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Industry Study Report

Final Report
Energy

The Dwight D. Eisenhower School for National Security and Resource Strategy
National Defense University
Fort McNair, Washington, D.C. 20319-5062

ENERGY INDUSTRY

ABSTRACT: Energy underpins all of United States industry and economic security. It is no wonder that multiple references equate energy security to national security, and the U.S. is in the midst of an energy renaissance. The Eisenhower School Energy Industry Seminar spent its academic year studying this industry and came to the fundamental conclusion that it is extraordinarily diverse. In order to derive and formulate substantive policy recommendations, the authors analyzed the industry through the prisms of three megatrends (Climate Change, Socio-Economic Change, and Technology Change) that significantly interact with the energy sector. The policies identified in the conclusion section synthesize the specified tasks from each of the megatrend sections and provide a holistic and implementable path forward for establishing a coherent U.S. energy policy.

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Domestic:
Department of Energy, Washington, DC
Department of State, Washington, DC
Canadian Embassy, Washington, DC
Energy Information Association (EIA), Washington, DC
Lawrence Livermore National Laboratory (LLNL), Livermore, CA
US Central Command (USCENTCOM), MacDill AFB, Florida
PJM, Norristown, Pennsylvania
Port of Houston Authority, Houston, Texas
U.S. Coast Guard Sector Houston-Galveston, Houston, TX
Cheniere Energy LNG Export facility, Sabine Pass, Louisiana
Tampa Electric Plant Company (TECO), Tampa Bay, Florida
Center for International Security and Cooperation (CISAC), Stanford University
Walter H. Shorenstein Asia-Pacific Research Center (APARC), Stanford University
University of Southern Florida (USF), Tampa, Florida
Solar Living Center, Hopland, CA
US Green Building Council (USGBC), Washington, DC
City of Santa Rosa, Santa Rosa, CA
Sonoma County Water Agency, Sonoma, CA
Laguna Water Treatment Facility, Santa Rosa, CA
Sonoma Clean Power, Sonoma, CA
Calpine Corporation, Sonoma, CA
Liquid Robotics, Sunnyvale, CA
AutoGrid Inc., Redwood Shores, CA
Facebook Headquarters, Menlo Park, CA

International:
J-Power Isogo Coal Power Station, Yokohama, Japan
Tokyo Gas Negishi LNG Import Terminal, Negishi, Japan
Ministry of Economy Trade and Industry (METI), Tokyo, Japan
Japanese International Cooperation Agency (JICA), Tokyo, Japan
New Energy Development Organization (NEDO), Kawasaki, Japan
Mitsubishi Corporation SPERA Hydrogen Facility, Kawasaki, Japan
Chubu Electric Company Hamaoka Nuclear Plant, Shizouka, Japan
Hitachi-GE Nuclear Energy, Ltd, Tokyo, Japan
Mutual Defense Assistance Office (MDAO), American Embassy, Tokyo, Japan

"Already the steam-engine works our mines, impels our ships, excavates our ports and our rivers, forges iron, fashions wood, grinds grain, spins and weaves our cloths, transports the heaviest burdens, etc. It appears that it must someday serve as a universal motor, and be substituted for animal power, waterfalls, and air currents."[1]

- Sadi Carnot (1824)

"As the saying goes, the Stone Age did not end because we ran out of stones; we transitioned to better solutions. The same opportunity lies before us with energy efficiency and clean energy."[2]

- Steven Chu (2013)

INTRODUCTION

Energy underpins the entirety of United States industrial capability and forms the cornerstone of its economic security. As the U.S. recovers from the recent financial recession, it is understandable that many government officials equate energy security to national security. The U.S. is in the midst of an energy renaissance, moving Americans toward greater energy security. The U.S. is the global leader in oil and natural gas production and is continuing to develop a diverse portfolio of renewable power generation sources.[3] Pipelines and associated facilities, originally constructed to accommodate imports, are being retrofitted for exports. Energy produced from practically every source has seen production costs reduced over the past ten years. International corporations that have traditionally located their manufacturing plants in countries with lower labor and regulatory costs are now moving their businesses to the U.S. to take advantage of these lower energy costs.

The composition of the U.S. energy industry spans a wide-range of corporations and individual entrepreneurs and is impacted by inputs and demands from international conglomerates to domestic households. The authors of this paper have spent the past academic year conducting an in-depth inventory and analysis of this industry.

The group met with government executives in the U.S. and the Ministry of Economics in Trade and Industry (METI) in Japan, as well as numerous private sector entities that are recognized experts in the energy field and are shaping energy policy and practices today.

They observed firsthand the emerging export operations at Sabine Pass Liquid Natural Gas (LNG) Terminal in Cameron Parish, Louisiana. When completed this complex will receive natural gas via pipeline and liquefy it through a complex process in preparation for export from the U.S. for the first time starting in late 2015.

To understand the electric grid and distribution operations the seminar toured Pennsylvania-New Jersey-Maryland (PJM) Interconnection in Norristown, Pennsylvania, the largest east coast regional transmission organization (RTO). There they were introduced to the sophisticated management processes PJM employs to regulate the economic market for electricity production by managing the distribution and costs of power from large nuclear, coal, and gas power plants to meet variable consumer demand.

To appreciate the energy extraction process, they examined a range of fuel sources. At one end of the spectrum they toured a conventional coal-fired power plant in Florida and an "ultra-super critical" coal thermal power station in Japan. At the other end of the spectrum they looked at the research and development efforts being conducted by the National Ignition Facility at Lawrence Livermore National Laboratory in California. Where research continues for new sources of power using cutting-edge technologies associated with nuclear fusion.

They viewed the physical and operational footprints of the full range of energy options, from inside a nuclear plant in Japan to the garage of a cutting edge clean energy advocate in California who uses solar power to support all the energy needs for two sizeable homes.

From supply to demand, old to new and imports to exports, the energy industry demonstrates one fundamental truth…the energy industry is highly diverse.

The largest portion of the U.S.' energy portfolio is heavily reliant upon fossil fuel resources to meet private and commercial needs. These are resources of finite supply and reserves. Advances in technology, the discovery of new reserves, and more efficient conservation practices will materially extend the longevity of these resources. However one thing is certain; at some time in the future, these fuel reserves will be depleted. The U.S. energy portfolio must recognize and adjust to this eventuality.

While global demand for energy continues to rise, seemingly unabated, there exists little consensus on how to get from where the industry stands today to where it needs to be in the future. It is within this complex environment that future U.S. energy policies must be crafted to address three primary goals: *1) assure a secure supply of energy; 2) keep energy costs low; and 3) protect the environment.*[4]

The U.S. energy industry supports and interacts in a complex way with all other sectors of the economy. It is an industry that exists in an environment characterized by rapid change. Against this backdrop, the U.S. energy industry must account for developments and impacts as well as accommodate broader global trends.

For the analysis of this project, Climate, Socio-Economic, and Technological Change mega-trends were selected because of the direct impact they exert upon U.S. energy industry and policy goals. Climate change, environmental protection, and resource stewardship go hand-in-hand. Socio-Economic factors will be influenced by the ability of the industry to provide affordable and accessible energy to all. Technology is leading the way to more efficient use of the energy sources used in power generation, transmission and consumption today and will continue to lead the industry to a cleaner and more secure supply of energy in the future. In order to make policy that is applicable in a global environment, it is important to understand how U.S. policies will interact within these mega-trends.

This report presents strategic analyses of the pros and cons of the energy industry when viewed through the prism of each of these mega-trends. It also presents options for policy makers to ensure the U.S. energy industry will meet the demands across all sectors in the future.

The "All of the Above" energy strategy acknowledges the current state of the industry but falls short of the specified actions outlined in appendix A. Considering the finite longevity of fossil fuels, increasing international competition for energy resources , and tightening environmental restrictions, a lack of a coherent national policy guiding the development of new energy sources, distribution methods, and related technologies leaves Americans with an energy future highly vulnerable to unpredictable energy market fluctuations. Energy is a national security concern. Energy underpins the economy. Energy provides a quality of life never before enjoyed in the history of man. *Adoption of the policy recommendations offered in this report leads the U.S. toward a future with more secure, affordable energy that protects the environment and provides a model for other nations of the world to follow.*

Figure 1: All of the Above Energy Strategy

CLIMATE AND THE ENVIRONMENT

"I'd put my money on the sun and solar energy, what a source of power. I hope we don't have to wait until oil and coal run out before we tackle that."[5]

- Thomas Edison

Introduction

Over the last few decades, leading scientists, backed by their scientific organizations, noticed and recorded significant changes in the global climate and environment.

> "Ninety-seven percent of climate scientists agree that climate-warming trends over the past century are very likely due to human activities, and most of the leading scientific organizations worldwide have issued public statements endorsing this position."[6]

The quantities of greenhouse gases (GHGs) documented in the polar ice caps provide an exact correlation between man's industrial age and the increased amount of GHGs proven to cause global warming (See Figure 2). For example, CO_2, a known and proven GHG, imprinted itself in Antarctica, preserving an 800,000-year-old report card for scientists to repeatedly compare and contrast. Figure 3 displays the last 2000 years of data, which demonstrates a frightening increase in the top three GHGs.

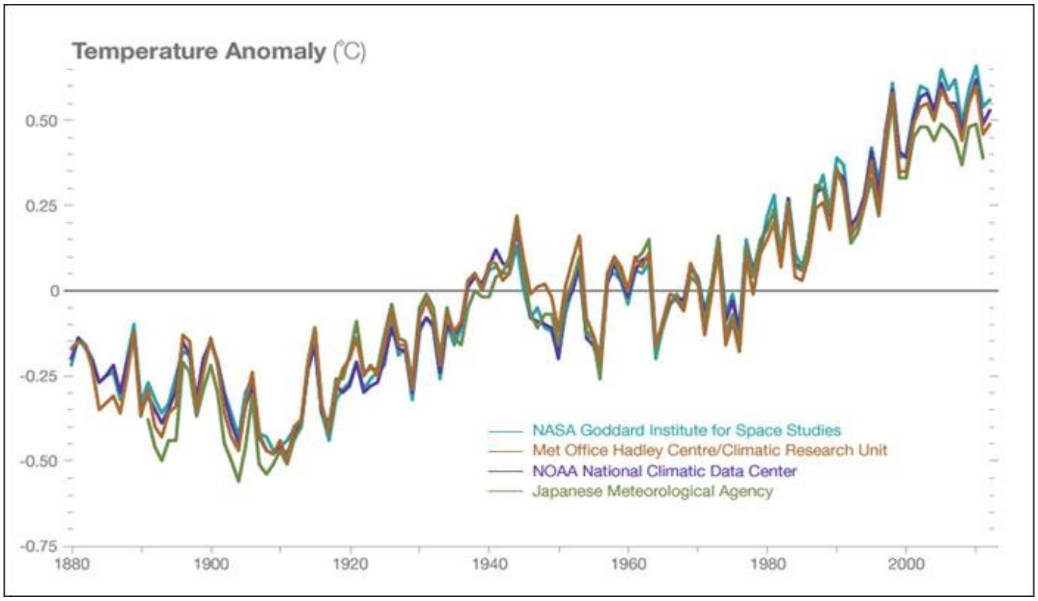


Figure 2: Rise in Global Temperature Since the Industrial Revolution[7]

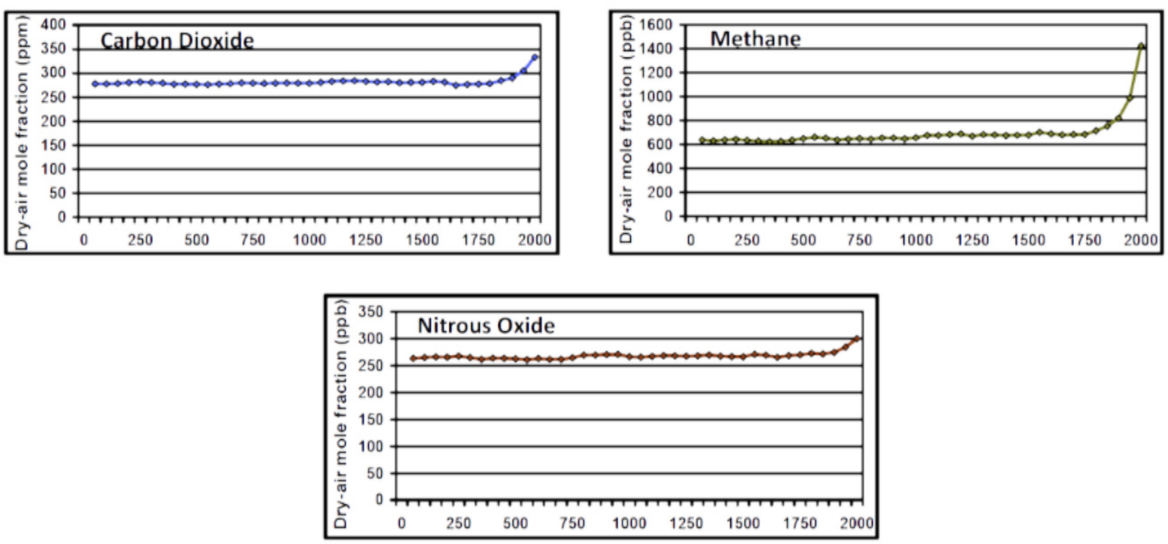


Figure 3: 2000 Year Records from Core Samples in Law Dome, Antarctica[8]

This chapter explores the planet's current energy sources: fossil fuels, nuclear power and renewables; and analyzes their role and impact on one of the most important three global megatrends - climate and the environment. This analysis will examine each energy source's specific strengths and weaknesses from the group's research together with information obtained from actual international and domestic site visits to energy facilities and plants, research institutions, universities and industry firms. The group researched the opportunities for balance and diversity of energy sources and climate impacts, as well as specific threats from each individual energy commodity and technology. These findings form the basis for the comprehensive policy recommendations available for review and consideration at the highest levels of government.

Beginning with the Industrial Revolution, the use of fossil fuels increased significantly with the discovery of coal and the invention of the steam engine.[9] America's energy use quadrupled between 1880 and 1918, primarily due to the abundance of coal. Following the invention of the automobile, the use and consumption of petroleum increased rapidly and eventually surpassed coal as the largest energy source in the US by 1950.[10]

Fossil Fuels

Fossil fuels are carbon based energy sources primarily in the form of coal, oil and natural gas. Fossil-based fuels currently provide about 85% of all the energy use both in US and worldwide. (See Figure 4). Fossil fuels are non-renewable energy sources that release harmful GHGs when consumed and many argue contribute heavily to global warming and cause significant damage to the planet.

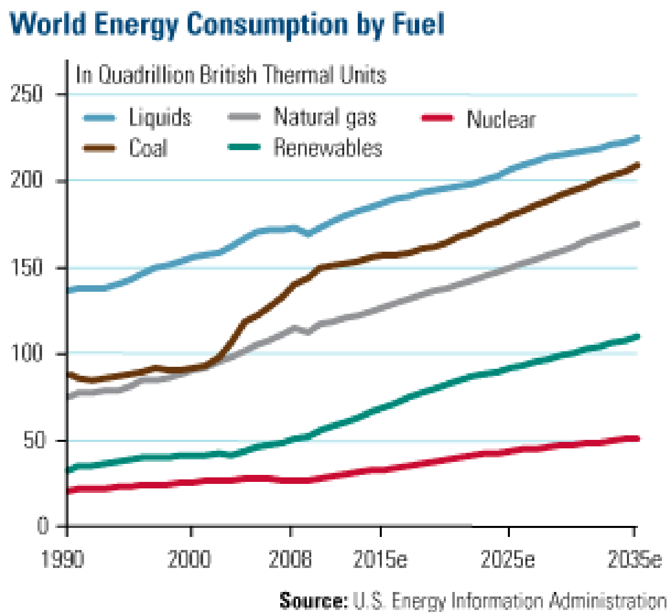


Figure 4: World Energy Consumption by Fuel Type

Fossil fuels currently are the most abundant, inexpensive and readily available sources of energy. However, EPA regulations require coal, oil and natural gas production facilities to comply with strict environmental policies to reduce climate impacts. Compliance with these regulations requires and will in future continue to require significant equipment modification and financial investment in the existing and future power generation infrastructure to reduce impacts on the environment.

For example, the Big Bend Electric Power Station owned by TECO Electric in Ruskin, Florida modified its coal burning facility with flue gas desulfurization systems, combustion modifications and electrostatic precipitators that eliminate 95% of sulfur dioxide (SO_2) and reduce nitrous oxide (NO_x) GHGs by 80%.[11] However, they still release about the same amount of CO_2 as traditional facilities. Responding to similar environmental concerns, the Isogo ultra-supercritical coal thermal power station in Yokohama, Japan demonstrated several technological advancements to reduce CO_2, SO_2 and NO_x. However, while these new innovations eliminate 98% of SO_2 and NO_x, they only reduce CO_2 emissions by 17% compared to non-ultra supercritical facilities. In comparison, the U.S. is hesitant to invest in ultra supercritical plants because of the cost associated with new facility construction and lack of confidence in the technology to meet the new stringent U.S. regulations for CO_2 emissions.

In contrast other fossil fuels such as natural gas and oil produce fewer emissions adverse than coal. For example, "Natural gas has a lower carbon intensity than other fossil fuels, releasing approximately 40 percent less carbon dioxide (CO_2) than coal and 33 percent less than oil when combusted." (See Figure 5)

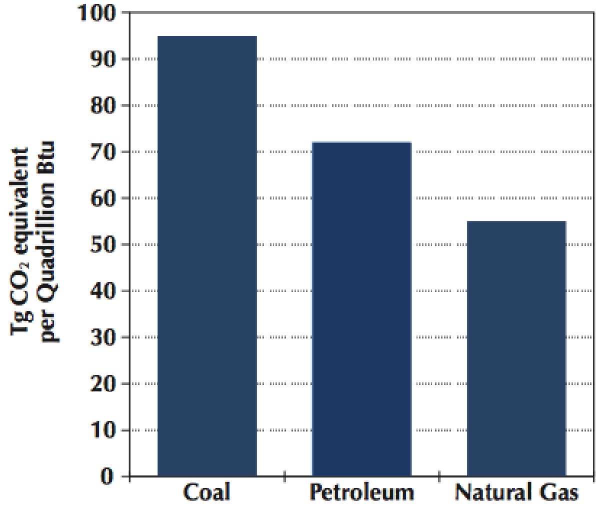


Figure 5: GHG emissions of Coal, Oil and Natural Gas

However, new methods of extracting natural gas such as hydraulic fracturing, or "fracking", require enormous amounts of fresh water which remains contaminated after use. "Fracking requires over 4.4 million gallons of water to drill and fracture one shale well, the equivalent quantity of water that 11,000 U.S. families use every day."[12] In addition to potential ground water contamination, fracking may also release harmful methane and other non-GHG toxins. Methane, extracted from shale gas fracking, may be the most harmful GHG because it "is far more effective at trapping heat in the atmosphere than is carbon dioxide, and so even small rates of methane emission can have a large influence on the greenhouse gas footprints."[13]

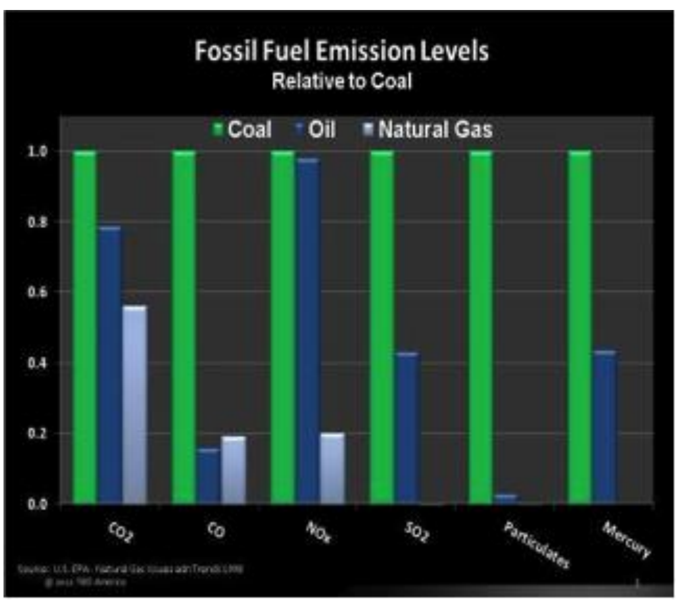


Figure 6: Fossil Fuel emission levels relative to Coal

While oil processing and consumption in power generation produces significantly less particulate matter and other harmful byproducts than coal, oil still produces significant GHG emissions compared to natural gas (Figure 6). In addition, past oil spills from transportation and drilling accidents have significantly and adversely impacted the environment such as the 15 car train derailment in Lynchburg, Virginia in 2014 where 50,000 gallons of oil spilled into the James River and the BP Horizon off-shore well disaster of 2010.

Renewables

In the face of diminishing fossil fuel resources and continuing climate change, the world's future energy consumption must include a significant amount of renewable energy. The U.S. must lead the way in innovation and technology development, capitalizing on a healthy market for renewable energy and a growing appetite for cleaner energy sources.

Renewable energy is abundant, clean, safe and sustainable. The leading renewable energy technologies in the U.S. include wind, solar, geothermal, biomass, and hydro. According to latest Energy Information Agency (EIA) statistics, renewable energy, including hydro, comprised 19% of the energy portfolio in the U.S. for 2014.[14] Additionally, more than half of the states enacted renewable energy portfolio standards to integrate and expand opportunities for renewable energy. This commitment to increasing renewable energy usage at the state level significantly reduces CO_2 emissions. By 2025, state standards will reduce total annual CO_2 emissions by more than 183 million metric tons, the equivalent of taking 30 million cars off the road or planting a forest large enough to cover the entire state of Washington.[15] A recent report, "Energy Revolution: A Blueprint for Solving Global Warming" details an energy scenario where nearly 80% of U.S. electricity can be produced by renewable energy sources. In addition, CO_2 emissions can be reduced 50% globally and 72% nationally without increasing nuclear power or new coal technologies. Furthermore, America's oil consumption can be reduced by more than 50% by 2050 with more efficient cars and trucks, an increased use of biofuels and a greater reliance on electricity for transportation.[16]

The advantages of renewable energy are numerous; especially because of its clean nature. Renewable energies are infinite in their supply, consume very little water as compared to fossil fuels and release no toxic byproducts. During a recent visit to the National Defense University, a representative from the American Wind Energy Association, noted that expanding wind energy use in the U.S. reduces water stress and carbon emissions (Figure 7). Renewable energy use on a large scale will improve the environment and potentially slow the effects of climate change.

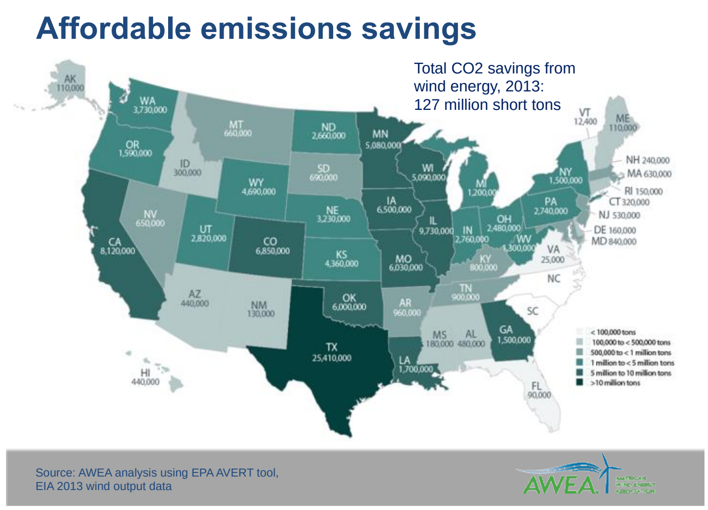


Figure 7: Affordable Emissions Savings from Wind

Despite the advantages of large scale use, renewable energy faces challenges that must be overcome to realize its full potential. Renewable energy, particularly wind and solar, are intermittent. Geographic location, terrain, time of year, time of day and local weather impact the availability of power output. A technology break-through in utility-scale electrical energy storage would allow utilities to balance intermittent renewable energy generation and requirements.[17] This storage challenge is a critical disadvantage of renewable energy that must be overcome for it to become a viable alternative to traditional power generation technologies.[18] Intermittency in power output causes frequency and voltage to fluctuate. Storage can smooth these fluctuations to help maintain power quality, improve grid performance and transmission overall.[19] Renewable energy production is expensive due to its high equipment costs and the need for large scale sites. Wind and solar farms require substantially more land to produce the same level of energy output than coal, gas and nuclear facilities.

Many opportunities exist for the development and utilization of renewable energy technologies. In a visit to the Eisenhower School, Scott Sklar, the founder and president of the American Council on Renewable Energy, provided many examples of net zero facilities and communities that provide their own electricity from numerous varied renewable energy sources. He explained that 32 states can meet all their energy needs with renewable energy using technologies we have today. Another visitor, from the National Hydropower Association, purported that currently only 3% of the 80,000 U.S. dams currently generate electricity and that there is significant room for growth. Urban applications of small scale renewable energy technologies like wind and solar also remain untapped. The innovative spirit, the seminar observed at the Solar Living Center in Sonoma County, California demonstrates the U.S. appetite to find more opportunities for renewable energy.

Nuclear Energy

Nuclear power remains the cleanest and most efficient means of producing electricity today. Lifecycle greenhouse gas emissions of coal and natural gas power plants far exceed that of a nuclear power plant, respectively.[20] Currently representing 19% of the electricity generating capacity in the U.S., the 62 plants produce 789 Gigawatt (GW) hours of electricity.[21] Nuclear power plants produce negligible greenhouse gas emissions such as carbon dioxide (CO_2), sulphur dioxide (SO_2) or nitrogen oxide (NO_x). In the Scientific American, noted University of Colombia Climatologist, James Hansen stated that nuclear power plants "avoided 64 billion metric tons of greenhouse gas pollution."[22] In the near and long-term, nuclear power is the largest producer of constant and clean electricity.

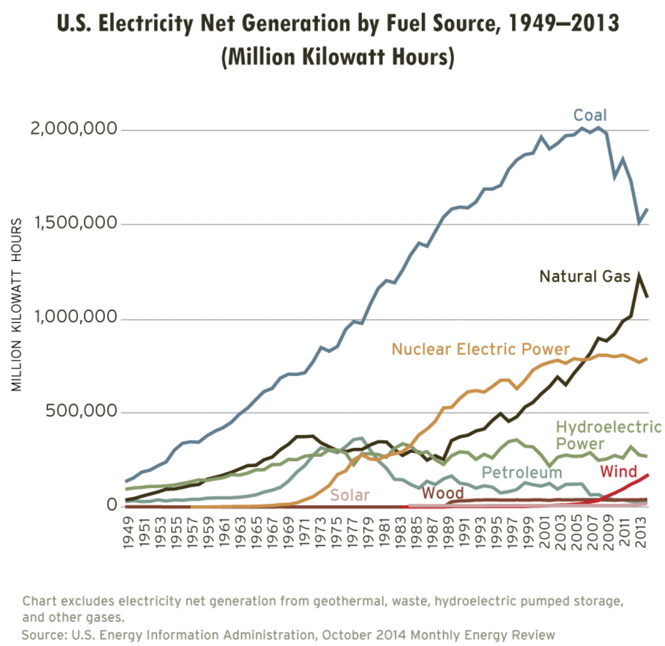


Figure 8: U.S. Electricity Net Generation by Fuel Source

Nuclear power does not come without downsides. "Critics of nuclear power cite the potential environmental impact of accidents at nuclear reactors ranging from a catastrophic meltdown of a reactor core to minor accidents that release relatively small amounts of radioactivity into the environment."[23] In fact, few people understand that what is coming out of reactor cooling towers is only harmless condensate water. Although changing, nuclear power still invokes emotional responses and memories of Chernobyl and, more recently, the disaster at the Fukushima-Daichi plant in Japan.

Prior to the Great East Japan Earthquake in 2011, Japan used nuclear power for 30% of its electricity needs with plans to expand to 40% by 2017.[24] During a recent visit to the Hamaoka Nuclear Power Station the seminar had an opportunity to view one of Japan's 54 plants, previously shut down in order to complete new tsunami and seismic mitigation measures. Although not damaged during the earthquake, Chugu Electric, complied with government requests, suspended operation and built a 22-meter sea wall, increased cooling water capacity, improved backup power generation and effected other improvements. When asked, the plant's operators contend their plant was never in danger and could begin providing clean power to Japan immediately. Since the earthquake, Japan greatly increased their natural gas power generation capacity to make up for the sudden loss of their nuclear infrastructure. This increase resulted in Japan developing a large trade deficit as they were forced to import more natural gas on the spot market. Their electricity prices have risen by 18%[25].

An indirect result of the shutdown of all nuclear plants, the emissions problem in Japan worsened. At the Warsaw Climate Change Meeting in November 2013, Japan's foreign minister was forced to change Japan's emissions projections. Instead of reducing 25% from 1990 levels, they now expect an increase of over 3% in CO_2 emissions.[26] Even worse, "[a]bout 100 million tonnes per year more CO_2 is being emitted than when the reactors were operating, adding 8% to the country's emissions. Emissions from electricity generation accounted for 486 Mt CO_2 (36.2%) of the country's total in fiscal 2012, compared with 377 Mt (30%) in 2010.[27] Figure 9 shows the dramatic rise in GHG emissions since they suspended all nuclear plant

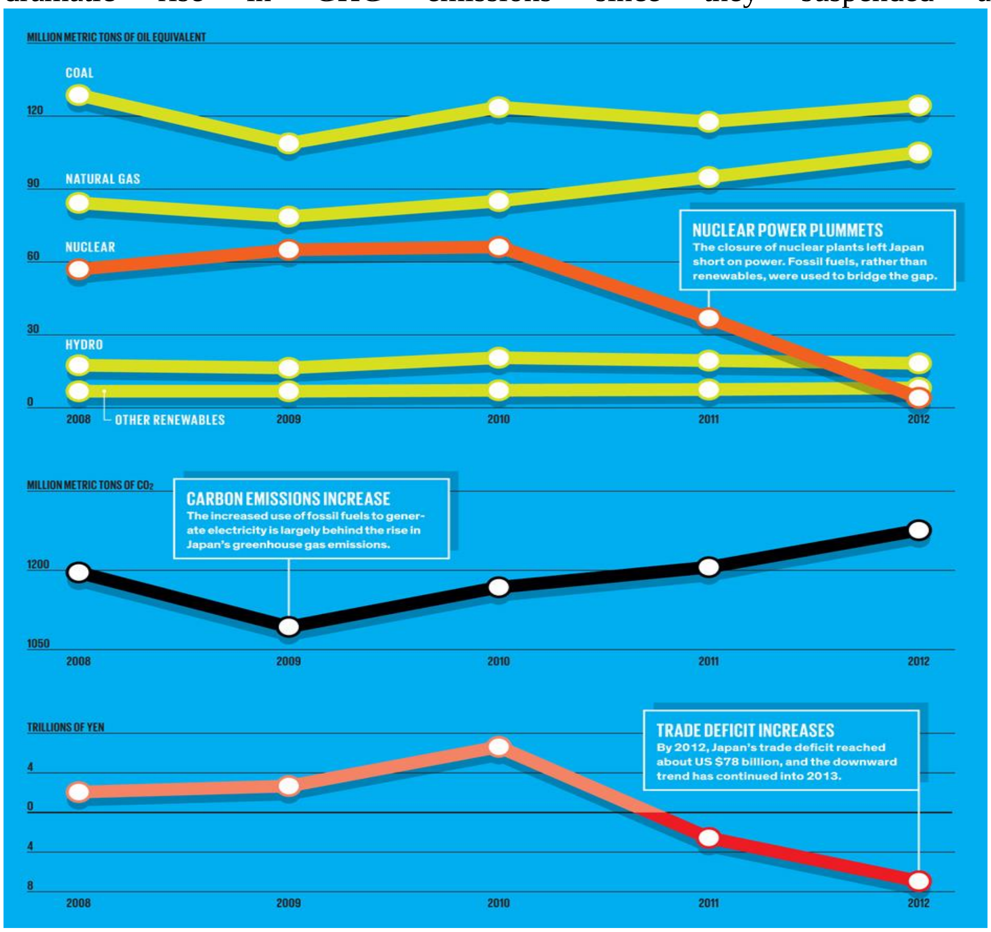


Figure 9: Japan's energy consumption and carbon emissions[28]

operations and increased the number of thermal coal and natural gas power generation plants.

The fuel used in nuclear reactors is radioactive before, during and after its use. Accidental release into the atmosphere, water supply or food system could result in genetic mutations, cancer, environmental disaster, sickness and death. Every 18 to 24 months operators remove spent fuel rods and place them in either in cooling pools that are designed to prevent the release of radioactivity or lead-lined dry storage containers. Handled properly, they do not pose a risk to the environment and surrounding population. By law, the U.S. Federal Government must manage the disposition of all spent nuclear fuel. However, until the Yucca Mountain site is approved or an alternative storage facility is identified, plant operators must store spent fuel on-site and under tight controls.

According to statistics managed by the World Nuclear Association, since 1950 there have been fewer than 100 deaths attributed to nuclear accidents. This is fewer than coal, where mining alone averaged in excess of 10,000 deaths globally each year.[29]

> "There have been three major reactor accidents in the history of civil nuclear power – Three Mile Island, Chernobyl and Fukushima. One was contained without harm to anyone, the next involved an intense fire without provision for containment, and the third severely tested the containment, allowing some release of radioactivity. These are the only major accidents to have occurred in over 15,000 cumulative reactor-years of commercial nuclear power operation in 33 countries."[30]

The current administration's emphasis on green and renewable energy sources presents a great opportunity for the nuclear power industry. During a speech at Georgetown University, President Barack Obama stated that "[s]omeday, our children, and our children's children, will look at us in the eye and they'll ask us, did we do all that we could when we had the chance to deal with this problem and leave them a cleaner, safe, more stable world?"[31] Now is an appropriate time to reinvest in nuclear and capitalize on the safer, cleaner and more efficient nuclear power technologies.

The interest in clean energy remains global. A United Nations based organization, the Intergovernmental Panel on Climate Change (IPCC) and the "leading international body for the assessment of climate risk, issued a desperate call for more non-emitting power sources."[32] The IPCC estimates that the world needs to "aggressively expand its sources of renewable energy, and it must also build more than 400 new nuclear reactors in the next 20 years."[33] The U.S. and China have agreed to significantly reduce their carbon emissions by 2020. However, currently, U.S. corporations are not be able to build enough wind turbines, solar farms or hydroelectric power plants given current power generation rates and costs associated with these energy sources.

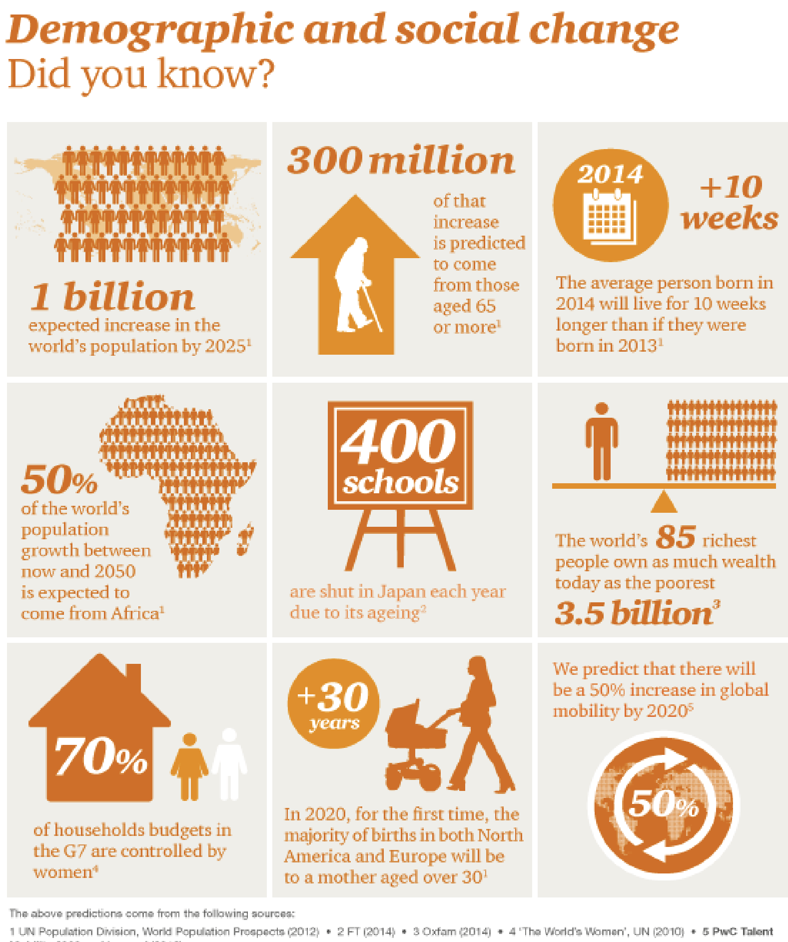
One of the biggest threats to the development of new or expanded nuclear power plants is the economic factor. It costs, on average, between $5-7 billion and requires 10 years to complete a current generation large reactor with a power generation capacity of 1000 Mw.[34] This is not insignificant. The lower cost per kWh of natural gas and coal is 40-60% less, but much more polluting.[35] Long-term health and environmental costs are not factored in to these cost estimates. The U.S. must determine if it is economically viable to build new nuclear power plants at such high capital costs. Also, based on current DOE policies, nuclear is considered a non-renewable source and does not benefit from clean energy initiatives and subsidies that promote the adoption of solar, wind and hydro.

Conclusion

Climate change and the deterioration of our air, land and water will occur rapidly and may accelerate out of control without aggressive, deliberate action. We must reduce or eventually minimize the impacts of fossil fuel energy sources and transition to a cleaner, renewable energy infrastructure.

The Environmental Protection Agency, the Department of Energy, and the Obama Administration set some goals, standards and guidelines in a Climate Action Plan in order to reduce carbon pollution and other GHGs. However, they stopped short of passing and enacting laws and regulations in order to achieve the necessary impacts. This seminar supports the Climate Action Plan, but provides additional suggestions towards a more aggressive and rapid transition and investment towards renewable and nuclear energy sources which are published in Appendix A.

SOCIO-ECONOMIC



The effects of social and economic changes today significantly impact the energy industry now and into the future and are closely linked with the effects on the climate and environment. As demographics shift, the world's population is estimated to increase by one billion people by 2025, increasing the total global population to approximately 8 billion. Compounding this global population growth, people in developed societies are also living longer and having fewer children. Consequently, the fastest growing segment of these populations is over the age of 65. Conversely, in developing nations, the life expectancy is relatively low but birth rates are high, making their median age much lower. For example, Africa's population is estimated to double by 2050, while Europe's will shrink. In Japan, the average age will be 54 in 2050, but only 21 in Nigeria.[36] Increasing populations in Africa are both a blessing and a curse – a blessing in that labor pools can be readily augmented, a curse in that the growing population will place additional strains on infrastructure that already suffers from a lack of energy resources.

Urbanization must be considered in any discussion of demographic changes. The recent growth of cities across the globe has been unprecedented. In 1800, 2% of the world's population lived in cities. Today it is 50%. Every week, approximately 1.5 million people move to the cities via migration and birth.[37] Major factors affecting social and economic change are shifting demographics, including an aging, and expanding population and urbanization.

From an economic megatrend perspective, global economic power appears to be shifting from developed to developing countries. This shift is a result of comparative growth rates of the economies of the developed G7 nations (US, Japan, Germany, UK, France, Italy, Canada) and developing E7 nations (Brazil, Russia, India, China, Indonesia, Mexico, Turkey). In 2009, the combined gross domestic product (GDP) of the E7 was approximately two-thirds that of the G7. Some estimates show these positions being reversed by 2050, with the E7's total GDP increasing to almost double that of the G7.[38] Regardless of these shifts, the concept of globalization and economic interconnectedness will remain key components of all countries' economies moving forward.

What do these social and economic trends portend for the energy industry? An aging population will place downward pressure on the size of the labor pool supporting the energy industry in developed nations, including the U.S. A growing population, primarily in developing countries, will place much more demand on energy production efforts and increased strain on the energy distribution infrastructure. As population densities shift and change, energy requirements must similarly shift and change to accommodate the demographics. In some areas, population growth will remain flat, or even decrease. In other areas, to include cities, increasing populations will strain existing energy infrastructure unless significant changes and modifications to the infrastructure are made.

A key challenge is the accommodation of both energy demand and development. The increased demand based on increasing population is a relatively straightforward dynamic. However, the development issue centers on the forecast that a significant amount of population growth will occur in developing countries. In these countries, technological advances in energy may be difficult to achieve and may well be unaffordable.

On the economic front, much of the increased growth in the developing countries will require ready access to energy resources. Industrialization, transportation, and importation of energy sources (such as oil, coal, LNG) will be primary drivers behind energy demand. To facilitate the developing countries' growth, affordable and readily available access to energy becomes paramount. With economic globalization becoming even more prolific moving forward, the economies of all countries, and hence the global economy, become more reliant on secure and ready access to energy. Obtaining natural resources and generating energy will not be an individual country's effort. It must be a collaborative endeavor in order to access and develop energy resources, and then produce the energy required to sustain and build economies. These trends are significant for the U.S., as much of the emerging technology in renewable energies originates in America. The U.S. will also continue to be a primary exporter of coal and LNG to those countries that need these resources. Pending a change in policy, the U.S. can also be a major exporter of crude oil.

Another important aspect of energy from an economic standpoint is the viability of exploration, production, and research and development efforts tied to the price of the respective commodities. If pricing is high, the incentive for exploration and production is high. If pricing is low, the opposite occurs. Regarding proposals to shift from fossil fuels to renewable sources, domestic economic issues including capital-intensive startup or transition costs associated with renewables, and the comparative low cost of fossil fuels further diminishes the incentive to switch to renewables. While oil and gas prices remain low, there is significant incentive to continue using those sources of energy, and less motivation to optimize renewables and nuclear.

Non-renewable energy sources provide a stable and relatively inexpensive base load to satisfy energy demands until the renewables and storage technologies come on line in a reliable, economical manner. Table 1 shows the projected average values of levelized costs for generating technologies that are brought online in the U.S. in 2019.[39] Levelized cost of electricity (LCOE) is a measure of the overall competiveness of different generating technologies that represents building and operating costs over the lifetime of a generating plant. It includes capital costs, fuel costs, fixed and variable operations and maintenance costs, financing costs, and an assumed utilization rate for each plant type. Government subsidies reduce the costs of solar, advanced nuclear and geothermal technologies. Less expensive sources include conventional coal and natural gas.

With increased population and energy demand, the U.S. will need additional energy resources. Fortunately, the current U.S. energy infrastructure is quite robust, and is poised to incorporate additional moderate energy requirements with some modifications, such as new pipelines and grid upgrades. Additional energy will be derived from renewable sources and added

U.S. Average LCOE (2012 $/MWh) for Plants Entering Service in 2019

Plant Type	Capacity Factor (%)	Levelized Capital Cost	Fixed O&M	Variable O&M (including fuel)	Transmission Investment	Total System LCOE	Subsidy[1]	Total LCOE including Subsidy
Dispatchable Technologies								
Conventional Coal	85	60.0	4.2	30.3	1.2	95.6		
Integrated Coal-Gasification Combined Cycle (IGCC)	85	76.1	6.9	31.7	1.2	115.9		
IGCC with CCS	85	97.8	9.8	38.6	1.2	147.4		
Natural Gas-fired								
Conventional combined Cycle	87	14.3	1.7	49.1	1.2	66.3		
Advanced Combined Cycle	87	15.7	2.0	45.5	1.2	64.4		
Advanced CC with CCS	87	30.3	4.2	55.6	1.2	91.3		
Conventional Combustion Turbine	30	40.2	2.8	82.0	3.4	128.4		
Advanced Combustion Turbine	30	27.3	2.7	70.3	3.4	103.8		
Advanced Nuclear	90	71.4	11.8	11.8	1.1	96.1	-10.0	86.1
Geothermal	92	34.2	12.2	0.0	1.4	47.9	-3.4	44.5
Biomass	83	47.4	14.5	39.5	1.2	102.6		
Non-Dispatchable Technologies								
Wind	35	64.1	13.0	0.0	3.2	80.3		
Wind – Offshore	37	175.4	22.8	0.0	5.8	204.1		
Solar PV[2]	25	114.5	11.4	0.0	4.1	130.0	-11.5	118.6
Solar Thermal	20	195.0	42.1	0.0	6.0	243.1	-19.5	223.6
Hydroelectric[3]	53	72.0	4.1	6.4	2.0	84.5		

Table 1: Estimated levelized cost of Electricity (LCOE) for new generation resources, 2019

carbon-based energy. In the US, oil is used primarily for transportation since most combustion engines require a petroleum-based fuel. Additional pipeline capacity is needed for less expensive and less hazardous transport compared to rail or roadway. America has a network of existing pipelines that is slated for upgrade to meet the future demand for liquid fuels generated and refined in the U.S. Today's electrical grid provides reliable power to over 300 million Americans. In order to meet increasing demand and expanded use of distributed generation, supporting emerging technologies and increasing resiliency and upgrades will be necessary.

Energy from solar is plentiful. It produces no GHGs and solar energy generation reduces waste heat that is common in conventional fuel generation. Distributed Solar PV will help build greater resiliency into the grid, especially with a diversity of power sources closer to consumers. The growth in renewable energy sector requires a new set of skills for installation, operation and maintenance and promotes job growth. In the U.S., and especially in California, trained solar energy technicians are quickly employed.[40] In poorer countries, accessible, affordable and reliable energy has helped to raise the standard of living. Harnessing the sun's energy has improved several areas of rural non-electrified communities including electrification, hot water, solar cookers, and desalination plants to produce fresh drinking water. Barefoot College, a non-governmental organization, teaches men and women to fabricate, install, use, repair and maintain sophisticated solar units through basic knowledge and hands-on training[41]. Even at a small scale, broadening the implementation of residential and commercial solar PV can create employment for people with little education.

As urbanization continues, existing energy infrastructures in U.S. cities will be challenged to support such growth. To that end, significant infrastructure improvements must be made to accommodate the migration shift. Poverty continues to be an important aspect of the energy discussion. Energy consumption patterns and the public's limited access to energy tend to exacerbate poverty. Poverty alleviation depends on widespread access to energy resources that are affordable, reliable, and of good quality.[42] This will certainly prove a challenge in developing countries. Where and to what extent the U.S. supports these efforts will remain an energy planning factor.

Within this context looms the discussion of alternative energy sources, particularly wind and solar. As the populations of poor and developing countries expand, they will look for additional sources of energy. Fossil fuels provide the cheapest source of energy. Renewables are characterized by significant initial capital investment. The populations of these countries don't necessarily care what the energy source is or the amount of pollutants emitted. Their primary desire is reliable access to electricity. Therein lies the dilemma. Developing countries will use the cheapest forms of energy and power generation at their disposal. For the foreseeable future, more affordable fossil fuels will best satisfy their energy consumption requirements. So, while many pine for expanded use of renewables, economic realities may preclude their implementation in the developing world.

Another issue, or weakness, from an economic perspective is the volatile and dynamic nature of global energy markets. This can best be seen on the world stage with the dramatic downturn in oil prices over the past 12 months. The market is very susceptible to the actions of a few, and nowhere is this more apparent than with the Organization of the Petroleum Exporting Countries' (OPEC) ability to drive the market. All eyes turned to OPEC in November 2014 to see how they would adjust production levels in response to rapidly plummeting oil prices. This factors into the discussion of the rise of national or state owned oil companies. As national oil companies become more substantial participants in the global oil market, their ties to countries that might not be aligned with U.S. interests becomes a greater concern. In essence, the actions of only one player can have significant ripple effects on energy markets. It is in this vein that U.S. energy independence and its associated positive impact on national security comes to the forefront of the energy discussion.

In recent years, advancements within the energy industry resulted in an annual increase of at least 0.3 percentage points in the U.S. GDP.[43] The U.S. is now postured to become a net energy exporter. The shale and fracking renaissance continues despite the dramatic decrease in oil and gas prices globally. As seen at the Cheniere LNG facility in Sabine Pass, Louisiana, several LNG import facilities are being retrofitted for export. Trade partners such as Japan, who have an increasing appetite for more LNG, eagerly anticipate access to less expensive and more secure American LNG. The shale fracking renaissance has also enabled the U.S. to gain access to significant oil reserves. Should this oil be made available for export, the U.S. economy could further benefit. The net effect will be enhanced U.S. national security, increased U.S. influence with trading partners, and a major boost to the American economy.

Studies indicate "coal exports are estimated to grow 1.8% annually from 2010 to 2035, reaching 129 million tons of coal (11% of total U.S. production) in 2035."[44] The increase in coal mining will domestically create more jobs in mining and all related industries. New "clean coal technologies" result in dramatic reductions of SO_2, NO_x, CO_2 and other undesirable pollutants. But this comes at significant cost, changing the levelized cost of coal from one of the cheapest sources of energy to one of the more expensive. J-Power's Isogo Coal Power Station in Yokohama, Japan demonstrated how clean modern plants can truly be, as it operates near the city center and within plain sight of most of Yokohama city.

Continued R&D is expected to make future clean coal technology affordable. Even if coal is eventually phased out of use in the U.S., it will continue to be heavily used in the rest of the world where environmental regulations may not apply or may not be as restrictive. Developing cost effective "clean" technology that can be exported to other locations will lessen the environmental impact of burning this abundant and available and cheap fossil fuel. If coal is going to be burned for making power, it should be used in the cleanest and most responsible way. The U.S. is one of the very few countries with the resources to invest in clean coal technologies, and Americans have the opportunity to lead developing nations in the effort to reduce GHGs while increasing energy production and availability.

Renewable energy sources, notably wind and solar PV, have made tremendous technological progress in the past decade, and their real-world market penetration has been particularly significant. Companies specializing in renewable energies receive generous federal loans, which helped the design and manufacture of these technologies. Federal, state, and even municipal financial incentives motivated commercial and residential consumers, and even power companies, to install widespread solar PV and windmills. High gas and oil prices provided additional motivation for the market to seek alternative means to generate electricity.

The situation is changing, and the solar and wind markets now face an uncertain future. First, oil now costs less than half of what it did as recently as last year and appears likely to remain at low prices for the foreseeable future. Furthermore, the incentives provided by state, municipal and particularly Federal tax credits are being reduced and, are expiring without being renewed in many cases. The Federal Residential Renewable Energy Tax Credit is at risk of not being continued past 2016. Federal investment in renewable energies, particularly those investments that were part of the economic stimulus in the American Recovery and Reinvestment Act of 2009, dramatically slowed and were also publicly tarnished with the high profile bankruptcy of Solyndra. Residential and commercial utilization of solar PV will also be challenged to accommodate expanded utilization in urban environments as a result of population growth. Collectively, all of these new circumstances will likely dampen investment and slow technological development and market application.

While the future for solar and wind energies appears cloudy based on a forecast of uncertain incentive, they will definitely continue to play an important role in the portfolio of electrical power generation in the U.S. and will continue to grow and expand, albeit at a lower rate. Utility companies struggle daily and seasonally to manage dynamic loads and must have a stable source of on-call power to quickly handle these changes. The development of utility-scale energy storage is needed to ensure wind, solar and other renewables reliably contribute to meet electricity demand. This necessary energy storage capacity is currently not technologically feasible or available. As coal plants reach retirement age, affordable and large scale storage will be necessary to accommodate increased demand with reduced generation capacity. Therefore, the reliance on nuclear and fossil-fueled plants will not and cannot be offset by use of these renewable energies until the aforementioned challenges are overcome.

Coal has been a primary source of energy in the U.S. for years, but is suffering from an apparent “war on coal.” Emission requirements levied against coal plants are nearly impossible to achieve in a cost effective manner. Coal plants that come up for re-certification and are unable to install “clean coal” technologies that are efficient and clean enough to meet increasingly restrictive emissions standards, may be at risk to be closed permanently. Even the newest and “cleanest coal” generating plant in Japan, the J-Power Isogo plant, would fail to meet some EPA standards.

Similarly, there has been a resistance to building nuclear power plants for decades. The disaster at Fukushima Daiichi nuclear power plant following the Great East Japan Earthquake in 2011 not only caused the immediate suspension of all nuclear power plants in Japan, Germany followed suit and permanently shut down eight of its 17 reactors immediately and accelerated the phase out of all remaining reactors. In 2012, the Vogtle nuclear power plant in the state of Georgia was the first new nuclear power plant approved for construction by the Nuclear Regulatory Commission in over 30 years.[45] Also in 2013, the San Onofre Nuclear Generating Station in California suffered from material deficiencies and was shut down after going through extensive and expensive repairs that began in 2010. The owner, Southern California Edison, was unable to get the Nuclear Regulatory Commission (NRC) to approve repair measures, suffered from massive lost revenue while indefinitely waiting to re-start, and ultimately succumbed to political pressures to remain shut down.[46] Besides being expensive to design, engineer, build and operate, the nuclear power industry, as highlighted in the previous section on climate change and environment, has large public and political resistance to overcome.

Conclusion

While there are multiple social and economic factors that prove important on the energy front, there are specific actions that contribute to this paper's overarching policy recommendations moving forward. These recommendations are captured in appendix A. What is clear is that future social and economic changes will significantly impact the energy industry. It is important that these trends and developments become integral planning elements in any future energy deliberations and development.

The Socio-Economic megatrend discussion identified and addressed demographics, urbanization and economic shifts. It is important the U.S. Government and the energy industry take these issues into consideration and understand their impacts on energy in the future. Socio-economic change is happening now. Understanding the impacts sooner rather than later will allow for the accommodation, or mitigation, of the consequences of these dynamic global changes.

TECHNOLOGY AND ENERGY

In recent years, society has benefited from fundamental and significant advances in technology. These advances are coming faster than ever and are being quickly adopted throughout our economy, influencing the composition and direction of virtually every major industry. A notable aspect of this megatrend has been the increasing importance of the digital realm as a major focus of technological advancement. Looking ahead, this progress will continue. but in unexpected ways and likely at an unanticipated speed.

Nowhere is this technology megatrend more evident than in the energy industry where recent technological breakthroughs opened new frontiers for energy exploration and extraction. Examples include new techniques for harnessing and finding energy sources such as hydraulic fracturing and satellite monitoring for locating new fuel sources. These advances often marginalize some legacy energy technologies, when improvements in information technology and the shift of economic power to the digital realm help create efficiencies in energy consumption.

Strengths

Technology has played a major role in revitalizing the U.S. energy sector. The real cost of producing a unit of energy continues to decline while the variety of possible sources continues to expand thanks to new production and generation processes. For example, the cost of solar PV panels dropped by 60% on a per watt basis in only two years from 2011 to 2013. [47] Wind turbine efficiency has skyrocketed with capacity factors more than doubling in the past ten years.[48] Over the last 35 years the distance an average car can travel on a gallon of gas has risen by over 50%.[49] Technology has helped make the energy sector a competitive advantage for the U.S. economy.

Many of the advances in energy technology were achieved through R&D that was either directly sponsored by the DOE or via the private sector; motivated in part by federal and state incentives. In an effort to spur research, the total estimated cost between 2013 and 2017 of tax-related provisions supporting the production of renewable energy (tax expenditures and grants designed to replace tax expenditures) is estimated to be $39.6 billion.[50] The DOE requested an additional $3.8 billion for fiscal year (FY) 2015, an increase of 8.3% over FY 2014[51] (Figure 10 shows a breakdown in DOE's Energy Research funding). Over the past 15 years, industry funding of R&D accounted for approximately two-thirds of all energy R&D in the U.S.[52] Government policy continues to be a significant driving factor in how and where the U.S. advances the frontiers of knowledge in energy technology.

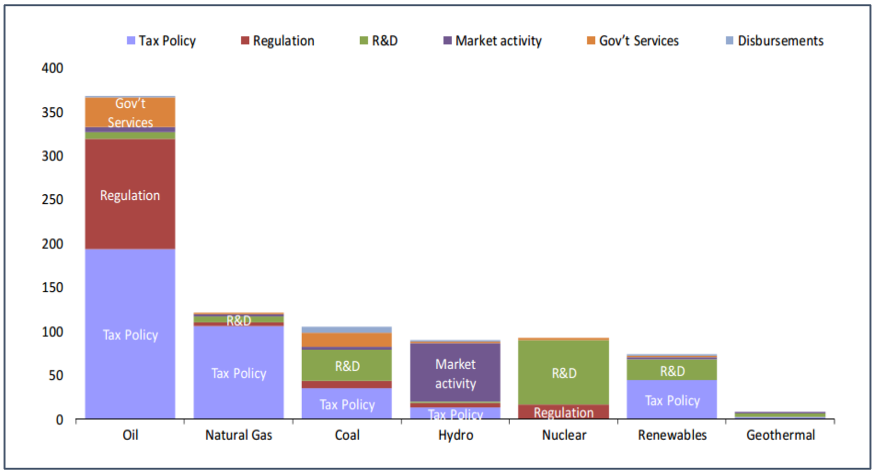


Figure 10: DOE Technology Cumulative Funding Totals (Billions of 2013 Dollars)

This new research enabled a number of key energy technologies that are transforming the US energy landscape. Hydraulic fracturing, which has benefited from this research, enabled the country to transition from being a net LNG importer to an LNG exporter and now the largest producer of crude oil and natural gas in the world. Another example is the evolution in the use of coal for generating electricity using emission reduction equipment and more efficient coal burning methods. Real world application of this technology was observed at the TECO coal plant in Florida and the Isogo plant in Yokohama, Japan permitting coal to be used in a more environmentally sound and affordable manner.

Other new technological developments illustrate the promise of an optimistic energy future. Technology is helping to make energy production more environmentally safe, economically viable and more readily available. America's national security and economic prosperity are both enhanced by pushing the limits on new energy sources for electricity production and transportation, as well as improving the electric grid reliability and resiliency. The U.S. Government is a contributing factor in the advances in energy technology but private sector's initiatives are the principal drivers. Technology advances garnered by corporations reduce their costs of energy consumption thereby helping them become better stewards of the environment. The American Energy Innovation Council is an example of the collaborative efforts by industry to share best practices and foster clean energy technology development.

Weaknesses

While technology advances the energy industry, it also increases system-wide vulnerabilities. The energy requirements of our economy have risen in recent years, due in large part to the progress and demands of technology and this, in turn, has magnified the impact of the energy sector on the economy. Widespread efficiency gains in the consumer market offset this effect, but do not erase it completely. In theory, a kilowatt not needed due to efficiencies is a kilowatt that need not be generated. However, the reality is that continued growth needs a lot more kilowatts.

The current electrical grid provides reliable service with moderate security and resiliency, but it is ill suited for accommodating emerging changes such as the increased use of distributed energy from microgrids and residential and commercial solar PV. Today's grid was built in piecemeal fashion over the past 100 years and was based on a centralized, one-way energy flow from large power generation facilities to local distribution systems via long, networked transmission lines. From a security perspective, the transmission grid is highly susceptible to physical attack. Power generation facilities, interconnections and regional transmission offices are susceptible to cyber attacks. The overall grid is also susceptible to severe damage from electromagnetic pulses and solar radiation events. System outages whether natural or man-made, can affect local, regional or national-level production and distribution.

The high upfront costs for installing renewable energy are an obstacle to its full implementation. Government incentives encourage R&D and installation of wind and solar via tax initiatives and subsidies. These incentives reduce the individual risk of transitioning to these new technologies. Several of these subsidies, however, are scheduled to sunset at the end of 2015 and 2016. Under the current constrained fiscal environment there is concern they will not be renewed, thereby negatively impacting the increased use of renewables. In addition, existing incentives can also lead to contradictory policy goals, such as tax credits for renewable energy along with regulations favoring utilities aiming to limit renewable generation.

Opportunities

Energy technologies will enable the U.S. to meet its energy goals if properly resourced. Improving energy efficiency makes the U.S. economy more competitive and reduces pollutant emissions (Figure 11). Continued technological innovation and improvement will be required to sustain this trend.

Perhaps the most significant technology in development is carbon capture and storage (CCS) which can capture up to 90% of the CO_2 emissions produced from the use of fossil fuels in electricity generation and industrial processes, preventing the carbon dioxide from entering the atmosphere. Coal is the world's most abundant and widely distributed fossil fuel; therefore technological advancements in capturing CO_2 are critically important.

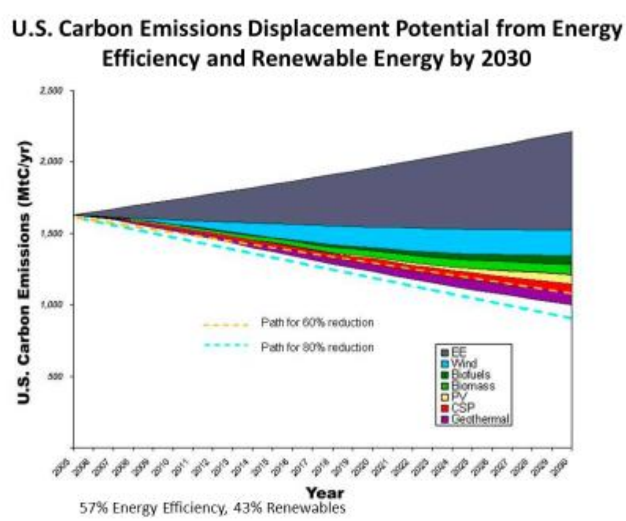


Figure 11: U.S. Carbon Emissions Displacement Potential from Energy Efficiency and Renewable Energy by 2030

Despite substantial federal subsidies for research and development, progress in developing cost-effective methods remains slow. Upcoming U.S. Government CO_2 emission limits will provide an added inducement to acquire this technology. Simultaneously, the government must develop policies that pique industry interests to begin early deployment of CCS systems.

As previously mentioned, the electrical grid is ripe for being updated with modern day technologies that improve system reliability, efficiency, security and resiliency. Rather than building in incremental solutions for each of these issues, they can all be addressed simultaneously as a new “smart grid” is built. The smart grid must be able to accommodate distributed generation and enable the grid to rapidly, automatically, and effectively deal with dynamic events, catastrophic attacks and variances caused by weather. One organization creating new opportunities is the DOE’s Advance Research Project Agency Energy (ARPA-E) an agency created in 2007 by the America Competes Act. Modeled after the DoD’s Advance Research Project Agency (DARPA), it is charged with funding and promoting advanced energy concepts and technologies. Currently, ARPA-E is expected to be a driver in finding low risk, high reward advances with projects ranging from improvement in batteries, electricity distribution and renewables among many other projects.

U.S. prowess in developing new technology to solve the nation's energy problems depends on a process of continual innovation. A critical building block of innovation is human capital, yet the U.S. is faltering on producing adequate numbers of scientists and engineers to maintain the current pace of technological advancement. While "the number of jobs in science and engineering is expected to surge in the years to come, close to 60% of the nation's students who begin high school interested in science, technology, engineering, and math, or STEM, change their minds by graduation.”[53] Vocational STEM training for installing, operating and maintaining new energy systems is also essential to the development and adoption of new technologies. The country should increase the efforts to incentivize young minds to invest their efforts in STEM and energy studies.

Furthermore, collaborating with international partners is an excellent means to advance energy technology. The DOE participates in a number of international collaborative endeavors such as the ITER Project,[54] a collaboration among seven international members working together in France to design, build, and operate the first international research fusion facility. The ITER Project aims to achieve a peak output of 500 MW thermal power, and is expected to provide the scientific and technical basis to proceed to a fusion demonstration plant.[55]

Threats

The threats posed by technology to the energy industry are diverse and can result from advancements of another form of energy or the way a particular energy source is incentivized or dis-incentivized. Existing policies and regulations on certain segments of the energy sector are a significant constraint on the adoption of some energy technologies. While a developing smart grid may solve many issues and improve the network, it could be increasingly vulnerable to crippling cyber attacks. Furthermore, there is an uneven approach to taking advantage of new energy technologies which distorts the U.S. energy market. For example, coal’s potential has been shortchanged by the technology revolution affecting renewable technologies. While renewables carry considerable promise, there has been a dearth of attention on how to effectively integrate their contribution with existing infrastructure.

Technology sometimes advances beyond human ability to manage or comprehend it. Incidents at nuclear power stations, notably Fukushima, Chernobyl and Three Mile Island, over the past 30 years have cost the industry a loss of public understanding and support in many countries' populations. Construction on all the 100 reactors now operating in the U.S. commenced by 1977 or earlier.[56] Even though regulatory permitting is being pursued for construction of several new nuclear plants, there is still widespread resistance to nuclear power.

Conclusion

The U.S. remains the pre-eminent global technological innovator in the energy sector. The lack of a comprehensive, thought out and conceived government policy on energy creates confusion, economic stress and distortions. As a result, innovation falls short of its potential. Moreover, some aspects of the national energy policy actually contradict each other as the Administration, Congressional and business priorities clash. The inevitable result is hesitation on the part of energy producers to develop and deploy new technologies to drive their business forward. America is unable to maximize one of our greatest inherent strengths.

A comprehensive energy policy and strategy would be a critical means to coordinate all sectors within the energy industry with government regulations. The energy sector is accustomed to change and is more influenced by world markets and events than most other sectors of the U.S. economy. Washington needs to devise policies that capitalize on inherent U.S. strengths in technology development and are consonant with other important policies designed to address environmental concerns and promote economic growth. A deliberate and comprehensive energy strategy can be a stepping stone to a more deliberate, thoughtful, and effective energy management and consumption system.

SUMMARY AND CONCLUSIONS

The U.S. is not insulated from the impacts these mega-trends present. The inertia of these mega-trends is pushing everyone and everything forward, creating opportunities and presenting threats previously unimagined. Climate change, socio-economic developments, and improved technology will affect all aspects of U.S. national interests. The impacts of these mega-trends on the American energy industry cannot be overlooked or avoided.

U.S. energy policy must shape the access, production, and development of a diverse set of energy options. The goal of having secure energy from environmentally responsible sources at reasonable costs should remain the hallmark of the U.S. energy industry. As reserves of coal, oil and natural gas diminish, market dynamics will be a powerful force moving companies currently founded on fossil fuel development toward renewable energy sources. Comprehensive and focused government intervention is required to guide the industry and markets where companies relying on lower cost and well-established network of fossil fuels for steady profits and shareholder dividends begin the move to renewables sooner. Market forces are not as responsive to environmental concerns as international opinion and scientific concerns might warrant.

Appropriately targeted subsidies and incentives may be needed to push energy related companies to a quicker transition to cleaner energy while allowing them to keep consumer energy costs at an affordable level. Thoughtful actions initiated today can make these goals a reality tomorrow. The policy recommendations that follow can put the U.S. on a path towards achieving this future.

Recommendations

Without a concerted, organized and integrated plan to ensure America continues to have access to secure, affordable energy in an environmentally responsible way, we cannot realistically expect the energy industry to collectively move in this preferred direction. The following recommended actions, along with the specific recommendations in appendix A, should be included in U.S. energy policy:

1. Continue to increase electric power production from renewables. Implement a series of goals, with an associated incentive structure, to wean the energy industry from fossil fuels and encourage development of economically viable and nationally available renewable energy sources. Specific actions should include setting increasingly higher mile per gallon standards and placing tighter GHG emission standards on fossil fuel fired power plants, eventually reaching a goal of zero emissions. The rate at which emission restrictions are tightened should be tempered by the rate of affordable technological advancement in "clean" energy production capability. Further develop and implement "clean" technologies for use on existing and new power plants that use fossil fuels - remaining mindful of the finite nature of these fuel sources. Increase use of nuclear energy (from fission today to fusion, when available) as a bridge to ease this transition. This will help meet base load electricity needs while applying incentives to energy storage capability development to fill the production gaps inherent in power from wind and solar.

Enacting this policy will allow Americans to retain access to and employ a diverse portfolio of energy sources. The use of renewable energy will gradually increase and environmental impact of power production will continue to be minimized. Doing this will position the U.S. as the leader in a cleaner energy future where American industry will garner economic benefits from the transfer of clean, efficient energy technology to other countries.

2. Restructure existing subsidies within the energy industry. Redirect funding to public and private research and development initiatives to improve efficiency and environmentally friendly technologies. This will extend the life of existing fuel sources and enable the movement to greater use of renewable energy sources. Ultimately improving the security and reliability of the nation's electric grid as well as enable energy sources to compete more equitably and accelerate access to new capabilities.

3. Remove regulatory impediments to crude oil export and domestic transport and trade of energy-related products. Taking a free market approach such as this will reduce unnecessary costs associated with the energy industry and promote national economic growth. This would include repealing restrictions on shipping associated with the Jones Act, permit the export of domestically produced crude oil and other fossil fuels, and remove barriers to the flow of energy related resources across the Canadian and Mexican borders, including the completion of the Keystone XL pipeline.

Freeing the U.S. energy industry from restrictive export laws, and reducing costs associated with moving energy resources within U.S. borders will help America keep energy costs affordable for its citizens and allow the business of energy to better compete in global markets. Recanting regulations like the Jones Act will face resistance by certain special interest groups and sectors but is in the best interest of the country. Building national consensus and support for initiatives that give the U.S. a competitive advantage and that improve the quality of life for all Americans can help overcome this resistance.

4. Work with the Department of Education, state governments and other education stakeholders to promote STEM programs to help develop a steady and reliable pool of employable personnel that possess the requisite knowledge and skills necessary to help develop, engineer and operate all components of the energy sector on a continual basis.

This is a long-term effort with potentially long-term benefits. Changing the landscape of the American education system will be neither easy nor quick, but change is needed. Encouraging greater participation and achievement in STEM related subjects is critical if America is to continue enjoying the innovative spirit and know-how necessary to take it through the 21st century and beyond.

5. Establish an energy efficiency and awareness campaign, under DOE oversight, to educate the American people on energy-related policies and programs and how these actions will improve U.S. national security and wellbeing. This campaign should make Americans aware of the finite nature of fossil fuel reserves, the actions being taken to promote cleaner production of energy from fossil fuels and the inherent safety and security of nuclear power.

Americans need to know what it takes to get light at the flip of a switch, or to always have air-conditioning and heating available on demand as well actions they can take as consumers to conserve energy. They must understand why we need cleaner power production, and what must be done to get it. If U.S. consumers are made aware of the benefits, and embrace the actions necessary to realize those benefits, then they will support the policy changes and influence government and the energy industry to make those changes.

There will be resistance to some of these recommendations, from special interest groups, profit-driven businesses, regulators and policy makers. However, to keep America's energy industry pointed in the right direction and to best meet our policy goals of secure, available energy at affordable costs in an environmentally responsible way, we need to take these actions – the sooner we start, the sooner we will accomplish these goals.

Appendix A: Specified actions by megatrend

Climate Policy Elements

- U.S. requires a national energy strategy that includes strict regulations on carbon emissions that are achievable and not cost prohibitive.
- Promote initiatives and development to eventually achieve zero carbon emissions.
- Provide incentives to technologies and initiatives that support the production of clean energy sources and requisite associated energy storage.
- Provide long-term extension of tax credits and subsidies for clean energy sources, to include renewables and clean carbon.
- Increase (R&D) funding for grid-level storage.
- Expand nuclear power opportunities and explore tax incentives and subsidies similar to renewables. Fast track and clear all red tape for new permitting from NRC.
- Invest in R&D to further develop Small Modular Reactors and Advanced Reprocessing Centers and immediately approve the Yucca Mountain storage site.
- Increase grants and partnership with academic institutions for the advancement of clean energy and grid-level storage research.
- Development of a climate "X-Prize" that awards an individual or organization that develops a utility-scale storage system that can support renewable energy storage and eliminate the problem of intermittent energy production from wind and solar.

Socio-economic Policy Elements

- Incentivize renewables via subsidies, grants and tax credits: Many municipal, state and federal subsidies or tax credits are being reduced or eliminated. This in turn stymies R&D investment as well as installation of these renewable technologies. Incentives must be long term to allow for long term investment.
- Lift the ban on crude oil exports: Unrefined crude oil exports have been banned since the OPEC oil embargo crisis of 1973. Lawmakers wanted to ensure a ready supply of oil by mandating that supplies of crude oil derived from domestic production be kept in the U.S. versus exported it to other countries. The shale oil renaissance serves as a game changer in which the U.S. is poised to better influence the crude oil market pricing, but only if it can export. Now is the time to have serious discussion on balancing the economic benefits with environmental concerns associated with lifting this ban.
- Safety/regulatory oversight of horizontal drilling and fracking: The issue here is whether the fracking process is or is not harmful to both underground and surface water sources. Policies and regulations must be implemented that enforce and facilitate clean and safe

practices by the drilling companies, and encourage practices that reutilize water used in fracking.

- Finish the Keystone XL pipeline: Completing the pipeline will allow access to Canadian oil, significantly increasing U.S. and North American energy security. Economic growth and energy independence facilitated by finishing the pipeline are not in question. These benefits must be balanced against responsible and pragmatic environmental concerns associated with tar-sands oil production and transshipment of the oil.

- Repeal/amend the Jones Act: This outdated act requires all goods traded between U.S. ports to be transported by U.S. owned, U.S. built, U.S. flagged, and at least 75% U.S. crewed ships. Repealing the act will dramatically reduces costs of domestic seaborne transportation. A free market approach to shipbuilding will drive down prices.

- Focus U.S. support in developing countries: Ready access to energy resources in developing countries will prove a challenge, particularly as these countries grow and increase industrialization and transportation efforts. The U.S. can facilitate this development by providing energy resource commodities and facilitating exploration and production efforts within these countries.

Technology

- Undertake a comprehensive review of subsidies and tax credits in support of technology R&D and deployment of all power generation methods in the energy industry. All sectors should be supported, to include power generation from nuclear, oil, gas, coal, and renewables.

- Incentivize R&D efforts to affordably and capably capture carbon emissions.

- Review and update ARPA-E program guidance and increase its budget allocation; adopt Japanese approach for supporting national companies operating in foreign markets to ensure involvement with the latest technology worldwide; review USG efforts to encourage international collaboration on development of key energy technologies.

- Provide leadership through direction, subsidies, regulation and procurement to industry efforts to upgrade the electricity grid. Guide or coordinate regulatory efforts among the state governments to reduce market confusion and ensure a more singular nationwide energy market.

- Shape efforts to support more STEM training and education toward jobs in the energy industry to develop, manufacture and install new technologies.

- Review the regulatory frameworks of the energy industry impacts on the development and usage of new technologies. Consider international trade policies, particularly rules to protect intellectual property and regulate government procurement.

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