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Rapporteur's Summary

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"Energy Security: Policy Considerations for the New Congress," the third conference in the current series, was held in San Juan, Puerto Rico, February 22 to 27, 2011. Fourteen Members of Congress participated. The intent of this and related conferences is to offer lawmakers the chance to focus on the interrelationships among U.S. energy policy, climate, and national security issues and to explore policy options.

Anne Korin, Co-director of the Institute for the Analysis of Global Security, led the opening session, "Energy and Transportation: Policy Options." She explained that oil has become a strategic commodity because the U.S. transportation system is almost entirely dependent on petroleum-based fuels, and thus oil also is essential to a vibrant economy. The real challenge before the country, she stated, is to reduce oil dependency—not, as many believe, to reduce oil imports or consumption per se. She offered an analogy to salt, which at one time was considered a strategic commodity, providing the only means of preserving foods until refrigeration, canning, and other methods emerged. Today, salt is an ordinary commodity without strategic value. The goal for U.S. national policy should be to make oil, like salt, an *ordinary* commodity.

Many Americans believe that new energy sources—solar or additional nuclear capacity, for instance—will solve the oil dependency problem. But these other energy sources are used to generate electricity, not fuel transportation, at least in the near term; only one percent of oil demand today goes to produce electricity. To reduce oil dependency the challenge facing the country is to develop a more competitive market for transportation fuels along with greater competition among modes of transportation. These goals have both near-term and long-term policy implications.

In the near term, the easiest step is to create an open fuel standard mandating that all new cars—at a cost of $100 or less per vehicle—be flexi-fuel, that is, capable of operating not only on gasoline but on a variety of alcohol-based fuels such as ethanol, which is made from corn, sugar or cellulosic materials, or methanol, which can be produced from natural gas, coal, agricultural wastes, or potentially recycled carbon dioxide though this last option is far from being commercially ready. These alternative fuels are cost-competitive with oil priced at $55 or more a barrel.

If consumers have ready access to a choice of fuels "on the fly" (that is, when they fill up their tank), this would undo transportation's dependency on oil and undermine the hold of OPEC, the Organization of Petroleum Exporting Countries, on oil supplies. OPEC claims more than three-fourths of world oil reserves yet produces only one-third of the world's supply as a deliberate means of constraining supply to keep oil prices high, in part to help fund member countries' domestic budgets.

Over time, electrification of transportation holds promise. Plug-in electric cars can be flexi-fuel, as hybrids are, though electric vehicles today are more expensive than gasoline-powered cars. With the average car lasting 16 to 17 years before it is scrapped or sold abroad, it will take time—even with sizable tax credits encouraging sales—for the vehicle fleet to turn over and to realize the potential of electric cars in reducing oil dependency. Moreover, if large numbers of vehicles are to be fueled by electricity, including from cleaner renewable sources, electricity distribution over the grid needs to be bolstered. Battery storage in electric vehicles also must be improved to enable long-distance travel. Because vehicle batteries are now produced chiefly in Asia, the U.S. is promoting a domestic battery manufacturing capability lest the country trade dependency on foreign oil for dependency on batteries made abroad.

New forms of energy may also hold promise for automobiles. Experiments are under way, for example, to produce fuels from algae using solar energy, a fuel source that has been tried in aviation. Such innovations must make economic sense. Subsidies to support research and to demonstrate feasibility may be warranted but the fuels should have to meet a rigorous cost test to ensure they will be able to compete in the marketplace.

A number of concerns have been raised about the feasibility of these new fuels. Conventional gasoline has twice the energy value as, say, methanol. Corn ethanol, to take another example, competes with corn for food, driving the price up. Dedicated pipelines do not exist to move ethanol from where it is produced to population centers, thus requiring costly transport by truck. Most states do not have a sufficient number of filling stations to make alternative fuels a real choice for motorists.

How, then, should public policy promote the development and use of alternative fuels? One approach is an open fuel standard for cars. In two to three years, once 15 percent of the automobile fleet is flexi-fuel, up from 2 percent today, the business case for filling stations to install alternative fuel pumps should become clear. (It costs up to $30,000 to retrofit a pump, up to $70,000 to install a new one). In other words, the service station infrastructure would follow once the standard was set. Brazil offers an instructive example: it developed ethanol from sugar cane and mandated that all cars be flexi-fuel. In three years, 70 percent of cars were enabling Brazil to weather oil price spikes because consumers had a competitive choice in fuels. The potential exists for a political coalition in the United States to secure an open fuel standard that would reduce oil dependency, uniting corn states, natural gas and coal states, climate activists, and national security advocates.

A complementary thrust to fostering fuel choice is to diversify transportation modes to provide more options for the greatest number of people. At a minimum, this requires better information for consumers, especially accurate price signals. Currently, there are so many subsidies to different modes that consumers don't really know what they are paying and, thus, cannot make informed decisions. Highway users, for instance, do not now pay the full cost for road and associated transportation infrastructure and services.

Public transit is often cast as an alternative to continued reliance on automobiles for transportation, with universal access as the goal. Yet transit is not an unvarnished "good" in and of itself. From the standpoint of energy consumption, transit that operates with few riders can be worse than large gas-consuming vehicles. Public transit, rather, should be considered with respect to the specific need or needs it is supposed to meet. If mobility for less affluent households is the need, for instance, it may be more cost-effective to subsidize these consumers directly—say through vouchers—thereby enabling public transit systems to raise fares and deliver better service for those who can afford to pay. Currently, an estimated 40 percent of public transit costs, for example, goes for compliance with the Americans with Disabilities law through para-transit requirements.

Public transit systems are being asked to meet many competing demands with insufficient resources. Private operators for the disabled, older Americans, or low-income consumers may be able to serve these groups more cost-effectively. The Zip Car, Super Shuttle service in some cities, and the so-called Chinatown buses between New York City and Washington, D.C., offer examples of private-sector initiatives meeting the varied transportation needs of Americans. For this approach to succeed, it is critical to remove obstacles to the entry of new private-sector services—jitneys, for instance—that are cost-competitive without subsidies. To meet safety, environmental performance, and other conditions, government regulators could impose standards, as needed, on the private operators.

It is not clear, however, that the private market will be able to meet the diverse needs of different population groups profitably, especially those of the neediest Americans. Nor it is clear that off-peak service or service in remote locations where ridership is low would attract private operators. The question thus arises, how much should taxpayers be asked to subsidize public transit services. Shouldn't people who choose to live in, say, low-density suburban settings pay the full price of the local transportation mode?

Because oil has proven its value over decades, it will be hard to displace as a transportation fuel. A transition will be even harder as long as subsidies and hidden costs distort price signals for consumers. The cost of U.S. military operations to protect the global flow of oil from the Persian Gulf and elsewhere, for example, is costing tens of billions of dollars, which is not factored into the price of gasoline.

Federal grant requirements also may thwart a transition if funds are available for, say, light rail but not for other transportation needs. It typically falls to local or metropolitan governments to take the initiative in requesting federal transportation dollars and providing the local match. It is in their self-interest to do the ridership, cost-benefit, and other studies that ensure their investments can be justified and sustained economically without long-term subsidies. These officials are typically the best informed to make decisions and tradeoffs among competing citizen demands and priorities across the transportation system.

As Congress takes up reauthorization of the surface transportation law, several points should be prominent: tying funding to performance metrics, favoring transit options with adequate ridership, putting a priority on repairing and maintaining existing infrastructure, and considering whether or how federal requirements skew local transportation decisions, by setting, say, a low cost-sharing requirement for certain types of infrastructure or imposing a bias for new infrastructure when operating costs may be the local concern.

Market price signals have a key role to play but government must set the direction. Though all proposals face political hurdles, the current budget and national debt crises, coupled with the need for funding energy research and development, provide a rationale for a new formulation to finance transportation investments. Some have proposed an oil security tax that would be revenue-neutral, offsetting payroll or income taxes. Other proposals include a fee per barrel of oil or an oil import fee. As oil prices are set in the global marketplace, these revenue options may not reduce oil dependency or break OPEC's hold on supply, but they could address other national objectives, including debt reduction, improved balance of payments (about $300 billion goes overseas for oil each year), and funding research that leads to new energy sources.

Ultimately, Americans need to recognize that improved transportation will cost them more. And more of the cost must be shifted to users through tolls, fee-per-mile payments or other means. The burden must shift if financing is to be available over the long term.

William K. Reilly, Co-chair of the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, was the featured speaker at an evening discussion outlining the Commission's key findings and recommendations. The Commission was created by President Obama in response to the April, 2010 incident in the Gulf of Mexico. The President's directive was to look for the root cause of the disaster and to recommend measures to minimize the chance that such an event could occur again. Completing its work on time and under budget, the seven-member Commission spent six months investigating the well explosion and the spill, assessing the response and the impacts, highlighting restoration needs, and developing proposals for government and the industry.

The BP incident was the largest in U.S. waters, spilling 172 million gallons into the Gulf of Mexico. Along with lax government oversight, the chief counsel's team pinpointed the cause of the explosion as no single decision made that day on the rig, but rather a series of bad decisions by the three involved companies, BP, Halliburton, and Transocean. Failed tests, faulty cementing, missed warning signs, poor communication, and more contributed to the disaster. That the last line of defense, the blowout preventer, failed really did not matter: hydrocarbons had already entered the riser and caught fire after reaching the rig floor, causing the explosion.

A key question for the Commission from the start was whether the incident resulted from one rogue company or signaled a more systemic problem across the oil drilling industry. Although some major companies have superior safety records, the Commission drew what has proved a controversial conclusion; namely, that a culture of complacency permeated the entire industry. Several reasons underpin this conclusion:

- Companies involved in the Gulf incident operate worldwide, not just on the Deepwater Horizon rig.
- Despite the threat of a blowout, the industry had no containment technology to cap an out-of-control well in deep water.
- The response plans prepared by all major companies operating in the Gulf were embarrassingly deficient.
- The industry had failed to improve response technologies in the aftermath of the last major spill, in 1989 in Alaska's Prince William Sound.
- The fatality rate associated with drilling in the Gulf is several times the rate in the North Sea, a more punishing environment.

That thousands of wells had been drilled in the Gulf in shallow and deep waters without such an incident caused the industry to believe it simply could not happen. The well explosion, which killed 11 men and injured more, and the spill served as a wake-up call for the industry.

A key recommendation by the Commission is for the industry to create a safety institute to share best practices, undertake third-party audits, and foster higher management standards. This proposal draws on the experiences of the nuclear industry and the chemical industry, which successfully created analogous institutes to improve their safety cultures in the aftermath of their own disasters.

Among other Commission recommendations:

- Beefed-up Interior Department inspection capabilities—including increased funding for more inspectors, better pay, and better training—paid for by a small fee on each barrel of oil
- An organic statute that would separate Interior's regulatory and safety functions from the leasing and revenue offices
- A new approach in which regulators keep pace with the complex, constantly advancing drilling technology by focusing on the risks associated with each *individual* well, much as Norway does in what is widely

regarded as the best drilling regulatory structure worldwide

- A higher liability cap
- Greater attention to incorporating critical scientific information and consulting relevant federal agencies to assess drilling and response plans, along with a clearer and stronger role for local governments in response planning
- The need for international protocols to set high standards for drilling and response planning in the Gulf of Mexico and in the Arctic

The Commission recognized that the oil industry, along with tourism and fisheries, is an economic driver in the Gulf region, having co-existed with the other sectors for more than 50 years. Because of the country's dependency on oil for transportation, the Commission also explicitly acknowledged that the United States will need to extract oil in deep waters in the Gulf of Mexico, where reserves are substantial. If the United States doesn't tap domestic oil, more oil will be imported from countries with far less regard for safety and environmental protection.

Former Assistant Secretary of Energy Susan Tierney led the discussion on "Policies for a Secure Energy Future: Issues in Supply and Demand. She emphasized that aside from oil for transportation, the energy used by Americans comes from domestic resources—chiefly coal, natural gas, and nuclear power. She stressed that the energy story—the economics, the resource base, the regulatory framework, the culture, and so on—differs markedly from one part of the country to another. The American heartland relies on coal for electricity in a major way whereas coastal states are less dependent on coal, instead relying on natural gas, nuclear and renewable power sources. Though no new nuclear plants have been built in the past 20 or more years, this energy source gained market share in places with serious air pollution, chiefly in densely-settled coastal states. Some states have extra generating capacity while others need more. Some states, especially where energy costs have historically been high, have ambitious energy efficiency programs; others with lower energy costs—considered a competitive advantage—have not made efficiency a priority. Another obvious difference is weather, with some regions prone to drought which can limit the water needed for energy production. Others need the capacity to meet demand in cold winter or hot summer months.

A mismatch exists between where energy resources are located and where people live, prompting the need for large transmission networks. By and large, siting energy facilities is a state function although the federal government at one point pre-empted the siting of natural gas transmission lines. In most places, because buildings and power plants—two of the largest energy users, transportation aside—are long-lived, it is difficult and costly to make major changes in the near term.

Regulation, too, varies state by state. High-cost states sought to introduce competition in electricity markets to constrain costs. Other states retained the traditional regulatory model where utilities can recover their costs plus a guaranteed rate of return.

Energy policy today, consequently, comprises a mix of federal, state, and local policies, as well as decisions by private investors and utilities, large and small, reflecting significant regional differences. Tierney highlighted three major challenges:

- **Siting:** A tenth of the U.S. power plant capacity is more than 50 years old; half of that capacity is coal-fired and inefficient, lacking controls even on conventional air pollutants. Siting new energy infrastructure—generating facilities, transmission lines, pipelines, for example—can face steep hurdles. Energy systems cross state lines, and few places welcome new infrastructure intended to meet out-of-state demand.

- **New Rules:** The U.S. Environmental Protection Agency is under court order to produce new rules to control air pollutants—mercury emissions, for instance, which have adverse health effects. These rules could encourage the oldest inefficient plants to shut down and thereby encourage new natural gas-fired plants, which would have access to the transmission capacity once reserved for the older facilities. Without the new rules, however, older plants are likely to stay in operation. And yet, the rules are likely to be expensive and would increase electricity rates, making them particularly controversial in economically difficult times. Another forthcoming EPA rule would regulate cooling water for power plants. A lot of energy is used to move and treat water; and a lot of water is used for cooling in nuclear, coal, and natural gas power plants.

- **Shale Gas:** The potential for shale gas is large, potentially a game-changer. Abundant in many parts of the country, relatively cheap, and environmentally preferable to coal, natural gas nonetheless has encountered public mistrust about whether its extraction can be done safely.

Notwithstanding this, natural gas is seen as a transitional or intermediate fuel for producing electricity on the way to a lower-carbon energy economy. The industrial footprint of a natural gas operation is large, which is not well appreciated. Regulation of natural gas extraction is a patchwork among the states and federal agencies. Some states have long experience from overseeing numerous wells and do not want federal regulation to intrude; whereas other states, especially those where discovery of reserves is recent, have little experience. At the federal level, the Department of the Interior's Bureau of Land Management has authority over extraction, royalty payments, and other aspects of natural gas found on federal lands while EPA has regulatory authority over some but not all of the fluids used in so-called fracking, that is, pumping a mix of fluids into a formation to release the gas. Notwithstanding several decades of use of so-called fracking, some people fear it will lead to contamination of water supplies.

The use of best practices is uneven from state to state. Disposal of produced water—that which is discharged after being used in drilling—can be a problem because of its saline or mineral content. Some states have good disposal requirements in place, including encouraging recycling or reusing produced water. Others do not.

A key question for utilities is whether, given the history of volatility in natural gas prices, supplies will be available over the long term at a decent price. Recent explosions of natural gas pipelines have introduced more uncertainty. Natural gas pipelines are aging, and require adequate inspection and maintenance. In turn, this means that utilities need to be able to recover the cost of replacement and improvements.

Besides natural gas, other energy sources show potential but also face serious hurdles. Efficiency, often called the cheapest "source" of new generation, offers a huge opportunity to reduce the need for new generating capacity and to help meet forthcoming air pollution standards. One consortium of architects concluded that better insulation in existing and new buildings would obviate the need for new power plants. Such is the potential for efficiency to curb growth in demand. If energy prices are low, however, there is little incentive to conserve or improve efficiency of use.

Technological improvements can boost efficiency, too. DC, or direct current transmission lines, for example, are efficient carriers, especially over long distances, although this form of transmission is relatively expensive as it requires a converter at the point of end use. New, more efficient materials also are being tried for transmission in urban areas over short-distance lines where added capacity is needed and digging up large swaths of land is not practical.

Smart meters are yet another new technology promoting more efficient electricity use, as well as reducing the need for on-site billing visits and the accompanying pollution from driving so many miles to make such visits. In some communities, however, consumers have been suspicious of these meters, worrying that they are being imposed by distant operators and are collecting personal information. And if electric bills continue to rise after installation, as they sometimes do, consumers become even more wary.

Cogeneration offers another practical contribution to U.S. energy supply. In some institutional settings, consumers generate heat and power on site, typically more than is needed, and can supply the excess power to the grid. That excess can be used by other nearby facilities if there is a market and there are no barriers (crossing a utility's service area, for instance). A feed-in tariff, that is, a guaranteed price per unit of excess electricity paid to the supplier, can create a market for cogeneration, as well as encourage new renewable energy sources. Getting the tariff right is critical. Germany, Spain, and Portugal offered generous feed-in tariffs that brought on a lot of new wind power. But some observers allege that these three countries set the tariff too high, they overpaid, and thus undermined the cost-effectiveness of this tool. A new strategy being tried in India is a reverse auction, in which the lowest bidder receives the payment.

Although a rebirth of the nuclear industry has been predicted, licensing of new facilities has been moving slowly. The licensing process is long and cumbersome, and even with federal loan guarantees, new plants are very expensive, especially when compared with the cost of new natural-gas powered facilities, the fuel for which is relatively inexpensive. Siting new facilities is also an issue. What to do with spent fuel rods is another problem. Now that the Yucca Mountain waste repository is being shelved, alternative disposal methods are needed. Fortunately, it appears that interim, on-site storage is feasible. Recycling or reprocessing fuel rods is also getting new attention as technology develops to minimize plutonium as a side product—the long-standing issue of those concerned about the proliferation of bomb-making material. This approach, being tried in the Savannah River plant, also utilizes far more of the energy content of uranium than is now possible.

Small-scale or modular nuclear reactors—up to 300 megawatts in size—are a promising development suitable for industrial complexes, campuses, military bases, and other institutional applications. Two different technologies are being reviewed by the Nuclear Regulatory Commission. One, a modification to a light water reactor, is close to being licensed, with the industry poised to capitalize on the technology. The other, a so-called fast reactor, requires additional research before licensing can begin. One test for both of these approaches will be whether the economies of scale realized by a large nuclear facility will be matched by the economics of an industrial approach to manufacturing smaller modular nuclear units.

Cost uncertainty is also a factor for other promising sources. Offshore wind, for example, could provide ample power but there are high capital costs, especially for early movers, as the supporting infrastructure does not exist. The feasibility of small-scale renewable generators—fuel cells, micro wind turbines, solar roof shingles, for instance—hinges on the economics of their replacing electricity from the grid, especially the relationship between capital costs for installation and electricity rates. These technologies are more likely to prove acceptable to consumers if the payback rate is favorable. Geothermal sources are attracting growing interest. There are several variations with more research, development, and demonstration needed over the next decade to scale up application. The costs of the technology and the potential impact of seismic activity on the sources need to be understood better.

Finding the mix of policies and technologies to ensure the U.S. continues to have access to abundant, reasonably affordable, and cleaner energy choices is daunting. Having future options depends on investments in research by the public and private sectors today. Yet the current level of investment is woefully inadequate, and further investments could be constrained by budget deficits. Efficiency needs to be pursued aggressively but may not be if energy prices remain low. Cleaning up old coal-fired facilities will improve public health and encourage capital stock turnover but the costs to ratepayers could be significant. The transmission grid needs serious attention, especially if renewable technologies are to realize their potential in bringing electricity from where wind and solar are abundant to population centers, yet siting new lines has proved difficult. The efficacy of intermittent renewable technologies requires advances in battery storage to make large-scale applications in solar and wind energy more reliable options. A national clean energy standard would spur innovation and cleaner sources though with these and other hurdles an effective energy strategy for the nation will not come easily.

Ernest Moniz, former Undersecretary of Energy and now at the Massachusetts Institute of Technology, led the discussion on "Coal as a Viable Energy Source: Opportunities and Hurdles in Using the Resource Wisely." He began by noting that U.S. coal reserves are the largest of any country. Following China, the United States is the second largest coal consumer, with about 45 percent of the nation's electricity coming from coal. India is the third major coal user. The three countries together account for 70 percent of coal use. Along with being first in natural gas production and third in oil, and with the largest nuclear fleet, the United States is the world's top energy producer. The overall energy system is robust and diverse.

As noted earlier, a sizable portion of the U.S. coal fleet is small, old, inefficient, and lacking controls over conventional air pollutants. Coal prices are rising and some percentage of coal-fired capacity will close down as utilities make business decisions about which fuels are the most cost-effective to use. These closings can prove economical because natural gas—a cleaner, cheaper fuel—is abundant and there is significant underutilized capacity in a large existing fleet of natural gas plants that were designed to deliver base load electricity generation.

EPA's new rules, which would require that coal plants further reduce nitrogen oxide and sulfur dioxide emissions and clamp down on mercury emissions, are likely to reinforce the business case for closing some plants. Scrubbers retrofitted on old coal plants are almost as expensive as building a new natural gas plant. In other words, over the next decade, even without building new plants, natural gas could displace up to a third of coal used to generate electricity. This will have consequences for coal-producing regions of the country—and for mining jobs—offset somewhat by rising coal exports to China.

Unlike the nation's dependency on oil for transportation, electricity generation per se is not a national security issue. But concern about the carbon dioxide content of coal and the link to climate change has international dimensions, making the United States, China, and India the linchpin in any international climate agreement. Reduction of carbon dioxide in coal combustion will have to be part of the formula.

In this context, one hope for continued coal use in the United States and China is carbon capture and sequestration. Of the two pieces, the ability to sequester carbon dioxide seems nearer at hand. Large-scale demonstrations are needed, to be sure, along with a credible regulatory regime and the resolution of long-term liability issues. These will be necessary for public acceptance.

Carbon capture, on the other hand, is currently very expensive because it was not developed to remove large amounts of carbon dioxide from coal. Multi-billion-dollar investments in applied research, development, and demonstrations are essential to drive down the cost. Two promising avenues are now being investigated—post- and pre-combustion—each of which faces different prospects and costs. Needed investments in research and development (R&D) could be paid for by a line charge on each kilowatt hour used, set at a rate low enough that it would barely be noticed on monthly electric bills.

Another approach to handling carbon dioxide from coal combustion is to use it for enhanced oil recovery, for which it has been used for years, especially by oil producers, primarily independent operators, who are finding it harder to obtain natural sources of carbon dioxide in large enough quantities. For this option to be viable, though, about 30,000 new miles of natural gas pipeline are needed to link major coal-producing areas to oil fields in Texas and the Rockies. With sufficient investment and an economical price, large amounts of carbon dioxide could become an asset rather than a pollutant.

The approach could spur greater domestic oil production in old fields where perhaps half the oil remains because it was not economical to extract it, while absorbing large amounts of carbon dioxide over the next two to three decades. As long as oil remains above roughly $55 a barrel and carbon dioxide could be obtained for $30 a ton, enhanced recovery makes economic sense. There is a practical limit to this application, however, as more and more of a field's residual oil is extracted.

Why focus so intently on coal and fund expensive research to reduce its carbon emissions? Some observers question whether such investments make sense when other, cleaner energy sources may have more to offer in the transition to a low-carbon energy economy. For one, de-carbonizing the energy system is an extraordinary challenge, necessitating efforts on many different fronts, including coal. There is no guarantee that any given technology, including carbon capture and sequestration, will prove cost-effective.

Second, coal use has significant public health impacts. As long as coal provides so large a share of electricity, it will be in play for years to come. And thus, as it has in the past, reducing conventional air pollutants associated with coal combustion will benefit Americans' health.

Third is the political dimension. Many states, especially in the Midwest, have enjoyed relatively inexpensive electricity because coal has been cheap and the old plants have long ago been paid off. Some states generate more than 90 percent of their electricity from burning coal. This relatively inexpensive electricity is seen as a competitive advantage in boosting a state's economy, and consumers are loathe to upend this with higher rates.

Coal mining has major job implications. Western coal production is less labor-intensive than in Appalachia though, even in Appalachia, the highly controversial mechanized approach to mining coal called mountaintop removal—where waste material, which may include toxic contaminants, is dumped in valleys and waterways with the attendant pollution consequences—has already reduced the number of jobs. Technology advances continue to cut the number of workers needed. Political and corporate officials, thus, fight hard to preserve remaining jobs.

Ironically, by one study, coal production looks to be the least effective job creator among energy sources as measured by jobs per kilowatt hour of electricity. Efficiency is the best, followed by distributed generation (that is, decentralized, small-scale, on-site sources), with large-scale renewable production and natural gas coming in third. Though a switch to natural gas could employ many coal workers, this would not happen absent support for worker retraining.

Another reason to focus on coal is China's large consumption, which is used to provide more of its population access to affordable electricity. China is building a lot of new, much more efficient coal plants, which will run for 50 years or longer. If reducing carbon dioxide emissions is the key to mitigating the worst scenarios for climate change, then carbon capture and sequestration will have to become cost-effective. Though some argue that the United States would benefit economically if the technology were developed at home and sold abroad, U.S. and Chinese interests in advancing the technology coincide and it may be possible with sufficient joint funding to collaborate on research and demonstration efforts. One obstacle to cooperation is the concern by U.S. companies to protect intellectual property rights, which has been a challenge in other joint ventures with China. Another is the structure of such a venture. China uses an integrated, centralized model to advance technology. In the United States the industry is highly fragmented—extractors, builders, utilities, combustion specialists, and others—which is to say carbon capture and sequestration is no single company's core business.

U.S. energy options, in coal and with respect to other sources, depend largely on inventions, which depend on wise, disciplined research, development, demonstration, and deployment. Raising the level of public funding for R&D to $10 billion a year, an amount considered adequate to make progress, is a tall order at a time when the nation's budget deficit and debt dominate political discourse. Some argue these economic concerns must be dealt with before new expenditures are made, even for such worthwhile purposes as energy R&D in which the United States lags behind other countries. Others contend that public funding is not the only way to encourage innovation: a price on carbon emissions would send a strong market signal and provide the private sector greater incentive to innovate.

How research and development is conducted matters, too. Hubs or clusters of laboratories and research centers, university programs, specialty businesses, major equipment, and the like—as found in Research Triangle Park in North Carolina and in California's Silicon Valley—have proved their value. Energy Secretary Steven Chu has championed these hubs along with complementary centers devoted to breakthrough inventions and to moving technologies into the marketplace. In an open competition for research dollars under the ARPA-E program (the Advanced Research Projects Agency-Energy), DOE awarded 37 grants; 3,500 proposals were submitted, indicating strong interest and an ample supply of ideas. Every aspect of the learning curve needs attention in technology innovation—breakthroughs in science, engineering refinements that drives costs down, and commercializing new products. Although the United States is still considered a leading innovator, it has failed in the past to capture the manufacturing jobs and export benefits that follow from innovation.

Ultimately, given the growth in energy demand worldwide and the prospect that adverse climate change will occur if energy systems continue to emit large amounts of carbon dioxide into the atmosphere, technological innovations across a range of energy sources—solar, wind, coal, nuclear, natural gas, and more, perhaps even entirely new, as-yet-unknown technologies—will be needed. And their availability when they are needed will depend on sufficient investments in R&D today coupled with policy directions that send appropriate market signals.

Rosina Bierbaum, Dean of the University of Michigan's School of Natural Resources led the session on "Adapting to a Warmer World: Understanding What the Future Might Hold and U.S. Options for Responding." She began by defining adaptation as coping with changes already underway, as well as building resilience into infrastructure and other community development.

Global temperatures have been relatively stable over the past 2,000 years. Today, however, signs of a changing climate are widespread and have been confirmed by scientists and scientific academies worldwide. The indicators include, for example, rising temperatures, rising sea level, loss of sea and glacial ice. Other signs: spring is coming earlier, fall later; plant zones are shifting and pest zones are expanding; the oceans are acidifying; more precipitation has been recorded—both rain and snow—with more coming in more intense storms; wildfires and droughts, too, are more prevalent; and millions of trees in Alaska, Arizona, and elsewhere died because of excessive heat, drought, and pests. Along with direct observations, scientists have much greater confidence today in climate modeling as the results—historically and for recent years—align with what has been documented in temperature and other records. Although no particular weather event can be attributed to climate change, the patterns of climate change conform to what models and scientists have been forecasting.

Though impacts will vary by region, climate change will have even more profound consequences for agriculture, forestry, public health, coastal communities, energy facilities, water supplies, and more. Better preparedness and response planning are clearly warranted. Also needed are more refined assessments of regional impacts to help states and communities prepare for what's coming. Numerous federal programs—from flood insurance to coastal zone management to agricultural research to infrastructure investments—should be examined to help the country prepare for and respond to inevitable climate change. Cost-benefit analyses, which many federal projects have to pass, need a more realistic discount rate; a low discount rate deflates the value of action today to forestall problems tomorrow. It would also be helpful to examine public subsidies that encourage consumer choices that put people at risk and will be expensive to address as climate change continues. Building in low-lying, flood-prone areas is one example.

No amount of reduction in carbon dioxide emissions will stop what is already under way though reductions could help forestall even worst-case scenarios. As temperatures rise, it will become more challenging to adapt, especially if the rate of change accelerates. Slowing temperature rise will provide more time to institute prudent measures that can enable communities to cope better, to develop options for the future, to conduct the research and demonstrations that can lead to deployment of innovative energy technologies, and to explore the potential and risks associated with so-called geo-engineering, that is, global-scale interventions like injecting sulfates into the atmosphere to reflect heat and check the rise in temperature that would otherwise occur.

The country can begin with small, near-term, incremental measures that are relatively inexpensive and cost-effective, especially in guiding new development. Many states and communities are already engaged in this—California and New York City offer two prime examples—motivated most perhaps by the recognition that substantial development in those places is threatened by rising sea levels. Federal agencies are moving more slowly but beginning to incorporate thinking about climate change into their activities and programs. The private sector, too, is beginning to factor climate change into decisionmaking, especially insurance companies, whose rising premiums reflect the growing cost of reimbursing policyholders for a larger number of weather-related disasters. Disclosures of company vulnerabilities to climate change have also been demanded by large pension funds and advocated by savvy investors.

Ultimately broader public support will be needed to spur major action at the national level. That support will depend on a better understanding of how climate change directly affects the lives of Americans and their communities. Many Americans have come to accept that changes are occurring—they see some evidence. But public and political support for large-scale action is lacking and recent opinion polls suggest a drop in support. Many people are preoccupied with the country's economic woes and the priority for creating jobs, which understandably are seen as first-tier issues by the public. Advocates for climate action do recognize, moreover, that economic recovery will lead to a more prosperous country better-positioned to adjust and adapt over time to climate change.

Neither scientific reports nor accounts of serious problems in other parts of the world, as important as they may be, have sufficed to make the case for action. Though scientists state with confidence that the magnitude of temperature changes cannot be explained by natural climate variation, yet can be by factoring in the growing level of greenhouse gases in the atmosphere due to human activity, some Americans remain uncertain about the linkage. Confused about the science, some view cold winters and heavier snowstorms as running counter to the notion of global warming. They demand greater certainty that the climate is changing and that human activities are contributing to it before they would accept national actions that cost money. Amidst this uncertainty, asking Americans to pay more for energy now to avoid long-term climate change has proved a hard sell. Besides the cost concern, there are significant economic and other interests invested in preserving the status quo, along with well-funded campaigns to discredit scientific findings or individual scientists.

Still others argue that Americans for the most part distrust large-scale, rapid change in national policy, as well as those who advocate "doom-and-gloom" scenarios without offering a ray of hope. In this context, both the message and the messengers delivering it are important elements in building public trust and support. Younger Americans, especially on college campuses, seem ready to support action for they appreciate that they may well inherit a much less climate-friendly world.

A clean energy future is potentially a motivating vision around which Americans could rally. It offers abundant opportunities for new jobs, for growth, and for innovation. National security as a rationale also is more likely to unite Americans across otherwise fractured political lines to garner support for prudent, near-term measures—better planning for preparedness and response, greater R&D, solutions grounded in market economics, tighter building standards, more energy-efficient vehicles and appliances, cleaner fuels and a choice among those fuels. These could gain public acceptance. At some point, however, to reach the carbon reduction target scientists say is necessary to avert calamitous change, a significant price on carbon emissions will be necessary.

In other periods of American history, looming threats were downplayed. Take the 1930s, for example, during which the threat of war in Europe was not widely regarded in the United States. At least some of the nation's leaders, however, were able and willing to take measured steps—not all that may have been desirable nor as soon, but prudent steps to prepare the country for what they saw as an inevitable war. War did come, with the attack on Pearl Harbor finally mobilizing the country to act. Some observers have posited that a comparable situation may exist today regarding Americans' attitudes on climate change and adaptation. At some point, experts say, nature will underscore the compelling need to take climate change far more seriously, and then America will act.

Stripping Oil of Its Strategic Status

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Until the end of the 19th century, salt was one of the world's most strategic commodities. As the only means of food preservation, it was fundamental to national economies. Salt deposits conferred national power and wars were even fought over their control. Countries that controlled salt aimed to keep production tight and prices high so as to extract maximal revenue for their treasuries. As Mark Kurlansky notes in *Salt: A World History*, some 2,300 years ago a Chinese government minister purportedly advising his ruler emphasized the power that the importance of the commodity yielded to his state by saying that "in some non-salt-producing areas people are ill from the lack of [salt] and in their desperation would be willing to pay still higher prices," and concluding that "salt has the singularly important power to maintain the basic economy of our state." Eventually, competing means of preserving food—canning, electricity and refrigeration—decisively ended salt's monopoly over food preservation and with it its strategic importance.

Petroleum today occupies the strategic ground that salt did many years ago: just replace salt in the above anecdote with oil and China with Saudi Arabia. The U.S. consumes a quarter of the world's oil yet has only three percent of the world's conventional oil reserves. As a result, it must import over 60 percent of its oil; and this figure is growing. Because the vast majority of the world's oil is controlled by regimes that are undemocratic and/or hostile to the U.S., this dependency undermines U.S. national security.

There are also concerns about the negative impact on American interests of China's and India's growing demand for energy. The two countries' foreign policies are increasingly driven by the need to secure their energy supply, often at the expense of vital U.S. interests. Oil dependence also impacts the U.S. economy. Oil crises over the last half century—including the one in 2007-2008—have generally been followed by economic downturns. As oil prices approach $100 a barrel, the International Energy Agency (IEA) has warned that, again, "oil prices are entering a dangerous zone for the global economy." Oil imports constitute a full half of the U.S. trade deficit. Last year over $350 billion—money that domestically could have created jobs and investment opportunities—were transferred overseas to finance America's petroleum requirements.

It's not about imports, it's about salt. It's not about electricity, it's about transportation.

Oil's status as a strategic commodity does not stem from the magnitude of petroleum imports. The U.S. uses more salt now than ever before, yet nobody is particularly concerned about the magnitude of U.S. salt imports. In 2008, the United Kingdom produced most of the oil it needed, yet the global oil price spike affected all consumers, including those in the

UK, where it resulted in protests by frustrated truckers.

Just as salt's strategic importance derived from its monopoly over food preservation, oil's derives from its virtual monopoly over transportation fuel. Transportation, not electricity, is the source of oil's importance: since the 1970s, the U.S. has weaned its power sector off of oil. Today only one percent of U.S. electricity is generated from oil and only one percent of U.S. oil demand is due to electricity generation.

A strategic commodity dominated by a cartel

In addition to oil being a strategic commodity, oil reserves are dominated by a cartel—the Organization of Petroleum Exporting Countries (OPEC)—which by its very nature is engaged in a deliberate effort to manipulate production to drive up world prices in order to maximize the revenue of its member regimes. Incredibly, despite the fact that OPEC controls 78 percent of world oil reserves and even though the global economy and non-OPEC production have roughly doubled since the 1980s, the cartel today produces about the same amount of oil today as it did then, about 26 million barrels a day (mbd) accounting for about a third of world petroleum supply. OPEC's flush-with-petrodollars members seem unconcerned by the pain inflicted on the global economy by oil's periodic meteoric price rises. OPEC has repeatedly claimed it holds significant spare production capacity. This claim is impossible to verify, thanks to OPEC's notorious lack of transparency. If true, it means OPEC could, when prices spike, inject a significant amount of oil into the market almost immediately, dropping prices significantly. But this is not what the cartel is after.

Reducing the strategic importance of oil: tactical approaches aren't sufficient

Historically, since the Carter Doctrine the U.S. has focused from a foreign policy perspective on ensuring uninterrupted access to oil including by military force if necessary, and from a domestic policy perspective, on policies that increase either the availability of petroleum or the efficiency of its use. These approaches are tactical rather than strategic. Reducing oil demand through fuel economy absent competitive markets—in transportation fuels, transportation modes, or both—while it serves to reduce the trade deficit as well as emissions, is insufficient to change the strategic status of oil or the influence of OPEC. When oil-consuming countries reduce net demand (or increase non-OPEC production), OPEC can respond by throttling down supply to drive prices back up. The 2008 oil price spike provided a good example of how OPEC responds to reduced demand. Oil soared to $147 a barrel, and gasoline and diesel prices at the pump increased accordingly. Consumers, responding rationally to higher prices, drove less and the U.S. alone reduced its oil demand by as much as one mbd. In response to weakening demand, OPEC cut production by three mbd in an effort to send prices back up.

Needed: two types of competitive markets

To fully de-fang this cartel, consumers must have viable choices that enable them to respond quickly to changes in oil prices, rendering the cartel's machinations ineffective. Drivers can't rapidly change the fuel economy of their vehicles but, with vehicles that enable fuel competition, they could quickly change what fuel their vehicles use; and with a competitive market among transportation modes, they could quickly change how frequently they use those vehicles.

A competitive market among transportation fuels would place a *de facto* ceiling on the price of oil once market penetration of vehicles that enable fuel competition is sufficiently high: If oil surpasses the threshold price at which competing fuels are economic (on a cost-per-mile comparison,) then consumers whose vehicles enable choice will prefer to purchase these competitors. Consumers faced with high petroleum fuel prices could immediately choose to fuel with substitutes.

A competitive market among transportation modes, achieved by approaches such as fully embodying pricing and removing obstacles to market entry, would increase economic resilience by reducing the ability of an oil price spike to wreak economic havoc. This is readily apparent in the case of tele-working or tele-shopping: the larger the portion of economic activity that can be accomplished on an internet highway rather than a physical one, the less impact an oil price spike would have on our economy.

Economic resilience is also increased by competition among physical transportation modes (car, bus, transit, bicycle, train, plane or even walking). Should the price of oil rise above a threshold at which the cost of driving a car becomes unaffordable, a competitive market would allow people to rapidly switch to modes of transport that offer lower costs of travel per mile per passenger and still engage in day-to-day activities.

Fuel competition

For a cost of roughly $100 extra as compared to a gasoline-only vehicle, automakers can make virtually any car a flex-fuel vehicle (FFV,) capable of running on any combination of gasoline and a variety of alcohols such as ethanol and methanol, made from a variety of feed stocks. While ethanol is made from agricultural products like sugar cane and corn, methanol can be made from natural gas, coal, any form of biomass, and in the future, perhaps recycled carbon dioxide. Should the economics of natural gas in the U.S. remain favorable due to progress in shale gas extraction, delivering that natural gas to the vehicle would be most economic from an infrastructure and vehicle perspective if it is converted to methanol and vehicles are flex-fueled.

Flex-fuel vehicles provide a platform on which liquid fuels can compete, thus placing a variety of commodities in competition at the pump and letting the market determine the winning fuels and feed stocks based on economics: comparative per-mile cost. The proliferation of flex-fuel vehicles in Brazil has driven fuel competition at the pump to the point where in 2008, when oil prices were at record highs, more ethanol was used in Brazil than gasoline. Drivers in Brazil were able to defend themselves from high oil prices by choosing a different fuel: they compared the relative per-mile-costs of ethanol and gasoline, found that ethanol was less expensive, and adjusted their fuel purchase choice accordingly.

An Open Fuel Standard ensuring new cars are gasoline-ethanol-methanol flex-fuel vehicles would serve as a low-premium insurance policy against excessive oil price rises. It is a critical, yet low-cost, pathway to breaking oil's virtual monopoly over transportation fuel and thus reducing its strategic importance. In the absence of an Open Fuel Standard, most of the 10-15 million new vehicles that roll onto America's roads every year, each with a street life of over 16 years, will be shut to anything but petroleum fuels.

Electric cars and plug-in hybrid electric vehicles (PHEVs) place electricity—which in most oil importing countries is for the most part not generated from oil—in competition with liquid fuel. The strategic importance of vehicle electrification derives from the much lower cost per mile of fueling with electricity as compared to the cost of fueling with gasoline or diesel, even when oil prices are relatively low. To undercut electricity, OPEC would need to drop oil prices to under $10 a barrel. The upfront cost of electrified vehicles is higher, but this cost should drop as the technology evolves and production scales increase. Tax credits for plug-in hybrid and electric vehicles keyed to battery size, already enacted into law, are the most effective policy tool for helping this technology move past the early adopter hump and into the mass market. Vehicle electrification, though it will take much longer to proliferate, should be viewed as complementary to liquid fuel choice. Combining the technologies into flex-fuel plug-in hybrid electric vehicles enables electricity and alcohols from a variety of energy sources to compete against petroleum-based fuel every time the consumer makes a fuel purchase.

Such competition will not only drive down the price of oil, it will also alter the geopolitical balance of power in favor of oil importers and developing countries with resources to become alternative-fuels producers.

Mobility choice

Opening the market to competition among transportation modes requires:

- Removing regulatory obstacles that thwart market entry by entrepreneurial public transportation providers
- Moving to more transparent and accurate pricing so transportation users can make economically-grounded comparisons among modes
- Increasing accountability as to how taxpayer dollars on transportation are spent and tying such spending to performance metrics and increasing local, rather than federal, control over allocation

Removing regulatory obstacles

- Taxpayer-supported subway, train, and bus stations should not be allowed to thwart private operators from picking up or dropping off passengers. Transit information and ticket-selling systems that are taxpayer supported should be open to all transit systems in a given area, whether operated by the public sector or by private businesses.
- State regulations that prevent insurance companies from offering consumers the option of pay-as-you-drive insurance should be lifted. In the absence of such an insurance option, low-mileage drivers are forced to subsidize risk for high-mileage drivers, distorting price signals for driving.
- Barriers to telecommuting in state and local tax codes should be eliminated, and tax incentives can be provided for telecommuting infrastructure setup and maintenance costs, similar to the tax-free benefits currently provided for other workplace transportation costs (parking and transit use).

Accurate pricing

- To better reflect the hidden costs of oil, primarily those associated with its national security impact, a revenue neutral oil security fee could be levied either per barrel or at the pump, matched with an equivalent reduction in income tax. This fee would send a more accurate signal to consumers about the real cost of their gallon of gasoline or diesel. Reflecting the hidden costs of oil at the pump will enable consumers (assuming modal choices exist and vehicles are platforms on which fuels can compete) to make more economically-informed transportation choices. Payment for highway, bridge and tunnel infrastructure should be to the extent possible shifted to user fees comprised of tolls, incorporating congestion pricing where appropriate.
- Instead of blanket subsidies to transit agencies, transportation vouchers could be provided for low-income households. Subsidies should be laser focused on helping the people that actually need help. Vouchers would help transit agencies recover more revenue from the fare box by giving them the chance to charge the bulk of their users market-driven fares. Similar to school vouchers or food stamps, they could be redeemed with either existing transit agencies or entrepreneurs running private-sector buses, shuttles, vanpools and jitney buses, facilitating choice for low-income consumers and a more competitive market. This would also spur public transit agencies to focus resources as effectively as possible. Federal legislation could provide incentives for states and communities to enable more compe-

tition by changing regulations that thwart private-sector entrants and establishing transit voucher programs.

Accountability and local control

Spending of taxpayer moneys on transit and other high-occupant transportation options—running the gamut from rail transit, to bus rapid transit, to shuttle buses, vanpools, and carpools—should be tied to the goal of achieving modal choice in a cost effective manner for the greatest number of people. Thus taxpayer monies allocated to buses or rail should not support routes that very few people use, but rather should be focused on capital improvements that would improve service on, and recapitalize to maintain a state of good repair to existing high-load routes and add new routes that are expected to be consistently high-load. That means more frequent service during peak usage hours and reduced travel times on routes that are expected to run consistently quite full. Taxpayer monies spent on transit infrastructure should only be spent where population density is sufficient to offer at least a chance that a transit option could be economic.

As economic growth resumes and the global appetite for oil grows, we can expect prices to hit record highs again, to the detriment of the global economy. A fleet-wide deployment of vehicles that enables fuel choice could take place relatively quickly. It will take more time to open the market to competition among transportation modes, but this approach would greatly increase economic resilience.

But such transformations will not occur by themselves. Indeed, economic theory clearly shows that market forces alone are incapable of breaking cartels and monopolies. It is the role of government. Only through committed leadership and government can the U.S. diminish the power of anti-market forces and eliminate coercion by non-democratic energy exporters.

The world economy grows, OPEC production doesn't

	1980	2010
World population	4.5 billion	6.8 billion
Number of automobiles	400 million (U.S.: 148 million)	900 million (U.S.: 240 million)
World GDP	$11 trillion	$60 trillion
Global oil demand	60 mbd	84 mbd
OPEC production	26 mbd	26.8 mbd

Policies for a Secure Energy Future: Issues in Supply and Demand

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Policy interest in energy tends to ebb and flow. When prices are high or volatile, policy makers focus on actions to improve markets, diversify fuel and technology options, open up access to new resources, and improve the efficiency of how we use energy. When events cause high levels of pollution or natural resource damages related to energy production or delivery, the focus shifts to finding energy options with lower environmental risk. Typically, energy policy action occurs in the context of crises, not during calmer times that might allow for more measured consideration of the inevitable trade-offs and balancing of interests.

In July 2007, for example, only three and a half years ago but a year before the global economic collapse would help to drive down energy prices, the National Petroleum Council's study, "Facing Hard Truths About Energy," opened with "The American people are very concerned about energy—its availability, reliability, cost, and environmental impact." Coming only two years behind the enactment of the comprehensive Energy Policy Act of 2005, the NPC report noted that energy was still "a subject of urgent policy discussions." By the end of 2007, Congress had enacted the Energy Independence and Security Act, designed to support those named goals by increasing the production of clean renewable fuels and the efficiency of products, buildings, and vehicles, by promoting research on and deployment of greenhouse gas capture and storage options, and by improving the energy performance of the federal government.

Just a few months later, in July 2008, well-head prices of natural gas peaked at $10.79 per million cubic feet (mcf); by the end of 2010, prices were a third as high ($3.71 per mcf).[1] Overall energy demand dropped, of course, with the economic collapse, and by 2010 was still almost 5% lower than it was in 2007.[2] And while energy is still on the agenda of some policy makers, consumers and producers (a notable example being this past summer's oil spill in the Gulf of Mexico), energy is hardly the subject of "urgent" discussions in very many places.

Thus, this year's Aspen Institute Congressional Program explores our nation's energy security needs in the absence of a perceived crisis. Recent polls indicate that Americans do not list energy issues as among "important issues facing the country now."[3] In fact, there may be as much good news on energy security issues as there is bad, with recent developments in natural gas being the best example of a good news story. But the challenges are still real and the issues important. The papers and sessions at this year's meeting examine separate in-depth issues related to oil drilling, coal, transportation, green jobs, and adapting to climate change. The topic of this paper, then, is to examine the overall context for our energy economy, with more attention to issues not covered in other panels: natural gas, renewables, nuclear, and energy efficiency.

Setting the stage—some facts:

What are the energy resources that Americans depend upon, and where do they come from? There are some simple but important features of the U.S. energy landscape:

1. **Overall Energy Use:** Overall energy use has risen approximately 20% since 1980. (Figure 1). Before the recent economic decline which caused energy demand to fall in absolute terms, U.S. energy use from 1980 to 2007 had grown by 30%.

2. **Trends in Energy Use by Customer Type:** Households and industries use most of the nation's energy, with commercial customers not far behind. This may sound intuitively obvious, but this fact is inherently hidden in the traditional governmental data on energy use, which often depict "the power sector" and the "transportation sector" as users of energy, alongside of residential, commercial and industrial customers, muddying the fact that it is citizens and businesses who are the ultimate users of energy. (Figure 2). Considering that residential customers (households) currently make up over 1/3 of the transportation sector's energy use (in driving motor vehicles) and nearly 2/5 of all electricity (in their homes), and industrial customers use approximately 1/4 of all electricity and a substantial portion of energy used for transportation, then the data would show that these two sectors use most energy today. Commercial users' electricity use, however, is growing relatively fast (especially due to growth in electricity use in commercial buildings), so that commercial customers' overall share of total energy is slowly rising. In parallel, industrial customers' share of total energy is dropping the fastest over time, with industrial energy use having peaked in absolute terms in 1997 at a level 20% higher than it is at present. (Figure 3). Over time, electricity production and delivery takes up an increasing share of total energy.

3. **Household Energy Use:** Taking into account energy used in homes and motor vehicles, half of the typical person's direct energy use is electricity in buildings,[4] 30% is from driving cars, and the rest is for some other energy sources (e.g., natural gas or oil for heating homes).[5]

4. **Energy Use in Buildings:** Buildings (that is, residential and commercial buildings) and the activities inside of them (including heating, cooling, lighting, electrical equipment and appliances) now use approximately 43% of all energy in the U.S. economy, higher than in the transportation sector (29%) or the industrial sector (30%). And electricity in buildings now constitutes approximately 3/4 of total energy use in buildings.

5. **Manufacturing Use of Energy:** The largest manufacturing users of energy are petroleum and coal products (33%), chemicals (24%), paper (11%), and food (6%). Not counting use of non-fuel energy products by the petroleum/coal products group, natural gas is the dominant fuel used in manufacturing, and makes up just under 2/5 of energy used in manufacturing. Electricity, including on-site generation, makes up another fifth.

6. **More Efficient Use of Energy:** The U.S. economy has become more "energy intensive" over time: It takes less energy to produce economic output today compared to all other years in the last three decades. (Figure 4). This is a measure of underlying productivity improvements as well as the extent to which energy efficiency measures have been adopted by households, businesses and others, in buildings and motor vehicles. End-use efficiency is particularly important, since buildings use so much electricity and in light of the fact that *for every unit of fuel consumed in the production of electricity, 2/3 of its full energy value is lost to conversion inefficiencies (at the power plant) and delivery losses (on the wires).* Electricity, while vitally important to the economy, exacts an inefficient toll as fuel is turned into

power to run motors and computers, light up spaces, and perhaps a large number of tomorrow's cars.

7. **Fuel Shares:** The portion of U.S. energy supplied by different fuels has remained remarkably stable over the years. (Figure 5). In 2009, more oil was used than any other fuel (37% of total energy), with most oil used for transportation (except in the Northeast, where heating oil is important). Natural gas now provides 25% of total energy, with coal supplying 21% (almost entirely used for electricity), nuclear 9%, and renewables 7%. The shares were only slightly different in 1980, with 44% oil, 26% natural gas, 20% coal, but only 4% nuclear and 7% renewable. Fossil fuels continue to play the dominant energy role, providing 83% today, with nuclear, wind and biomass making up the growth in non-fossil energy in recent decades.

8. **Domestic Production of Energy—Part 1:** By far, the U.S. produces most of the energy its consumers use. (Figure 6). Imports make up 40% of total energy production and provide 30% of total energy use. The amount of oil imports has steadily increased (until the post-2008 economic downturn): roughly 3 out of every 5 barrels of oil now used in the U.S. economy come from outside the U.S. (Figure 7). Oil imports account for 92% of all energy imported into the U.S., and nearly 3/4 of the oil consumed in the U.S. goes to move people and things. The transportation sector, thus, is the most dependent on foreign energy sources.

9. **Domestic Production of Energy—Part 2:** By far, the two energy resources which have undergone significant growth in recent years are natural gas and renewable energy. Figure 8 shows the growth in production of natural gas relative to production of onshore and offshore oil in recent years. The trajectory for natural gas is significant, with new resources now economically available from shale gas and other unconventional gas areas. U.S. shale gas production has increased 14-fold in 10 years.[6] Additionally, domestic production of biofuels is strong, as is wind generation—which has dramatically increased, both in number and capacity of wind turbines and total output from these facilities. (Figure 9).

10. **Domestic Power Production:** Almost all of the nation's electricity comes from domestic energy resources,[7] with over 2/3 generated at power plants that use a fossil fuel: coal (45%), natural gas (23%); and oil (1%). (Figure 10). The remainder comes primarily from low-carbon fuels: nuclear (20%), conventional hydroelectric power (7%), and wind (2%). The last nuclear plant to come on line was in 1996, but "uprates" (or added capacity) at existing plants since then have totaled 4,582 MW (roughly the size of 4-5 large new reactors).[8] All of the nation's commercial nuclear energy and nine out of every ten tons of coal go into power production. By contrast, only 29% of U.S. natural gas produces electricity; the rest heats and cools buildings and runs industrial processes. The vast majority of power plant capacity added in the past decade is fueled by natural gas or wind, however. Given the combined effects of the cost advantage of natural gas, the policies supporting renewable energy, and the low cost to build a new gas-fired plant rather than a coal or nuclear facility, most of the new generating capacity likely to be added in the near term will be gas-fired and renewable capacity. By contrast, most of the oldest and least efficient generating capacity on the grid today burns coal; a third of coal-fired capacity is older than 40 years old. Half of the older plants have no pollution control equipment to address conventional air pollutants—like sulfur dioxide (contributing to acid rain), nitrogen oxides (contributing to smog), and mercury—and may face economic pressure to retire. The prospects for investment in nuclear plants are weak in the near term, especially in the absence of policies that

value low-carbon power production.

11. **Energy Prices:** Energy prices continue to exhibit mixed trends. (Figure 11). On the one hand, both oil and coal prices have risen recently, after having dropped with the economic collapse in 2008. Meanwhile, natural gas prices are much lower than their all-time highs in 2008, in part the result of significant improvements in technology that provide economical access to shale gas resources in the U.S. These countervailing trends tend to make natural gas all the more economically attractive—relative to other fossil fuels and new nuclear and renewable power plants as well.

12. **Greenhouse Gas Emissions:** Finally, although greenhouse gas emissions from the energy sector have dropped in recent years in conjunction with lower energy use, energy activity (especially oil used for transportation and coal used for power generation) remains a key source of GHG emissions and other pollutants. And without additional policy action, the long-term trend indicates increasing emissions and increasing requirements for significant adaptation to climate change.

Some observations and issues:

Different lenses help to make sense of today's complex U.S. energy landscape. Each provides a different angle on the realities of energy in America: the structure of its markets, key patterns of production and use, their relationships to larger strategic issues in the nation, and their implications for policy. Because issues relating to the transportation sector and coal are addressed by others, the observations here focus on key themes in the overall context.

1. **Regional variations:** Major regional differences are central to understanding energy systems, politics and policy in the U.S. These regional variations affect the character of the energy economy in different parts of the nation—whether, for example, a region views itself as an energy producer versus a consumer, or what are the prevailing attitudes about different fuels and their value. Texas and Louisiana are oil-producing areas; Appalachia and the Rockies have large coal resources; Pennsylvania is an up-and-coming shale gas production region, with prospects for a small role for coal; the sunny Southwest and the windy Upper Plains states have renewable energy potential; the Northeast is increasingly a gateway to offshore wind resources and energy imports. These facts create challenges for energy policy. Those aimed at creating incentives to build new transmission to connect remote windy areas with distant population centers, for example, face major hurdles, in part because the new lines may need to cross areas with people who don't want or need the power. (Figures 12-14).

2. **Regional differences** in attitudes about coal versus gas for power generation provide another good example: "coal country" states (Figure 15) have economies that are based, in part, on access to relatively inexpensive power; these states tend to have higher than average energy consumption per capita. (Figures 16-17). States like California, Texas, and New York that have little coal in their energy mix, rely more heavily on gas and nuclear power; these areas' historically poor air quality made it hard to site new power plants (such as coal plants) with high air emissions. These are also places that have had high electricity costs and restructured their electric industries to introduce competition as a way to help lower energy prices. These regional variations mean that environmental regulations affecting coal plants pose significantly different impacts and politics in parts of the nation.

3. **Natural gas—especially shale gas—is perhaps the best energy story in decades.**[9] Changes in production technology ("directional drilling" and "fracking") have opened

up vast areas of U.S. shale gas formations for economical development. (Figure 18). According to the newly released *Annual Energy Outlook,* "The technically recoverable unproved shale gas resource is 827 trillion cubic feet (as of January 1, 2009)…, 480 trillion cubic feet larger than in [last year's] *Annual Energy Outlook*…The larger resource leads to about double the shale gas production and over 20 percent higher total lower 48 natural gas production in 2035, with lower natural gas prices, than was projected [last year]….Shale gas offsets declines in other U.S. supply to meet consumption growth and lower import need."[10] (Figure 19). This is such big news because it offers the promise of access to relatively low-cost, abundant and relatively low-carbon gas to consumers in industry, at power plants, and in homes and office buildings. It means relatively stable, non-volatile prices—something that was unheard of just five years ago. Shale gas reserves are located close to consumers, with implications for pipeline and storage infrastructure. Domestic and international gas and oil prices may no longer move in tandem; international gas resources may no longer be so strongly controlled by countries (like Russia) willing to use gas for strategic advantage. Low gas prices are putting pressure on old and inefficient coal plants to retire—with improvements in air emissions; but they also put pressure on new nuclear and renewable projects because when the gas alternative is so attractive, it is harder to justify investment in these other technologies that can't be supported by investment in the near term based on market prices alone. Also, access to shale gas resources involves large quantities of water, raising concerns about water supply, water quality and industry practices that more resemble manufacturing activities than traditional oil and gas extraction.

4. **Buildings are a big deal in the energy system.** They use a lot of energy (43% of total energy use). Since 1980, residential and commercial buildings' energy use grew 55% (compared to 21% overall growth in U.S. energy use, and 37% growth in transportation energy use). Commercial buildings' energy use, especially, has dramatically increased: up 71% in that period, in light of overall growth trends in commercial square footage, the heavy air conditioning loads of such buildings, and the proliferation of electrical equipment. Electricity use in buildings has grown 104%, and now constitutes approximately one-third of *all* energy used in the U.S. economy. This means that energy use in buildings is heavily responsible for driving growth in the power sector. And changes in buildings' use of energy (through such things as building codes, appliance efficiency standards, efficiency programs, and "demand response" pricing models) can have a profound impact on companies' total energy requirements, their expenditures on energy, and the environmental impacts associated with production and delivery of electricity.

5. **In fact, electricity itself is a big deal.** This is hardly news: around the globe and historically, economies evolve and develop as they electrify their energy systems. This is part of the reason for the establishment of the Tennessee Valley Authority nearly 80 years ago. Electricity is a powerfully flexible form of energy for consumers, but it also suffers from inherent inefficiencies in that considerable energy (2/3 of the total energy value of fuels used to produce power) is lost in the process of converting fuel (such as coal, or natural gas, or uranium) into electricity, and then delivering electricity to retail customers. This means that for each unit of electricity able to be "conserved," there are two units of fuel not consumed, thereby avoiding its emissions to the atmosphere. Future growth of electricity depends upon such things as the adoption rates for energy efficiency measures and appliance/building efficiency standards, additions of electricity-

using equipment (e.g., battery technology, electro-technologies), the pace of economic recovery, and the impact of future environmental policies. In fact, deep reliance on electric vehicles in the future might lead to even-faster growth in overall electricity requirements.

6. **Americans are becoming more energy efficient:** The trend shows considerable improvement in the productivity of energy in the economy. (Figure 4). "Since 1992, the energy intensity of the U.S. economy has declined on average by 2 percent per year, in large part because the economic output of the service sectors, which use relatively less energy per dollar of output, has grown at a pace almost 6 times that of the industrial sector (in constant dollar terms)." There is still a huge potential for further improvement, both in the existing buildings and in the energy use of new appliances, buildings, and manufacturing processes. Appliance efficiency levels are set by the U.S. Department of Energy; building codes tend to be governed by state and local policies, with considerable variation in efficiency levels and enforcement of standards. China sets a clear example of having aggressive overall efficiency targets for its economy as a matter of national policy: Since 2005, Chinese policies have led to the closure of inefficient factories and power plants and a major push on energy efficiency (in vehicles, buildings, appliances), leading to a nearly 15% improvement in overall energy intensity in five years.[12] China has recently proposed to reduce its energy intensity by another 17% by 2016.[13] By contrast, the EIA estimates that market forces and existing policies will lead the U.S. to reduce its energy intensity by 40% between 2009 and 2035.[14]

7. **The environmental footprint of energy production, delivery and use has improved in the U.S., but remains challenging.** This was obvious during the summer of 2010, as the Gulf of Mexico's natural resources and fisheries were hit by the oil spill resulting from the Macondo offshore incident. More routinely, combustion of fossil fuels emits pollutants affecting public health, natural systems, visibility, and global climate change. Extraction of shale gas requires significant quantities of water. Hilltop coal mining can lead to run-offs, affecting the quality in neighboring water systems. From a technology point of view, the game changers would be tied to:

   - improvements in the efficiency of power production, delivery and use;
   - the ability to develop or otherwise gain access to technologies and practices that produce electricity with lower greenhouse gas emissions, and lower harmful and hazardous air pollutants;
   - the development of storage devices to render low-carbon but intermittent renewable resources more steady sources of power;
   - the application of "smart" grid technologies (an array of hardware and software technologies and systems) that will allow current systems to be operated more reliably and at lower cost over the long run;
   - the ability to safely extract natural gas and oil safely and with minimum use of other natural resources like water;
   - processes to safely manage high-level radioactive wastes from nuclear generation.

8. **Energy infrastructure is very long-lived, and near-term investment decisions have long-lasting impacts.** Many of the nation's current energy facilities—natural gas pipelines, electric transmission lines, coal power plants, large hydroelectric and nuclear facilities, refineries, and other facilities—are old. Many are aging, having served decades beyond their original planned lives. Many will need to be replaced with more modern technology and materials. These investments will undoubtedly lead to efficiency gains but will come through investment

needed to just maintain the system, rather than to grow or improve it. From a short-term economic point of view, adoption of currently available technology to replace the old may minimize costs (and prices to today's consumers), but introduce long-term obligations for energy use with potentially large environmental and energy security impacts. Advanced technology (such as coal gasification with carbon capture, large and small-scale nuclear reactors, gasification systems that use various waste streams as a feedstock, energy storage systems to support more efficient grid operations, or off-shore wind supported by high-voltage transmission systems) may face significant hurdles in entering commercial markets, but offer improvements over current technology and long-term pay-off from an inter-generational point of view. The fact that a significant share of energy systems in the U.S. are supplied through competitive markets means that, although they provide many economic benefits to consumers, such markets also can make it harder for new advanced technologies to gain traction. Many, in fact, may require public support in one form or another in order to move into commercial demonstration projects in U.S. installations.[15] This may be particularly true in light of the otherwise "good news" about low natural gas prices, which raises the relative cost of other fuel/technology combinations. But such support may constitute a big bet that could pay off in the long-term for American economic, energy and environmental security, but involve costs in the near-term that may be hard to swallow in times of tight budgets and hopes for economic recovery.

Some policy issues and suggestions:

These observations point to several potential priorities in U.S. energy policy:

- First is ensuring that the opportunities afforded by America's vast shale gas resources are realized with minimum-to-no bad surprises. This means adoption of practices and policies to support safe exploitation of the gas supply with acceptable risks to natural resources and the environment. Several studies are underway to assess industry practices and identify the trade-offs associated with new forms of regulation by state or federal environmental authorities (or both). The goal should be to find a workable combination that supports prudent development of the shale-gas resource potential for near- and long-term strategic advantage for the U.S.
- Second is tapping deep reserves of energy efficiency and demand reduction in existing buildings and industrial processes, and to adopt standards for efficient electrical and other energy use in new buildings, appliances and equipment. Statutory authorities supporting energy efficiency reside in many places within federal and state jurisdictions, including under the Department of Energy, policies of the Federal Energy Regulatory Commission and state public utility commissions, state building codes, market rules and practices of grid operators, practices of energy efficiency service providers, public housing authorities, city and town governments, and countless others.
- A third suggestion is to find and adopt policies to improve the pathways to develop and deploy modern and advanced energy technologies. Some of these may include tapping the purchasing power of large entities, such as the Department of Defense with its long-term strategic interests in improving the efficiency of its energy use and securing alternative fuels, and in reducing taxpayers' payments for energy.
- Other ideas may involve relying on utilities as agents to accomplish larger public policy objectives, through providing long-term contracts to support investment in renewable energy projects, or small-scale nuclear plants, or access to natural gas fields.

- Another option is to support the implementation of environmental regulations of traditional air pollutants under existing law that will, in combination with low natural gas prices, encourage some of the oldest and least efficient coal plants to retire. This could allow for the introduction of more modern power plants, yielding a more efficient fleet of plants, producing new construction jobs related to replacement capacity, and reducing unhealthy levels of air pollution.

- Other options involve developing mechanisms to map out and fund investment in advanced energy research, development and deployment (RD&D), such as was recently recommended by the President's Council of Advisors on Science and Technology.[16] PCAST recommended a substantial increase in federal support for RD&D and identified the importance of "roadmaps for key energy technologies" and the assessment (and where appropriate, elimination) of existing energy subsidies and incentives. Similar recommendations were offered this past year by the American Energy Innovation Council,[17] which recognized two reasons for a governmental role in accelerating energy innovation:

  First, innovations in energy technology can generate significant, quantifiable public benefits that are not reflected in the market price of energy. These benefits include cleaner air and improved public health, enhanced national security and international diplomacy, reduced risk of dangerous climate change, and protection from energy price shocks and related economic disruptions. Currently, these benefits are neither recognized nor rewarded by the free market. Second, the energy business requires investments of capital at a scale that is beyond the risk threshold of most private-sector investors. This high level of risk, when combined with existing market structures, limits the rate of energy equipment turnover. A slow turnover rate exacerbates the historic dearth of investments in new ideas, creating a vicious cycle of status quo behavior.

Endnotes

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1 Natural gas wellhead price data from the U.S. Energy Information Administration ("EIA"). For prices through October 2010, see http://www.eia.gov/dnav/ng/hist/n9190us3m.htm; for prices; for quarterly prices, see the Short Term Energy Outlook, January 11, 2011, Table 1, http://www.eia.gov/emeu/steo/pub/steo_full.pdf.

2 Energy Information Administration ("EIA", Short Term Energy Outlook, comparing information for the four quarters of 2007 (from the March 2008 STEO) with the four quarters of 2010 (from the January 2011 STEO).

3 Bloomberg National Poll conducted by Selzer & Company. Dec. 4-7, 2010. N=1,000 adults nationwide. Margin of error ± 3.1. Energy did not appear in the top priorities mentioned by those surveyed. The results were: Unemployment and jobs (50%); federal deficit and spending (25%); health care (9%); war in Afghanistan (7%); immigration (5%); other or unsure (4%).

4 This figure is based on a view of energy use that assigns energy for production and delivery of electricity to the end users who purchase/consume electricity.

5 This is based on 2008 data for (a) total energy consumption in residential buildings (reflecting both primary use of energy directly in residential buildings, retail sales of electricity to residential customers, conversion and delivery losses associated with electricity production, transmission and distribution of electricity); and (b) energy consumption in passenger vehicles. See EIA Annual Review of Energy, and data on number of passenger vehicles from the Bureau of Transportation Statistics, http://www.bts.gov/publications/national_transportation_statistics/,

6 Howard Gruenspecht, EIA, "Shale Gas and the U.S. Energy Outlook - Recent Developments," presentation to The Energy Council, Global Energy and Environmental Issues Conference, Santa Fe, New Mexico, December 10, 2010.

7 U.S. nuclear plants use uranium produced at U.S. and foreign mines. In 2009, over 80 percent of uranium delivered to U.S. reactors was from foreign sources. http://www.eia.doe.gov/cneaf/nuclear/umar/summarytable1.html

8 Source: Nuclear Energy Institute, cumulative uprates 1996-2010, http://www.nei.org/resourcesandstats/documentlibrary/reliableandaffordableenergy/graphicsandcharts/usnuclearindustryyearlypoweruprates/

9 See John Deutch, "The Good News About Gas: The Natural Gas Revolution and Its Consequences," *Foreign Affairs,* January/February 2011.

10 EIA, "Annual Energy Outlook: 2011," Early Release Overview, December 2010, page 1.

11 EIA "Annual Energy Outlook 2011," Early Release Overview, page 7.

12 http://www.wri.org/publication/uscc-testimony-green-energy-policy-in-china.

13 http://af.reuters.com/article/energyOilNews/idAFTOE69C00X20101013.

14 EIA, "Annual Energy Outlook 2011," Early Release Overview, page 7.

15 See James Fallows, "Dirty Coal, Clean Future," The Atlantic, December 2010.

16 "Our most important recommendation is that the Administration establish a new process that can forge a more coordinated and robust Federal energy policy, a major piece of which is advancing energy innovation. Many Executive Branch agencies and departments must be engaged, with leadership from the Executive Office of the President. This is needed because "energy policy" is an amalgam, and often derivative, of policies for environment, competitiveness, security, finance, land use, and more. The President should establish a Quadrennial Energy Review (QER) process that will provide a multiyear roadmap that lays out an integrated view of short-, intermediate-, and long-term energy objectives; outlines legislative proposals to Congress; puts forward anticipated Executive actions coordinated across multiple agencies; and identifies resource requirements for the development and implementation of energy technologies." PCAST, "Accelerating the Pace of Change in Energy Technologies Through an Integrated Federal Energy Policy," November 2010, pages 1-2.

17 The AEIC's members include Norm Augustine, former chairman and chief executive officer of Lockheed Martin; Ursula Burns, chief executive officer of Xerox; John Doerr, partner at Kleiner Perkins Caufield & Byers; Bill Gates, chairman and former chief executive officer of Microsoft; Chad Holliday, chairman of Bank of America and former chairman and chief executive officer of DuPont; Jeff Immelt, chairman and chief executive officer of GE; and Tim Solso, chairman and chief executive officer of Cummins Inc.

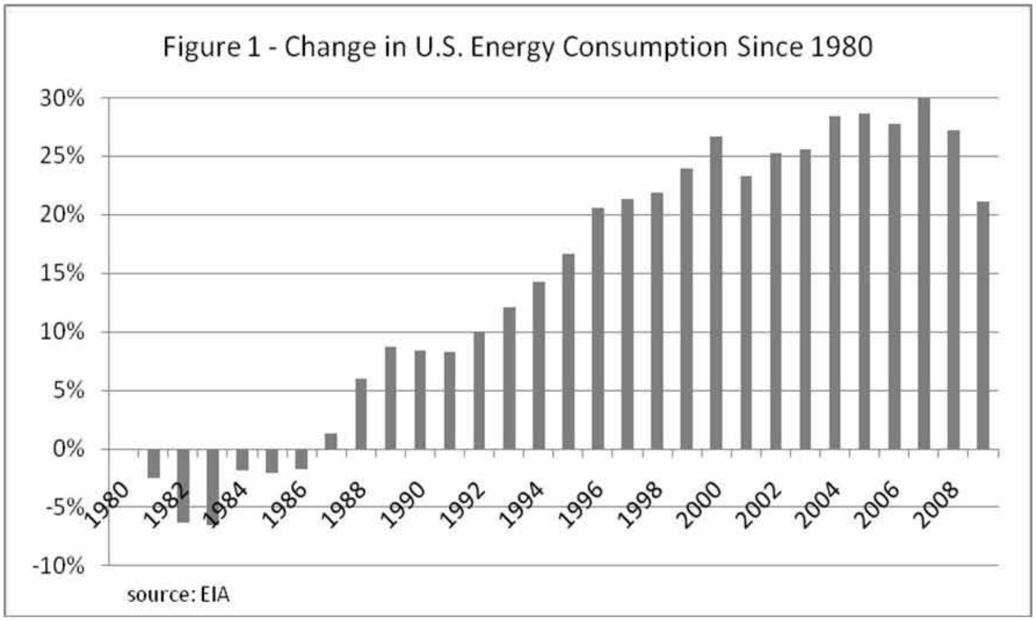

Figure 1 - Change in U.S. Energy Consumption Since 1980

Tierney – Energy Security Figures – Aspen Congressional Program, 2011

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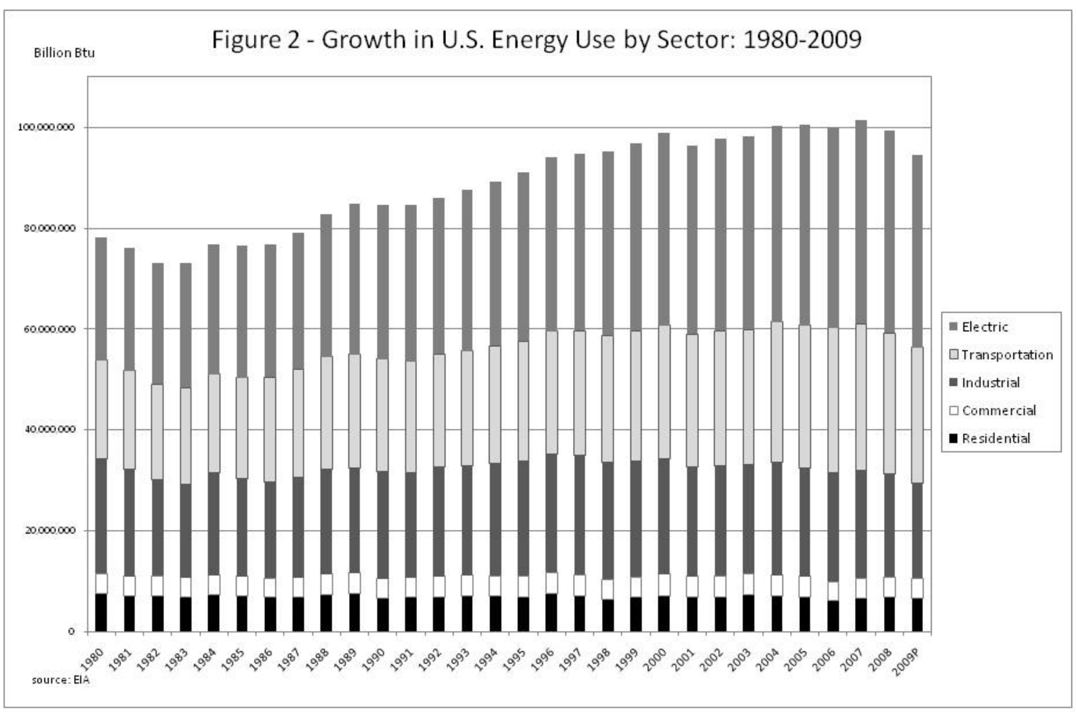

Figure 2 - Growth in U.S. Energy Use by Sector: 1980-2009

Tierney – Energy Security Figures – Aspen Congressional Program, 2011

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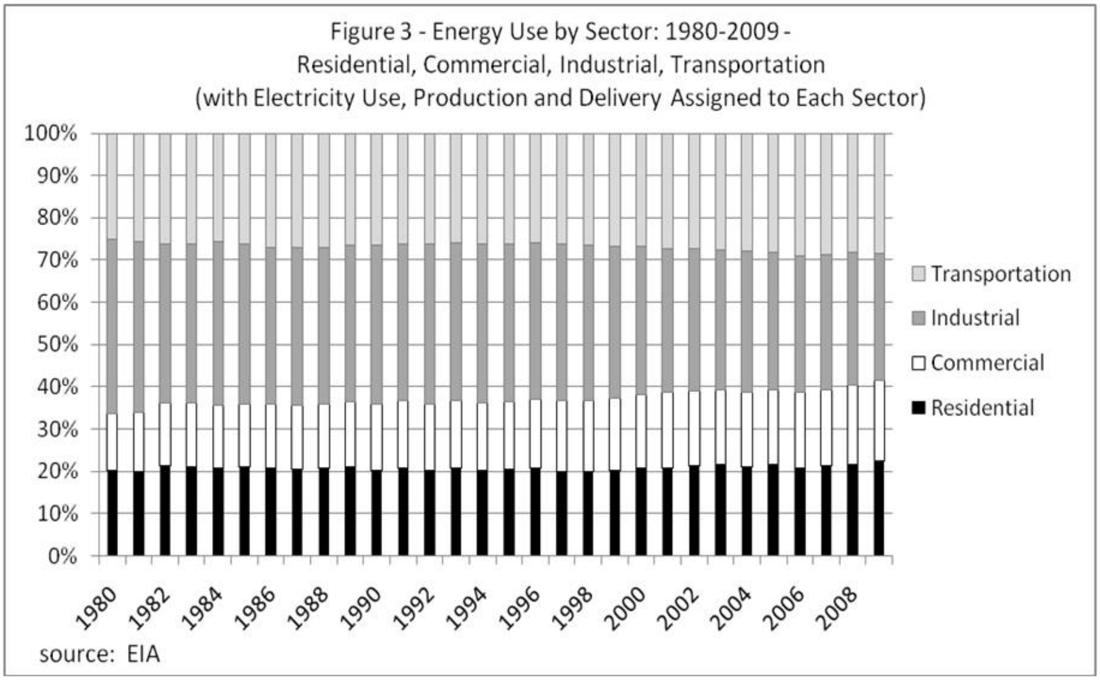

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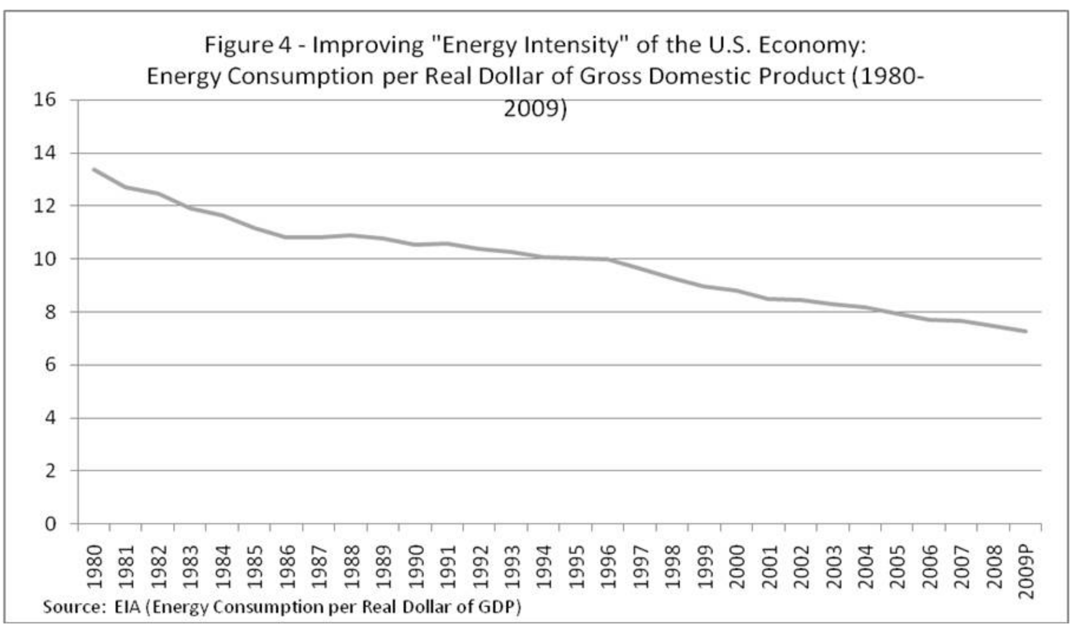

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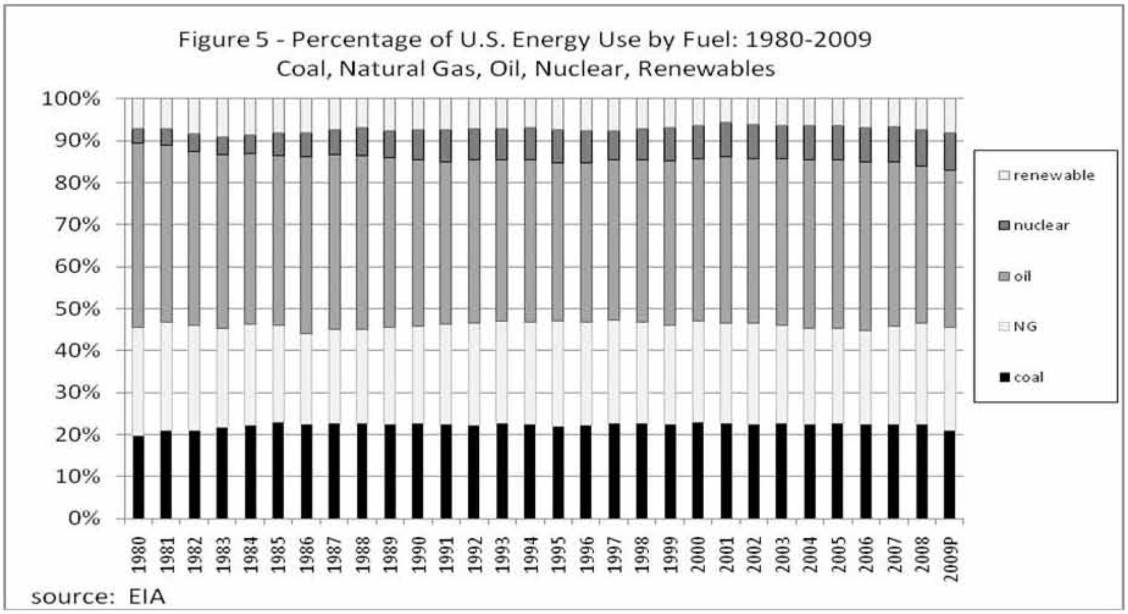

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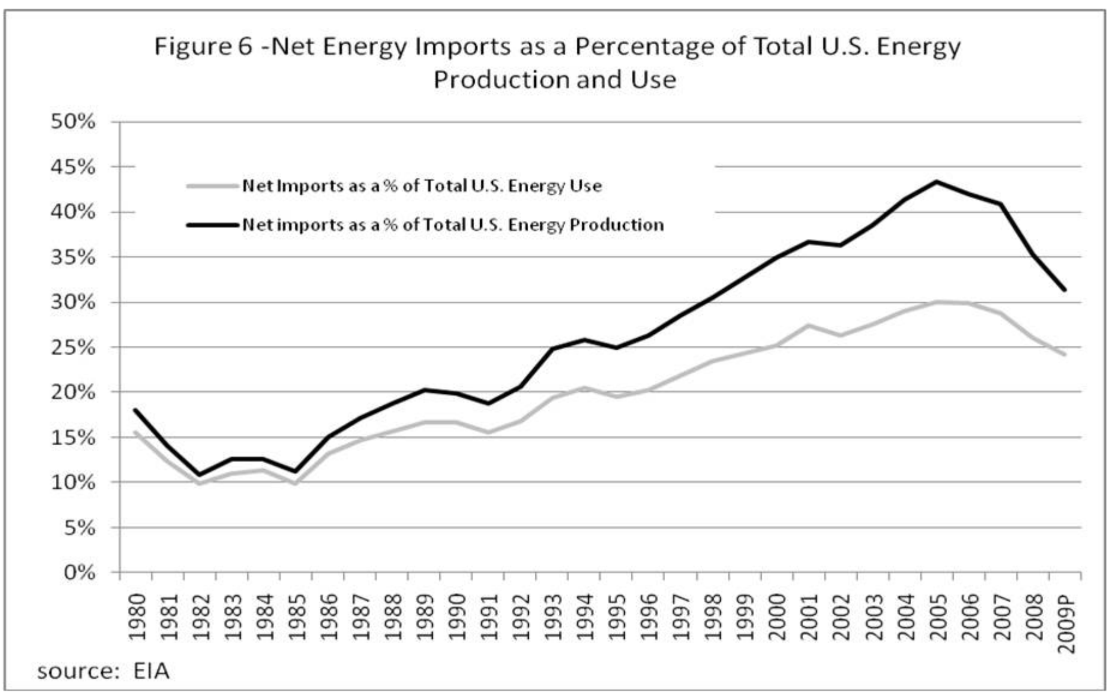

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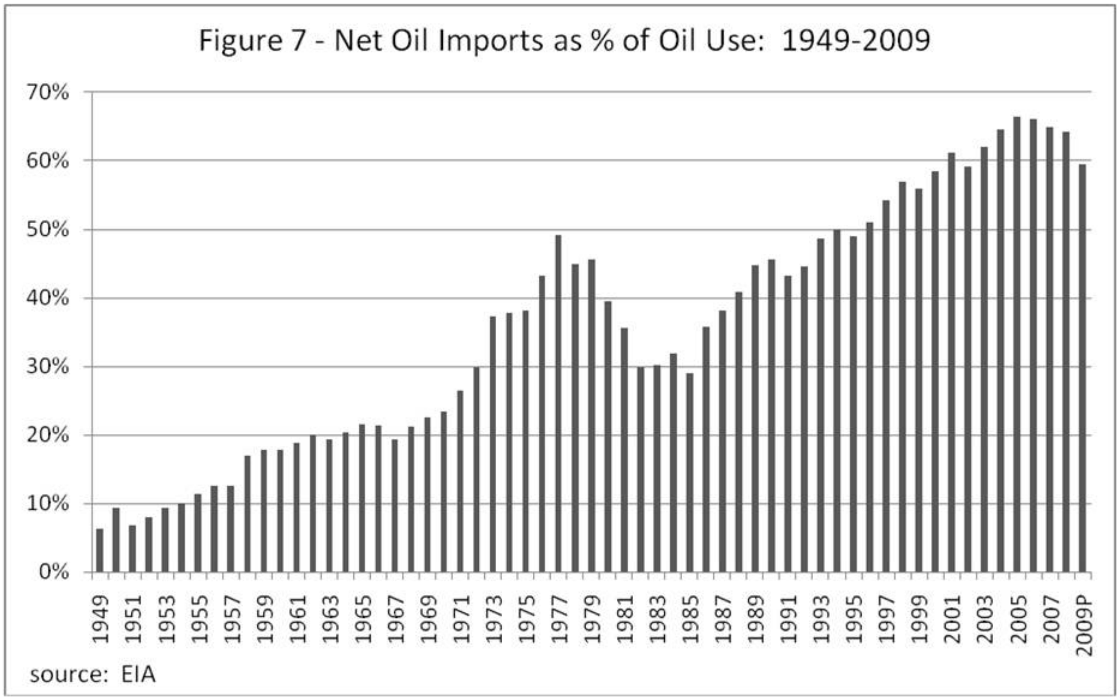

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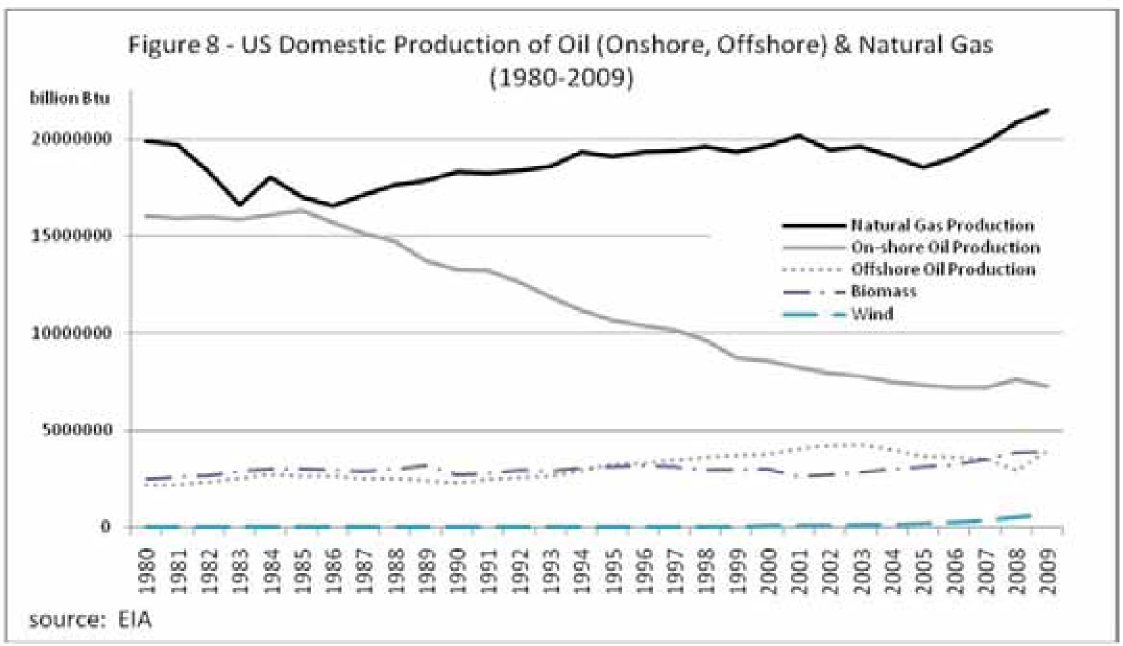

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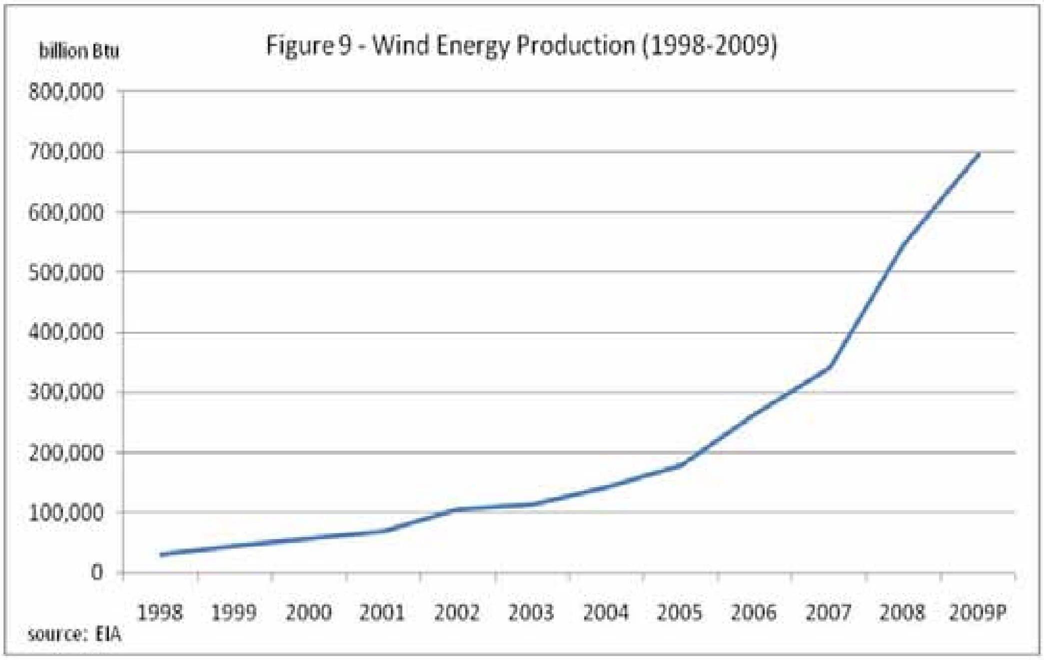

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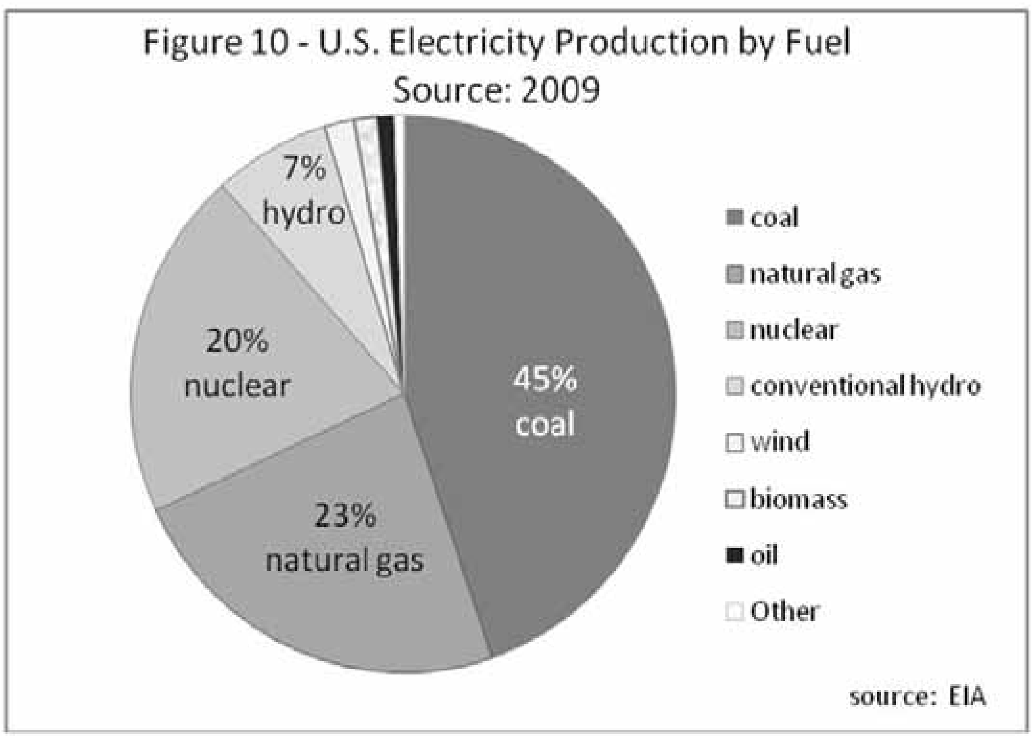

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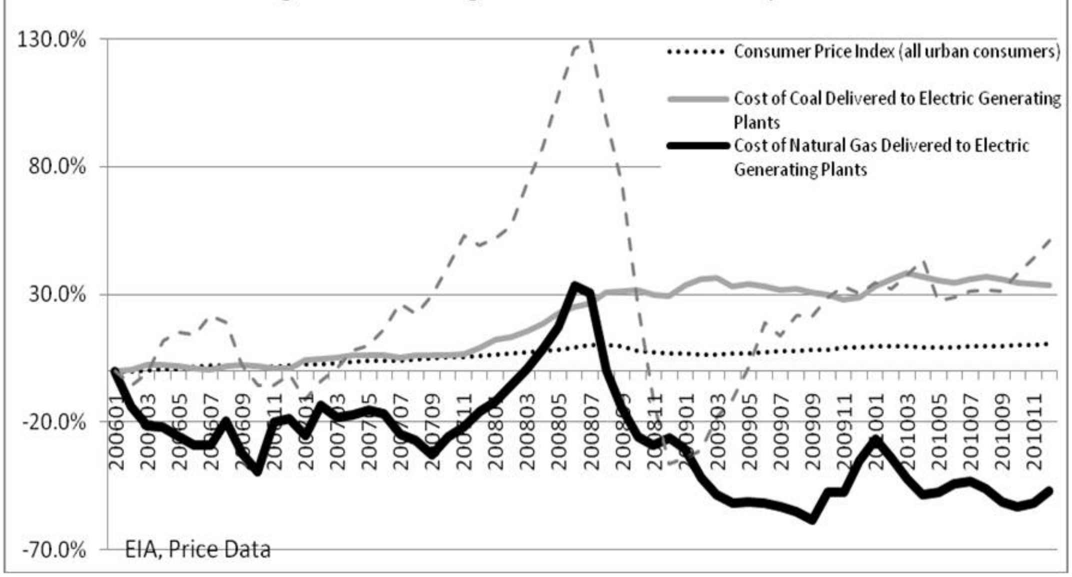

Figure 11 - Change in Price Since January 2006:

Tierney – Energy Security Figures – Aspen Congressional Program, 2011

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Figure 12 - Wind Tends to Be Located Where People Are Not

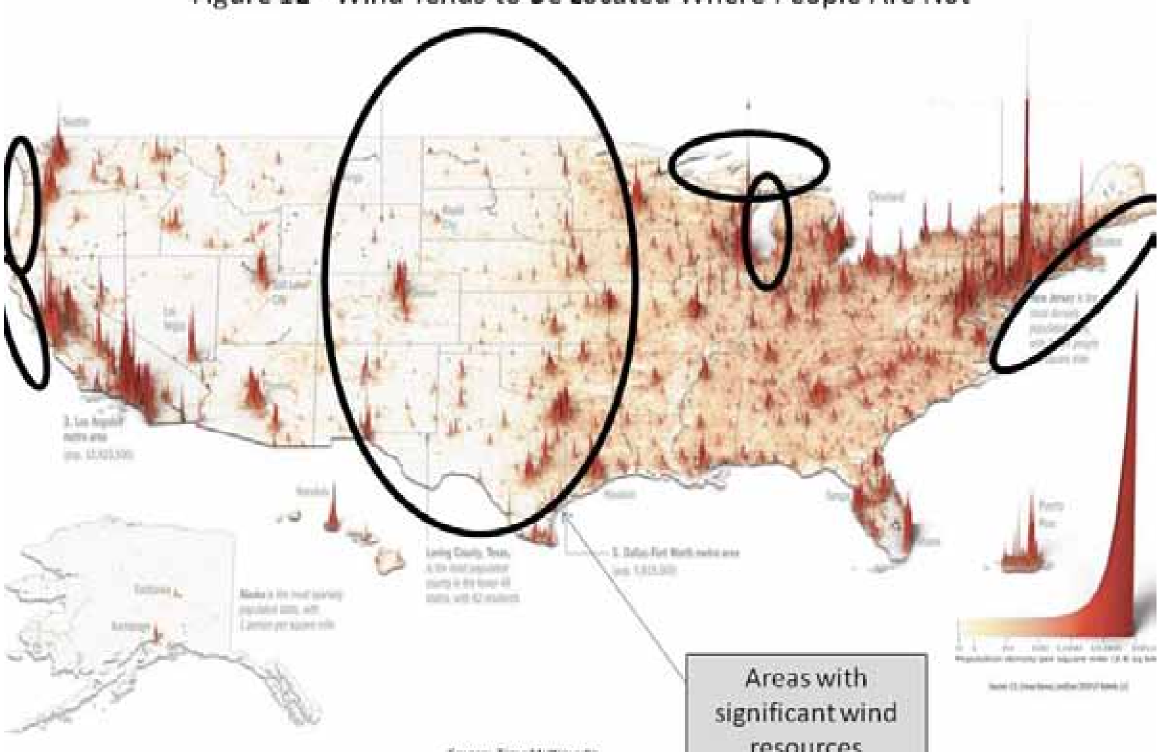

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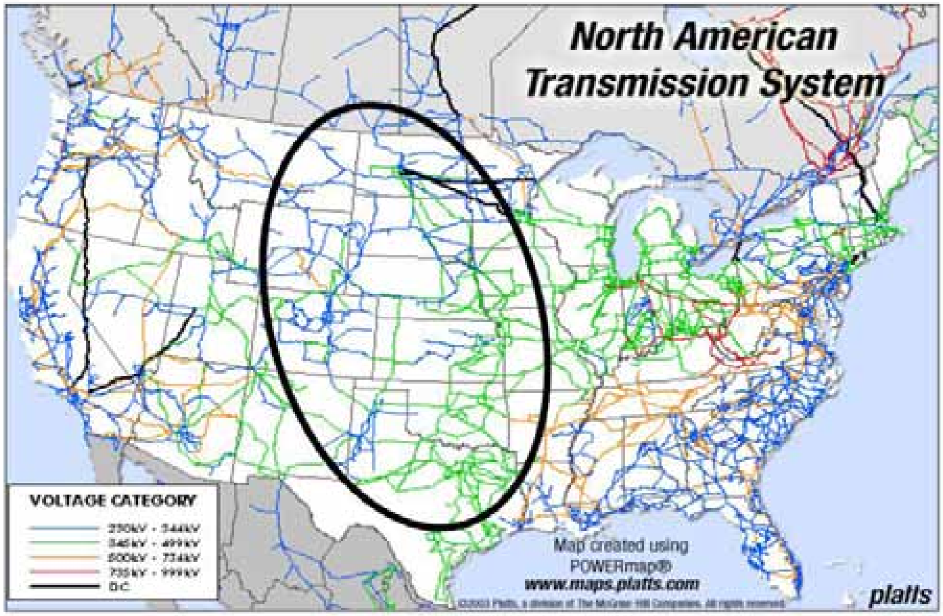
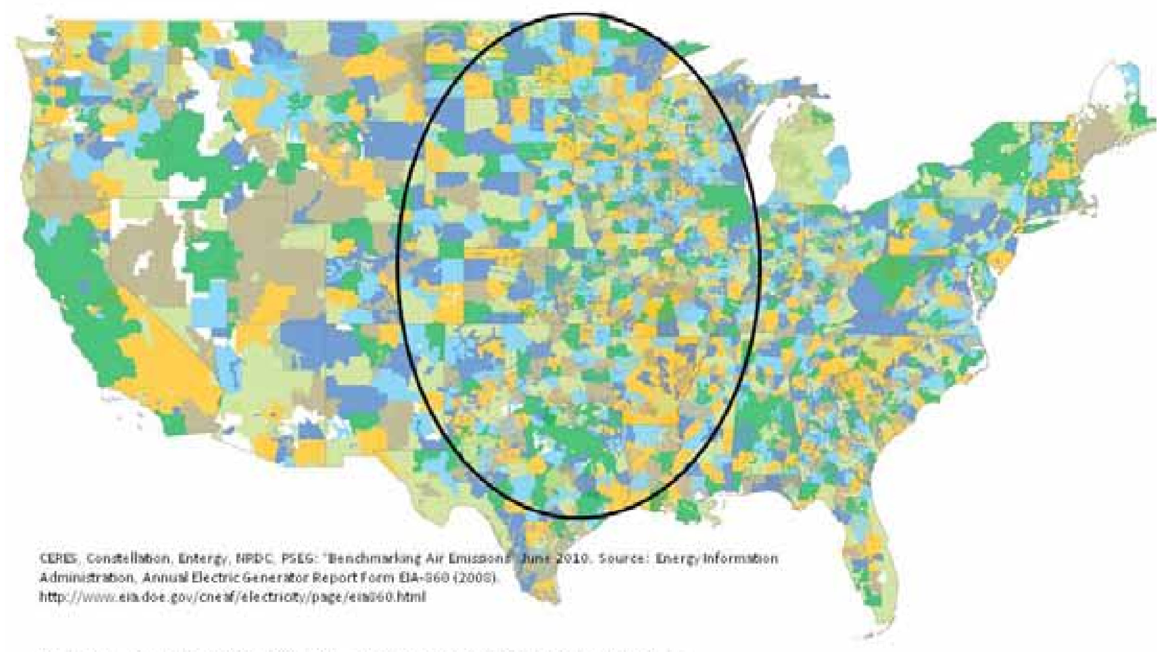
Figure 13 – The Electric Grid is Weakest in Areas
Where the Best Wind Resources Are Located



Source of maps: Platts

Tierney – Energy Security Figures – Aspen Congressional Program, 2011

Figure 14 – To Connect Wind Resources to Consumers,
New Transmission Lines Must Cross Multiple Electric Utility Service Territories and States



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http://www.eia.doe.gov/cneaf/electricity/page/eia860.html

Tierney – Energy Security Figures – Aspen Congressional Program, 2011

Figure 15 - Coal Country – Resources and Power Plants

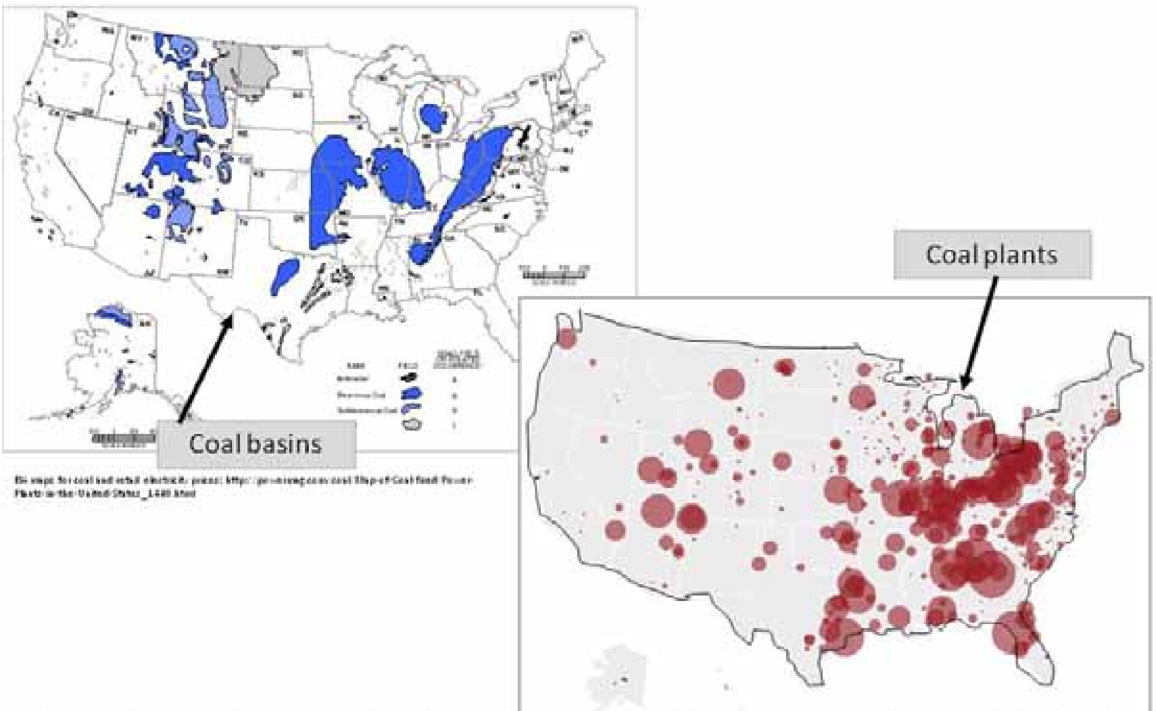

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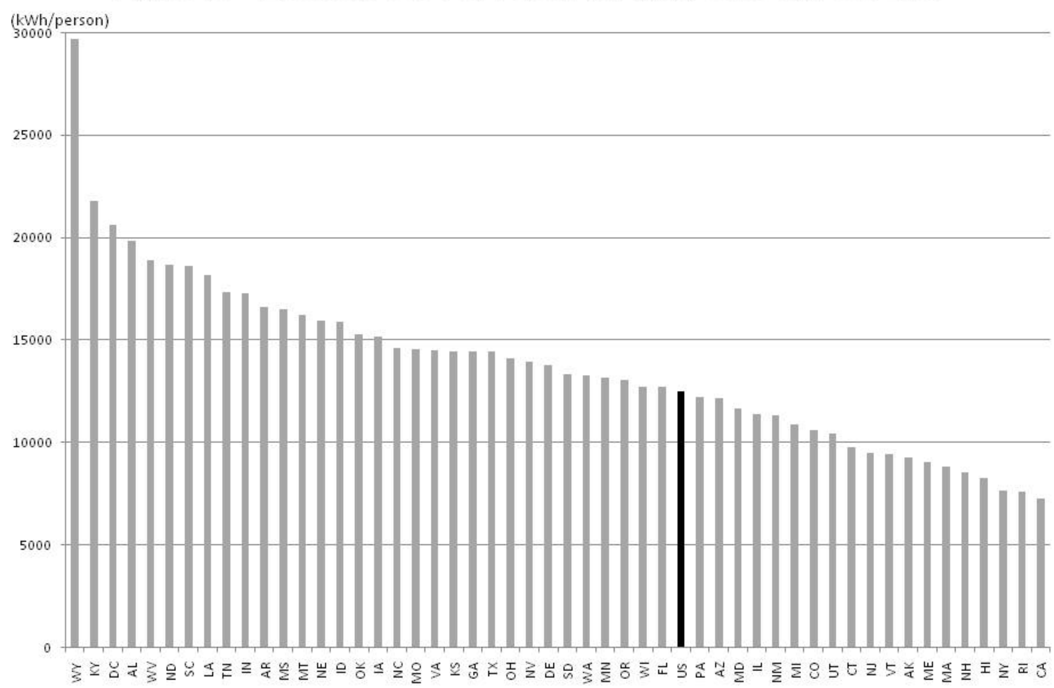
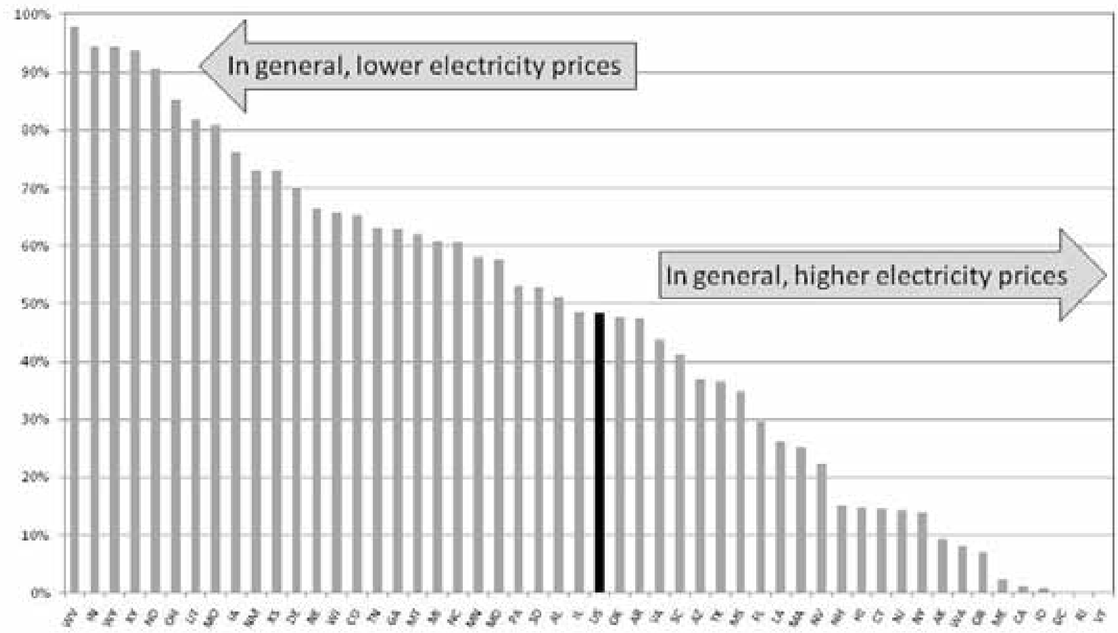
Figure 16 – Electricity Use Per Person (KWh) by State and US: 2007



Data: Energy Information Administration, State Energy Data System (most recent annual data available as of 3-12-10)

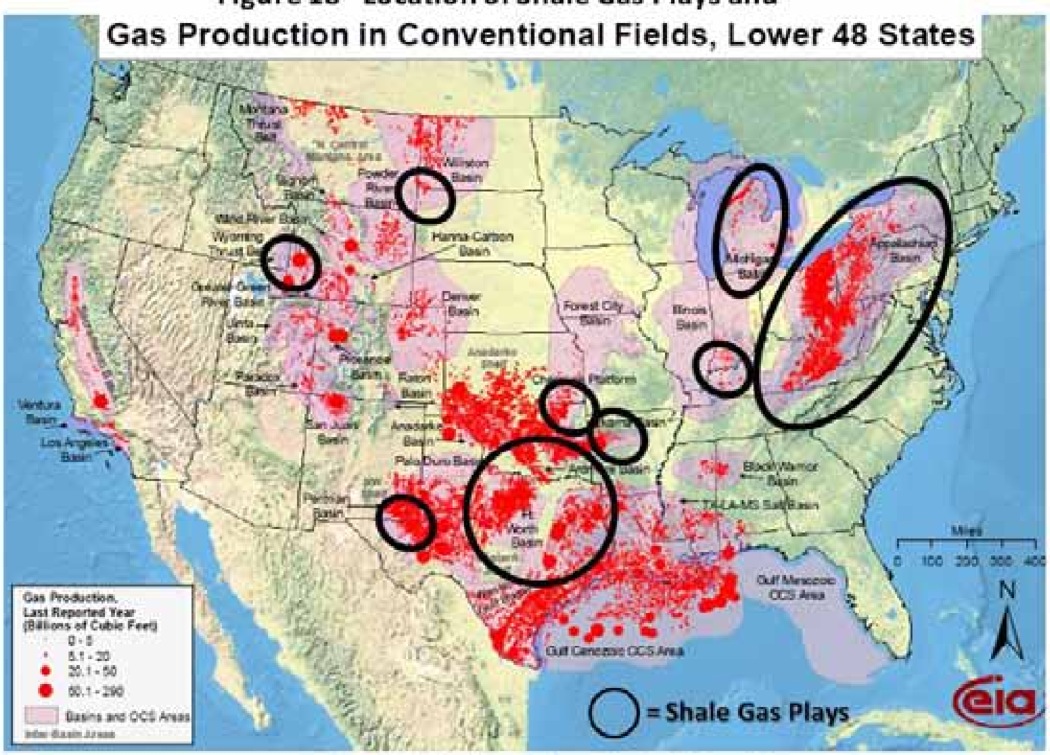
Tierney – Energy Security Figures – Aspen Congressional Program, 2011

Figure 17 – Percentage Coal in a State's Electricity Generation Mix



Tierney – Energy Security Figures – Aspen Congressional Program, 2011

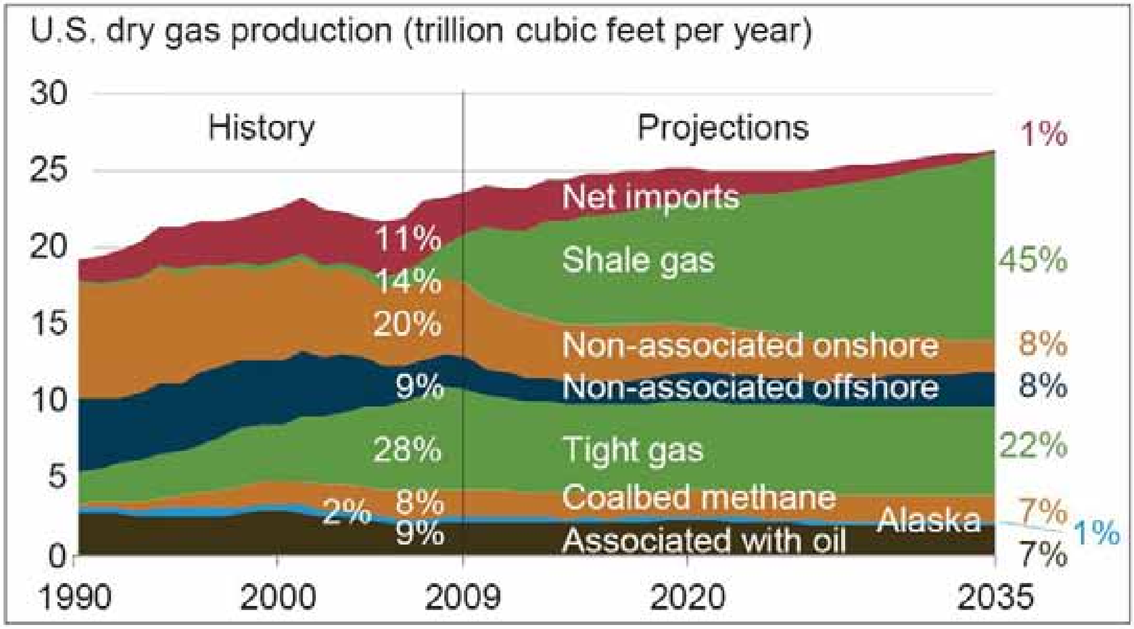
Figure 18 - Location of Shale Gas Plays and Gas Production in Conventional Fields, Lower 48 States



EIA, March 2010, http://www.eia.doe.gov/oil_gas/rpd/shale_gas.pdf

Tierney – Energy Security Figures – Aspen Congressional Program, 2011

Figure 19 – Increasing Role of Shale Gas in U.S. Dry Gas Production



Source: EIA, Annual Energy Outlook, Early Release Overview.

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The Future of Coal

Ernest J. Moniz, Ph.D.
Director, MIT Energy Initiative
Massachusetts Institute of Technology

Summary

Coal reserves: *The U.S. has the world's largest recoverable coal reserves* [1], about 250 years worth at the current consumption rate of about one billion tons/year. The quality of the coal varies significantly across the country. For example, Eastern coal generally has a higher heat content but also more sulfur than Western coal. This is an important consideration for meeting environmental constraints on emissions. Coal is produced in over twenty states. Almost all of the coal consumed in the U.S. is for electricity production.

China is the world's largest coal consumer [2]—about three billion tons/year—and has about 35 years of recoverable resources at this consumption rate. China is likely to continue to increase coal imports both to meet coastal demand and to ameliorate urban pollution by import of higher quality coal (e.g., lower sulfur content than domestic coal).

China and the U.S. together account for well over half of global coal use.

Coal for electricity: Coal fuels nearly 40% of global electricity generation. In the U.S., it is even higher—about 45%—followed by natural gas and nuclear [3]. These three sources account for nearly 90% of U.S. electricity supply, providing an excellent security of supply situation for the U.S. (especially since the remainder is mostly renewables, with oil playing a very minor role). Almost every state generates some fraction of its electricity from coal. [4]

With today's fuel prices, *new natural gas plants have lower levelized electricity costs than do new coal plants.* [5]

The existing fleet of U.S. coal power plants totals about 340GWe of capacity, and much of it is very old. About 30% still lack major pollution emission controls, and about half specifically lack flue gas desulfurization (FGD) equipment (scrubbers); we note that FGDs are also an important part of mercury control.

Relatively small plants (less than 300 MWe) make up more than a quarter of the total coal plant capacity, most have no scrubbers, and the majority are over forty years old. These plants are strong candidates for retirement as a result of utility business decisions. Many already have marginal costs higher than natural gas plants (at today's coal and natural gas prices), and forthcoming EPA rules (discussed below) that bring these plants into compliance with the standards already met by the majority of coal plants will further lessen their economic competitiveness with natural gas, another abundant U.S. resource (as recognized fairly recently by the dramatic increase in shale gas production). [6]

Environmental impacts: The end-to-end environmental impacts of coal use—from mining to combustion—are considerable and have called for strong regulation. In particular, sulfur

dioxide, nitrogen oxides, mercury, and other hazardous air pollutants (HAPs) emissions are dominated by coal-fired power plants. The EPA has two rule makings in process: a Clean Air Transport Rule for SOx and NOx, and, as required by the Clean Air Act, a Maximum Achievable Control Technology rule for mercury and other HAPs. The latter rule may be the more difficult for the non-complying plants to meet, especially for the old, small, inefficient plants without control equipment. The capital cost of retrofits can approach that of a new-build efficient natural gas combined cycle (NGCC) plant, making retrofit an unlikely business decision.

It is widely anticipated that a minimum of 15% of the coal capacity (again: old, small, inefficient) will be retired in this decade, possibly as high as 30%, after the EPA rules come into effect (2014, or possibly a bit later). However, the U.S. also has a large underutilized fleet of NGCCs, the legacy of an earlier exuberant construction period. The fleet is running at about 40% capacity factor. Model calculations indicate that about 20% reduction in coal capacity can be absorbed just by increased existing NGCC utilization. Consequently, this substitution of natural gas for coal can be accomplished with relatively little impact on the overall U.S. electricity system. [7, 4]

The associated reduction in domestic coal requirements is likely to be offset to some extent by increased coal exports from the U.S., including to China. Today, over 7% of U.S. coal is exported. [8] Infrastructure projects are underway to increase the export capacity.

Climate change: Coal is also the *most carbon-intensive of fossil fuels,* accounting for over 80% of CO_2 emissions from U.S. power plants. Accounting for the higher efficiency of NGCC plants relative to supercritical coal plants, coal emissions are more than double those of NGCC for the same amount of produced electricity. There is not an expectation that the Congress will implement explicit policies to price CO_2 emissions in the next few years, although EPA actions might limit emissions through the Clean Air Act.

The vast majority of engaged scientists anticipate that nature will be providing increasingly strong signals about the need for prudent government action to lower greenhouse gas (GHG) emissions. There is **no** *credible pathway towards stringent GHG stabilization targets without substantial CO_2 emissions reduction from existing coal power plants.* This requirement falls most heavily on the U.S. and China and suggests that marketplace options be developed now for coal use in the event of strong CO_2 controls.

For the U.S., the substitution of natural gas for coal, as discussed above, would accomplish much of the CO_2 emissions reduction called for in this decade (supplemented by the many energy demand reduction actions that meet economic tests). However, it will also be *important to make major Research, Development and Demonstration (RD&D) advances in this decade that lower the costs of "carbon-free" supply* so that increasingly stringent targets can be met in the future. Among the important options to be pursued is *carbon capture and sequestration (CCS)* from coal (and natural gas) power plants.

CCS: The challenges with carbon capture and with sequestration are quite distinct, although they must work together as a system. For a single utility-scale coal plant, several megatons per year of CO_2 will need to be captured, compressed, piped, injected, and stored in geological formations.

The *U.S. appears to have considerable capacity for CO_2 sequestration* located suitably in relation to coal plants. [9] Nevertheless, there is much to do to establish sequestration as a commercially viable option: reservoir characterization, design of monitoring and verification systems for CO_2 storage, determination of injectivity and ultimate reservoir capacity, design of the regulatory regime and assignment of responsibilities, assumption of long-term liability and monetization of the stored CO_2. *The U.S. has been slow to field large-scale, integrated, sustained demonstrations* that are needed to provide public confidence and inform industry risk management. Strong government support is needed for these demonstrations, especially in the absence of a CO_2 emissions price signal. Nevertheless, we anticipate a successful outcome if an effective program is carried through.

Carbon capture presents a different challenge. Technology exists today, but it is too expensive and too big. As much as 30% of a power plant's output is needed to operate the capture process to provide transportation-ready CO_2, which makes it very expensive indeed even apart from the capital cost. A *dramatic cost reduction is needed*, and this calls for a large scale research program that emphasizes new concepts and scales the promising ones to commercial demonstration. If this is not accomplished, coal would eventually be squeezed out of the U.S. electricity mix by future stringent CO_2 emissions constraints. [10]

An aggressive and sustained RD&D program is needed now (at least $1B/year) for CCS RD&D if this technology is to be economically viable and implemented at large scale in 15-20 years. A promising approach for funding such a program (and many other crucial areas for the power sector) is through a small "line charge" on electricity sales, as has been proposed in Congress and advanced recently by the President's Council of Advisors on Science and Technology (PCAST). The scale is such that a *1 mill/kWh charge yields about $4B/year.* Clearly, industry and consumer support is essential for such an approach to be viable.

Relatively large (300 MWe or greater), high-efficiency coal plants with installed FGD and selective catalytic reduction (SCR) equipment are the best candidates for CCS retrofits. This represents a bit more than half of the current fleet. However, additional site-specific criteria are also important, such as proximity to sequestration sites, available land, and access to increased water supply. These would substantially lower the number of suitable retrofit opportunities with current capture technology.

An important *near term opportunity for advancing sequestration may be government support for enhanced oil recovery (EOR) using CO_2 from anthropogenic sources* (e.g., coal-fired power plants). This turns the CO_2 from a "waste" into a valuable product, especially given a growing shortage of CO_2 from natural sources, and can partially offset the high costs of CCS development.

If readers wish to view these charts in color, this entire document and color charts are available at: http://web.mit.edu/mitei/

Fig 1. **COAL RESERVES BY COUNTRY**

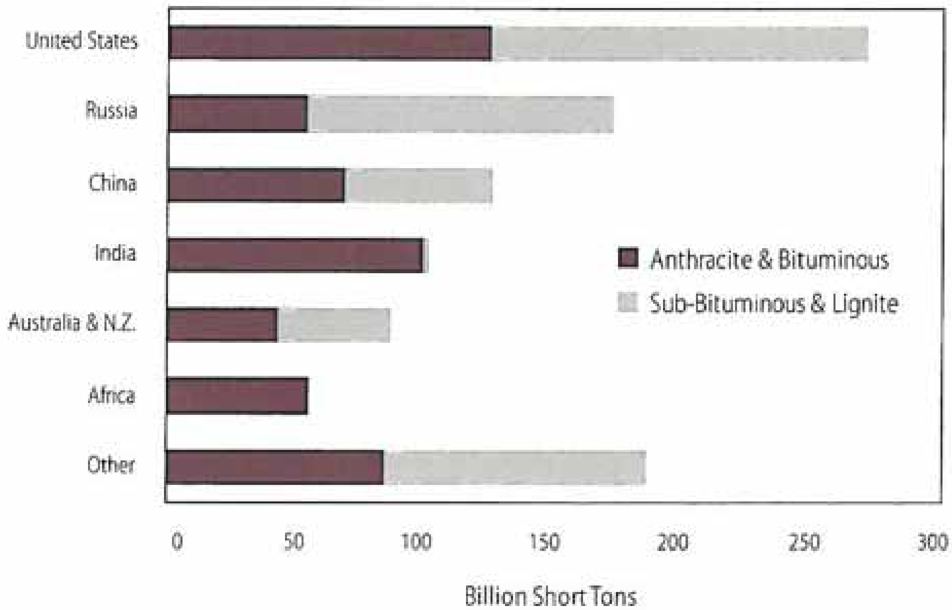


Figure 2.1 on page 5 of the MIT Future of Coal study (2007)

Fig 2.

COAL CONSUMPTION BY COUNTRY

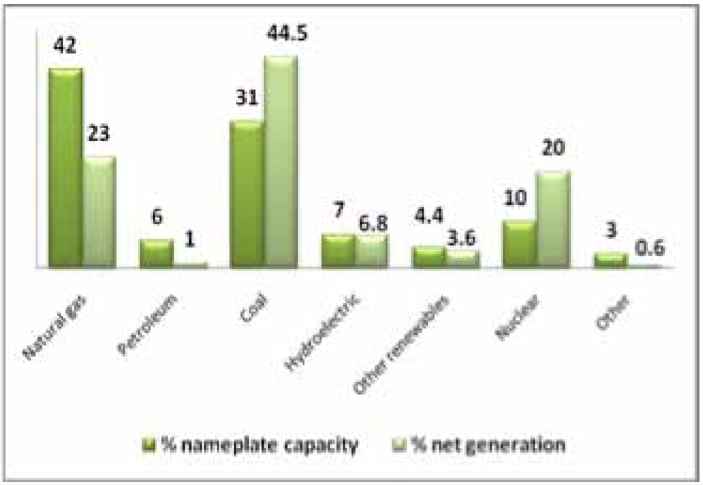
[2009, Millions of short tons]

U.S. Energy Information Administration
International Energy Statistics

China	3,475
United States	1,000
India	686
Germany	250
Russia	223
South Africa	199
Japan	181
Australia	150
World total	7,577

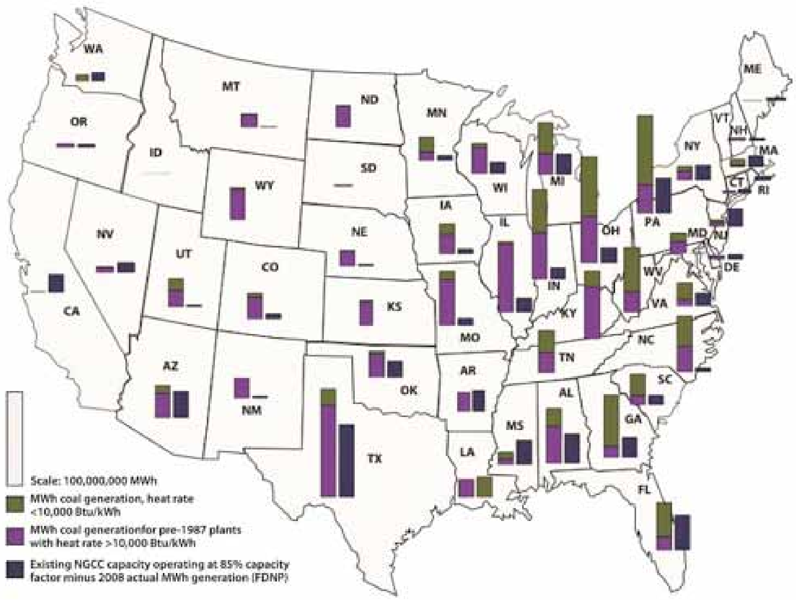
Fig. 3

U.S. Electricity Generation and Capacity by Fuel (2009, U.S. Energy Information Administration)



Coal	Petroleum	Natural Gas CC	Natural Gas other	Nuclear	Hydroelectric Conventional	Other Renewables	All energy sources
73.6	13.4	42	11.4	91.8	36.3	40	48.7

Figure 4. Coal generation and underutilized NGCC capacity by state



from the MIT Future of Natural Gas Interim Report – Fig. 4.4

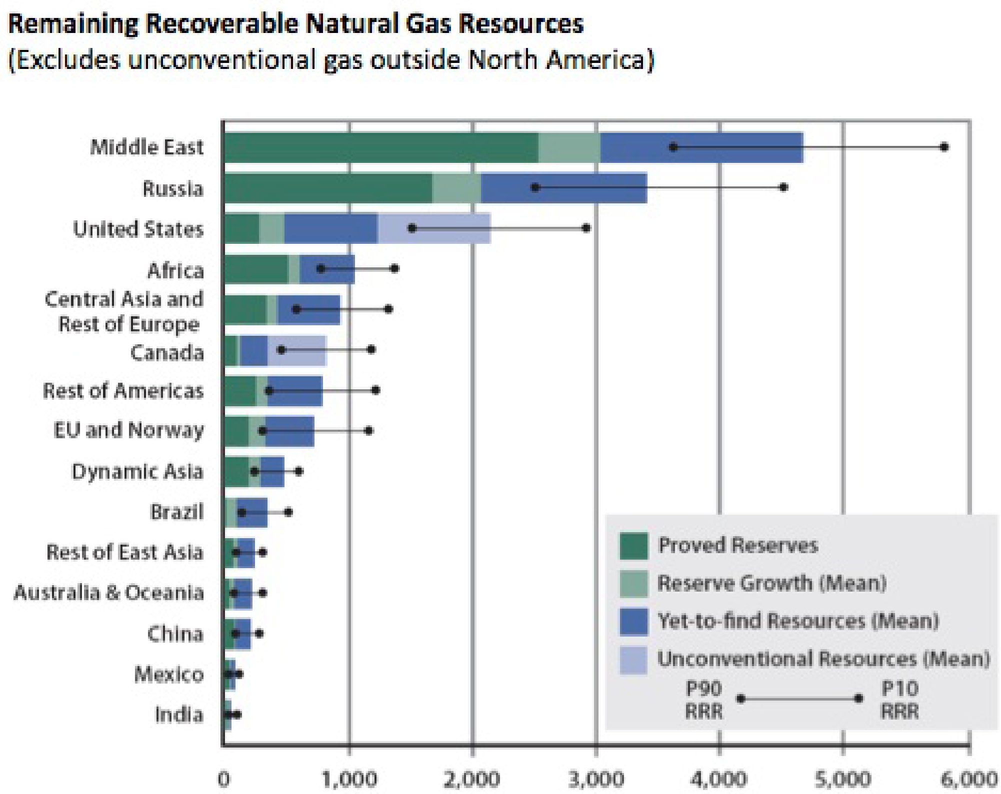
Fig 5. COSTS OF ELECTRIC GENERATION ALTERNATIVES

(2007$)

	Overnight cost ($/kW)	Fuel cost ($/MBtu)	Levelized cost of electricity (cents/kWh)		
			base case	$25/ton-CO2 price	same cost of capital
Nuclear	4000	0.67	8.4		6.6
Coal	2,300	2.60	6.2	8.3	
Gas	850	4/7/10	4.2/6.5/8.7	5.1/7.4/9.6	

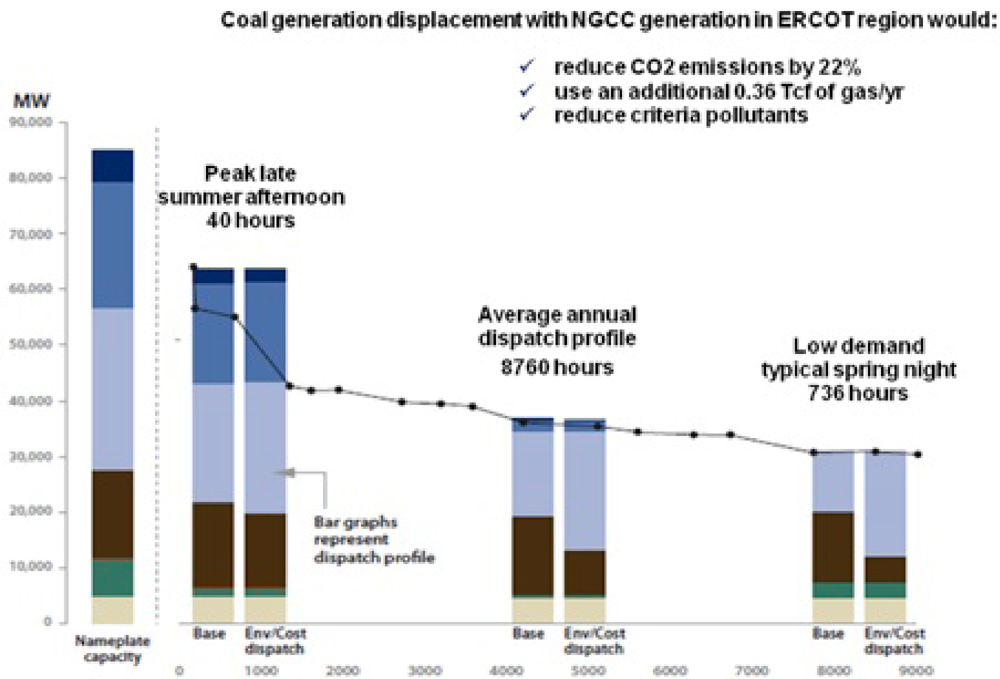
Taken from MIT Future of the Nuclear Fuel Cycle summary report (2010)

Figure 6.



from the MIT Future of Natural Gas Interim Report – Figure 2.2

Fig. 7. NG substitution for coal in the electricity sector (ERCOT)



from the MIT Future of Natural Gas Interim Report– Figure 4.5

Fig 8.

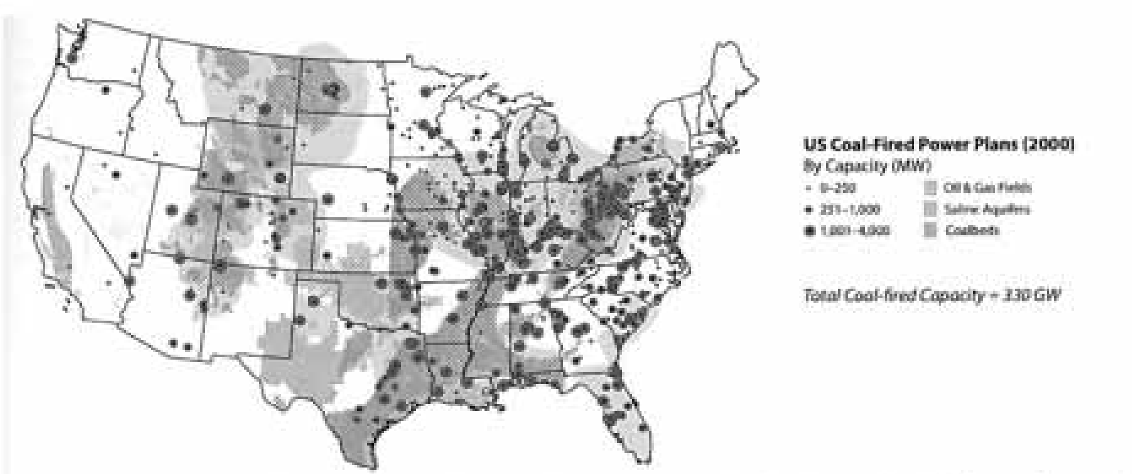
U.S. COAL PRODUCTION AND EXPORTS

[Millions of short tons]

U.S. Energy Information Administration

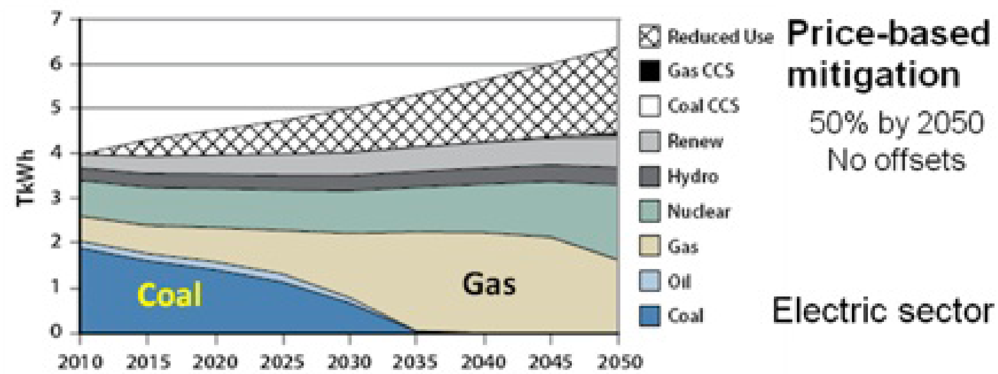
	Production	Exports
2004	1,112	48.0 (4.3%)
2005	1,131	49.9 (4.4%)
2006	1,163	49.6 (4.3%)
2007	1,147	59.2 (5.2%)
2008	1,172	81.5 (7.0%)
2009	1,075	59.1 (5.5%)
2010 (9 mos)	809	60.8 (7.5%)

Fig 9. LOCATION OF COAL PLANTS RELATIVE TO POTENTIAL STORAGE SITES



Map comparing location of existing coal-fired power plants in the US with potential sequestration sites. As stated earlier in the report, our knowledge of capacity for sequestration sites is very limited. Some shaded areas above may prove inappropriate, while detailed surveys may show sequestration potential in places that are currently not identified.

Fig. 10 Evolution of U.S. power sector with CO2 emissions pricing



Economic model for evolution of U.S. electricity sector with CO2 emissions pricing so as to effect 50% reduction by mid-century. No breakthroughs assumed in technology costs (e.g. carbon capture).

Taken from MIT Future of Natural Gas interim report (2010)

from the MIT Future of Natural Gas Study – Figure 3.3a

Adapting to a Warmer World: Understanding What the Future Might Hold and U.S. Options for Responding

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Over the past few years, the focus on the climate change issue has finally shifted from the question "Is it changing?" to the important questions of "So what?" and "Can society manage the unavoidable changes?"

The recent release of a series of reports from the U.S. National Academies,[1] the U.S. Global Change Research Program,[2] the Intergovernmental Panel on Climate Change (IPCC),[3] the United Nations,[4] and the World Bank[5] underscore the recognition that humans are changing the climate rapidly and that the world must act collectively to damp the unsustainable trajectory of greenhouse gas emissions.

"Adaptation" is no longer a forbidden word. For too long, talking about adaptation or "coping with climate change" implied that no serious mitigation or emissions reductions were being contemplated. However, the accumulation of scientific evidence in the last few years makes it abundantly clear that climate changes are underway, impacts are already being felt, and humanity faces more in the future. Thus, the world needs to respond to ongoing changes now and prepare for those yet to come. Both mitigation and adaptation are needed. A sensible strategy to minimize the damages from anthropogenic climate change must work in parallel to mitigate the pace and ultimate magnitude of the changes that occur and to adapt to the changes that cannot be avoided.

A "mitigation only" strategy won't work because it is already too late to avoid substantial climate change. An "adaptation only" strategy won't work because most adaptation measures become more costly and less effective as the magnitude of the changes to which one is trying to adapt gets larger.

The study of adaptation is nascent compared to the many analyses of costs and technologies to reduce emissions. Congress presciently commissioned its first and only comprehensive report on adaptation to climate change in 1991 via the Congressional Office of Technology Assessment (OTA).[6] The report called for actions to reduce institutional and geographic fragmentation, improve communication of risk, and enhance contingency planning to prepare for extreme events, as well as a research program to fill vast gaps in the understanding of vulnerability and resilience. It suggested ways that existing legislation and regulations could incorporate concerns about climate change to increase the resilience of ecological and economic systems. Little such activity has occurred to date.

More recently, two National Summits on Adaptation were convened, in 2007 and 2009.[7] These conversations have served as input to an ongoing interagency climate change adaptation task force that is assessing what the federal government is doing to adapt to climate change and to develop recommendations for additional actions to support a national adaptation strategy.[8] Summit participants representing industry, academia, environmental groups, and policymakers from city, state, regional, national, and international levels met and discussed the problems climate change would pose. As well, they discussed options to enhance the ability of our social and ecological systems to withstand current and future changes. They highlighted, as OTA had two decades earlier, that it will require fundamental changes in planning, management, institutional arrangements, technologies, and research and development strategies.

Some key conclusions include:

1) ***"Past is not prologue:"*** Infrastructure and natural resource management and planning based on the last 100 years of climate will be wrong. The design features of infrastructure and tolerances of species will be exceeded as climate change proceeds. Society needs to prepare for the climate of the future, not the past.

2) ***Degrees of warming matter:*** Both the rate of climate change and the magnitude pose problems for ecological and social systems. Aggressive mitigation can lessen the impacts of climate change and increase the time to develop solutions.

3) ***"Average" change may not be most important:*** There will also be changes in extreme events such as droughts, floods, maximum temperatures, and hurricane intensities. These cause tremendous human pain and economic loss, and they are not handled well now.

4) ***A portfolio approach is needed:*** Both mitigation and adaptation measures need to be developed and implemented in concert. There are interrelationships between options that can reduce emissions and those that enhance adaptive capacity.

5) ***Adaptive management will be needed:*** "Best practices" to cope with climate change need to be shared now. But they may need to be refined and evaluated regularly since the detailed impacts superimposed on other environmental stresses are not yet fully understood. Different regions will have different needs.

6) ***Investment is not commensurate with the urgency of the problem:*** The research, development, demonstration, and deployment funding for both mitigation and adaptation research is inadequate.[9] More integrative science assessments should be conducted with a focus on understanding regional impacts and multiple stresses, resulting in a strategic prioritization of research needed by policymakers.

What changes are underway?

Human activities have changed the climate of the earth, with significant impacts on ecosystems and human society; and the pace of change is increasing. The global average surface temperature is now about 1.4°F above its level in 1750, with most of the increase having occurred in the 20th century and the most rapid rise occurring since 1970. It was just announced that 2010 has tied for warmest year of the instrumental record (Figure 1).

Temperature changes over the continents have been greater than the global average, and the changes over the continents at high latitudes have been greater still. The year-round average air temperature of the U.S. has already risen by more than 2°F over the past 50 years. Temperatures in Alaska have increased by approximately twice as much as in the rest of the nation, with significant impacts on sea ice, ecosystems, and coastal communities.[11] The pattern of the observed changes matches closely what climate science predicts from the buildup in the atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4), and other greenhouse gases (GHGs), taking into account other known influences on the temperature. The largest of all of the human and natural influences on climate over the past 250 years has been the increase in the atmospheric CO_2 concentration resulting from deforestation and fossil fuel burning. The CO_2 emissions in recent decades, which have been responsible for the largest part of this buildup, have come 75% to 85% from fossil fuels (largely in the industrialized countries) and 15% to 25% from deforestation and other land-cover change (largely from developing countries in the tropics).

More than half of the increase in temperature since pre-industrial times has occurred since 1970. The warmer temperatures are amplifying the water cycle of the planet, leading to great evaporation and greater precipitation worldwide; both droughts and intense rainfalls are increasing. There are fewer light rains and more heavy rains in every region of the U.S. The largest percentage increases in the heaviest downpours have taken place in the Northeast (67%) and Midwest (30%) (Figure 2).

Heat waves, ice melt, shifting ranges of plants and animals, sea level rise, droughts, floods and wildfires are increasing, as expected. The ocean is acidifying, making it hard for shell-forming creatures, key to the food chain, to live. Mountain glaciers are melting all over the world. The rate of sea-level rise has increased over this century and the phenomenal melting of the Greenland ice cap—a new record set in 2010[12]—and West Antarctica exceed model expectations, leading scientists to question whether meters, not feet, of sea-level rise are possible in this century. Weather-related disasters are climbing and by 2040 their costs could reach $1 trillion a year.[13] Changes have been documented on every continent. Some 20,000 data sets confirm that species are shifting towards the poles at six kilometers per decade, or altitudinally upwards at six meters per decade.[14] And more changes are in store. Perhaps 20 to 30% of the world's species could be facing extinction over this century. Crop yields in both temperate and tropical zones are expected to decline, but the poorest countries of the world will suffer the most. Tens of millions of environmental refugees could be homeless as rising seas claim their homelands and beachfront properties. While the World Health Organization attributes 150,000 deaths to climate change already, that number is projected to double by 2030.[15] There will likely be increases in waterborne diseases, in vector borne diseases, and heat stress. Worldwide, an additional two billion people could be without enough clean water.

Even if emissions were completely halted today, the total temperature increase from greenhouse gases already in the atmosphere would approximate another 1°F globally. To avoid the risk of crossing tipping points that could lead to intolerable impacts on humans, many experts are calling for a world agreement to prevent global average temperatures from exceeding 4-5°F above pre-industrial levels.[16] To put the matter in perspective, an increase of 10°F equals the difference between the height of the last Ice Age and the present warm period. Current predictions indicate global temperatures could average 6 to12°F above pre-industrial temperatures by 2100. Governments must begin the task of managing the changes that are already occurring and preparing for those yet to come.

What does climate change mean for the United States?

Congressional mandate[17] has helped characterize U.S. vulnerability to climate change by requiring periodic assessments of the likely impacts of climate change; two National Assessments[18] were completed in 2000 and 2008. More than 1,000 stakeholders participated in the workshops, analyses and review of each of these reports. From these documents, it is clear that the impacts of climate change are already manifest in the United States.

One of the press stories that really brought this fact home was the announcement that the U.S. plant hardiness zones have changed since 1990[19] (Figure 3). Michigan's growing zones today are more like Kentucky's of 1990. Twenty-eight states' trees and flowers won't live in them by the end of the century. Dogwoods are now flourishing in Nebraska. It raises the question of "What constitutes a native plant in a region?" The effort to plant and preserve native species has become much more complicated.

Maples are migrating north to Canada, affecting U.S. fall foliage and maple syrup production. The character of particular regions will change as the temperatures increase (Figure 4). Massachusetts is expected to feel more like South Carolina in the coming decades. Parts of Texas could endure more than four months of temperatures over 100°F.

Recent results suggest changes may not be gradual but that there may be physiological or ecological "tipping points." In the southwest of the United States, droughts that were not abnormal in intensity coupled with slightly warmer temperatures could lead to massive tree die-off.[20] The drought and intense heat stressed the trees; bark beetles delivered the final blow. For example, in Colorado alone, nearly two million acres of forests were killed by beetles. Similar situations occurred on 23 million acres in British Columbia and on 10 million acres of black spruce in Alaska.

Infrastructure built to withstand the historic 100-year floods are proving insufficient to handle changing hydrological regimes in many places, including California.[21] Water managers everywhere are declaring: "Stationarity is dead"![22] The attached **Box 1** describes particular concerns for the energy sector. As well, there may be tipping points in societal responses and institutions. The inability to evacuate Louisiana in the face of Hurricane Katrina was an example of failed preparedness and retreat strategies.

This changing world poses huge challenges for wise governance of natural resources at all scales, and climate change is not occurring in isolation. Increasingly, adaptation measures must be designed to be robust to the suite of environmental stresses of which climate change is one. There are interactions of climate change with air and water pollution, with invasive species, biodiversity loss, and habitat fragmentation. These connections must be recognized before strategies to cope with only one problem are designed. Species cannot keep pace with the climate map shifting over them if cities and roads are in the way. Perhaps migration corridors and greenways can be designed to facilitate movement, but fundamental research questions remain about corridor efficacy and optimal shape and size. Some coastal wetlands will certainly be inundated as sea level rises; and, therefore, the goal of preserving wetland habitat should incorporate that concern in the calculus as lands are prioritized.

In the Midwest, about 60% of wetlands and prairie potholes have already been lost. Given that enhanced evaporation and drying conditions will be expected more frequently as climate changes, perhaps preserving the deepest ones first, those that are likely to persist, would be a good strategy. In Florida, the Everglades are being replumbed at great expense to restore more natural water flows, yet a third of the Everglades will likely be inundated as sea level rises. Solutions should integrate the desire to improve ecosystem services, maintain water flow, and protect species in the face of climate change and other ancillary stresses. Options that are robust to the suite of concomitant environmental problems must be designed, or adaptation will be inefficient or worse, ineffective.

Another example of the intersection of multiple stresses is that the northeast region of the U.S. may not be able to achieve the ozone standards as temperatures increase and exacerbate smog formation.[23] Different strategies may be required to achieve health-based air quality standards in the future as climate changes.

Carbon dioxide enhances plant growth, if other necessary nutrients are not limiting, but it also enhances the allergenic compounds in the noxious weeds of poison ivy and ragweed.[24] There are "devils in the details" yet being discovered about the impacts of climate change and the interactions with other issues. For the most part, these details only heighten concerns rather than increase confidence. Climate change must be addressed together with other multiple stresses.[25]

The Way Forward

Adaptation is currently constrained by *lack of available technology/decision support tools, by institutional barriers and by limited information.*

In the first category, *technology/decision support tools,* it is clear that water intake pipes, combined sewer overflows, levee levels, transmission lines, reservoirs, and power plant design and management will all potentially need to be altered as climate changes. Additionally, rules for managing Great Lakes levels, reservoir levels, and dam dredging times will need revision; surveillance for disease outbreaks and extreme events such as floods, droughts, and heat waves will need to be heightened; and new tools to characterize 'break-points" in management and infrastructure must be increasingly developed and shared. The nation is currently developing a "Climate Services" capacity[26] which should incorporate information that can guide these decisions.

Current best practices for disaster preparedness, response to floods and hurricanes, heat stress management, and drought planning could easily be assembled and shared across regions to help define "Climate Resilient Communities." It may be possible to create 'buddy systems,' that is, to link cities, watersheds, and ecological zones with similar problems to jointly find solutions. A national clearing house for such "best practices" is needed, and existing networks could be networked. Building blocks could include the existing Agricultural Extension services, the Sea Grant Programs, and the Regional Integrated Science Assessments (RISAs) of the Department of Commerce.

The second category, *institutional barriers,* is also ripe for attention. Climate change will not only affect natural ecosystems and infrastructure. It will also stress existing social, institutional and legal arrangements. Disruption of settled expectations and arrangements will have real and significant costs, tangible and intangible. As stream water flows change due to a changing hydrological cycle, Total Maximum Daily Loads (TMDLs), a key component of the Clean Water Act that depends on flow, will need to be recalculated. Building codes (and landscaping provisions) will need to be updated not only for energy efficiency, but also to protect against disease vectors, reduce susceptibility to heat stress, and improve protection against extreme events. There are national and international jurisdictional issues of replumbing the Great Lakes to mitigate reduced lake levels, or to manage the Columbia River to adapt to declining snowpack, or to manage the Colorado River to deal with drought. Both "bottom up" community planning and "top down" response strategies will be needed to help regions deal with increases in brownout, heat stress, floods, and wildfires. Increasingly, national, state, and local operational agencies will need to incorporate climate risks and adaptation planning into their programs.

The mix of necessary changes to adapt zoning laws and building codes to climate change varies greatly around the U.S., depending on a region's vulnerability. The authority to undertake needed changes varies among levels of government. For example, land-use planning generally occurs at the local government level. Yet the need to identify needed changes at the appropriate scale and move forward to implement them is nationwide. The challenge is to assure, by mandate if necessary, that existing institutions, agencies, and networks identify the likely threats posed by climate change and move forward with an appropriate transparent and collaborative process to develop and implement effective adaptation plans and measures. Only the federal government can assure this occurs systematically and thoughtfully and with adequate provision of relevant information and needed resources.

In the third category, *limited information,* it is clear that there is still a need for basic and applied research—e.g., very little is known about managing the resources of an acidifying ocean. Similarly, regional scale analyses of impacts need to be conducted and refined. No one lives in the "global average temperature" and climate change impacts will play out in concert with existing regional conditions; thus, bringing back the regional assessments conducted in 1997-2000 by the federal government would be a good start and should be part of the new National Assessment that is just beginning.[27] Stakeholders must be included from the outset, to define the key questions to be answered and to identify feasible options for coping with climate change that address regionally-specific needs. Regional vulnerability mapping, and regional 'listening fora' will be key to determine which impacts are of greatest concern for different regions in order to develop effective response strategies. As well, a short- and long-term research agenda must be developed that will provide answers to decision makers in a timely fashion; the U.S. Global Change Research Program is currently designing its next 10-year strategic plan, also mandated by Congress.[28] Not all good research can be done at once, but an integrated federal research program geared to help planning and management decisions now, while also insuring needed new information will be available in future years, is needed.

None of this will happen without an increased emphasis on adaptation at all levels of government. As the 2010 Progress Report of the Interagency Climate Change Adaptation Task Force[29] concludes:

"The Government should consider how Federal policies may lead to unintended consequences that increase the Nation's vulnerability to climate risks, thus making adaptation more costly and difficult. For example, certain policies may lead to increased development in the very areas that climate risks would suggest people avoid.

The Federal Government also has an important stake in adaptation because climate change directly affects a wide range of Federal services, operations, programs, assets (e.g., infrastructure, land), and our national security. The Government must exercise a leadership role to address climate impacts on Federal infrastructure interests and on natural, cultural, and historic resources that it has statutory responsibilities to protect. The Federal Government should identify its most significant adaptation risks and opportunities and incorporate response strategies into its planning to ensure that Federal resources are invested wisely and that its services and operations remain effective in the context of a changing climate."

Adaptation options may involve innovative land-use planning to avoid invasive species or preserve biodiversity or facilitate migration or help wetlands persist. Options may require new technologies and management criteria to cope with changing water supply, demand, timing, and quality so that both humans and ecosystems have needed water. Early warning systems and monitoring and surveillance techniques will be key to preparing communities for impending disasters. Adaptation will involve emergency response plans for coping with droughts, floods, hurricanes, and heat stress. Increasingly, changes will be needed in existing institutional structures, incentives and disincentive systems, and insurance policies to encourage more sustainable practices.

In conclusion, national and international action on adaptation to climate change is overdue and desperately needed to protect people and resources in the coming decades.

Endnotes

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7 *Coping with Climate Change:* National Summit Proceedings (R. Bierbaum, D. Brown, J. McAlpine [eds.]), University of Michigan/Island Press (2008), 256 p., ISBN: 9781597265560, and National Climate Adaptation Summit Committee (2010). *National Climate Adaptation Summit*, http://www.joss.ucar.edu/events/2010/ncas/ncas_report.pdf.

8 The interim report can be found at: The White House Council of Environmental Quality (October, 2010), *Progress Report of the Interagency Climate Change Adaptation Task Force: Recommended Actions in Support of a National Climate Change Adaptation Strategy,* http://www.whitehouse.gov/sites/default/files/microsites/ceq/Interagency-Climate-Change-Adaptation-Progress-Report.pdf,. The Task Force is co-chaired by the Council on Environmental Quality (CEQ), the National Oceanic and Atmospheric Administration (NOAA), and the Office of Science and Technology Policy (OSTP).

9 The U.S. Global Change Research Program budget is currently $2.6 billion, but most of the money has been historically spent on the physical climate system and modeling. A recent National Research Council (NRC) report (*Restructuring Federal Climate Research to Meet the Challenges of Climate Change*, Committee on Strategic Advice on the U.S. Climate Change Science Program; National Research Council [2009]) concludes that understanding and predicting physical climate change is progressing well but that the national program is failing on several fronts. Observational capabilities are being lost, both from satellite instruments and from in situ measurements such as from stream gages. The NRC also notes that there has been little progress in assessing impacts on human well-being and vulnerabilities, in providing knowledge to support decision making and risk analyses, and in communicating results and engaging stakeholders in a two-way dialogue. The total spent for human dimensions funding, calculated at $30 million, was deemed "inadequate." Similarly, mitigation efforts need bolstering; A recent President's Council of Advisors on Science and Technology (PCAST) report calls for an immediate infusion of about $10 billion per year for clean energy technologies. (http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-energy-tech-report.pdf).

10 The 12 warmest years on record have all occurred since 1997. See the conclusions of four different analyses: the National Aeronautics and Space Administration (NASA) (http://www.giss.nasa.gov/research/news/20110112/); the National Oceanic and Atmospheric Administration (NOAA) (http://www.wmo.int/pages/mediacentre/news/index_en.html); the United Kingdom Met Office (http://www.metoffice.gov.uk/news/releases/archive/2011/2010-global-temperature); and the World Meteorological Organization (http://www.wmo.int/pages/mediacentre/news/index_en.html.

11 *Global Climate Change Impacts in the United States*, op. cit.

12 http://www.physorg.com/news/2011-01-greenland-ice-sheet-video.html.

13 The World Bank, op. cit.

14 Martin Parry et al., eds. (2007). *Climate Change 2007-Working Group II Report: Impacts, Adaptation and Vulnerability,* New York, NY: Intergovernmental Panel on Climate Change, http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-intro.pdf.

15 Jonathan A. Patz, et al., "Impact of Regional Climate Change on Human Health," *Science*, 17 November 2005, http://www.nature.com/nature/journal/v438/n7066/full/nature04188.html.

16 The World Bank, op. cit.; United Nations Scientific Expert Group on Climate Change, op. cit.; *Stern Review on the Economics of Climate Change*, Cambridge, U.K., and New York: Cambridge University Press (2006), http://www.hmtreasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm.

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Difference Between 1990 USDA Hardiness Zones and *2006 arborday.org Hardiness Zones Reflect Warmer Climate,* http://www.arborday.org/media/map_change.cfm.

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27 See http://www.globalchange.gov/what-we-do/assessment/nca-overview.

28 Public Law 101-606, Section 104. (See: http://globalchange.gov/whats-new/554-usgcrp-strategic-planning-underway and http://www.gcrio.org/gcact1990.html).

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Box 1: The Energy Sector: An example of Adaptation Concerns

The majority of U.S. emissions of carbon dioxide are a result of the combustion of fossil fuels and for that reason, the focus on this sector has historically been on reducing emissions. Much less work has been devoted to adaptation of energy systems to a changing climate[i]. The energy sector is not only a driver of climate change, but also subject to the effects of that change. Whether the U.S. can continue to supply reliable energy services to its citizens depends on how robust systems will be to the changing climate. The warming from climate change is expected to increase the demand for cooling (mostly electricity) by 5-20% per 1˚C [1.8˚ F] and decrease overall demand for heating (mostly natural gas) by 3-15% per 1˚C[ii]. Water availability concerns and increased frequency of severe storm events are the two most worrisome impacts of climate change on the energy sector.

Climate change will directly affect energy production and supply. Tropical storms and hurricanes will be more intense as climate changes, thus exposing energy production and delivery systems in off-shore, coastal areas and other low-land areas to more severe weather conditions. During Hurricanes Katrina and Rita, 109 of the 4,000 offshore oil and gas drilling platforms in the Gulf of Mexico were destroyed and 31 were damaged. Approximately 91% of oil production and 72% of gas production capacity was out of service, and energy companies were forced to shut down more than 25% of the refining capacity in the U.S. Sea level rise may also impact energy infrastructure. Increased temperatures may reduce the capacity of transmission lines due to increased sagging of the lines. The reduction in transmission capacity may compound the impacts of warming temperatures and the concomitant increased demand for electricity potentially increasing the incidence of brownouts. Climate change may affect the viability of some renewable energy technologies requiring a lot of water such as solar thermal, or biofuels.

In the regions most affected by heat and drought-like conditions, the effects on availability of water appear to be three-fold, with less water available to cool nuclear and thermal power plants, less water to float coal on barges to supply powerplants, and less water to flow through dams for hydroelectric power generation. This is particularly problematic during hot periods when demand for cooling from electricity is at its peak, but reduced water flows could exacerbate competition for over-allocated water resources

Climate change may also have indirect effects on energy supply and demand, including effects on: risk management; energy technology research and development and resource choices; energy prices; and energy security.

Incorporating climate change into ***planning*** efforts is important on a number of levels. First, utilities and energy companies should include climate change in their forecasts of energy demand and supply. Second, when planning infrastructure improvements, including repair, replacement, or installation of new equipment, changes should be made that make sense considering the likely impacts of climate change. Third, water managers, utilities and others in the energy sector should coordinate planning efforts to recognize the energy–water nexus and the impact of climate change on both sectors. And lastly, when planning for future events, learn from past failures such as the Midwest blackout and the California energy crisis.

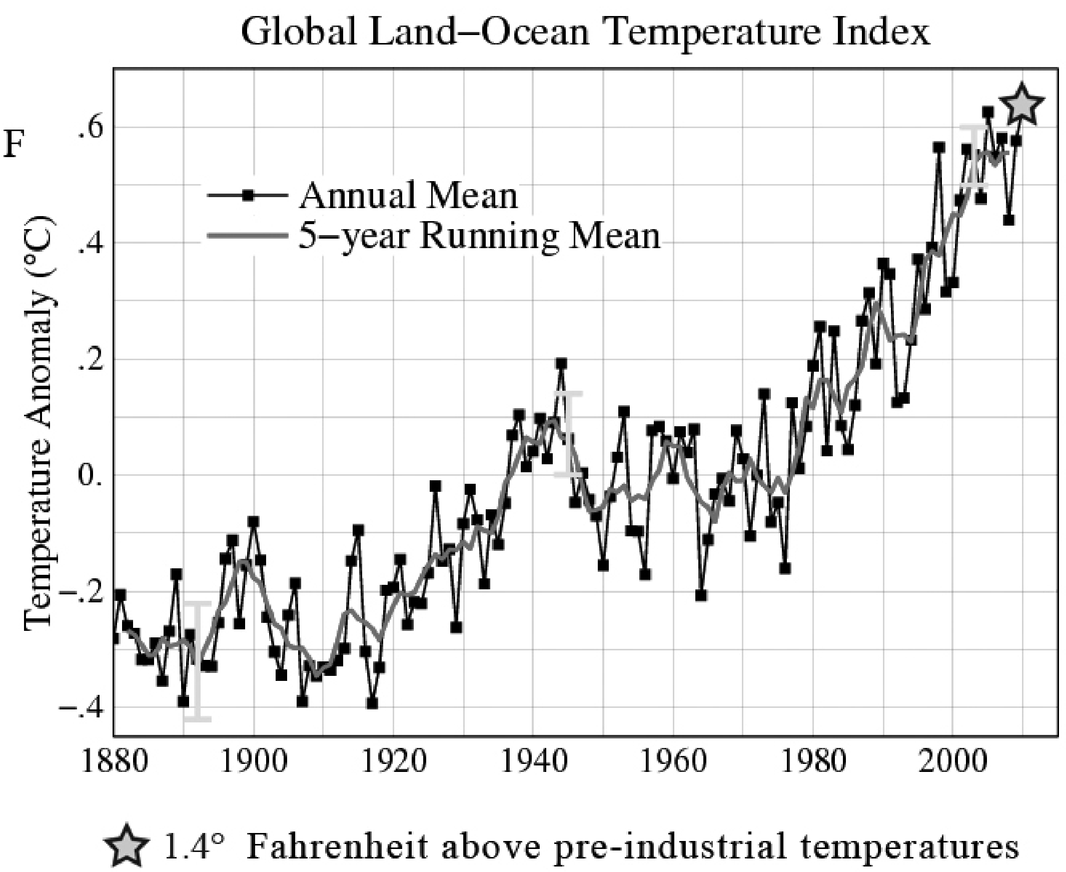
Efforts should be made to conduct or facilitate multi-state planning to accommodate large geographic scale extreme weather events. Diversification of energy supply may also be a viable adaptation option. Renewable energy technologies can modularize energy supply and possibly build in resilience to climate change.

Research on extreme weather events and large scale weather patterns is absolutely critical for utility and energy company planning and management and to assist government actors in understanding effective adaptation options. As well, improved surveillance and emergency response systems will need to be developed to protect people and to cope with extreme weather events.

Planned adaptation is preferred over reactive adaptation. The long-term investment horizons necessary for energy investment coupled with the lag in capital stock turnover means that taking proactive action is crucial.

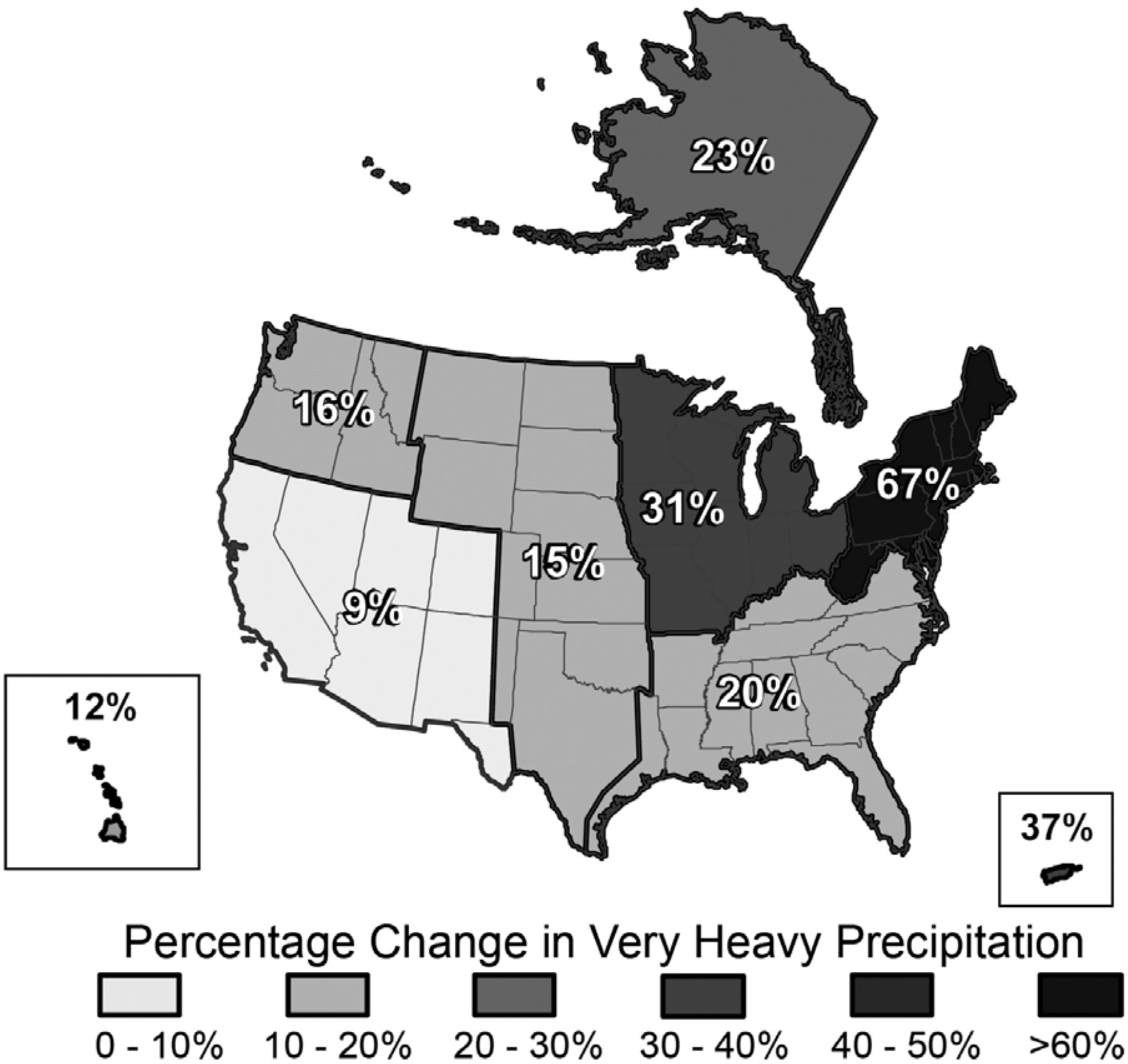
i CCSP, 2007: *Effects of Climate Change on Energy Production and Use in the United States.* A Report by the U.S. Climate Change Science Program and the subcommittee on Global Change Research. [Thomas J. Wilbanks, et al., (eds.)]. Department of Energy, Office of Biological & Environmental Research, Washington, DC., USA, 160 pp. (http://www.climatescience.gov/Library/sap/sap4-5/final-report/sap4-5-final-all.pdf)

ii These generalized estimates of increased demand cannot yet account for: (1) the effect of changes in humidity, (2) changes and effects in peak loads, (3) human migration patterns and resultant effects on regional energy systems, (4) changes in behavior of energy use, or (5) the effect of increased energy demand for pumping/moving water.



http://data.giss.nasa.gov/gistemp/graphs/ updated January 12, 2011

Figure 1



Updated from Groisman *et al.*[113]

The map shows the percentage increases in very heavy precipitation (defined as the heaviest 1 percent of all events) from 1958 to 2007 for each region. There are clear trends toward more very heavy precipitation for the nation as a whole, and particularly in the Northeast and Midwest.

http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts/full-report/national-climate-change

Figure 2

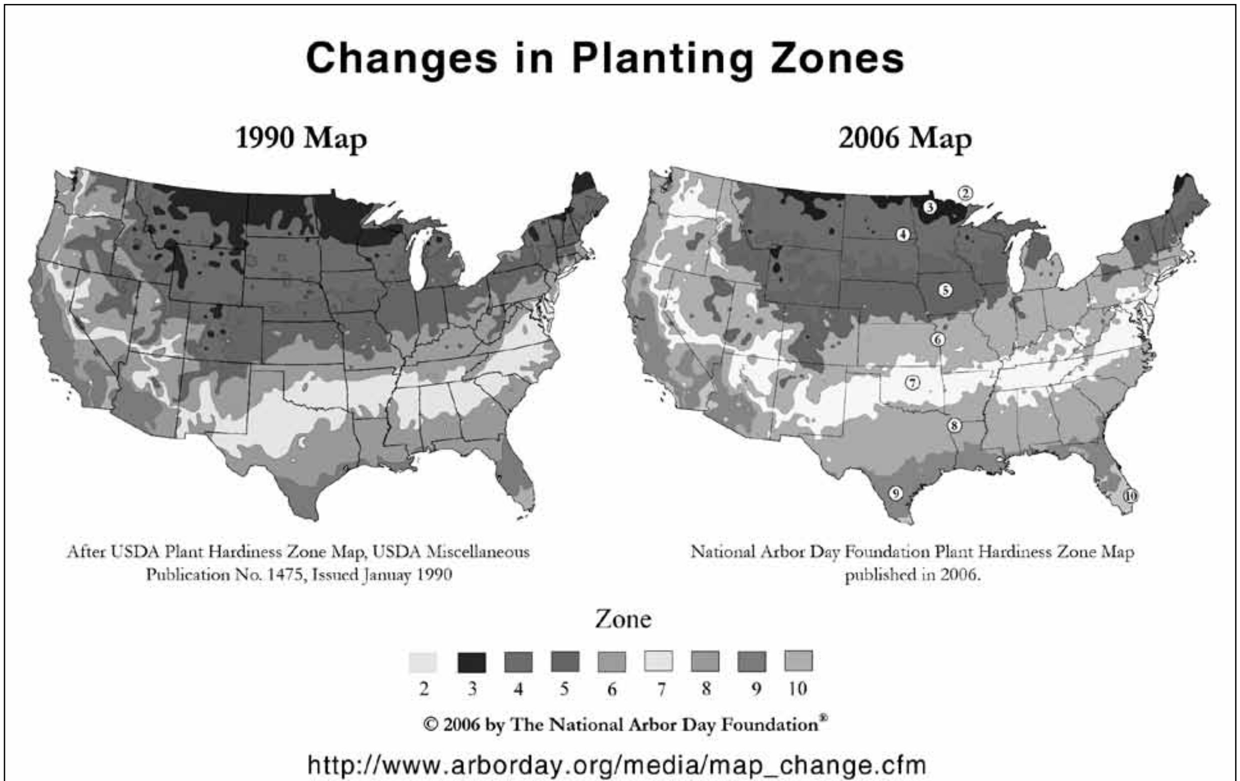
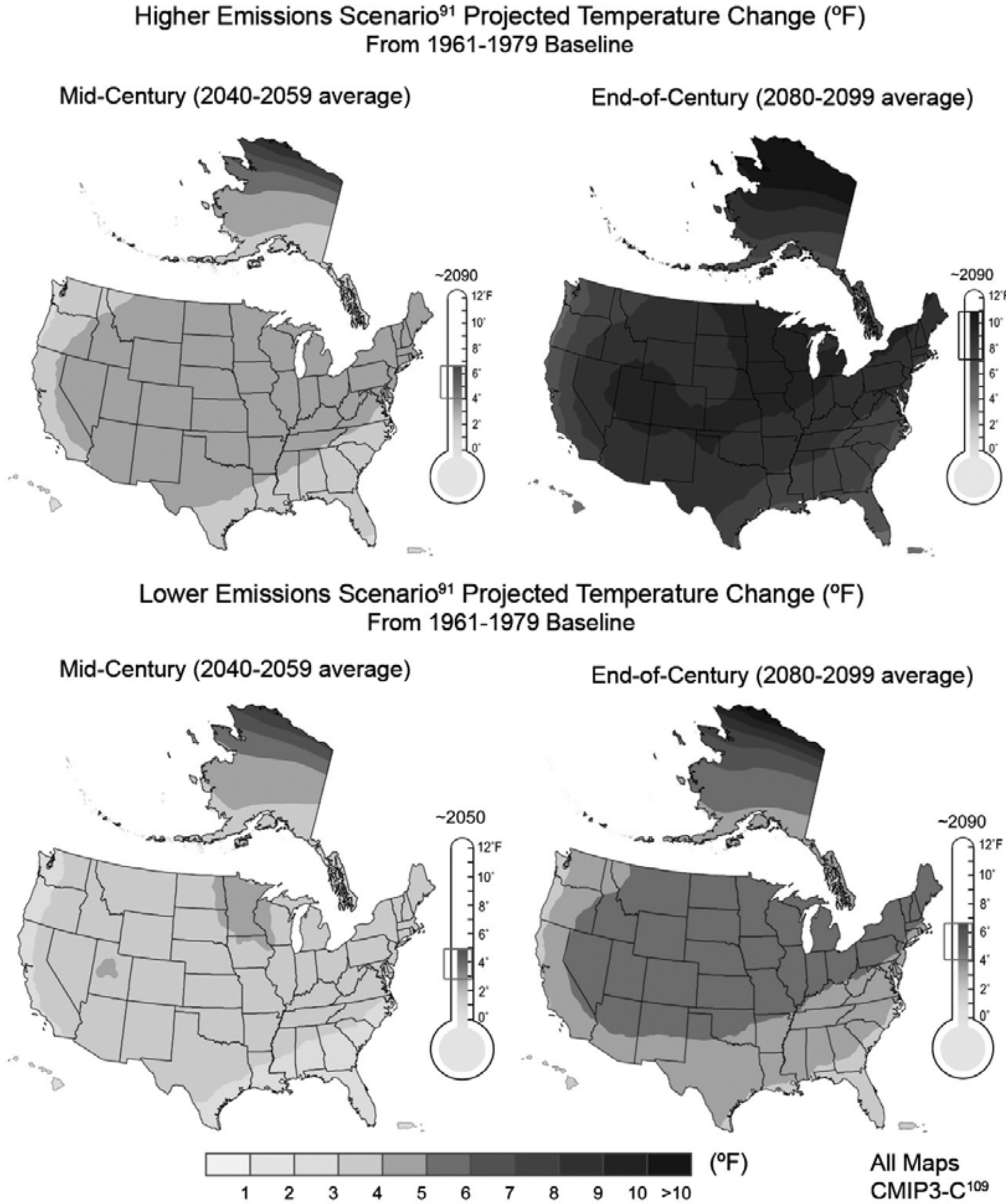

Changes in Planting Zones
1990 Map
2006 Map
After USDA Plant Hardiness Zone Map, USDA Miscellaneous Publication No. 1475, Issued January 1990
National Arbor Day Foundation Plant Hardiness Zone Map published in 2006.
Zone
2 3 4 5 6 7 8 9 10
© 2006 by The National Arbor Day Foundation®
http://www.arborday.org/media/map_change.cfm

Figure 3



The maps on this page and the previous page are based on projections of future temperature by 16 of the Coupled Model Intercomparison Project Three (CMIP3) climate models using two emissions scenarios from the Intergovernmental Panel on Climate Change (IPCC), *Special Report on Emission Scenarios* (SRES).91 The "lower" scenario here is B1, while the "higher" is A2.[91] The brackets on the thermometers represent the likely range of model projections, though lower or higher outcomes are possible.

http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts/full-report/national-climate-change

Figure 4

Energy Security and Climate Change: Policy Challenges for the New Administration and the New Congress

PARTICIPANTS

February 22-27, 2011

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and Janis Berman
Representative Tom Cole
and Ellen Cole
Representative Jim Cooper
and Martha Cooper
Representative John Garamendi
and Patricia Garamendi
Representative Gene Green
and Helen Green
Representative Maurice Hinchey
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Representative Rush Holt
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Senator Richard Lugar
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Energy Security:
Policy Considerations for the New Congress

AGENDA

February 22-27, 2011

Energy and Transportation: Policy Options

Anne Korin, Institute for the Analysis of Global Security

The United States is almost wholly dependent on oil, a global commodity—about 60% of which is imported—to fuel the nation's transportation systems. The transportation sector also accounts for about one-third of carbon dioxide emissions, which have been associated with the threat of climate change. The adverse consequences of failing to curb demand include vulnerability to price volatility, a worsening balance of payments, and continuing environmental degradation and other problems in oil-drilling countries that don't have adequate safeguards in place. Moreover, the implications of relying on growing imports from some countries whose interests may diverge sharply from those of the United States worry national security experts. One approach to lessening oil dependency may be to broaden the choices Americans have in their transportation options. Much is already under way. Overdue steps have been taken to improve the fuel efficiency of cars and light-duty trucks. Awareness is growing that community development patterns, coupled with innovative traffic management strategies, have roles to play in reducing demand for oil. Alternative fuels have benefited from research and demonstration projects, and hold promise, yet also face significant hurdles. Hybrid and electric vehicles are entering the marketplace though their initial cost remains high and significant market penetration will require bolstering U.S. electricity generation, including improving the transmission grid. Until these measures can realize their potential, in the interim, it is generally recognized that greater domestic oil production is essential. What are the policy options for the U.S. government to reduce the nation's oil dependency?

Discussion Questions

- How can federal policy encourage more transportation options for Americans? What would be the necessary investments in infrastructure to broaden mobility choices? How would these investments be paid for?
- What are the job implications that might flow from investments in alternative transportation modes? What impact would they have on low-income households?

- How are communities responding to mobility needs and traffic congestion? Which strategies hold promise for reducing the demand for oil? How might innovative pricing and market-based measures—tollways, congestion pricing, private transit services, for example—factor in? What is the federal role in working with metropolitan areas to reduce oil dependency in transportation?
- What is the status of alternative fuels? What further investments in research and demonstration and infrastructure would offer a good return? What policies might further their potential?

The Findings and Recommendations of the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling

William Reilly, Co-Chairman of the Commission

Last April's tragic Deepwater Horizon rig explosion in the Gulf of Mexico, which cost 11 Americans their lives and injured others, along with the associated spill of oil, dramatically focused attention on deepwater drilling for oil and gas: the industry's safety record, the adequacy of complex drilling technology, standards and permitting procedures, preparedness for disaster response, and the substantial impacts on the lives and livelihoods of people in the region and the natural systems that have sustained local economies and a way of life for generations. In response to this disaster, the President declared a moratorium on further deepwater drilling, which proved controversial because of its economic impact on the region, until questions were answered about how deepwater offshore drilling could be renewed with greater safeguards, oversight, and response capabilities. Investigations have been under way to root out the causes and recommend new procedures to govern offshore oil drilling in deep waters.

Discussion Questions

- What lessons can be derived from the Deepwater Horizon rig explosion and the oil spill in the Gulf? What went wrong? Why?
- What can be learned from other countries that engage in deepwater drilling regarding effective safety, preparedness, and response protocols?
- What additional policies and standards should be considered for future deepwater drilling? At what cost and with what benefits?
- How could federal regulatory oversight be improved?
- What improvements are needed with respect to planning, preparedness, and response in dealing with disasters like the Gulf oil spill?

Policies for a Secure Energy Future: Issues in Supply and Demand

Susan Tierney, Former Assistant Secretary, U.S. Department of Energy

During the past session of Congress, legislators introduced and debated numerous proposals intended to ensure sufficient and affordable energy for the country—for the economy, mobility, consumer and household use, and other activities. At the same time, many are seeking to reduce the environmental, safety, and other impacts of the way Americans obtain and use energy. The President and many

Members of Congress have been promoting various approaches to securing cleaner fuels and energy production, the full potential for which will likely take many years if not longer to realize. These initiatives need to be grounded in a practical understanding of how Americans use energy and where and how they get their supplies.

Discussion Questions

- How much energy do Americans use? For which purposes? What are the trends in energy demand—in manufacturing, agriculture, household use, transportation, and other major sectors?
- Where do Americans get their energy? How does this vary according to use, economic sector, or source of supply? How does U.S. consumption and supply compare to other countries?
- What is the potential for efficiency to constrain the growth curve for energy demand in the United States? At what cost? What are the hurdles?
- What are some of the promising technologies or other approaches that may help meet U.S. energy needs?
- What will be needed in policies, investments, and other measures to ensure that adequate, reliable, affordable supplies are available over the next few decades as the transition to cleaner energy sources proceeds?

Coal as a Viable Energy Source: Opportunities and Hurdles in Using the Resource Wisely

Ernest Moniz, Massachusetts Institute of Technology

Coal is one of the most abundant domestic energy sources in the United States and in other countries as well. About half of U.S. electricity generation is powered by coal in plants across the country. It is among the lowest-cost electricity produced, albeit often in older and inefficient facilities. Coal combustion is also a major source of carbon dioxide released into the atmosphere, as well as of conventional pollutants such as mercury and sulfur dioxide and of waste by-products such as coal ash, which may have potential for beneficial re-use. The consequences of relying on coal have received greater scrutiny since the mine accident in West Virginia last April claimed 29 lives, and the recent attention to so-called mountain top removal—a method of mining coal that levels mountains and deposits the sediments, contaminants and other wastes into waterways with potentially adverse effects. These concerns all present challenges to the continuing large-scale use of coal in environmentally responsible ways to meet U.S. energy demand.

Discussion Questions

- What are the principle hurdles in using coal to meet U.S. energy needs?
- What is the status of coal as an energy source in other economies around the world?
- How would a U.S. program to reduce greenhouse gas emissions affect the use of coal for electricity generation? What is the status of carbon capture and sequestration as a technology to help reduce the emission of carbon dioxide in coal-fired power plants? What are the R&D needs?
- Which environmental regulatory requirements beyond carbon reduction are coal plants likely to face in the coming years?

- What are the prospects and constraints for siting new coal-fired power plants? In upgrading or improving the performance of older or inefficient coal plants?
- What statutory or regulatory changes might facilitate environmentally-sound use of coal?

Adapting to a Warmer World: Understanding What the Future Might Hold and U.S. Options for Responding

Rosina Bierbaum, University of Michigan

When concern first arose over two decades ago about the potential that climate change could bring disruptive changes to natural systems, the debate was chiefly driven by computer modeling, which at the time had major limitations. Today, not only do scientists have at their disposal far better models with far better data for examining climate change, but they also are documenting widespread changes already taking place attributed to a warming climate. Among affected areas: public health, water resources, wildlife, the productivity of forests and other natural systems, temperature increases, melting glaciers, sea level rise, ocean acidification, the spread of pests and diseases, and more. Though the timing, magnitude, and place-specific effects are still being debated, these changes portend far-reaching impacts on the United States and governments at all levels, the private sector, coastal communities and others, which have to contend through policies, expenditures, and other responses.

Discussion Questions

- What are the impacts associated with climate change that the U.S. is likely to experience? With what level of confidence do scientists believe these changes will occur? What don't we know that we need to know?
- Recognizing that there are still uncertainties in this area, what policies or other measures should the federal government consider to anticipate and prepare for potential changes due to climate change?
- What are the likely impacts elsewhere around the globe that may signal concerns for U.S. foreign policy, commerce, security, development assistance, and diplomacy?
- Which priorities should guide future research to provide policy makers better information upon which to base decisions? What are the merits of unilateral and multilateral approaches?