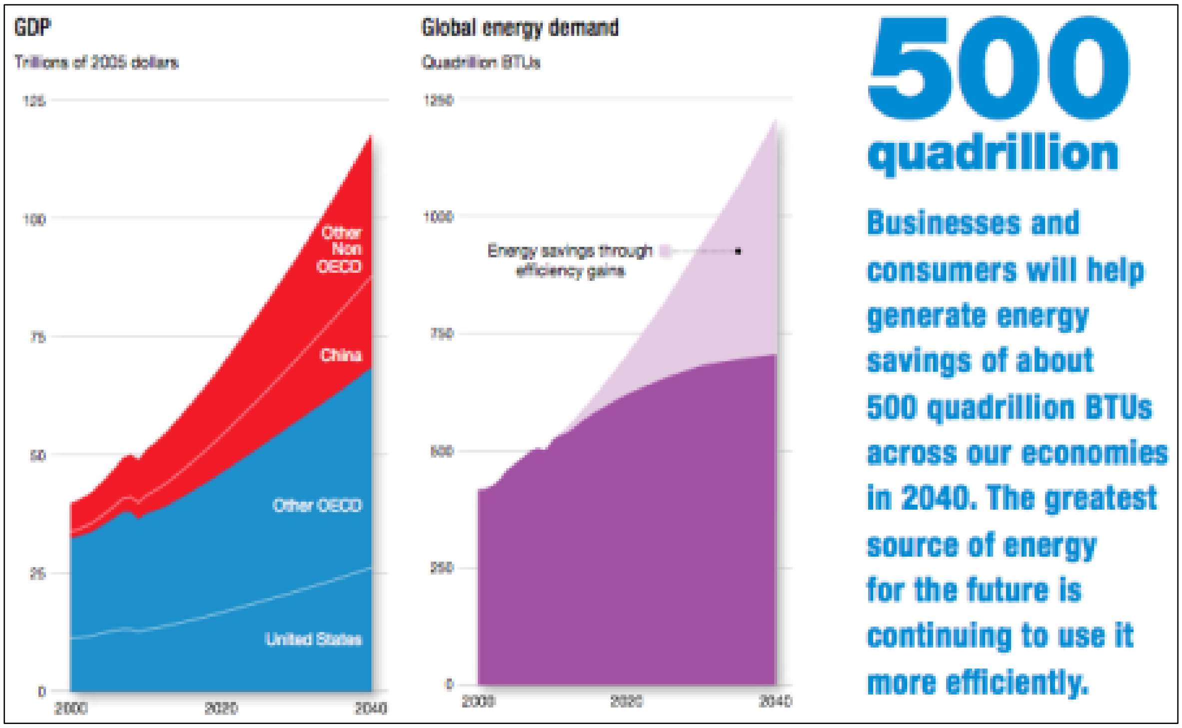

Figure 5. Global Demand Reduction Through Efficiencies. Source: IEA

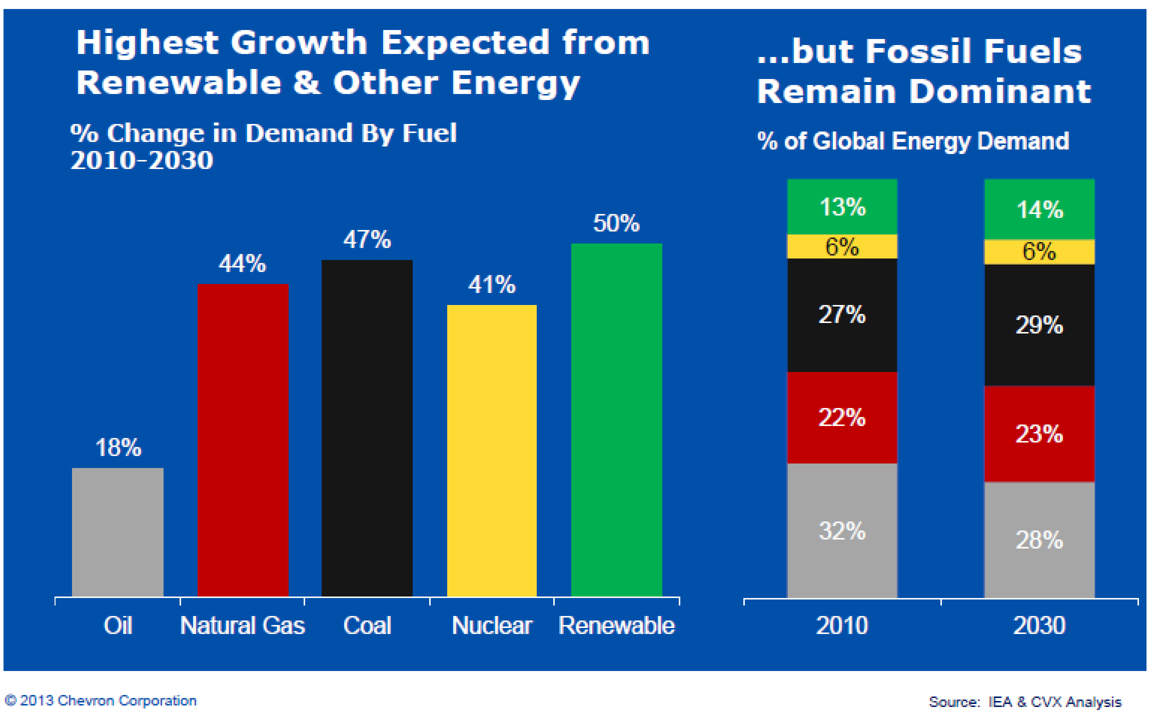

Figure 6. Future Trends in Energy Sector Growth. Source: IEA and CVX Analysis cited in Chevron 2013 Energy Presentation.

ENDNOTES

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