# Developing a Realistic and Balanced United States Electric Power Generation Portfolio

## Assuring Energy, National, Economic and Environmental Security


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# Foreword

Over the past several years, the Council has invited key organizations and experts from industry and government to become directly involved in meetings designed to identify concrete recommendations for increasing official governmental and industry cooperation. An important step in this dialogue process is the development of a common understanding of the United States' (US) electricity outlook and energy-related challenges, and related national policy. To foster this dialogue, the Atlantic Council hosted a workshop in Washington, DC on October 26, 2009, "Perspectives on Developing a Realistic and Balanced United States Electric Power Generation Portfolio: 2010 to 2050."

The workshop focused on how the US can develop a realistic electricity generation portfolio that ensures energy, environmental, economic and national security. Attendees discussed electricity demand and supply forecasts as well as issues such as regulations, financing, and the realities surrounding current baseload and renewable electricity technologies. Participants were frank in their ideas concerning how to improve the current electricity generation portfolio in a carbon-constrained future, and discussed a number of projects at the government level aimed at fostering these improvements. Despite a number of challenges, participants concluded that the US must make a concerted effort to restructure its electric power generation portfolio.

The Council would like to thank all those who led the project: our energy program chairman and board member Richard L. Lawson for his vision and invaluable guidance; program director John Lyman for his leadership, Blythe Lyons for serving as the workshop organizer and rapporteur, and Griffin Huschke for research support and proofreading.

Special thanks go to Senator John Warner for presenting the keynote speech on the intersection between energy and national security issues. The Council gratefully thanks all the meeting participants for their gift of time and knowledge including, the experts representing Areva, as well as others from the private energy industry such as GE, Hyperion Power Generation, Babcock & Wilcox, and ADAGE; representatives from groups like the Alliance to Save Energy, Alliance of Automotive Manufacturers, the American Wind Energy Association, America's Natural Gas Alliance; government laboratories, such as, National Renewable Energy Laboratory the National Energy Technology Laboratory; government agencies such as the US Department of Energy; non-profits such as the Edison Foundation, the Pew Project on National Security, Energy and Climate, the World Resources Institute, the Edison Electric Institute, the Galvin Electricity Initiative; research institutions such as the Electric Power Research Institute; and consulting, legal and financing firms including Energy Resources International, Inc., FTI Consulting, Deutsche Bank, Decker Garman Sullivan and Associates, LLC., Gee Strategies and Fraser Energy. In short, there was a wide range of participants closely involved with the US electricity portfolio. Some participants reviewed the report, but were not asked to endorse the observations or conclusions.

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# 1.0 Executive Summary

The Atlantic Council Program on Energy and the Environment convened a one-day workshop on October 26, 2009, "**Perspectives on a Realistic United States Electric Power Generation Portfolio: 2010 to 2050,**" to address the challenge of transitioning the United States' (US) energy industry into a more secure and sustainable structure and to better understand the wide variation in projections and outlooks regarding future domestic energy needs. The workshop tackled one of the major issues of our day-how a realistic electricity generation portfolio can evolve over the next four decades in such a way as to protect the US's energy, national, economic and environmental security. In this Executive Summary, key electricity-related data are summarized, and the Atlantic Council's observations and recommendations are highlighted.

**US Electricity Outlook**

- According to the Energy Information Agency (EIA), by 2035 electricity demand is expected to grow 22% from current levels. Even though **electricity demand** in 2050 may be affected by greenhouse gas emission limits, the Environmental Protection Agency (EPA) and the Massachusetts Institute of Technology (MIT) forecast electricity demand increases of 20% and 7%, respectively, between 2030 and 2050.

- The current energy debate focuses in part on how on to provide **a balanced electricity portfolio with low $CO_2$ emissions.** According to the EIA's most recent forecast, absent greenhouse gas emission restrictions, energy industry-related $CO_2$ emissions are expected to grow by 8.7% (0.3% annually) through 2035.

- By 2030, even without $CO_2$ emission restrictions, EIA projects that the US energy mix for electric power will change. However, it is clear that **none of the significant forecasts for likely electric power generation portfolios agree substantively.** While several agree there will be some growth in nuclear power capacity, MIT only foresees a slight increase of 3% and EPA believes there will be a moderate 12% growth. MIT predicts a large 24% growth in natural gas whereas EIA expects a more moderate increase of 15%. With regard to renewables, MIT signals a modest increase of over 17% while EIA predicts a rather large increase of 114%. While EIA and EPA believe fossil fuel use will increase, MIT makes the case that there will be an increase of 54%.

- A comparison of EIA, EPA and MIT **generation portfolios under a Waxman-Markey** scenario shows agreement that fossil fuel use predominates even under carbon cap constraints and all predict a large increase in the percentage of power provided by renewables by 2030. There will be reductions in electricity demand due to energy efficiency improvements and other conservation measures. However, there is a wide discrepancy in the forecasts with regard to the future fuel mix. Five factors may radically alter such forecasts: rising raw material costs, increases in electricity prices, technological innovation, climate change assessments, and energy/ climate change policy responses.

- There are approximately 1,450 **coal fired generating units** in the US with 83 potential new plants on the horizon, representing a total of over 47GWe additional capacity. A small number of new coal plants will be built with demonstration stage carbon capture and sequestration (CCS) technology. There may then be some CCS retrofits on modern new coal plants. Thereafter, new coal facilities could be built with CCS capacity and other plants could be retrofitted with CCS capability. Older coal plants that could not be retrofitted would be closed. From the industry perspective, clean coal technologies (CCT), and, in particular, CCS technologies are at hand. Large commercial-scale demonstrations must be done soon to have an impact.

- As of 2007, natural gas accounted for 22% of US energy consumption. While coal is the nation's main fuel for electric power, natural gas is the fastest growing fuel. The potential for large increases in the production of **domestic natural gas supplies** from fracturing shale may allow for natural gas to play a significant role in the next few years in rebalancing the US electric generation portfolio. In addition to the positive reports on the potential availability of shale gas, there are technological improvements that bear close scrutiny for the role they might allow natural gas to play in short-term efforts to decarbonize the electricity supply. While utilizing natural gas for electricity (or transportation fuels) does reduce $CO_2$ emissions, they are not entirely eliminated as conventional gas-fired plants emit only 40%less $CO_2$ than coal-fired plants. Hence, eventually CCS technologies will also be needed on gas power plants.

- There is a question as to the extent the nuclear renaissance happening around the world will be come a reality in the US. EIA forecasts that by 2035 the **US nuclear power capacity** will slightly increase by 8% from 101 GWe today to reach 109 GWe. New nuclear plant capacity will be needed just to maintain the status quo. EPA estimates that 187 new nuclear reactors might be needed by 2050 to meet $CO_2$ emission reduction requirements as envisioned in the Waxman-Markey legislation. One of the key issues impacting new nuclear plant construction is the lack of progress on the federal government's promise to accept ownership of the spent fuel and provide for a permanent commercial waste repository. Federal efforts to provide construction loan guarantees to get past the initial hurdle for new plants are underway. For the future, well-designed carbon pricing policies could lead to adequate private sector investments in new nuclear power plants.

- EIA forecasts that by 2035, the US will add 93 GWe of new **renewable capacity** (biomass, geothermal, hydro, solar, and wind) to the existing 139 GWe of installed renewable electric generating capacity. In general, with the exception of hydropower, each of the renewable energy supply sources face similar obstacles, including the need for transmission/grid improvements, their intermittent nature and questions as to how much back up power or storage capacity is necessary or economical.

**Observations**

- **Electricity Demand Growth Patterns are Changing, Forecasts Signal the US Requires Additional Baseload Electric Capacity, But Questions Linger Regarding the Impact of the Recession.** While electricity demand will grow in absolute terms, the rate of growth has been slowing for many years. Structural changes in the economy due to the recession, efficiency programs and higher electricity price are expected to slow electricity demand growth further and continue the downward trend. However, the potential exists that the US may require more than the forecast electric power over the next 5 to 10 years to meet the needs of a growing population, a higher than anticipated uptick in the nation's economy, and/or a slower than anticipated implementation of energy efficiency and conservation measures.

- **Electricity Supply Planning Requires Flexibility and Capability.** If the US wants to maintain the ability to preserve its options and have the flexibility to meet unexpected needs should the deployment of new technologies be slower than expected, then the capability to produce additional baseload capacity must be maintained. This has obvious implications for US energy policy: the US must continue to support the two main pillars of baseload capacity, coal (with ability to retrofit with CCS) and nuclear power. Furthermore, to provide low-carbon electricity, aging US infrastructure will have to be replaced and new clean energy capacity expanded. Failure to establish and maintain a technological lead and a robust domestic manufacturing and supply chain capacity would eventually cause the US to rely on foreign technology and imported plants with the attendant loss of US jobs.

- **There is an Urgent Need to Comprehensively Reassess the US Electricity Strategy.** Comprehensive, integrated planning, based on technical strategies, is needed to preserve all of our domestic energy options, equally focus on the short-term and long-term options, and provide an expanded commitment to RD&D. Layered on top of this is the need to maintain flexibility to meet increased demand if it materializes, and to provide technologies in a diverse geographic environment. A balanced portfolio with many (domestic) options is the way to deal with price volatility-the economic security part of the equation. The energy mix will change but will hopefully never be too reliant on any one fuel source.
- **Every Electric Generation Option Faces the Same Issues: Financing and Public Acceptance.** Developing any form of new electricity generation and its supporting infrastructure, or expanding current ones, face public acceptance issues. Financing structures are a key barrier for all energy technology options.

**Recommendations**

The challenges to establishing a realistic electric power generation portfolio that transforms the power sector to meet the country's requirements for electricity while addressing environmental concerns must not be underestimated. The economic realities associated with the need for new investments and the need to reduce emissions from fossil fuels can be met, but probably only at higher electricity prices. **In a relatively orderly fashion, by identifying and prioritizing the key actions that can be taken, starting now, significant transformative efforts are indeed possible.** The highest priority should be given to these six recommendations:

1. **The United States Should Move Forward Now to Rebalance its Portfolio, and all Agree that the Starting Place is Energy Efficiency.** Energy efficiency and conservation measures are recognized as having significant near-term potential to reduce demand and, of course, reduce attendant $CO_2$ emissions.
2. **Uncertainty Regarding National and International Greenhouse Gas Emission Policies Dictates that Federal Financial Support be Provided Now for Critical Energy Technology Programs.** To this end, construction of coal-fired plants with CCS and new nuclear plants should be supported so that these projects can be initiated as soon as possible to assure the continuing viability of baseload capacity for the US electrical grid in the near term future.
3. **Kick-start Decarbonization Efforts by Using Natural Gas as a Bridge Fuel.** It is recommended that the US use the expanding availability of natural gas from shale formations and other domestic deposits as a bridge fuel-as backup for renewables and as required pending the availability of CCTs with CCS and new nuclear baseload capacity.
4. **Rebalance the Electricity Portfolio with Diverse, Broad-based Options.** Start with low or no cost efficiency measures; build on commercially available technologies such as natural gas, some renewables, and nuclear power instead of relying on the eventual availability of very long-term technology silver bullets; undertake the necessary infrastructure improvements to allow for efficiency improvements and to bring renewable sources into the grid as quickly as possible; and, significantly ramp up RD&D on CCTs, next generation nuclear power plants and fuel cycles, and transportation fuel options.
5. **Leadership is Needed to Establish Public and Private Sector Support for US Energy Policies and their Attendant RD&D programs.** Public and private agencies need to merge their efforts to properly inform the public regarding the potential options available to an evolving electricity generation portfolio; their timing, availability and costs; and their impact on the environmental, economic and national security issues. The American public deserves frank talk on the timing and costs of its energy supply.

6. **The Federal Government Must Continue to Address the Siting of Transmission Lines, Grid Improvements and Incentives for More Renewables.** In the "grace period" of reduced electricity demand growth the US now enjoys thanks to the recession, the US must focus its efforts immediately on the siting and building of transmission capacity and on ways to improve the grid to allow better integration of renewable power sources into the US electricity supply. Congress must provide the authority to the federal government to issue the permits to build the needed transmission lines and to give the Federal Energy Regulatory Commission the power to properly allocate costs of building needed lines.

**The Atlantic Council concludes that success can be assured if the US uses all of its domestic energy supplies and leaders develop, today, the policies to bring forth the technologies needed to embark on a safe and secure low-carbon path. Our leaders must educate the public regarding the time it will take, the new plants and infrastructure that must be built, and the costs that must be borne to achieve energy, national, economic, and environmental security.**

# 2.0 Introduction

The Atlantic Council Program on Energy and the Environment convened a one-day workshop on October 26, 2009, **"Perspectives on a Realistic United States Electric Power Generation Portfolio: 2010 to 2050,"** to address the challenge of transitioning the United States' (US) energy industry into a more secure and sustainable structure and to better understand the wide variation in projections and outlooks regarding future domestic energy needs. The workshop was specifically focused on the electric power sector and was designed to review a number of prominent electric power projections and to examine the potential for various technologies to make a substantial impact on actual power usage over the next 40 years. While the workshop looked at the 2050 horizon, with the uncertainty for the long term surrounding both the pace of technological developments and the extent to which legislation and regulations will impact portfolio choices, attention was focused on likely developments over the next twenty years.

The Atlantic Council assembled a broad range of experts on electric power in the US from government agencies, think tanks, associations, industry, consulting groups, foundations and national laboratories. Senator John Warner presented the keynote speech on the interdependence of US energy, national, economic and environmental security goals. The list of participants is provided in the contributors list.

Throughout the day [1], presentations were given on electric power demand and supply forecasts; how federally mandated emission reductions and policy measures concerning efficiency, conservation, regulatory structures, emerging technologies and smart grids might impact electricity demand and supply; and, projections for the electric power generation mix of coal, nuclear, natural gas, renewable and distributed power options (such as solar, wind, geothermal, and biomass) over the short and long terms. The workshop concluded with a frank, roundtable panel and participant discussion. The workshop Agenda is included in Appendix A.

**The workshop tackled one of the major issues of our day-how a realistic electricity generation portfolio can evolve over the next four decades in such a way as to protect the US's energy, national, economic and environmental security.** This report, Perspectives on Developing a Realistic and Balanced United States Electric Power Generation Portfolio, presents the highlights of the information presented in the workshop. It synthesizes major observations resulting from the dialogue among the experts and formulates recommendations for US policy makers.

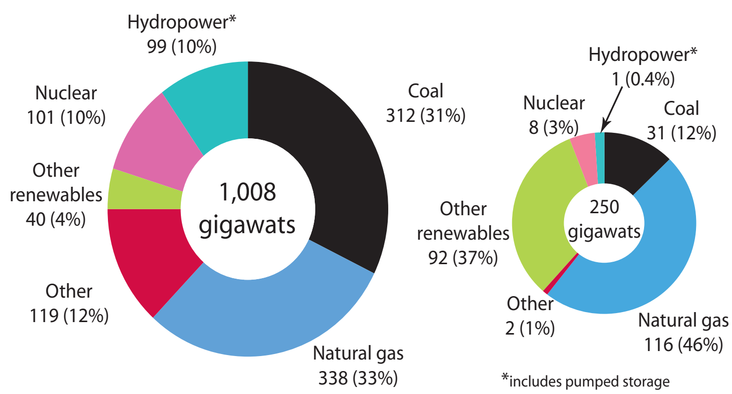
# 3.0 Global Energy Outlook

## 3.1 Overview of US Energy Consumption, Electricity Demand and Generation Capacity

The US annually consumes 106 exajoules or 37% of the world's 499 exajoules of primary energy.[2] US energy supply is produced 40% by oil, 23% by natural gas, 23% by coal (for a fossil total of 86%), 8% by nuclear, 2.8% by hydropower, 2.8% by biopower, 0.4% by geothermal, 0.1% by wind, and 0.06% by and solar.

The US Energy Information Agency (EIA) projects that in its "reference case" (or status quo without enactment of legislation or regulations regarding greenhouse gas emissions), US electric power generation will increase from 4000 billion kilowatt hours (kWh) in 2005 to over 5000 billion kWh by 2030.[3] As displayed in Figure 1, electric generation capacity grows from 1,008 GWe in 2008 to 1,258 GWe by 2035.[4] Based on 2008 capacity figures, coal will modestly increase by 31 GWe to total 343 GWe; natural gas increases by 116 GWe to total 454 GWe; nuclear capacity slightly increases from 101 GWe to 109 GWe; hydropower stays roughly the same at 100 GWe (up 1 GWe); and renewable energy capacity dramatically increases from 40 GWe to 132 GWe. Wind power will drive the growth in the renewables sector with increases from 2008 to 2015 of 25 GWe to 66 GWe; its growth then slows to reach a capacity of 71.4 GWe by 2035. The other renewables are comprised of 41 GWe of biomass, 14.6 GWe solar and 3.8 GWe geothermal by 2035. While non-fossil use grows rapidly, in the EIA forecast, fossil fuels will still provide 78% of US energy supply in 2035.

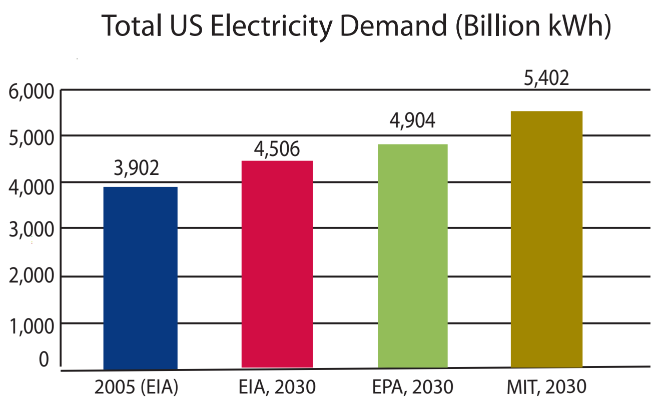
**Figure 1: 2008 Installed Electric Generation Capacity and EIA Projected - Capacity Additions to 2035 (GWe)**




Source: Newell, Richard. "Annual Energy Outlook 2010: Reference Case." US Energy Information Administration. http://www.eia.doe.gov/neic/speeches/newell121409.pdf (accessed on January 19, 2009.

According to the EIA's 2010 forecast, **by 2035 electricity demand is expected to grow 22% from current levels.[5]** EIA's projection is compared to that of the Environmental Protection Agency (EPA) and Massachusetts Institute of Technology (MIT) forecasts in Figure 2. Both are higher though MIT's is significantly so. **EPA estimates that 2030 electricity demand will be up by 26% over 2005 levels while MIT sees almost a 40 % rise by that time.**

## Figure 2: EIA, EPA and MIT Projections of US Electricity Demand by 2030




Source: Data compiled from: EPA Economic Analyses-EPA's H.R. 2454 Data Annex. Environmental Protection Agency. http://www.epa.gov/climatechange/economics/economicanalyses.html#hr2454; p. 66 Paltsav et al. MIT Joint Program on the Science and Policy of Global Change Report 146. The Massachusetts Institute of Technology. htttp://web.mit.edu/globalchange/www/MITJPSPGC_Rpt146_AppendixC.pdf; U.S. Energy Information Administration. EIA Annual Energy Outlook 2010 Early Release. Table 8, Electricity Supply, Disposition, Prices, and Emissions (cell Z29) <http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html>.

Electricity demand in 2050 will likely be affected by greenhouse gas emission limits. Figure 3 compares EPA's and MIT's forecasts for US energy and electricity consumption by the year 2050.[6] EPA and MIT are forecasting increases in US energy consumption to 121 and 136 exajoules, respectively. EPA and MIT forecast 2050 electricity usage increases to 5,888 and 5,861 billion kilowatt hours (kWh), respectively. It is interesting to note that while the electricity usage projections are similar for MIT and EPA, there is a dramatic difference in natural gas price estimates. **Even with greenhouse gas constraints, EPA and MIT signal electricity demand increases of 20% and 7%, respectively, between 2030 and 2050.**

## Figure 3: Comparing 2050 Energy and Electricity Consumption Projections

| | 2005 | 2050 | |
|---|---|---|---|
| | | EPA | MIT |
| U.S. Economy | | | |
| Population | 296 | 400 (35%) | 439 (48%) |
| GDP | $12,614 | $35,377 (180%) | $38,349 (204%) |
| Energy Prices | | | |
| Natural Gas | 8.7 | 10.0 (15%) | 24.5 (182%) |
| Electricity | 8.1 | 10.6 (30%) | 12.5 (54%) |
| Energy Use | | | |
| Total (Quadrillion BTU) | 100.5 | 115.0 (14 %) | 129.2 (29%) |
| Electricity (Billion kWh) | 3,902 | 5,888 (51%) | 5,861 (50%) |

Source: Caldwell, John. "US Electricity Supply and Demand: The Long View" Conference Presentation, Atlantic Council, Washington D.C., October 26, 2009. Note that the 2005 data is from the EIA. All prices are in 2005 dollars. MIT data is complied from p. 19 Paltsav et al. MIT Joint Program on the Science and Policy of Global Change Report 173. The Massachusetts Institute of Technology. http://globalchange.mit.edu/files/document/MITJPSPGC_Rpt173_AppendixC.pdf

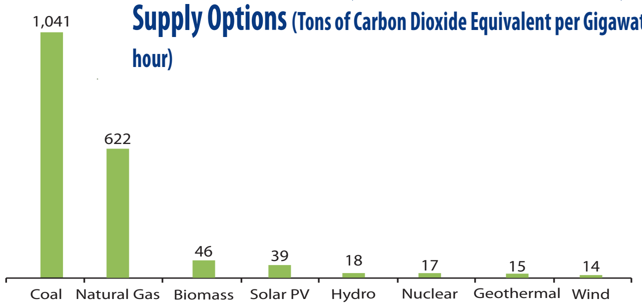
## 3.2 Electric Power Generation Portfolio Forecasts

### 3.2.1 $CO_2$ Emissions Drive the Electric Power Generation Debate

The current energy debate is driven by efforts to provide a balanced electricity portfolio with low $CO_2$ emissions. According to The Annual Energy Outlook (AEO) 2010 reference case,[7] **absent greenhouse gas emission restrictions, energy industry-related $CO_2$ emissions are expected to grow by 8.7% (0.3% annually) through 2035,** from 5,814 to 6,320 million metric tons.[8]

No source of energy is totally $CO_2$ emission free. Figure 4 shows the life cycle emissions in tons of $CO_2$ equivalent per GWh for each fuel. Coal produces the most life cycle $CO_2$ emissions (1041 tons of $CO_2$ equivalent per GWh) while natural gas emits approximately 40% fewer emissions.[9] At the lowest end of the spectrum, **hydro, nuclear, geothermal and wind produce very small amounts of $CO_2$, in the 14-18 tons of $CO_2$ equivalent per GWh range.** Today in the US, nuclear power provides the largest source of low-emissions electricity, at 72.3%; hydro provides 21.7% and solar, wind and geothermal provide the remaining 6.1%.

**Figure 4: Comparisons of Life Cycle Emissions of Electricity Supply Options** (Tons of Carbon Dioxide Equivalent per Gigawatt-hour)




Source: Southworth, Finis H. "The Nuclear Power Baseload Option: 2010 to 2050." Conference Presentation, Atlantic Council, Washington D.C., October 26, 2009.

### 3.2.2 EIA Electricity Generation Portfolio Forecasts

The EIA cautions that its long-term generation portfolio projections are filled with uncertainties, especially as passage of federal legislation requiring greenhouse gas emission reductions is not guaranteed (although the EPA's $CO_2$ endangerment finding under the Clean Air Act could lead to a regulatory limits on greenhouse gasses such as $CO_2$).

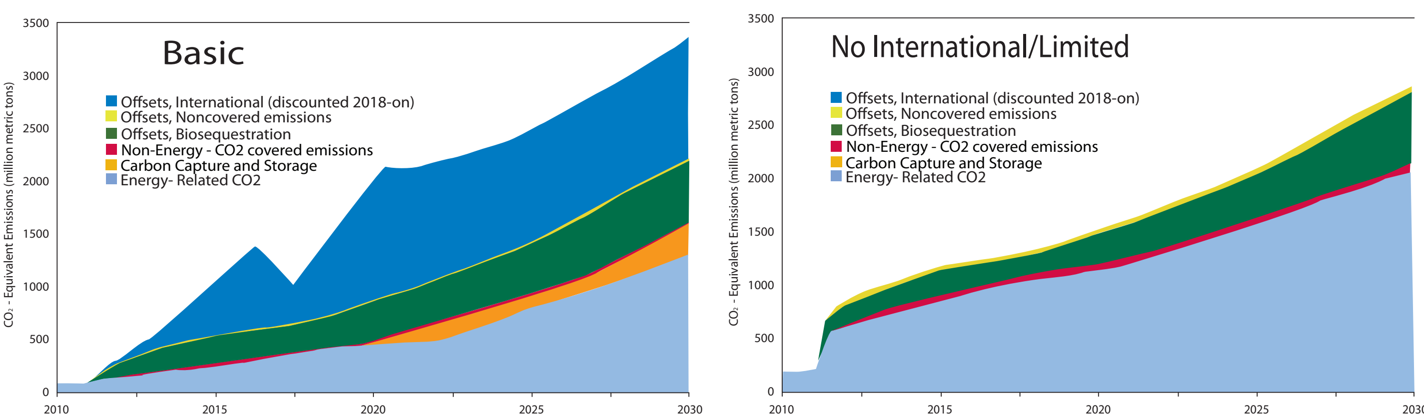
In its most recent reference case projection through 2035, even without federal emission restriction mandates, EIA projects that the US energy mix for electric power will change. **In the 2035 generation mix, EIA predicts that the percentage share of renewables will grow from 9.1% to 17.0% while the percentage shares of all other energy supplies face declines.** Natural gas's market share goes from 21.4% to 20.8%; coal declines from 48.5 % to 43.8%, oil and other fuels decrease from 1.5% to 1.4% and nuclear power's share declines from 19.6% to 17.1%.

The EIA estimated what an electric power generation portfolio might look like if The American Clean Energy and Security Act (H.R. 2454, referred to as **Waxman-Markey** throughout this report) were to be signed into law. **The pending climate change legislation would require the electricity sector to account for the vast majority of reductions in domestic greenhouse gas emission reductions through 2030.** It further concluded:

- Coal plants without Carbon Capture and Sequestration/Storage (CCS) would need to be displaced by low-emission technologies such as nuclear and renewables.
- Capacity additions would parallel the shifts in the fuel mix with large increases in renewables, nuclear and fossil fuels with CCS.
- Natural gas use would grow sharply if new construction of nuclear, coal plants with CCS and biomass would be constrained.

Under EIA's 2030 Waxman-Markey scenario, EIA projects the US would add 119 GWe of renewables, 96 GWe of nuclear power, 42 GWe of natural gas with CCS, and 69 GWe of coal with CCS. EIA considers an addition of 96 GWe of nuclear capacity challenging

**Figure 5: Comparison of Emissions Reduction Compliance Sources with/without International Offsets**




Source: Beamon, Alan J. "Outlook for US Electric Power." Conference Presentation, Atlantic Council, Washington D.C., October 26, 2009.

but doable. (In the past the US built far greater capacity.) For comparison, without emission limits, the EIA forecasts that between 2008 and2035, the US would only add 8 GWe of nuclear capacity (see Figure 1).

During the workshop, **questions were raised about a key underlying assumption in the Waxman-Markey legislation that the majority of required emissions reductions would primarily be achieved by international offsets.** Participants voiced concern whether these international offsets would in fact materialize, and if not, what changes in the domestic generation mix would be required to achieve emissions reductions.[10] For example, it was said that under the Kyoto Protocol's Clean Development Mechanism, only 300 million tons of offsets have been achieved to date and the expected additional 1.5 billion tons in offsets between 2008 and 2012 will not satisfy Annex I country emission reduction targets.

Figure 5 compares the reliance on international offsets in the EIA's "basic case" (under the Waxman-Markey scenario) and then the magnitude of reductions that would need to come from industry without the use of offsets. Without international offsets, it would not be feasible to reach the Waxman-Markey scenario emission reductions by 2030. Additionally, **without these international offsets, the US energy industry would have to increase their annual $CO_2$ reductions from approximately 1250 to almost 2000 million metric tons of $CO_2$ by 2030.**

### 3.2.3 Electric Power Research Institute Electricity Generation Portfolio Forecasts

The Electric Power Research Institute (EPRI) has developed a second-generation Prism model[11] to evaluate electricity generation portfolio projections out to 2050 utilizing the EIA 2009 Annual Energy Outlook reference case estimates of $CO_2$ emissions from the US electricity sector. Key underlying assumptions include economy-wide $CO_2$ reductions without relying on international offsets, maximizing US GDP growth, and emission reductions in 2030 of 42% below 2005 levels (as projected in the **Waxman-Markey** legislation) and of 83% by 2050.[12] Figure 6 compares the EIA 2030 **Waxman-Markey** basic case and EPRI's full technology generation portfolio. **EPRI's analysis shows that in comparison to EIA's, the same emission reduction targets could be met with an increase in efficiency measures, more than double the amount of renewables, a five-fold increase in new nuclear capacity, and deploying CCS on the existing and new coal plant fleet.**

**Figure 6: Comparison of EIA's Base Case to the 2009 PRISM Target Scenario**

| Technology | EIA Base Case | EPRI Prism Target |
|---|---|---|
| Efficiency | Load Growth +0.95%/yr | 8% Additional Consumption Reduction by 2030 |
| T&D Efficiency | None | 20% Reduction in T&D Losses by 2030 |
| Renewables | 60 GWe by 2030 | 135 GWe by 203 (15% of generation) |
| Nuclear | 12.5 GWe New Build by 2030 | No retirements; 10 GWe New Build by 2030; 64 GWe New Build by 2030 |
| Fossil Efficiency | 40% New Coal, 54% New NGCCs by 2030 | +3% Efficiency for 75 GWe Existing Fleet; 49% New Coal; 70% New NGCCs by 2030 |
| CCS | None | 90% Capture for New Coal + NGCC After 2020; Retrofits for 60 GWe Existing Fleet |

Source: Novak, John. "Creating a Secure Low-Carbon Future." Conference Presentation, Atlantic Council, Washington D.C., October 26, 2009.

EPRI updated its MERGE model to determine the most economic combination of technologies over time to meet a specified $CO_2$ emissions constraint. Based on current and projected technology costs, consideration of fuel costs and reserves, and competition for resources with other parts of the economy, MERGE projects electricity generation from different technologies, electricity costs, $CO_2$ prices, and the overall cost of implementing $CO_2$ emissions reductions.

As seen in Figure 7, the MERGE analysis shows how remarkably different the energy mix would look in 2030 and 2050 depending upon whether or not the US pursues a full or limited portfolio of electricity sector technologies.[13] **EPRI argues emission reduction goals are technically feasible through aggressive end-use efficiency measures and full-throttle pursuit of a complete, diverse portfolio of generation technologies.** If, however, the US were only to pursue a limited portfolio approach, EPRI estimates that by 2050, 52% greater demand reduction would be required, the US would rely more than 50% on renewables, and natural gas consumption would increase by 275% (from 2010.) In both cases, the US would heavily rely on energy efficiency improvements. EPRI estimates that electricity prices will increase 80% over 2007 levels in the full technology approach versus a whopping 210% in the limited technology portfolio.

EPRI shows **the benefits of pursuing the full portfolio of energy technologies.** The critical conclusions reached by EPRI in its analyses are that:

- Aggressive but technically feasible levels of technology deployment could lead to $CO_2$ emission reductions of 41% by 2030.
- If the US were to combine aggressive end-use efficiency measures and a diverse generation technology portfolio, then this strategy would reduce compliance costs by approximately 37% and would ensure technological resiliency.
- All technologies are not yet ready and the US must enhance its research, development and demonstration (RD&D) programs over the next 20 years.

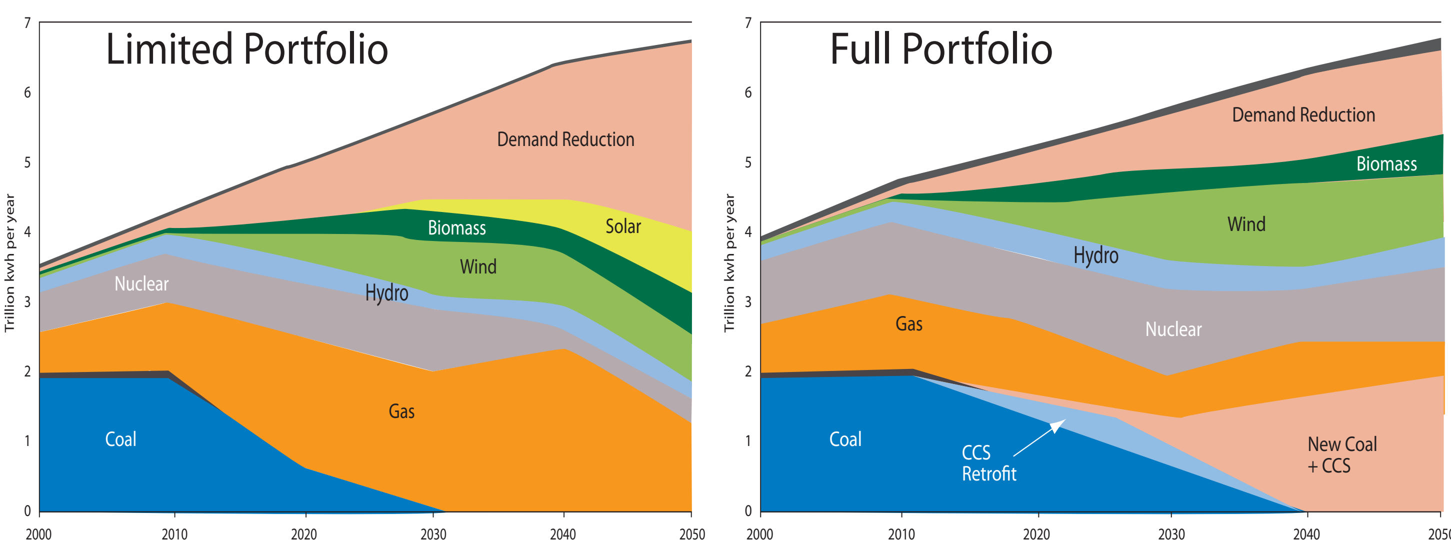
### 3.2.4 National Renewable Energy Laboratory Portfolio

The National Renewable Energy Laboratory (NREL) presented two generation portfolios out to 2050: a "base case" and a "carbon cap case", as shown in Figures 8 and 9. NREL's base case electricity generation forecast for 2050 is 5,746 TWh and under the carbon cap case, 5,577 TWh. This base case approximates the EPA's outlook of 5,888 billion kWh which is similar to the MIT comparative case which is for 5,861 billion kWh.

By 2030, NREL forecasts the following technology generation mix under the base vs. the carbon cap cases:

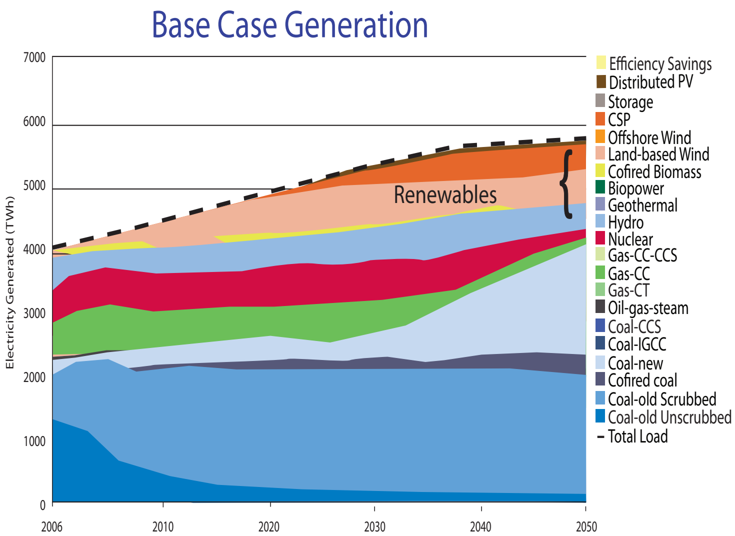
- Renewables would increase in the base case from 1011 to 2188 TWh under carbon caps.
- Coal would decrease from 2702 in the base case to 1188 TWh under carbon caps.
- Coal with CCS/IGCC only slightly increases from 4 to 6 TWh under carbon restraints.
- Nuclear generation is forecasted to remain stable at 741 TWh in either scenario.
- Natural gas increases from 397 in the base case to 678 TWh under the carbon cap scenario (which is only slightly larger than NREL's 2020 projected capacity).

**Figure 7: EPRI's Comparison of Limited and Full Technology Portfolios MERGE US Electric Generation Mix**



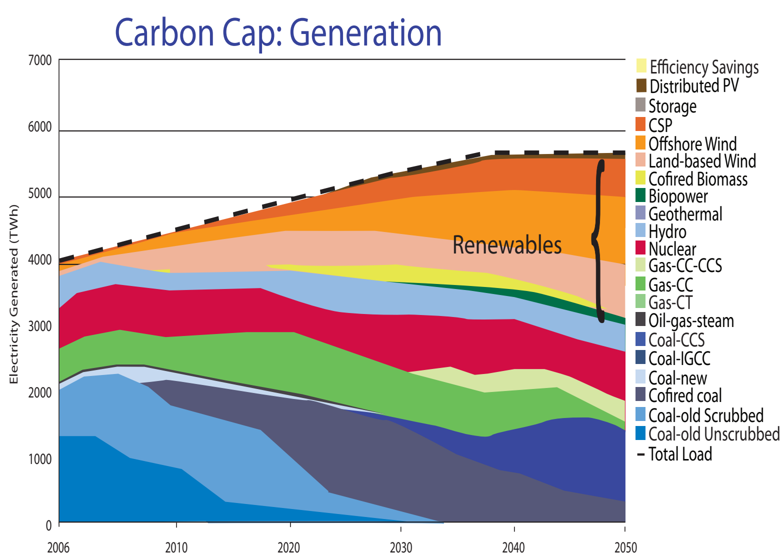

Source: Novak, John. "Creating a Secure Low-Carbon Future." Conference Presentation, Atlantic Council, Washington D.C., October 26, 2009.

**Figure 8: NREL Base Case Portfolio Forecast through 2050**




Source: Short, Walter and P. Sullivan. "Wind Energy in the Mitigation of Carbon Emissions." Presentation, Windpower 2009 Conference & Exhibition, American Wind Energy Association, Chicago, Illinois, May 4-7, 2009.

**Figure 9: NREL Carbon Cap Portfolio Forecast Through 2050**




Source: Short, Walter and P. Sullivan. "Wind Energy in the Mitigation of Carbon Emissions." Presentation, Windpower 2009 Conference & Exhibition, American Wind Energy Association, Chicago, Illinois, May 4-7, 2009.[14]

### 3.2.5 Comparing the Generation Portfolios

The "business as usual" electric power generation forecasts by MIT, EPA, and EIA differ significantly even though they agree on the assumption that the US economy will grow approximately 2.5% per year. As depicted in Figure 10, predictions for electricity production increases range on the EIA's low end of 15% to MIT's high end growth forecast of 35%. Disparities between these predictions largely arise from the differing assumptions about demographics, economic growth rates, raw material prices, increase in electricity prices, technological innovation, and differing estimates of the current generating capacity, as well as on political points of view.[15]

**Comparing the MIT, EPA and EIA non-carbon cap generation mix 2030 outlooks, there do not appear to be even modest areas of agreement between the forecasts. Their electricity production forecasts even range from 16% to 35%. Other comparisons include:**

- While all agree there will be some growth in nuclear power capacity, MIT only foresees a slight increase of 3% and EPA believes there will be a moderate 12% growth.
- MIT predicts a large 24% growth in natural gas whereas EIA expects a more moderate increase of 15%.
- There is an across the board agreement by forecasters that renewables are poised for growth; however, MIT signals a modest increase of 17% while EIA predicts a spectacular increase of 114%.
- While EIA and EPA believe fossil fuel use will modestly increase, MIT makes the case that there will be an increase of 54%.

## Figure 10: Comparison of MIT, EPA and EIA No Carbon Cap Generation Portfolios: Percentage Increase Electricity Generation 2010 to 2030

| | Nuclear Power | Natural Gas | Renewable | Fossil Fuels | Total Electricity Production Increase |
|---|---|---|---|---|---|
| EIA | 10% | 15% | 114% | 5% | 16% |
| EPA | 12% | N/A | 49% | 21% | 22% |
| MIT | 3% | 24% | 17% | 54% | 35% |

Note: Numbers are rounded to nearest decimal. EPA and MIT data compare 2010 to 2030 whereas the EIA data compare 2007 to 2030. N/A refers to data not available.

Sources: EPA data are compiled from: EPA Economic Analyses-EPA's H.R. 2454 Data Annex. Environmental Protection Agency. http://www.epa.gov/climatechange/economics/economicanalyses.html#hr2454; MIT data are complied from p. 66 Paltsav et al. MIT Joint Program on the Science and Policy of Global Change Report 146. The Massachusetts Institute of Technology. http://web.mit.edu/globalchange/www/MITJPSPGC_Rpt146_AppendixC.pdf and note that MIT data includes all fossil fuels in the coal category shown here; EIA's data are compiled from Tables A1 and A8, U.S. Energy Information Agency. EIA Annual Energy Outlook 2010 Early Release Summary Reference Case Tables US EIA available at http://www.eia.doe.gov/oiaf/aeo/pdf/appa.pdf .

A comparison of EIA, EPA and MIT generation portfolios under a Waxman-Markey scenario is illustrated in Figure 11. **All predictions agree that fossil fuel use predominates even under carbon-cap constraints and all predict a large increase in the percentage of power provided by renewables by 2030.** Other observations include:

- At one extreme, EIA estimates that fossil fuels' share of generation capacity drops from over 70% in 2008 to almost 42% while MIT only predicts a decrease to 55%.
- Both the EIA and the EPA roughly agree that the US will increase its nuclear power capacity from almost 20% to a range of 28% to almost 31%. MIT actually predicts a decline in nuclear power's capacity share.
- The models also foresee reductions in electricity demand due to energy efficiency improvements and other conservation measures.

## Figure 11: Comparing EIA, EPA and MIT Generation Portfolios assuming Carbon Caps

| | Generation Mix in 2008 | Projected Generation Mix in 2030 | | | |
|---|---|---|---|---|---|
| | EIA | EIA Base Case | H.R. 2454 (EIA) | H.R. 2454 (EPA) | H.R. 2454 (MIT) |
| Renewable | 9.7% | 15.9% | 20.3% | 15.2% | 17.4% |
| Fossil Fuels | 70.7% | 66.4% | 41.8% | 45.7% | 55.3% |
| Nuclear | 19.6& | 17.7% | 30.8% | 27.6% | 18.6% |
| Reduced Consumption | | | 7.1% | 11.5% | 8.6% |

Source: Caldwell, John. "US Electricity Supply and Demand: The Long View" Conference Presentation, Atlantic Council, Washington D.C., October 26, 2009.

# 4.0 Potential Impacts on Electric Power Demand and Supply

As seen in the figure comparing generation portfolio forecasts, there is a wide discrepancy especially with regard to the future fuel mix. **The workshop zeroed in on five factors that could radically alter power generation forecasts: rising raw material costs, increases in electricity prices, technological innovation, climate changes, and energy/ climate change policy responses.**

## 4.1 Rising Raw Material Costs, Energy Price Increases and Volatility

While the recession dampened the upward trajectory of raw material and commodity prices, over the past five years, raw material costs significantly increased: concrete costs by 39%, aluminum 93%, iron and steel 103%, and copper ore 347%.[16] These increases resulted from the growth in the world economy especially in Asian countries. Moving forward, as the world economy inches out of the recession, cost increases may be expected once again as many of the developing economies are expected to grow potentially as much as three times faster than the US economy.

In the pre-recession period, increased raw material prices led to higher energy costs and price volatility. Continued economic growth in Asian nations with attendant rising energy consumption signals likely US electricity price increases into the future. **Unless there is significant technological innovation to lower the costs of generating power, price increases for end use customers may dampen US electricity demand by encouraging greater end use efficiencies.**

## 4.2 Technological Innovation

In the short term, **major anticipated innovations impacting US electric supply and demand revolve around the potential for technology to allow energy efficiency measures to reduce electricity demand and to improve the expansion of renewable energy supplies into the grid.** Examples of technologies on the near-term horizon include plug-in electric hybrid vehicles that utilize off peak electricity supply and/or supply electricity back into the grid, energy storage, zero energy buildings, CCS and other CCTs. A caveat is in order as it is not yet known what these technologies will cost, whether they will be acceptable to the public, and to what extent they will reduce electric demand. Ocean and tidal power are under near term development with pilot demonstrations in place, and hydrogen is a strong mid-term opportunity. "Silver bullet" technologies that could impact electric power supply and demand in the long term involve satellites that could beam solar power to earth, floating or flying wind farm platforms, and nuclear fusion. However, much can be achieved with a continued rapid development and evolution of already available technologies.

## 4.3 Environmental Impacts of $CO_2$

**On the environmental front, concerns over the consequences of greenhouse gas emissions on our climate are currently driving the energy debate.** While this workshop was not focused on the consequences of greenhouse gas emissions on climate change, information was provided regarding the acidification of the oceans.[17] The environmental impacts of $CO_2$ emissions are believed by some experts to have major impact on ocean life. A number of studies indicate that projected increases in atmospheric $CO_2$ levels will create acidity levels in the oceans that could kill many forms of sea life that form carbonaceous skeletons or structures, such as coral, and that these effects may be irreversible for tens of thousands of years. The impact of atmospheric $CO_2$ on ocean acidity is directly measureable, although the impacts on individual species varies and is under study. [18] This information and a summary of potential greenhouse gas effects are presented in Appendix B.

**Another concern is the extent to which $CO_2$ emissions increase temperatures and what affect that will have on electricity demand.** For example, demand may increase modestly to meet needs for air conditioning, but could decrease due to lower heating needs. For each annual average temperature increase of 1 degree Fahrenheit, US electricity use is expected to increase 1%.[19] It has been recently reported that temperatures have remained relatively unchanged over the last decade.[20]

## 4.4 Impact of Water Availability

Although the impact of water availability was not discussed extensively, **it was noted that reduced water supplies could affect the choice of energy sources since several technologies-**-such as coal with CCS and extraction of natural gas from shale formations, have large water requirements. In response to water shortages, dry cooling technologies are being developed, such as for concentrated solar power facilities. **The interaction between power requirements and water requirements is a subject that will need to be further assessed.**

## 4.5 Climate Change Policy Responses

US policy addressing potential climate change impacts may take several forms, some required on a regional basis, and some nationally imposed. Policies under consideration include: expanded markets that allow for consumer energy supply choice, renewable fuel standards, production tax credits, appliance efficiency standards, investment tax credits, renewable portfolio standards, corporate average fuel economy standards, regulatory restructuring to allow utilities to divest stranded coal assets, and the biggest unknown of all, a greenhouse cap and trade program or some form of a carbon tax.

**If greenhouse gas emission reductions are adopted, the electricity sector will see some significant changes in the mix of generation technologies,** including the early retirement of some coal fired generation, increasing reliance on natural gas, and large scale integration of renewable resources into the grid. The role of nuclear power is unclear even though it is hard to imagine how the US would meet carbon emission reduction targets without increasing baseload nuclear power capacity. New policies could also bring about demand reduction with a more efficient utilization of power and conservation efforts. There is broad consensus that energy efficiency measures can and will reduce demand (and hence emissions) and that there will be a significant increase in the use of renewable energy in the US. **Apart from a consensus on increased use of renewables, there is widespread disagreement as to which combination of technologies will best meet reduction targets.** The generation portfolio forecasts shown above reflect the uncertainties as to which combination of technologies will ultimately be used.

## 4.6 Energy Efficiency and Demand Response Measures

According to the Edison Foundation, energy efficiency is a cost effective tool, on average costing $0.035 per kWh saved, to reduce carbon emissions and moderate expected growth in electricity demand. In 2007, energy efficiency programs saved about 70 billion kWh of electricity and achieved peak demand savings of about 30 GW.[21] The most recent EIA data shows almost 88 billion kWh of energy savings in 2008.[22] The EIA's 2010 AEO estimates that by 2035, energy efficiency measures will reduce energy consumption 15% below what the status quo consumption would have been, and the status quo itself has substantial energy efficiency improvements over time built into it—typically improving 1% per year. Fifteen states currently have energy efficiency resource standards (with a few more pending) and 32[23] have renewable portfolio standards (RPS). Of the 32 states with RPS, 7 of them allow efficiency measures to count as a resource to fulfill the standard. [24] If the US enacted a 20% renewable electricity standard for 2020, as called for in the Waxman-Markey legislation, energy efficiency measures would be eligible to meet up to one quarter of the renewable electricity requirement (i.e., 5% of the 20%).

**Energy efficiency and demand response measures[25] can have significant impacts on demand growth and peak load requirements.** EPRI forecasted that energy efficiency measures could "save" 372 TWh relative to the EIA's AEO 2008 baseline forecast, decreasing 2020 electricity consumption by 9% from the forecasted 4,253 TWh to 3,881 TWh.[26] EPRI forecasts that energy efficiency and demand response programs could realistically reduce 2020 peak load capacity requirements by 79 GWe, with demand response measures providing 44 GWe of the summer peak demand savings. The Federal Energy Regulatory Commission (FERC) forecasts even greater potential peak load reductions by 2020 of between 82-188 GWe.[27] FERC's estimate of 188 GWe is based on some extremely optimistic assumptions regarding smart meter and smart rate deployment; EPRI's estimate of 79 GWe is a realistically achievable estimate.

US utilities are making significant investments in energy efficiency. In 2008, utilities spent just over $3 billion on energy efficiency and, in 2009, budgets for energy efficiency exceeded $4 million based on Consortium for Energy Efficiency data. Lawrence Berkeley National Laboratory forecast that utility efficiency expenditures could escalate to $6 billion by 2015 and $7.5 billion by 2020.[28] However, given budgets already exceeding $4 billion in 2009, that forecast may be an underestimate. As expenditures on energy efficiency increase, it becomes even more important that utilities have business models that align incentives to make these energy efficiency investments. Features of such business models typically include decoupling or some type of fixed cost recovery mechanism and some type of performance incentive or a "return" for energy efficiency investments. These features ensure that investing in energy efficiency is on a level playing field with investing in a power plant. In addition to traditional energy efficiency programs, the deployment of smart meter platforms and home area networks has the potential to make a significant impact on both efficiency and peak demand savings.

Over the last forty years, energy efficiency and conservation measures have reduced US annual energy consumption by 50 quads and the Alliance to Save Energy has indicated there is substantial room to further enhance energy productivity.[29] However, it has also been noted by the World Business Council for Sustainable Development that although the economics of energy efficiency measures may be positive with a $60/ton carbon penalty (equivalent to 2 cents/kWh), in order to drive major investments in efficiency, up to a $170/ton carbon penalty (almost 6 cents/kWh) might be needed.[30]

**Smart grid measures[31] can optimize US electric supply and improve the utilization of electricity-related assets across the board.[32]** Smart grid measures have the potential to reduce overall electricity demand through demand response measures, conservation and reduced transmission and distribution losses. Smart grid measures may also play a role in increasing energy independence through the integration of electric vehicles. This would be of benefit as they could be used as generation and storage devices, and increased electric vehicle usage will reduce oil imports. Finally, smart grid devices may reduce annual electricity demand 4% by 2030 and summer peak demand by 20% according to EPRI.

In November 2009, DOE announced the award of $3.4 billion in grants (out of the total approved $4.5 billion in stimulus funding) for utility-sponsored smart grid projects nationwide. Utilities will deploy over 58 million smart meters to mass market customers over the next 5 to 7 years, and even more deployments are possible as DOE spends the total $4.5 billion in available stimulus funds.[33]

For smart grid measures to reach their full potential, a number of technological, regulatory and social issues must be addressed. Standards are needed to protect customers' data privacy. The National Institute of Standards and Testing must develop interoperability and cyber security standards. Regulatory structures governing utility investments must also be modernized so that incentives are aligned. Workforce training must be focused on more information technology skills. Consumers must be educated on the methods and the cost and benefits of accepting smart grid technologies. Consumers must be assured of the privacy, control and trustworthiness of the technologies.

According to media reports there may be some consumer pushback to smart grid techniques perhaps due to a lack of effective consumer outreach concerning the potential benefits. For example, California's attempts to install smart meters are being questioned by some consumer-protection advocates who say they are not technically or economically sound. However, such attacks against new technologies are nothing new and have to be carefully analyzed. At the same time that smart meters were introduced into specifics areas of California, both new tiered rates approved by the California Public Utilities Commission (that had gone into effect earlier in the year) and extremely hot weather had an adverse impact on customer bills. This pushback shows how important it is to educate and communicate with customers as new technologies and capabilities are deployed.

Finally, as distributed generation sources enabled by the smart grid multiply, there is concern as to how national security would be safeguarded in the event of a massive black out with electricity distributed from thousands of individual generating sources. A significant amount of effort is now being devoted to the issues of cyber security and reliability of the nation's electricity grid.

## 4.7 Innovative Programs and Regulatory Initiatives

**Fundamental changes to the way communities and consumers will take charge of their electricity consumption are on the horizon and many state and local governments, as well as utilities, have enacted innovative programs.** Rather than wait for the federal government to act, 32 states have established renewable portfolio standards and 15 have established energy efficiency resource standards. Allowing new power purchase agreements has enabled consumers to choose their preferred electricity supply (and in many cases the consumers are choosing wind or solar renewable sources.)

A variety of regulatory initiatives are being proposed at local, state and federal government levels. Examples, and benefits thereof, discussed during the Atlantic Council's workshop include:

- Community financing via long term bonds would increase capital for energy efficiency and demand response measures.

- Community choice aggregation[34] in California and Illinois provides communities with the authority to pursue generation portfolios that meet their chosen needs.

- Multi-tenant building aggregation of electric meters in Ohio and Pennsylvania allow building owners to invest in efficiency measures and/or solar capacity and to finance these measures through customer bills.

- Electricity price transparency would allow entrepreneurs to provide competitive power packages to the consumer and possibly further facilitate demand response strategies.

- Allowing distributed generation and net metering could result in both self generation and potentially summer peak demand savings.

- Pending energy legislation that would allow tradable allowances for energy efficiency measures would increase their attractiveness.

Workshop participants endorsed evaluating and enacting regulations that promote energy efficiency, conservation, and increased financing for needed electric generating and transmission capacity. There is great potential for innovative ideas to change the electricity landscape in the US in the years to come.

# 5.0 Generation Portfolio Options: Technology, Status and Barriers

## 5.1 Baseload Options

### 5.1.1 Coal

According to DOE, there are approximately 1450 coal fired generating units in the US with 83 potential new plants on the horizon, representing a total of over 47 GW additional capacity. There are 23 plants under construction, 4 near construction, 9 permitted, and 47 announced.[35] The generation forecast for coal in the near term anticipates a small number of new coal plants will be built with demonstration stage CCS technology. There may then be some CCS retrofits on modern new coal plants. Thereafter, coal facilities could be built with CCS capacity and other plants could be retrofitted with CCS capability. Old inefficient coal plants that could not be retrofitted would be closed.

Coal is clearly in the bulls-eye of the $CO_2$ debate as fossil fuel related $CO_2$ emission reductions could be directed by either federal legislation or potentially from the EPA if Congress does not act. Legal challenges to the carbon reduction requirements could cloud the rules of the game going forward.

From the perspective of technology developers, CCTs, and in particular, CCS technologies, are at hand,[36] but only large commercial scale demonstrations will prove the technology and help to bring the costs down. These demonstration projects must be implemented soon to have an impact.[37] Michael Morris, Chief Executive of American Electric Power Co., stated that its CCS Mountaineer pilot project has shown promising results and that it would be possible to cover all of the CCS costs by roughly doubling the cost of electricity generation from 4 to 8 cents per kilowatt hour.[38] While the economic stimulus package has provided funding, it is not enough to support the wide array of CCS demonstrations that is needed. The DOE's CCT Initiative has been successful in jump-starting technology demonstrations, but Congress may not choose to fund it on an ongoing basis so other funding measures may need to be found.

Key barriers to CCS are the time required to develop and deploy CCS on an enormous scale; the need to develop standards for regulatory approval and permits as a first step; problems with financing in part due to the lack of access to insurance; and commercial demonstration target dates that are only conceptual estimates at present and do not take into account gaps in funding or the certainty of external delays to develop standards, permitting time and potential construction or operation glitches. Public acceptance and liability issues surrounding CCS must also be addressed.

### 5.1.2 Natural Gas

As of 2007, natural gas accounted for 22% of US energy consumption. While coal is the nation's main fuel for electric power, natural gas is the fastest growing fuel. According to the EIA's 2010 AEO, natural-gas fired generators will supply most of the new capacity in the 2010 to 2035 period, accounting for 116 new GWe or 46% of all new capacity. There is a possibility that more than 90 percent of the power plants to be built in the next 20 years will be fueled by natural gas. Natural gas is also likely to be a primary fuel for distributed power generators – mini-power plants that would be sited close to where the electricity is needed. By 2011, the NERC estimates that natural gas will overtake coal as the dominant fuel source for peak capacity as it is easier to site, and facility construction times are shorter.

For most of the past decade, natural gas was the most volatile component of the US energy supply chain. Most recently, prices shot up in 2008 as fears of supply shortfalls abounded but they have now settled well below the price spike of $12 to around $6.00 per million cubic feet. Going forward, the outlook has changed with a likely up tick in the use of natural gas for electricity production as utilities seek ways to reduce their greenhouse gas emissions.

A potential revolution in domestic natural gas supply may have occurred that is just now coming into better focus. There have been several natural gas breakthroughs in the exploration of gas from fracturing shale that may provide supply at a cost as low as $3.50 per million cubic feet.[39] If environmental issues and infrastructure requirements can be met at reasonable costs, these shale gas formations could have the lowest development costs of any US source of natural gas and may generate returns on investment in the 10 to 15% range. The emergence of gas from fractured shale formations that extend over massive geologic areas, and that are generally 10 to 20 times thicker than the best underground coal formations, could significantly affect the electricity market over the coming decades as incremental supplies could keep US gas prices from rising significantly.[40]

A June 2009 study by the Potential Gas Committee at the Colorado School of Mines found that the US has a total "available future supply" of 2,074 trillion cubic feet of natural gas resources, much of it in the shale formations.[41] The growing importance of shale gas is substantiated by the fact that, of the 1,836 trillion cubic feet of "total potential resources," shale gas accounts for 616 trillion cubic feet, or 33% of the total potential resource base. Proved reserves of shale gas grew by 8.9 trillion cubic feet to reach 32.8 trillion cubic feet as of the end of 2008. The reserves in the Marcellus Shale, located in the eastern half of the US, will significantly add to these reserve totals.[42]

Natural gas could play a significant role in the next few years in rebalancing the US electric generation portfolio. In addition to the positive reports on the potential availability of shale gas, there are technological improvements that bear close scrutiny for the role they may play in short term efforts to decarbonize the electricity supply. Potentially one of the most significant technology breakthroughs in the electricity sector in the past several decades, Combined Cycle Combustion Turbine (CCCT) plants are natural gas fired central generation power plants that reportedly can achieve efficiencies in the range of 50%. CCCT plants produce 70% less $CO_2$ than an average coal plant and consume about 40% less fossil fuel. During the restructuring boom, the private sector built about 150 GWe of new CCCT capacity, representing about $300 billion in investment capital. Moreover, existing natural gas plant capacity is under utilized and this massively under used capacity (at 25%) might be substituted for older coal fired plants thereby jump-starting US emission reduction efforts without even constructing a new facility.

Nevertheless, there are barriers and issues surrounding reliance on natural gas. While utilizing natural gas for electricity (or transportation fuels) does reduce $CO_2$ emissions, they are not entirely eliminated as conventional gas-fired plants emit only 40% less $CO_2$ than coal-fired plants. Hence, eventually CCS technologies will be needed on gas power plants. Also, some point out that past optimism about the abundance of natural gas was proved to be wrong and that shale gas may be only marginally economical to drill at today's relatively low prices. Growing reliance on natural gas increases potential reliability concerns due to fuel supply and storage and delivery infrastructure adequacy issues. Environmental objections to shale drilling are being raised due to the large amounts of water and chemicals needed to bring up the gas that could potentially deplete scarce water resources and/or contaminate groundwater-drinking supplies. Currently, the National Petroleum Council is undertaking a major study of the potential impact of shale gas on US gas supplies.

### 5.1.3 Nuclear Power

Worldwide, the nuclear renaissance is a reality with 60 countries, representing three-quarters of the world's population, maintaining or reconsidering the nuclear option. There are 40 power plants currently under construction outside of the US. China and India lead the world in announced power plant construction plans.[43]

There is a question as to the extent the nuclear renaissance happening around the world will be come a reality in the US. Currently there are 18 Combined Operating License applications before the Nuclear Regulatory Commission (NRC)[44] for 26 nuclear plant units. Going forward, EIA forecasts that by 2035 the US nuclear power capacity will reach 109 GWe. EPA's evaluation of the Waxman-Markey legislation found that 187 new nuclear reactors might be needed by 2050.

New nuclear plant capacity will be needed just to maintain the status quo. For the US to maintain its ability to continue to produce 19% of its electricity with nuclear power in 2025, a total of 128.3 GWe nuclear power capacity will be needed.[45] This translates into the requirement for over 27 GWe of new nuclear capacity. As shown in Table 1, assuming plant life extension and uprates in the current fleet, without new nuclear power plant construction, nuclear power capacity begins to drop in 2029, and precipitously declines in the 2030's.

This analysis points to the magnitude of new nuclear plant construction necessary for nuclear to play a serious role to decarbonize the US electric power generation supply. With the rest of the world moving forward (some aggressively) with nuclear power plans, the US would place itself in jeopardy of falling behind as a leader in manufacturing and technology innovation. Without a revival of the US nuclear industry starting today, the US would not be able to maintain its industrial, regulatory and workforce base to support future nuclear capacity needs.

### Table 1: Generating Capacity of the Current Fleet of Nuclear Power Plants (GWe)

| Year | GWe |
|---|---|
| 2025 | 104.82 |
| 2026 | 104.82 |
| 2027 | 104.82 |
| 2028 | 104.82 |
| 2029 | 102.09 |
| 2030 | 100.22 |
| 2031 | 98.53 |
| 2032 | 93.39 |
| 2033 | 83.95 |
| 2034 | 75.55 |
| 2035 | 70.75 |
| 2036 | 64.09 |
| 2037 | 61.29 |
| 2038 | 58.48 |
| 2039 | 58.48 |
| 2040 | 55.27 |
| 2041 | 51.06 |
| 2042 | 44.27 |
| 2043 | 40.08 |
| 2044 | 31.86 |
| 2045 | 25.02 |

Source: Tom Meade, Energy Resources International, December, 2009.

Nuclear power provides clean, efficient, affordable baseload electricity. In the US, nuclear power plants have an average capacity factor of 91.5%, the highest of all electricity producers.[46] Fuel costs have been very stable and low as compared to petroleum and natural gas feedstock. In 2008, nuclear power plants provided the cheapest method of electricity production at 1.87 cents per kilowatt hour (in 2008 dollars).[47] Furthermore, nuclear power can provide baseload power with almost no greenhouse gas emissions over its lifecycle.[48] With federal policy support, nuclear power could also provide power for non-traditional applications such as extracting hydrogen from splitting water molecules to provide a non-carbon emitting transportation fuel and for desalination to provide water for scarcity plagued areas.

Nuclear power's future in the US will be determined by how much baseload power demand the US will need and whether several political barriers can be surmounted. One of the key issues is the lack of progress on the federal government's legal mandate to provide for a permanent commercial waste repository. Although not unique to nuclear power projects, financing for new plants is difficult in the current economic climate and even more so perhaps because the huge up front construction costs are large relative to the balance sheets of the utilities. Federal efforts to provide construction loan guarantees to get past the initial hurdle for new plants are underway. For the future, well-designed carbon waste pricing policies could lead to adequate investments in new nuclear power plants. Other, surmountable issues include the adequacy of the materials supply chain, the need to expand the trained workforce and the ability of the NRC to license new plants and approve next generation technology designs in a timely fashion.

## 5.2 Renewable Options

### 5.2.1 Overview of US Renewable Power Sources

According to the US Department of Interior, the potential for renewable energy options is widespread. [49] The Bureau of Land Management (BLM) has identified about 21 million acres with wind potential in 11 western states, 29 million acres with solar energy potential in six southwestern states[50] and 140 million acres with geothermal potential in the West and Alaska.[51] Theoretically, the US has the potential for installed capacity of 206,000 GWe solar photovoltaic (PV), 11,100 GWe concentrated solar power (CSP), 8,000 GWe onshore and 2,200 GWe offshore wind, 39 GWe conventional geothermal, 520

GWe enhanced geothermal systems (EGS) and 4 GWe co-produced geothermal, 140 GWe hydro power and 78 GWe biopower.[52]

NERC in its 2009 Long-Term Reliability Assessment issued in late October 2009 forecasts the need for approximately 260 GWe of new renewable "nameplate" capacity (biomass, geothermal, hydro, solar, and wind) in the coming ten years, which would be more than double the 139 GWe of installed renewable electric generating capacity in 2008.[53] NERC further projects that of the forecasted 260 GWe new renewable capacity, roughly 96% of this total would be comprised of 229 GWe of wind, and 20 GWe of solar. NERC's prediction for significant increases in wind and solar capacity contrasts with the EIA's 2010 Annual Energy Outlook (see Figure 1) forecast that by 2035 the US will add 92 GWe of non-hydro renewables such as wind and solar.

### 5.2.2 Wind

US installed wind capacity as of 2009 is almost 28 GWe[54] at a generating cost of 5 to 9 cents per kWh at good sites, with no production tax credits. According to recently available data, in 2008 8.5 GWe of wind capacity was added in the US, representing 42% of all new installed electric generating capacity[55] and another 9.9 GWe was added in 2009. Recent analysis shows even larger and more widespread wind resources.[56]

A collaborative effort was undertaken by the DOE, NREL and the American Wind Energy Association (AWEA) to explore the feasibility of wind farms producing 20% of the US total electric generating capacity by 2030.[57] It found that 300 GWe of wind generation capacity—several times larger than the current total renewable generating capacity--at capacity factors ranging from 25 to 35% would be required and could be achieved. Meeting the 20% goal would take 186,000 of new 1.5 MWe, wind turbines over an area of land the size of West Virginia, and an additional 19,000 miles of transmission lines.[58] (However, only 2-5% of this land would actually be used for the turbines and access to them, while the other 95-98% of the land would still be available for farming, ranching, or other activities.)

Questions remain as to how and at what costs wind can achieve such high penetrations. Renewable portfolio standards, improved transmission systems, regional planning, and technological improvements are key factors that could improve growth potential. Consistent, long-term production tax credit policies are equally essential for motivating the investors and developers.

There are wide-ranging challenges for wind power in the US. Although the observed impact on birds is low, currently estimated by the National Academy of Sciences National Research Council at 0.003% of all human-caused avian mortality, reaching wind's potential will require better understanding of the impacts on "birds and bats" issues and how siting and other operating paradigms can mitigate potential impacts on wildlife.[59]

Siting of wind farms has encountered public opposition to "viewscape changes" and other "backyard" concerns. For example, in the Nantucket Sound, the public mounted a vigorous campaign against turbines on the basis of impeding their view and potentially harming commercial and military shipping lanes. After having obtained all the state, local and federal permits, the project as of early 2010 now faces additional delay due to Indian tribe opposition over disturbing burial grounds.[60] Providing an undersea transmission capacity, as is being done in Europe so that the turbines can be moved well offshore, might avoid "viewscape" concerns.

Wind farm developers have faced financing difficulties due to the recession but have been helped by the support that was provided under the American Recovery and Reinvestment Act. The Obama Administration is proposing a further $5 billion in production tax credits for wind farm and other green project developers. However, there may be some Congressional pushback as federal funds for over 10 US wind farms were used for overseas purchases of most of the turbines. The latest wind farm, announced for West Texas, is seeking stimulus funds and will import Chinese made turbines. Expiration of the production tax credit in 2012 may drag on future financing prospects. Wind farms, like many large energy projects, will face high costs for materials such as copper and steel as well as permitting and siting delay costs, although these can be much less for renewable technologies than for large site-built plants.

There are concerns due to the intermittency of wind energy and questions as to how much back up power or storage capacity is necessary or economical. Increased operating reserves may be necessary but new storage may not be economical. Utilities could instead rely on natural gas in the pipeline or in storage facilities, or rely on hydro power. Due to the 28 GWe of installed wind turbines to date in the US, there are data concerning the lifetime and maintenance costs associated with wind facilities. Further work is needed to fully understand maintenance issues, such as the causes of gearbox failures, and to address them so as to improve the long-term performance and reliability of the turbine drive trains.

Studies have shown that the variability of wind can be accommodated within the grid at levels of up to 20% wind generation by dispatching conventional systems just as they are dispatched today. [61] The ability to handle higher wind penetration levels are under study. Some grids now reach these levels of wind generation during certain periods. Further work is needed in this area to fully resolve the questions concerning the variability of wind energy and how to best manage it.

The US transmission system must be significantly expanded and upgraded to allow for wind to penetrate the electricity market. The sitting, permitting and cost-recovery for transmission systems is bogged down over jurisdictional issues and a lack of strong federal leadership (although the legislation is on the books and the DOE has proposed plans to improve the transmission system).

Wind and weather forecasting should be improved, to provide better scheduling of plant usage and transmission loading. To integrate wind power into a utility's footprint, more accurate hourly wind forecasts are needed to reduce potential line congestion and/or rebalance the system due to sudden shifts in wind output.

### 5.2.3 Geothermal

NREL estimates that currently there is 2.8 GWe of installed geothermal capacity in the US with another 0.5 GWe under contract. Generation costs are estimated at between 6 and 8 per kWh with no production tax credit, which is comparable to the current generation cost of existing, mostly depreciated coal or nuclear. With capacity factors reaching 90%, geothermal may someday become a baseload supplier. With sufficient research, development and demonstration (RD&D) over the next few decades, EGS should become a commercially competitive energy source. It will mostly be available in the Western and Southern Gulf states.

In addition to geothermal capacity for electricity production, there is interest in residential geothermal heating and cooling systems. The application of geothermal heating/cooling, also known as ground source heat pumps, has been named "the most energy-efficient and environmentally sensitive of all space conditioning systems", by the EPA. Geothermal technology is still relatively new, with only about 50,000 systems (approximately 1 percent) installed nationwide in 2008 with 150,000 units installed in homes at this time.

According to a recent MIT analysis, there is the potential in the US for 100 GWe installed "enhanced geothermal power"[62] systems by 2050 that would be cost-competitive with coal-fired generation.[63] NREL estimates that there are 30 GWe of undiscovered hydrothermal resources and the potential for 518.8 GW of enhanced geothermal systems (of 6 km depth).[64] NREL estimates that geothermal energy has the (optimistic) potential to provide between 5 to 20% of future US electricity needs.

The main technical challenges include the need for field experiments to better understand well productivity, heat exchange volumes, the drilling and control equipment needed to withstand 400 plus degrees, and well longevity. Other challenges include expiring production tax credits, the impact price volatility may have on project financing, and adequate transmission capacity.

### 5.2.4 Biomass

There is 10.4 GWe of installed biopower[65] capacity in the US as of 2009, which is comprised of 5 GWe pulp and paper, 2 GWe dedicated biomass, 3 GWe municipal solid waste and landfill gasses, and finally, 0.5 GWe co-firing capacity.[66] Biomass power costs currently are higher than wind and geothermal, and range from 8 to 10 cents per kWh.

The 2005 "Billion Ton Study"[67] prepared by the Oak Ridge National Laboratory identified sustainable wood biomass resources in the amount of 200 million bone dry tons/year, mostly from logging residues and fuel treatment facilities, which ADAGE[68] projects could sustain a 20 GWe installed capacity.[69] The greatest potential may likely be situated in the

Western section of the country where biopower can aid forest management and potentially cut down on insect infestations and fire prevention, and in the Southeast and Northwest regions, where large tracts of privately held land provide the amount of materials needed for economies of scale. While the wood burning process releases as much $CO_2$ as burning fossil fuels, the process may be considered to be carbon-neutral because the released $CO_2$ is largely balanced by the $CO_2$ that had been captured in the fuel's growth (depending how much energy was used to grow, harvest, and process the fuel). To remain carbon neutral, systematic replanting and forest harvesting practices will be required.[70] Such practices are today regularly practiced by many landowners.

The fuel component of biopower makes it more expensive than other renewable sources, requiring expanded efforts to improve technology and drive costs down. Biopower programs are sometimes not seen by the public as fitting the traditional definition of renewable and sustainable. Supporters will need to educate the public as to the benefits of providing better land management and forest stewardship, and that helping to reduce forest fires, reduces $CO_2$ emissions. Key to the success of the biopower industry will be a consistent and broad definition of biomass especially as it relates to the tax code, renewable electricity and fuel standards, and other climate policy requirements. The industry's potential will depend on proper carbon accounting so that it gets credit for the benefits of healthy forests.

### 5.2.5 Solar Energy Technologies: Photovoltaic (PV) and Concentrated Solar Power (CSP)

DOE is sponsoring the "Solar Vision Study" which will be published in draft form in 2010. It will evaluate the technical, economic and environmental feasibility of meeting between 10 to 20% of US electricity demand by solar technologies (central and distributed PV, CSP, solar water heating and cooling) by the year 2030, and what technology RD&D will be necessary to help reach such a goal. Already, global investment in solar technologies has rapidly increased from $66 million in 2000 to over $16 billion in 2008.[71] The US accounted for approximately one quarter of this investment.

US installed PV capacity is relatively small, with only 1 GWe of grid-connected PV systems, providing power at a price in the range roughly 18 to 23 cents per kWh, including incentives, down from $2.00 per kWh in 1980.[72] Table 2, citing 2008 DOE Solar Program Goals, displays the past, current and target prices for PV systems throughout the residential, commercial and utility markets. Meeting targeted prices decreases will allow for significantly increased market penetration levels for PV systems.

**Table 2: PV Costs in 2005 and DOE Solar Program Goals to 2015 in the Residential, Commercial and Utility Sectors Compared to Current US Market Costs for Electricity)**

| Market Sector | Current U.S. Market Price Range (¢/kWh) | Cost (¢/kWh) Benchmark 2006 | Cost (¢/kWh) Target 2010 | Cost (¢/kWh) Target 2015 |
|---|---|---|---|---|
| Residential | 5.8-16.7 | 23-32 | 13-18 | 8-10 |
| Commercial | 5.4-15.0 | 16-22 | 9-12 | 6-8 |
| Utility | 4.0-7.6 | 13-22 | 10-15 | 5-7 |

Source: Sam Baldwin, "Solar Energy: Challenges and Opportunities." Conference Presentation, Atlantic Council, Washington D.C., October 26, 2009.

As PV system costs decrease, the DOE forecasts significantly higher market penetration will occur with an increase to 4 GWe cumulative installed capacity by 2015 and as much as 16 GWe installed capacity by 2020. As costs decrease, residential PV systems will become increasingly attractive in many markets. Production constraints due to limited availability of PV materials, such as silicon, no longer appear to be stumbling blocks. The challenges will be cost, performance and reliability; developing a robust supply chain and distribution network; understanding and acceptance by financial, regulatory and utility sectors; and, system integration by improving the US grid. Public acceptance of large scale utility projects may also prove a stumbling block as thousands of acres of land are needed and conservationists have opposed projects on the basis of aesthetic, environmental and wildlife damage.[73] Distributed PV systems, such as on the roofs of buildings, do not face this particular problem.

NREL estimates that current installed CSP capacity is .419 GWe at a cost of 12 cents per kilowatt-hour, with the potential for reductions to 8.5 cents by 2010 and 6 cents by 2015. CSP facilities are primarily located in the Southwest in Arizona, California, Colorado, Nevada, New Mexico, Texas and Utah. NREL further estimates that there is a potential capacity of almost 6,900 GWe. There are 4.5 GWe of CSP projects under development.

Barriers to CSP deployment include its variable output; low capacity factor; location on weak circuits; and that the current economics of transmission work against it. In addition, projects located in the Southwest may face increased costs and reduced power production if they are forced to apply dry cooling techniques due to water constraints.[74]

### 5.2.6 Key Challenges for Renewables

The lack of transmission infrastructure is often cited as an obstacle to integrating renewable energy sources into the US electricity system. Even if the federal government and/or the states enact renewable power requirements, the mandates must be supported with a substantial expansion of the high voltage power lines that can bring power from where it is generated to where it is consumed. The grid also needs complex new computer models to anticipate, monitor and respond to the changes in weather that can suddenly alter electricity output from wind or solar units. Sophisticated new power flow monitors and controls will be needed. The political challenge of deciding who pays for the upgrading of the power grid required to handle more renewable power will be daunting.

Compared to other traditional generation options, renewable energy projects have a comparatively larger footprint than other electricity generation sources. This poses a dilemma with regard to the potential impacts that supporting infrastructure may have on land requirements, wildlife and endangered species. As noted in Table 3, a nuclear power facility takes up slightly more than one third of a square mile to produce 1 GWe, whereas 3,000 wind turbines scattered over 40 square miles are needed to produce the same amount of electricity.

**Table 3: Comparison of the Ecosystem Impact to Generate 1 GW Electricity**

| Method | Requirement | Land Area (sq. miles) |
|---|---|---|
| Solar PV | 100 $km^2$ at 10% Efficiency | 40 |
| Wind | 3,000 wind turbines | 40 |
| Biofuel | 16,100 km2 of corn | 6,200 |
| Biomass | 30,000 acres of woods | 12,000 |
| Nuclear Power | 1 $km^2$ | 0.33 |

Source: Ryskamp, Dr. John M. "A Technology Roadmap for Generation IV Nuclear Energy Systems." Conference Presentation, IEEE Power Engineering Society Meeting, April 28, 2003.

Finally, successful penetration of renewables energy projects into the electric grid will depend on their ability to meet cost reduction targets. Raw material and construction costs are increasing across the board. Technological improvements have been identified for most renewable energy technologies that promise to further drive costs down significantly, however, their success is not yet assured. Expiration of the federal tax credits for wind power, scheduled for 2012, could have a negative effect on consumer acceptance of wind power.

# 6.0 Workshop Observations

The future of America's national, economic and environmental security depends on the availability of abundant and affordable sources of electricity, preferably relying as much as possible on domestic sources for fuel while limiting pollution of the environment to the greatest possible extent. Today, the US is closer than ever to domestic energy security with the exploration and development of new sources of natural gas, a commitment to significantly increase use of renewables, expanding the reliance on safe nuclear power and keeping the domestic coal option open through the introduction of CCTs. These capabilities will only be available if actions are taken now by the federal government. **Sustainable domestic energy security directly translates into increased national and economic security.** The country can seize the opportunity it lost after the oil embargo of the 1970s, and through its leadership, encourage other countries to pursue the same national, economic and environmental energy security goals.

## 6.1 Electricity Demand Growth Patterns are Changing, Forecasts Signal the US Requires Additional Baseload Electricity Capacity, But Questions Linger Regarding the Impact of the Recession

With growing electricity demand, estimated by the EIA to total 22% from current levels to 2035, and the retirement of 30 GWe of existing capacity, 250 GWe of new generating capacity may be needed between now and 2035.[75] Even with curbs projected to be placed on the energy sector by possible greenhouse gas emission restraints, the EPA and MIT forecast electricity demand increases of 51% and 60%, respectively, by the year 2050. **While energy efficiency and conservation strategies make good environmental and economic sense, the US will want to replace aging facilities, meet expected demand increases, and most importantly, have the flexibility to produce even more electricity if needed, if for example, the electrification of the transportation industry significantly increases demand and/or summer cooling loads increase.**

Energy efficiency, smart grid, CCT and renewable technologies may take longer to deploy, or may deploy at an even greater cost than envisioned. The expansion of renewables could be limited by delays due to public disapproval of project sites, problems in getting upgrades to the transmission system, or a lack of project financing, among others. New nuclear capacity may also prove difficult to finance, and will face sitting and permitting obstacles. Similarly, new coal plants, which are the backbone of our electricity system, may become difficult to build/finance due to the costs of complying with possible $CO_2$ emission standards.

The US may require more than the forecast electric power over the next 5 to 10 years to meet the needs of a growing population, a higher than anticipated uptick in the nation's economy, and/or a slower than anticipated implementation of energy efficiency and conservation measures. Even with a gradual economic recovery, the current reduction in electric power consumption associated with the current economic downturn could be quickly reversed. The tendency of higher temperatures to add slightly to electricity usage has already been noted and growing fresh water shortages in some regions are likely to increase the need for desalinization that also consumes power. Although there is no consensus among the experts yet, the electrification of the transportation sector might have an impact on electric power demand. (The question is whether plug-in vehicles, hybrid and all electric, could be charged in off-peak hours eliminating the need for additional base load capacity.)

While electricity demand will grow in absolute terms, the rate of growth has been slowing for many years. Structural changes in the economy due to the recession, efficiency programs and higher electricity price are expected to slow electricity demand growth further and continue the downward trend. Growth slowed from an average of 2.4% in the 1990s, to 1.1% in the period 2000-2007, and is likely to slow to 1.0% in the 2005 to 2035 estimate. There is a longer term potential to reduce electricity consumption below current levels with very aggressive efforts to both conserve and increase its efficient use.

Counterbalancing factors raise doubts regarding increases in the amount of baseload generating capacity that may be needed. Existing generation and transmission systems are greatly underutilized.[76] The recent financial crisis severely reduced demand growth and may portend a fundamental shift in expected long- term economic growth rates, and electricity usage. The growth in peak load is even less certain if smart grid and demand side management techniques reduce it and allow a flattening of load factors. The tremendous push for energy efficiency through the economic stimulus package, coupled with likely breakthroughs in technology, the ready supply of commercial and residential building targets that are ripe for efficiency measures, and the ability of states to use efficiency gains as offsets to required emission reductions could significantly slow or even reverse the need for new baseload capacity. In some regions, the proliferation of policies that promote energy efficiency, solar and wind farms, distributed generation and demand reduction may lead to a decrease in conventional baseload grid demands.

**The bottom line is that the economic recession's "benefit" of reducing electricity demand growth in the short term has bought the US some time to address other pressing issues such as the transmission system and the resilience of the US grid to accommodate renewable power sources.**

## 6.2 Electricity Supply Planning Requires Flexibility and Capability

One certainty is that the structure of electricity portfolios will vary by region. **Policy and regulations need to provide consistency and flexibility to meet the specific requirements of regional supply and demand variations, which in turn are difficult to forecast in these changing times.** A recent NERC study summed up the uncertainty, "The pace and shape of economic recovery will dramatically influence actual load growth across North America over the ten-year period. Largely unpredictable economic conditions result in a degree of uncertainty in 2009 demand forecasts that is not typically seen in periods of more stable economic activity."[77]

**If the US wants to maintain the ability to preserve its options and have the flexibility to meet unexpected needs should the deployment of new technologies be slower than expected, then the capability to produce additional baseload capacity must be maintained. This has obvious implications for US energy policy that should continue to support the two main pillars of baseload capacity, coal (with ability to retrofit CCS) and nuclear power.** Furthermore, to gain the ability to provide low carbon electricity, aging US infrastructure will have to be replaced and expanded. Failure to establish and maintain a technological lead and a robust domestic manufacturing and supply chain capacity could eventually force the US to rely on foreign technology and imported plants with the attendant loss of US jobs.

Policies to transform the US electric power industry will only prove realistic if they are designed to accommodate a number of very fundamental conditions impacting global energy markets that are often overlooked. Leadership at the federal, state and municipal levels is needed to inform the public regarding the following realities:

- The cost of building new facilities for generation, transmission and distribution will be considerably more expensive than the costs incurred for existing assets. Globally, increasing demand has raised the costs of materials, and while new designs can soften the rate of increase, significantly higher construction costs are a given.
- In the US (and Europe) roughly 50% of existing power facilities are nearing the end of their useful lives. **Hence, even if there were to be no growth in demand, the US needs to start replacing existing facilities now and by 2050 most of existing facilities will need to be replaced at substantially higher cost.**

- Reasonable rate increases must be accepted to accommodate new investments. (Politicians who promise to hold down reasonable rate increases are actually doing the public a disservice, as without new investment, energy supply services will deteriorate.) The public needs to understand and appreciate the need to plan for greater efficiency, conservation, and its attendant higher cost of electricity.

- There needs to be more regional (multi-state) cooperation. Many innovative programs and policies are being deployed at the municipal and state level, but the future will require significantly more interstate cooperation to make the best use of energy resources and to allow for the transmission and grid interconnections to enable the cost efficient utilization of renewable power and the most productive location of new baseload facilities, whether coal with CCS or nuclear.

## 6.3 There is an Urgent Need to Comprehensively Reassess the US Electricity Strategy

Transformational change in the electricity industry is accelerating and there are many uncertainties about the generation mix in the electricity portfolio. The potential requirement to move toward a low-carbon world suggests a need to replace some of the fossil fuel facilities in the core infrastructure and add technology to the remaining fossil capacity to reduce its emissions. The electric power industry may bear a disproportionate burden in the overall effort to reduce greenhouse gas emissions in the US. However, these actions have large potential costs for the American consumer. It is hoped that there will be far reaching improvements in the efficiency with which power is generated and consumed and that smart grid strategies may result in a steep downward shift in the demand growth curve in the short term. Tackling the emissions from existing and replacement power plants will face remarkable engineering, technology and political challenges.

**The current proposals under consideration by our political leaders may not meet the challenge.** The current Administration's cap and trade policies and/or the pending Waxman-Markey legislation may not bring about the decarbonized electric supply that will be needed. The process for setting a price on carbon may take too many years to set a high enough price to force investments in non-carbon emitting sources. Its reliance on offsets and allowances may not sufficiently encourage long-term investments in low carbon emitting technologies and may serve to postpone actions. The economic reality of legislating a phased-in reduction may keep carbon market prices too low to create needed long-term investments. Furthermore, the goal of the proposed legislation is not to guarantee reliable low cost electricity-needed to keep America on a secure economic path. **While legislation should provide the flexibility to accommodate regional differences and capabilities in the supply of power, the costs of externalities do need to be recognized in electricity rates.** The workshop participants indicated that a carbon disposal tax, similar in concept to what the nuclear generators pay for spent fuel disposal, might be further debated.[78]

**Comprehensive, integrated planning, based on technical strategies, is needed to preserve all of our domestic energy options, equally focus on the short term and long-term options, and provide an expanded commitment to RD&D.** Layered on top of this is the need to maintain flexibility to meet increased demand if it materializes, and to provide technologies in a diverse geographic environment. For example, some Northeast areas of the country may not realistically be able to use as much solar energy as the Western states, offshore wind is available to some coastal areas, and onshore wind capacity varies geographically. **A balanced portfolio with many (domestic) options is the way to deal with price volatility-the economic security part of the equation.** The energy mix will change but will hopefully never be too reliant on any one fuel source. Delaying the introduction of steps to reduce pollutants and greenhouse gas emissions will make it significantly more difficult and disruptive to the economy to try to play catch up in the future.

Energy sources exist to meet growing demand, but there are caveats:

- Until recently the US was expecting to become increasingly dependent on liquefied natural gas supplies which are often priced in relation to petroleum. The recent US success in producing gas from shale may significantly increase the availability of low cost US supplies and natural gas prices have dropped to less than $6/million cubic feet, half what it was a few years ago. However, the absolute levels of these supplies and the eventual cost to handle environmental issues associated with drilling for shale gas has yet to be determined. Nevertheless, it is highly likely that for at least several decades there will be sufficient production of US gas to support gas being used as a back up fuel to intermittent renewable power supplies. Eventually natural gas plants will also have to employ CCS technology.

- Coal represents the US's most abundant and lowest cost source of fossil fuel, as such it needs to remain an important source of our electric power. However, the externalities associated with the by-products of burning coal will need to be addressed. This requirement could translate into a 30 to 70% increase in delivered cost to consumers; actual impacts can only be known once commercial scale CCS demonstration plants have been successfully completed.

- Nuclear power has evolved as a safe and highly reliable source of power. Without a continuing reliance on a significant level of baseload nuclear power, it will be virtually impossible to meet any meaningful $CO_2$ emission reduction targets. However, waste storage issues still need to be politically resolved and accepted by the public. For the next three or so decades there are sufficient uranium supplies to meet expected US and world demand.[79] Depending on the pace and extent of new construction, new fuel cycle policies may be required to ensure adequate longer term fuel supplies. Despite construction costs increases, nuclear power is expected to provide electricity at competitive rates. The provision of loan guarantees and long term funding is critical to reinvigorating the industry in the US. Nuclear power has the additional benefit of supporting large-scale desalinization plants in water stressed areas.

- Taken together, potential renewable reserves are virtually unlimited relative to expected demand for electricity. But this is very misleading. The technology to utilize the potential is still being developed and there are environmental (not carbon and emissions) issues related to wind, solar and geothermal facilities. With increased R&D, cost reductions have been achieved, and with tax credits and other subsidy policies, wind is competitive in a number of situations, as is solar and geothermal. But, today these situations remain relatively limited in relation to total electricity requirements. Significant further cost reductions will be needed for technologies such as solar. Continuing government support for renewables and state and possibly federal legislation on RPS will stimulate further deployment of renewables. Although there are projections suggesting extremely rapid deployment of such technologies, the combination of the need to restructure transmission systems, widely employ smart grids, and provide back up storage to support intermittent power supplies, suggest that achieving even a 20% reliance on renewables by 2030, as envisioned by the EIA in its Waxman-Markey scenario generation forecast, would be an outstanding achievement. Planning for a 40% reliance on renewables by 2050 would also be ambitious, but plausible.

## 6.4 Every Electric Generation Option Faces the Same Issues: Financing and Public Acceptance

Developing any form of new electricity generation, or expanding current ones face public acceptance issues. The US public says, "not in my back yard" or NIMBY, "not in my national monument back yard" or NIMNMBY, "not under my back yard" or NUMBY, "no water from my back yard" or NOWBY, and finally, "not in my desert" or NIMD! Renewable fuel plants have huge potential but they are in their "infancy" compared to coal, gas and nuclear power plants and will face public acceptance problems. Nuclear power is a mature technology; public concerns regarding safety have been diminished but an issue remains due to the political debate over the storage of wastes. The public has questions regarding CCS strategies due to their concerns over appropriate $CO_2$ underground storage. Developing shale formations to produce natural gas supplies elicits concerns over groundwater contamination. Reasons for opposition are endless and such opposition must be factored into a realistic assessment of what the US can feasibly build.

Financing structures are a key barrier for all energy technology options. To transform to a low carbon economy, the government will need to backstop private sector R&D and devise policies that incentivize both the rapid reliance on low carbon technologies by improving prospects for long term financing. In the short-term, federal government stimulus funding is aiding the wind industry, for example, but long-term, federal policies that incentivize the private sector are needed. These could include loan guarantees, accelerated depreciation, longer-term production credits that phase down after assets are depreciated, and/or a longer-term schedule for production credits that is available for new investments but declines consistent with expected industry cost reductions. Financing of needed new technologies would also be aided by creating a more level set of fiscal incentives at both the state and federal level that would require a re-assessment of the many subsidies and special supports that currently exist for most existing sources of energy.

# 7.0 Six Key Recommendations

The challenges to establishing a realistic electric power generation portfolio that allows the power sector to meet the country's requirements for electricity while addressing environmental concerns must not be underestimated. **The economic realities associated with the need for new investments and the need to reduce emissions from fossil fuels can be met, but only at higher electricity prices.** The US will be a major proving ground for the necessary changes and the US electric sector may be the one area where significant transformative efforts could take hold in a relatively orderly fashion.

**Key questions for policy makers are: what level of power costs will support a rebalanced portfolio? And what rate of change in rates would allow the public and industry to adapt?** The public needs to be able to shift consumption patterns over time and industry needs to stay competitive. Fortunately, other countries will also be incurring higher costs, and the introduction of higher rates will encourage energy efficiency and conservation.

Any transformation will be gradual, as developing power generation infrastructure entails long lead times. Typically, major power plant investments take seven to ten years and new CCTs and significant numbers of new nuclear plants will take 20 plus years to be deployed in significant numbers. Renewables can be deployed faster, but plant sizes are considerably smaller and will still take decades to be deployed in volume. The impact of covering the higher costs of such technologies can be scheduled to impact rates gradually over decades as they become a large portion of the system.

Even without a comprehensive, legally binding international treaty limiting greenhouse gas emissions, the complexity of developing the long-term solutions can be unraveled by identifying and prioritizing the key actions that can be taken, starting in 2010. Over the next few years the highest priority should be given to these 6 recommendations:

1. **The United States should move forward now to rebalance its portfolio and all agree that the starting place is energy efficiency.** Energy efficiency and conservation measures are recognized as having a significant near-term potential to reduce demand and, of course, reduce attendant $CO_2$ emissions.

2. **Uncertainty regarding national and international greenhouse gas emission policies dictates that federal financial support be provided now for critical energy technology programs.** To this end, construction of coal-fired plants with CCS and new nuclear plants should be supported so that these projects can be initiated as soon as possible to assure the continuing viability of baseload capacity for the US electrical grid in the near term future.

3. **Kick-start decarbonization efforts by using natural gas as a bridge fuel.** It is recommended that the US use the expanding availability of natural gas from shale formations and other domestic deposits as a bridge fuel-as backup for renewables and as required pending the availability of CCTs with CCS and new nuclear baseload capacity.

4. **Rebalance the electricity portfolio with diverse, broad-based options.** Start with low or no cost

efficiency measures; build on commercially available technologies such as natural gas, some renewables, and nuclear power instead of relying on the eventual availability of very long-term technology silver bullets; undertake the necessary infrastructure improvements to allow for efficiency improvements and to bring renewable sources into the grid as quickly as possible; and, significantly ramp up RD&D on CCTs, next generation nuclear power plants and fuel cycles, and transportation fuel options.

5. **Leadership is needed to establish public and private sector support for US energy policies and their attendant RD&D programs.** Public and private agencies need to merge their efforts to properly inform the public regarding the potential options available to an evolving electricity generation portfolio; their timing, availability and costs; and their impact on the environmental, economic and national security issues. The American public deserves frank talk on the timing and costs of its energy supply.

6. **The federal government must continue to address the siting of transmission lines, grid improvements and incentives for more renewables.** In the "grace period" of reduced electricity demand growth the US now enjoys thanks to the recession, the US must focus its efforts immediately on the siting and building of transmission capacity and on ways to improve the grid to allow better integration of renewable power sources into the US electricity supply. Congress must provide the authority to the federal government to issue the permits to build the needed transmission lines and to give FERC the power to properly allocate costs of building needed lines.

## 7.1 The United States Should Move Forward Now to Rebalance its Portfolio and all Agree that the Starting Place is Energy Efficiency

The current debate's focus on finding the "best solution" in the next 30 years is irresistible but may serve as a great distraction. The US alternatively should focus on what to do now to maintain our national, economic, environmental, and energy security. As part of the US's strategy to decarbonize as quickly as possible, it is recommended that the US pursue the cheapest and lowest hanging fruit first-energy efficiency.

Energy efficiency and conservation measures are recognized as having a significant near-term potential to reduce demand. Numerous assessments have indicated that such measures would provide substantial economic benefits as well as afford the US the opportunity to gradually introduce new technologies and soften the impact of rate increases associated with the introduction on new infrastructure investments. Unfortunately, there are anecdotal reports that residential and commercial consumers are reluctant to make the investments needed even when there are significant government subsidies.[80]

The US private sector is looking for markets that allow consumer participation and energy supply choices, tax credits, accelerated depreciation, altered building codes and performance standards. To expand efficiency and demand reduction measures that can be supported by the business community and consumers, suggested policies include:

- Increase and/or lengthen the time period of energy efficiency incentives at both the state and federal levels that include among other policies, tax credits for building improvements and the purchase of efficient consumer products.
- Provide consumers new long-term, low-cost financing options.
- Allow for efficiency improvements to count toward state-level RPS mandates.
- Strengthen building efficiency standards (especially for new construction).
- Encourage conservation, urban redesign efforts, greater use of rail transportation, and design financial incentives for smaller homes and, perhaps, penalties for larger homes.
- Educate consumers as to how to take advantage of new energy saving technologies, promise that their privacy will be maintained and that investing in new devices will lead to real energy savings (if not offsetting energy costs).

- Develop mechanisms for consumers to access in real-time, secure usage data and dynamic pricing mechanisms.

## 7.2 Uncertainty Regarding National and International Greenhouse Gas Emission Policies Dictates that Federal Financial Support be Provided Now for Critical Energy Technology Programs

With the uncertainty surrounding development of US energy policy in the post-Copenhagen environment, the federal government must support the construction of coal-fired plants with CCS and new nuclear plants so that these projects can be initiated as soon as possible to assure the continuing viability of baseload capacity for the US electrical grid in the near term future. The following recommendations should be adopted:

- The federal construction loan guarantees are a positive step and they must be expanded as necessary to ensure new nuclear plants can be built to meet the requirements for low $CO_2$ emission electricity supplies.[81]

- Congress must make the needed appropriations to maintain and expand the NRC's workforce so that it can issue in a timely fashion nuclear power plant license extensions and plant up-rates, as well as new plant licenses and new reactor design licenses. Congress and NRC should work together to agree on ways to further streamline the licensing process.

- It is essential that the US take steps to reinforce its nuclear industry supply chain and workforce to ensure over the long term the industry's capability to provide at least 20% of US electricity or even a greatly expanded amount of nuclear baseload capacity if warranted in the future for both conventional power demand and unique applications like desalinization for water supplies. Government and industry can partner to make sure the workforce is receiving the right education and that manufacturing capacity remains within the US borders.

- If the US is serious about its efforts to have clean supplies of electricity, then it should change the definition of the federally and state mandated "renewable portfolio standards" to "clean portfolio standards" so that there is a level playing field for clean power sources such as nuclear power to compete with clean renewable power sources, and eventually coal and gas plants with CCS.

- The federal government must resolve the impasse it created with halting the licensing of the Yucca Mountain waste disposal facility. It must not let this current political debate pose a roadblock in the licensing proceedings for license extensions and/or new nuclear power plant licenses.

## 7.3 Kick-start Decarbonization Efforts by Using Natural Gas as a Bridge Fuel

Short-term solutions are needed to achieve reductions during the period in which $CO_2$ limits are gradually imposed, renewables can be phased-in, and to bridge the gap to solutions that are still being developed, such as CCS and lower cost renewable technologies. Existing natural gas-fired capacity can be deployed immediately. **It is recommended that the US take advantage of the idle plant capacity and expanding supply of natural gas and use it as a bridge fuel-as backup for renewables and as a replacement for retiring coal capacity-while building substantial non-carbon emitting sources so that the US does not suffer another round of price spikes and over reliance on natural gas.** The benefits of this strategy are that it is a domestic fuel source and with the increase in its supply[82] there may be less price volatility in the future. The regulatory authorities must address and change policies that consider coal fired plants as stranded assets to open up new markets to competition from idle natural gas capacity.

## 7.4 Rebalance the US Electricity Portfolio with Diverse, Broad-based Options

The US's electric power system will continue to be heavily based on fossil fuels, though perhaps by half or more of what it is today, by the second half of the century. Fossil fuels are unlikely to be phased out, and though they are likely to lose market share, they will probably remain the plurality of energy resources for several generations. The development of alternatives, especially for transportation, is important if only to foster competition and to promote innovation. Oil's dominance in transportation, and coal and gas's preeminence in power generation will probably decline over the next forty years, but will likely not fade away. The US demand for power may grow more slowly, as more aggressive efficiency measures are imposed, but this trade-off will work only to the extent that economic growth enables new investments.

**The US must rebalance its electricity supply policies by encouraging all domestic electricity supply options-coal, gas, nuclear power and renewables.** This point was supported by both the EPRI and NREL modeling that indicate all forms of energy will be required even with substantial improvements in energy efficiencies and conservation. The workshop participants were divided as to whether the US government or the market should "pick the winners". But participants agreed that at a minimum, government should start by providing the legislative framework for the market to begin to finance needed generating (and transmission) capacity as quickly as possible. If the government does enact legislation and regulations to reduce greenhouse gas emissions, it will need to be done in a manner such that the impact on power costs can be largely offset through efficiencies while not driving US businesses overseas.

The decision-making framework should be based on the following considerations: available energy resources (local and regional), financing mechanisms, consumer ability to pay, the transmission and distribution network, and national and state economic goals. Options should be designed on regional levels and involve coordination among states. The process of developing such a framework would assess the parameters that decision-makers must take into account. Such an approach will allow the energy industry to then develop strategic plans and obtain financing for the chosen electric power generation and transmission policy.

## 7.5 Leadership is Needed to Establish Public and Private Sector Support for US Energy Policies and their Attendant RD&D Programs.

Public and private agencies need to merge their efforts to properly inform the public regarding the potential options available to an evolving electricity generation portfolio; their timing, availability and costs; and their impact on environmental, economic and national security issues. Leaders in industry and government must promote a better understanding of why a secure, reliable and sustainable energy supply is key to the long term success of the US economy. **Frank talk with the American people is needed on:**

- A realistic assessment of the timing of new energy supply and its costs.
- That to enable the private sector to clarify the rules going forward so that it may make its necessary strategic investment decisions, most energy policy experts agree that the US government should establish a price on the disposal of $CO_2$. In light of the reality that cap and trade legislation may not pass, US leaders need to consider other approaches. While regional differences and capabilities in energy supply must be accommodated, the workshop participants indicated that a carbon disposal fee (tax), similar in concept to what the consumers of nuclear power pay for spent fuel disposal, might be further debated.
- The public should not get bogged down on the merits of the "global warming " debate but should focus instead on the environmental consequences of burning fossil fuels. During the past Love Canal and acid rain debates, the US found the political will and funding for environmental remediation necessities.

**US leadership on electric power generation policies must be back-stopped with an aggressive RD&D agenda.** As noted in the workshop, all technologies are not yet ready and the US must enhance its RD&D programs over the next 20 years. The institutional and financing aspects of RD&D must be attended to. The federal government can play an important role in funding some R&D, especially for the longer term technologies that were mentioned in Section 4.2, and also in structuring incentives for the private sector to bring the best technologies into the marketplace. It should be recognized that the US government is well suited to:

- Provide longer-term certainty for support programs that would not abruptly terminate, but would phase down as the cost of technology is reduced. Government subsidies should not be forever, but likewise this is a long-term business and breakthroughs do not occur overnight. For example, production tax credits for wind should not be allowed to end in 2012, but may be able to be placed on a declining schedule, especially for new projects.

- Maintain a high level of R&D support for reducing the cost of currently uncompetitive renewables technologies like solar. Moreover, it can support efforts to expand the geographic viability of certain renewables like wind and geothermal.

Finally, it is recommended that the US government continue to foster opportunities for international cooperation. For example, it may be possible that supporting RD&D on CCTs in China could result in lower costs and faster development of CCS and/or other clean coal systems. International cooperation on "Generation IV" nuclear technologies should be maintained and perhaps even broadened to more advanced fuel cycle work. This cooperative arrangement might serve as a good model for the US and its European Union (EU) partners in the renewables arena.

## 7.6 Address Siting of Transmission Lines, Grid Improvements, and Incentives for More Renewables

**In the "grace period" of reduced electricity demand growth the US now enjoys thanks to the recession, the electric power industry can take its focus off immediately building new generating capacity and focus its efforts on the siting and building of transmission capacity and on ways to improve the grid to allow better integration of renewable power sources into the US electricity supply.** The state and federal governments must expedite siting and permitting processes so that the private sector can build new transmission lines and assure the reliability of those already built. The federal government should take advantage of its authority (or seek further power if necessary) to issue the permits to build the needed transmission lines and to give the Federal Energy Regulatory Commission the power to properly allocate costs of upgrading and building needed lines.

**With the renovation and expansion of the transmission system, and with the proper introduction of new technologies and policies, the US will be better able to integrate renewable power sources into the grid.** It is important that the US not force large volumes of renewables into grid until economically and technologically ready, or consumer backlash could set this option back. Policies that can support the goal of increasing renewable energy supplies into the grid include:

- Use US-EU Energy Council[83] to design feed in tariffs that support industry but reduce federal subsidies once costs become competitive.

- Use US-EU dialogues on Smart Grids, which involve industry, to improve utilization of incoming power from renewables and effective use of storage technologies.

- Expand federal support for investment in grid and transmission systems and the development and deployment of back up systems.

- Continue to fund and expand the activities of the US government's multi-agency smart grid task force and the National Institute of Standards and Technology's smart grid technology panel. This is especially critical to protect against cyber attacks as well as to ensure adequate response to natural disasters.

- Protect the safety and confidentiality of customer data needs to be protected. Consider the establishment of a National Academy of Sciences Task force to evaluate progress to date and recommendations as to how to protect smart grid customer security and the security of the grid itself.

With successful transmission line expansion and access to the grid improved, the US must then ramp up efforts to bring more renewable power sources into the grid. Supportive measures include:

- Address regulatory policies that consider coal plants as stranded assets and allow more market access for renewables to compete for power contracts.

- Expand the markets for renewables by enacting innovative policies such as demand response, capacity payments, real-time markets, and day-ahead markets.

- Develop market mechanisms that provide consumers with energy supply choices, access to transparent

# 8.0 Conclusions

The challenges to establishing a realistic electric power generation portfolio that allows the power sector to meet the country's requirements for electricity while addressing environmental concerns must not be underestimated. The economic realities associated with the need for new investments and the need to reduce emissions from fossil fuels can be met, but only at higher electricity prices. The US will be a major proving ground for the necessary changes and the US electric sector may be the one area where significant transformative efforts could take hold in a relatively orderly fashion.

In summary, the Atlantic Council concludes that the US must develop a new strategy to transition the electricity supply toward low CO2 sources and should start with low or no cost efficiency measures; build on currently available commercial technologies such as natural gas, some renewables, and nuclear power; undertake the necessary infrastructure improvements to allow for efficiency improvements and to bring renewable sources into the grid as quickly as possible; and, significantly ramp up RD&D on CCTs with CCS, nuclear power technologies, renewables, and transportation fuel options.

Following such an approach, it should be possible for the US to start to establish a sustainable electricity generation portfolio that meets the nation's energy, economic and environmental security objectives. Over time, there would be a steady decrease in CO2 and other harmful fossil fuel pollutant emissions. Costs will increase as necessary and unavoidable new investments are incurred. All energy resources and technologies will move towards a more level playing field. Market forces and entrepreneurial skill will determine the ultimate winners. The US will have a practical pragmatic game plan that provides for flexibility to respond to changing domestic and global events well into this century. Many components of the proposed action plan will also be applicable to other countries' efforts to address growing requirements for electricity in a carbon- constrained world.

US success in developing a sustainable path towards long-term energy and economic security will be challenged by the immense scale of the global energy industry and its interconnected market that will only increase in size and complexity as areas of the developing world strive to improve their economies. The US is fortunate to have a unique set of physical resources, institutions, and entrepreneurial skills that will enable the country to establish a leadership position in establishing policies and undertaking the activities and investments needed to dramatically transform the energy sector to enhance the country's energy and economic security in the 21st Century.

**Success can be assured if the US uses all of its domestic energy supplies and leaders develop, today, the policies needed to secure the technologies to embark on a safe and secure low carbon path. Our leaders must educate the public regarding the time it will take, the new plants and infrastructure that must be built, and the costs that must be borne.** The US will be a major proving ground for the kinds of evolutionary efforts that will be required globally. The rebalancing of the electric power sector is seen as crucial as this sector represents both a major source and user of energy in the economy. While the report focused on the US electric power industry, many of the observations and recommendations are applicable to the broader energy industry with electric power expected to play an increasing role in the transportation sector.

ATLANTIC COUNCIL

# Perspectives on a Realistic United States Electric Power Generation Portfolio: 2010 to 2050

**October 26, 2009 • Washington, DC**

## Workshop Agenda

**Opening Remarks:**

***General Richard Lawson,*** Chairman, Atlantic Council, Program on Energy and the Environment

**Session I:** ***Overall U.S. Electricity Demand and Supply and Electric Power Generation Portfolio Forecasts***

**Moderator: David Garman, Former Under Secretary of Energy, Decker, Garman Sullivan and Associates, LLC**

***Alan Beamon,*** Director, Coal and Electric Power Division, Office of Integrated Analysis and Forecasting, Energy Information Administration, U.S. Department of Energy

***John Caldwell***, Chief Economist, Edison Electric Institute

***John Novak***, Executive Director, Federal and Industry Environment and Generation, Electric Power Research Institute

**Session II:** ***Impacts on Electric Demand and Supply***

**Moderator: Kateri Callahan, President, Alliance to Save Energy**

*Efficiency and Conservation:*

***Lisa Wood***, Executive Director, Institute for Electric Efficiency

*Regulatory Structures:*

***John F. Kelly,*** Deputy Director, Galvin Electricity Initiative

*Emerging Technologies:*

***Tom Schneider,*** Managing Director, National Renewable Energy Laboratory

*Smart Grid Outlook:*

***Steve Bossart***, Director, Integrated Electric Power Systems Division, National Energy Technology Laboratory

**Session III:** ***Baseload Power Options: Coal, Nuclear and Natural Gas***

**Moderator: Tim Richards, Managing Director, International Energy Policy, General Electric**

*Coal:*

***Marshall Mazer,*** Manager, Market Development, Technology, Washington Operations, Babcock & Wilcox

*Natural Gas:*

***Andy Weissman***, Senior Energy Advisor to FTI Consulting, Inc.

*Nuclear:*

***Dr. Finis H. Southworth,*** Chief Technology Officer, Areva NP Inc.

**Keynote Speach:** ***US Energy Goals– Energy independence, national security, low carbon energy supply, and sustainable growth for a competitive America***

*Senator John Warner,* Pew Project on National Security, Energy and Climate

**Session IV: Renewable and Distributed Power Options: Solar, Wind, Geothermal and Biomasss**

**Moderator: Roger Ballentine, Founding Board Member, ACORE and President, Green Strategies**

*Wind and Geothermal Options:*

***Bob Hawsey***, Associate Laboratory Director for Renewable Electricity and End Use Systems , National Renewable Energy Laboratory

*Solar:*

***Dr. Sam Baldwin,*** Chief Technology Officer and Member, Board of Directors, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy

*Biomass:*

***Reed Wills***, President, ADAGE

**Session V:** ***Panel Discussion and Participants' Questions Regarding a Realistic Electric Power Generation Portfolio through 2050***

**Moderator: Mark Handschy, Senior Advisor for Science and Technology, Office of the Under Secretary, U.S. Department of Energy**

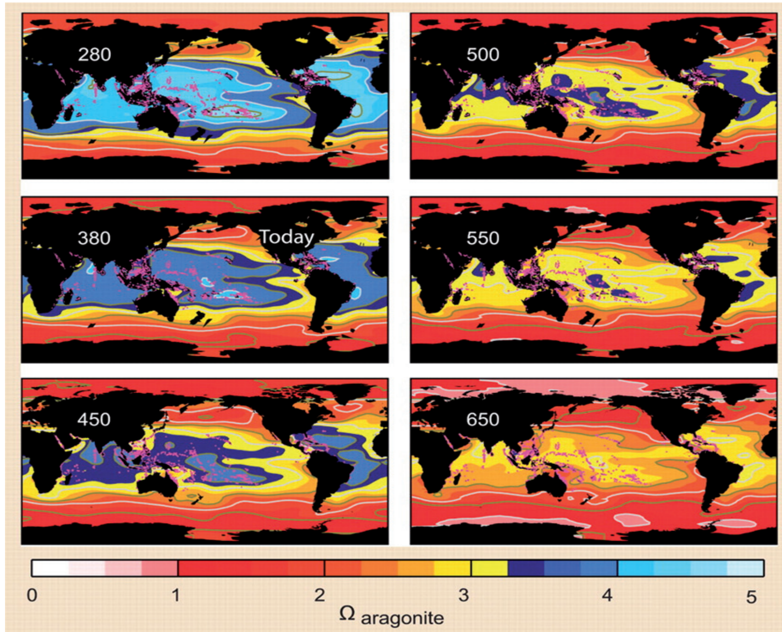
***Lisa Wood,*** Executive Director Institute for Electric Efficiency
***Rob Gramlich***, Senior Vice President Public Policy, American Wind Energy Association
***Peter Balash***, Sr. Economist, Office of Systems, Analyses & Planning, National Energy Technology Laboratory
***Rod Lowman***, President and CEO, America's Natural Gas Alliance
***Tom Schneider***, Managing Director, National Renewable Energy Laboratory
***Julian Steyn***, President, Energy Resources International Inc.

# Appendix B

## Information Regarding Greenhouse Gas Emissions' Impacts and Ocean Acidification

- Temperature Increases
- Precipitation Changes
- Glacier & Sea-Ice Loss
- Water Availability
- Wildfire Increases
- Ecological Zone Shifts
- Extinctions
- Agricultural Zone Shifts
- Agricultural Productivity
- Ocean Acidification
- Ocean Oxygen Levels
- Sea Level Rise
- Human Health Impacts
- Feedback Effects

U.S.: 5.9 GT CO2/yr energy-related
World: 28.3 GT CO2/yr




Source: Hoegh-Guldberg, et al, Science, V.318, pp.1737, 14 Dec.

## InterAcademy Panel Statement OnOcean Acidification, 1 June 2009

- **Signed by the National Academies of Science of 70 nations:**
  - Argentina, Australia, Bangladesh, Brazil, Canada, China, France, Denmark, Greece, India, Japan, Germany, Mexico, Pakistan, Spain, Taiwan, U.K., U.S. and others
- **"The rapid increase in CO2 emissions since the industrial revolution has increased the acidity of the world's oceans with potentially profound consequences for marine plants and animals, especially those that require calcium carbonate to grow and survive, and other species that rely on these for food."**
  - Change to date of pH decreasing by 0.1, a 30% increase in hydrogen ion activity.
- **"At current emission rates, models suggest that all coral reefs and polar ecosystems will be severely affected by 2050 or potentially even earlier."**
  - At 450 ppm, only 8% of existing tropical and subtropical coral reefs in water favorable to growth; at 550 ppm, coral reefs may be dissolving globally.
- **"Marine food supplies are likely to be reduced with significant implications for food production and security in regions dependent on fish protein, and human health and well-being."**
  - Many coral, shellfish, phytoplankton, zooplankton, & the food webs they support
- **Ocean acidification is irreversible on timescales of at least tens of thousands of years.**

Source: Sam Baldwin, "Solar Energy: Challenges and Opportunities." Conference Presentation, Atlantic Council, Washington D.C., October 26, 2009.

# List of Abbreviations

| | |
|---|---|
| AEO | Annual Energy Outlook |
| AWEA | American Wind Energy Association |
| B&W | Babcock and Wilcox |
| BLM | Bureau of Land Management |
| BTUs | British Thermal Units |
| CCS | Carbon Capture and Storage/ Sequestration |
| CCTs | Clean Coal Technologies |
| CO2 | Carbon Dioxide |
| CSP | Concentrated Solar Power |
| DOE | Department of Energy |
| EGS | Enhanced Geothermal Systems |
| EIA | Energy Information Administration |
| EPA | Environmental Protection Agency |
| EPRI | Electric Power Research Institute |
| EU | European Union |
| GDP | Gross Domestic Product |
| GHG | Greenhouse Gases |
| GW | Gigawatt |
| GWe | Gigawatt-Electric |
| GWh | Gigawatt Hours |
| HR | House Resolution |
| IGCC | Integrated Gasification Combined Cycle |
| IPCC | Intergovernmental Panel on Climate Change |
| kWh | Kilowatt Hours |
| MERGE | Model for Estimating the Regional and Global Effects of greenhouse gas reductions |
| MIT | Massachusetts Institute of Technology |
| NERC | North American Electric Reliability Corporation |
| NREL | National Renewable Energy Laboratory |
| NRC | Nuclear Regulatory Commission |
| PV | Photovoltaic |
| R&D | Research and Development |
| RD&D | Research, Development and Demonstration |
| RPSs | Renewable Portfolio Standards |
| T&D | Transmission and Distribution |
| Tcf | Trillion Cubic Feet |
| TWh | Terawatt Hours |
| UN | United Nations |
| US | United States |

# Endnotes

[1]The workshop participants were notified that the meeting would be subject to the rule that participants would be free to cite the information received, but not to identify the source of the comments during discussion periods.

[2]Primary energy consumption is defined as " Consumption of energy used in the same form as in its naturally occurring state, for example crude oil, coal, natural gas, e.g. before it is converted into electricity." See EIONET GEMET Thesaurus. Primary Energy Consumption. Eionet. http://www.eionet.europa.eu/gemet/concept?cp=6614h

[3]Newell, Richard. Annual Energy Outlook 2010: Reference Case. US Energy Information Administration. http://www.eia.doe.gov/neic/speeches/newell121409.pdf (accessed: 19 January 2009)

[4]Current electricity generation stands at 4224 billion kilowatt hours. Newell, Richard. Annual Energy Outlook 2010: Reference Case. US Energy Information Administration. http://www.eia.doe.gov/neic/speeches/newell121409.pdf (accessed: 19 January 2009)

[5]In 2007, the US generated 4,071 billion kWh. By 2030, EIA projects electricity demand to surge to 4506 billion kWh by 2030.

[6]The EPA Reference Scenario incorporates the effects of the Energy Independence and Security Act of 2007, but not the American Recovery and Reinvestment Act. However, the MIT scenario takes both the EISA and ARRA into account. While they are slightly different scenarios the differences are not prohibitive in this comparison.

[7]Energy Information Administration. EIA Energy Outlook Projects Moderate Growth in US Energy Consumption, Greater Use of Renewables, and Reduced Oil and Natural Gas Imports. US Department of Energy. http://www.eia.doe.gov/neic/press/press334.html.

[8]The World Meteorological Organization reported in its "Greenhouse Gas Bulletin" that in 2008, methane gas levels rose by 14 parts per billion (ppb)to 1,797 ppb. Global average $CO_2$ concentrations reached 385.2 parts per million, or 2 ppm higher than in 2007, a rate of growth 25% higher than the average concentration growth rates calculated for all the 1990s, at about 1.5 ppm more $CO_2$ per year. World Meteorological Organization. Greenhouse Gas Bulletin. World Meteorological Organization. http://www.wmo.int/pages/prog/arep/gaw/ghg/ghg5-online.html (accessed January 28, 2009).

[9]Natural gas is mainly composed of methane, which has a radiative forcing twenty times greater than $CO_2$. This means a ton of methane in the atmosphere traps in as much radiation as 20 tons of $CO_2$.

[10]EPRI has sponsored 6 dialogues to date regarding the availability of international offsets. Information on these discussions can be found at www.global.EPRI.com.

[11]In 2007,EPRI released its first PRISM, or Parameter-elevation Regressions on Independent Slopes Model and the Model for Estimating the Regional and Global Effects of Greenhouse Gas Reductions (MERGE). The Prism analysis provided a comprehensive assessment of potential $CO_2$ reductions in eight key technology areas of the electricity sector. The MERGE analysis identified the economically optimum technology portfolio in response to a given $CO_2$ emissions constraint. EPRI updated both analyses in 2009 to reflect economic and technological changes that have the potential to affect projected emissions and the technologies to address them.

[12]In 2005, US $CO_2$ emissions were 5982 billion tons. To reach the intended targets, emissions in 2030 would need to be reduced to 3470 billion tons and to 1017 billion tons in 2050.

[13]For a detailed description of the analysis and the full and limited portfolios, see EPRI. Prism/MERGE Analysis 2009 Update. EPRI. http://mydocs.epri.com/docs/public/000000000001019563.pdf

[14]See also: Short, Walter and P. Sullivan. "Wind Energy in the Mitigation of Carbon Emissions." Presentation, Windpower 2009 Conference & Exhibition, American Wind Energy Association, Chicago, Illinois, May 4-7, 2009. See also: "Wind Energy in the Mitigation of Carbon Emissions (Presentation)." Windpower 2009 Conference & Exhibition [Full Conference Materials. DVD-ROM. Washington, D.C: Fleetwood Onsite Conference Recording, 2009 Short, Walter and P. Sullivan. "Wind Energy in the Mitigation of Carbon Emissions." NREL Report No. PR-550-46839 (2009) p. 27 .

[15]Note also that the North American Electric Reliability Corporation released its estimate of current generating capacity in gigawatts, which differs from capacities given by the EIA: coal 307.764, gas 280.488, hydro 136.927, nuclear 113.056, dual fuel 111.207, oil 36.976, wind 27.922, pumped storage 21.071, biomass 5.406, geothermal 2.388, solar 528 North American Electric Reliability Corporation. 2009 Long-Term Reliability Assessment. The North American Electric Reliability Corporation. http://www.nerc.com/files/2009_LTRA.pdf.

[16]Caldwell, John. "US Electricity Supply and Demand: The Long View" Conference Presentation, Atlantic Council, Washington D.C., October 26, 2009.

[17]The Interacademy Panel on International Issues. IAP Statement on Ocean Acidification. IAD. http://www.interacademies.net/Object.File/Master/9/075/Statement_RS1579_IAP_05.09final2.pdf

[18]Hoegh- O Guldberg, et al., "Coral Reefs Under Rapid Climate Change and Ocean Acidification", Science V.318, 14 Dec. 2007, pp.1737-1742. Orr, James C., et al. "Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms." Nature, Volume 437, Sept 25, 2005, 681-685. Zeebe, Richard E., James C. Zachos, Ken Caldeira, and Toby Tyrrell. "Carbon Emissions and Acidification." Science, Volume 321, July 4, 2008, 51-52. The Interacademy Panel on International Issues. IAP Statement on Ocean Acidification. IAD. http://www.interacademies.net/Object.File/Master/9/075/Statement_RS1579_IAP_05.09final2.pdf

[19]Caldwell, John. "US Electricity Supply and Demand: The Long View." Conference Presentation, Atlantic Council, Washington D.C., October 26, 2009.

[20]Please see a related article in the Wall Street Journal in this regard: Naik, Gautam. Slowdown in Warming Linked to Water Vapor. The Wall Street Journal. http://online.wsj.com/article/SB20001424052748704194504575031404275769886.html

[21]Wood, Lisa. "Impact of Energy Efficiency and Demand Response on Electricity Demand." Conference Presentation, Atlantic Council, Washington D.C., October 26, 2009.

[23]US Department of Energy. States With Renewable Portfolio Standards. US Department of Energy. http://apps1.eere.energy.gov/states/maps/renewable_portfolio_states.cfm January 28, 2009 (accessed January 28, 2009).

[24]States with Renewable Portfolio Standards. Pew Center on Global Climate Change. <http://www.pewclimate.org/node/1303 (accessed 18 Jan 2009).

[25]Demand response measures include dynamic rates or other rate designs that incentivize customers to shift loads from high to lower priced periods and cash incentives to curtail or shift usage from peak to off-peak periods for example through direct load control programs.

[26]The Electric Power Research Institute. Assessment of Achievable Potential from Energy Efficiency and Demand Response Programs in the U.S. EPRI. http://mydocs.epri.com/docs/public/000000000001018363.pdf

[27]A National Assessment of Demand Response Potential: http://www.ferc.gov/legal/staff-reports/06-09-demand-response.pdf

[28]Barbose, Galen, et. al. The Shifting Landscape of Ratepayer-Funded Energy Efficiency in the US. LBNL. http://eetd.lbl.gov/ea/ems/reports/lbnl-2258e

[29]For an expanded discussion regarding the potential for energy efficiency measures to reduce greenhouse gas emissions, please see pages 16-18, Lyman, John R. A Shared Vision for Energy and Climate Change. Atlantic Council <http://www.acus.org/files/publication_pdfs/65/AtlanticCouncil-USEUEnergy-Rev4.pdf>

[30]P. 16-18, Lyman, John R. A Shared Vision for Energy and Climate Change. Atlantic Council <http://www.acus.org/files/publication_pdfs/65/AtlanticCouncil-USEUEnergy-Rev4.pdf>

[31]The installation of smart meters is a key step in allowing consumers to pay different rates at different times. The meters can help customers see exactly how much and when they are using energy, and they can automate a response to price incentives by adjusting their consumption.

[32]For more, see the Atlantic Council's Report to US and EU Leaders: US-EU Cooperation on Smart Grid Deployment at http://www.acus.org/files/publication_pdfs/65/AtlanticCouncil-USEUSmartGrid.pdf

[33]See: The Edison Foundation. Utility-Scale Smart Meter Deployments, Plans, & Proposals. The Edison Foundation. http://www.edisonfoundation.net/IEE/issueBriefs/SmartMeter%20Rollouts_0509.pdf (accessed on February 24, 2010)

[34]Community Choice Aggregation is a system adopted into law in the states of Massachusetts, Ohio, California, New Jersey and Rhode Island which allows cities and counties to aggregate the buying power of individual customers within a defined jurisdiction in order to secure alternative energy supply contracts.

[35]Shuster, Erick. Tracking New Coal-Fired Power Plants. National Energy Technology Laboratory. http://www.netl.doe.gov/coal/refshelf/ncp.pdf

[36]B&W is ready to demonstrate a commercial scale oxy combustion carbon capture plant with near zero emissions and greater than 90% $CO_2$ capture. It also has a Regenerable Solvent Absorption Technology scrubber process under development that could be applied to new or retrofitted coal, oil or natural gas plants.

[37]Smith, Rebecca. Big Utility Turns Bullish on Carbon Capture. Wall Street Journal. January 18, 2009.

[38]AEP announced the plant has captured 90% of the carbon from a 20 MWe portion of the demonstration facility. It is likely it could be scaled up to 240 MWe by 2013-2014.

[39]Andrew Weissman, who in 2001 predicted the significant run-up in natural gas prices due to surging demand and waning supply, brought this development to the attention of the workshop.

[40]If supplies are indeed abundant and low cost, compressed natural gas could also be used for bus and truck fuel, thereby contributing to a decrease in CO2 emissions from the transportation sector and decreasing oil imports.

[41]The Committee's year-end 2008 assessment of 1,836 Tcf , combined with the US Department of Energy's latest available determination of proved gas reserves, 238 Tcf as of year-end 2007, the United States has a total available future supply of 2,074 Tcf, an increase of 542 Tcf over the previous evaluation. Potential Gas Committee Reports Unprecedented Increase in Magnitude of US Natural Gas Resource Base. Colorado School of Mines. http://www.mines.edu/Potential-Gas-Committee-reports-unprecedented-increase-in-magnitude-of-US-natural-gas-resource-base (accessed June 18, 2009).

[42]Proved reserves are those quantities of crude oil, natural gas, and natural gas liquids which geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under existing economic and operating conditions. Potential reserves are estimates of unproved reserves which analysis of geological and engineering data suggests are less likely to be recovered than probable reserves. For estimates of possible reserves based on probabilistic methods, there should be at least a 10% probability that the quantities of reserves actually recovered will equal or exceed the sum of the estimated proved plus probable plus possible reserves. Experts have different definitions for terms such as proven , reserves and resources. For a tutorial on commonly accepted definitions of such terms, see http://en.wikipedia.org/wiki/Oil_reserves#Classifications (accessed on January 28, 2010).

[43]Pan Ziqiang, Director of Science and Technology Committee of China National Nuclear Corporation, told participants to an international summit on clean energy that China will adopt a target of 70 GW of nuclear power to be operational by 2020, and that some energy experts forecast 200 GW by 2030, to 400 GW by 2050. China nuclear power installed capacity to reach 70 GW by 2020, scientists. ChinaDaily.com. http://news.xinhuanet.com/english/2009-11/02/content_12373871.htm (accessed on January 28, 2010)

[44]Between July 13, 2007 and January 18, 2009, the NRC received 18 Combined Operating License applications. NRC: Combined License Applications for New Reactors. US NRC. http://www.nrc.gov/reactors/new-reactors/col.html accessed on February 22, 2010.

[45]1 GWe at a 90% capacity factor produces 7.884 billion kilowatt hours. 5323 billion kilowatt hours of projected base case generation times .19 and divided by 7.884 results in 128.3 GWe.

[46]Average capacity factors for nuclear 91.5%, steam turbine coal 70.8%, combined cycle gas 41.7%, steam turbine gas 14.6%, steam turbine oil 12.6%, hydro 27.4%, wind 31.1% and solar 21.1%.

[47]US electricity production costs in 2008 in cents per kilowatt hour: coal 2.75, gas 8.09, nuclear 1.87, and petroleum 17.26. Data from Ventyx Velocity Suite, updated 5/09, provided by the Nuclear Energy Institute.

[48]With the phase-out of coal-fired gaseous diffusion enrichment plants, CO2 emissions for the life cycle of nuclear power will be further reduced.

[49]Arvizu, Dan. Prepared Statement of Dan Arvizu, Director, National Renewable Energy Laboratory. NREL. www.nrel.gov/director/docs/arvizu_senate_energy_031709.doc

[50]Renewable Energy and BLM: Solar. Bureau of Land Management. http://www.blm.gov/pgdata/etc/medialib/blm/wo/MINERALS__REALTY__AND_RESOURCE_PROTECTION_/energy.Par.28512.File.dat/09factsheet_Solar.pdf

[51]Renewable Energy and BLM: Geothermal. Bureau of Land Management. http://www.blm.gov/pgdata/etc/medialib/blm/wo/MINERALS__REALTY__AND_RESOURCE_PROTECTION_/energy.Par.74240.File.dat/09factsheet_Geothermal.pdf

[52]Schneider, Dr. Thomas R.. "Emerging Technologies Impacting Supply and Demand." Conference Speech, Atlantic Council, Washington, D.C., October 26 2009.

[53]North American Electric Reliability Corporation. Transmission, Renewables, Integration top List of Issues in Ten-year Electric Reliability Outlook. North American Electric Reliability Corporation. http://www.nerc.com/fileUploads/File/PressReleases/PR_1029092_LTRA.pdf

[54]Total world wind installed capacity is 115 GW and estimates of world "technical potential" vary from 1 TW to 70 TW. Hawsey, Robert. "Options for Wind, Waterpower and Geothermal Energy." Conference Speech. Atlantic Council, Washington, D.C., October 26 2009.

[55]The American Wind Energy Association. Windpower Outlook 2009. AWEA. http://www.awea.org/pubs/documents/Outlook_2009.pdf (accessed February 24, 2010).

[56]National Renewable Energy Laboratory. Department of Energy Releases New of Nation's Wind Energy Potential. NREL. http://www.nrel.gov/wind/news/2010/816.html

[57]This study can be accessed at the site www.eere.energy.gov/windnadhydro. It assumed that electricity consumption by 2030 would be 5.8 billion MWh, wind turbine energy production capacity factor would increase by 15%, turbine costs would decrease 10%, and no major technology breakthroughs.

[58]Alexander, Lamar. The Real Reason for Fear. Washington Times. http://www.washingtontimes.com/news/2009/oct/09/the-real-reason-for-fear/

[59]For example, a federal court challenge has been filed to the Beech Ridge expansion at a West Virginia wind power farm under the Endangered Species Act alleging potential harm to an endangered Indiana bat species that lives in the adjacent limestone caves.

[60]The Aquinnah tribe is one of two Wampanoag tribes that say the 130-turbine wind farm would destroy spiritual sun greetings and disturb ancestral grounds that lie on Nantucket Sound's seabed. Their five-year complaint recently gained traction when the National Park Service determined the 560-square-mile body of water was eligible to be listed on the National Register of Historic Places, affording it more protection from development. See: Feather News. Mashpee and Aquinnah Wampanoag Tribes Oppose Nantucket Wind Project. Feather News.

[61]U.S. Department of Energy: Energy Efficiency and Renewable Energy. 20% Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply. U.S. Department of Energy http://www1.eere.energy.gov/windandhydro/pdfs/41869.pdf National Renewable Energy Laboratory. Wind Integration and Transmission Study. NREL. http://www.nrel.gov/wind/systemsintegration/ewits.html

[62]Enhanced systems refer to those that produce heat in the 200 to 250 degree centigrade range.

[63]Recently enhanced geothermal projects involving fracturing deep hot rocks have been cancelled due to concerns regarding triggering earthquakes.

[64]Hawsey, Robert. "Options for Wind, Waterpower and Geothermal Energy." Conference Speech. Atlantic Council Washington, D.C., October 26, 2009.

[65]Biopower refers to plants that burn biomass to produce power. Wood is the largest biomass energy resource today, but other sources of biomass can also be used. These include food crops, grassy and woody plants, residues from agriculture or forestry, and the organic component of municipal and industrial wastes. Even the fumes from landfills (which are methane, a natural gas) can be used as a biomass energy source.

[66]Biomass is less than 1 percent of electricity generation. P. 18, 32. Energy Information Administration. Annual Energy Outlook 2010 Early Release Overview-Summary Reference Case Tables. US Department of Energy. http://www.eia.doe.gov/oiaf/aeo/pdf/appa.pdf

[67]Krause, Carolyn. The Billion Ton Study. Oak Ridge National Laboratory. http://www.ornl.gov/info/ornlreview/v40_1_07/article03.shtml

[68]ADAGE is a joint venture between Areva and Duke Energy, launched in September 2008, to develop, own and operate 12 biopower plants in the US to utilize wood to produce electricity for sale to utilities and other municipal power authorities.

[69]Hawsey, Robert. "Options of Wind, Waterpower and Geothermal." Conference Speech. Atlantic Council Washington, DC, October 26, 2009.

[70]At the global level, the IPCC Third Assessment Report estimates about 100 billion metric tons of carbon over the next 50 years could be sequestered through forest preservation, tree planting and improved agricultural management. This would offset 10-20% of the world's projected fossil fuel emissions.

[71]Renewable Energy Policy Network for the 21st Century. Pre-Publication Summary: Renewables 2007 Global Status Report. Worldwatch Institute. http://www.ren21.net/pdf/REN21_GSR2007_Prepub_web.pdf

[72]Current US PV market price ranges, in cents per kWh for the residential sector are 5.8 to 16.7, for the commercial sector 5.4 to 15.0 and for the utility market 4.0 to 7.6.

[73]A proposed solar energy,440-megawatt, 4,000-acre Solar Electric Generating System project planned for public land in the Mojave Desert faces some opposition for its potential damage to the area's environment and scenery from the San Bernardino County Supervisor.

[74]These plants produce electricity by generating steam to spin the turbine and typically are cooled with water that replaces the steam lost to evaporation.

[75]Newell, Richard. "Annual Energy Outlook 2010: Reference Case." US Energy Information Administration. http://www.eia.doe.gov/neic/speeches/newell121409.pdf (accessed: January 19, 2009)

[76]US electric generation capacity is only 47% utilized, primarily reflecting low utilization of gas fired power plants. Utilization rates are even lower in other sectors of the power industry with transmission at 43%, distribution 34% and consumer systems (for example, residential solar), less than 1%.

[77]North American Electric Reliability Corporation. 2009 Long-Term Reliability Assessment. The North American Electric Reliability Corporation. http://www.nerc.com/files/2009_LTRA.pdf.

[78]For example, it has been suggested that a carbon tax with a 100% per capita rebate to the public might provide the necessary signal as it was ramped up to move away from carbon while at the same time providing a progressive tax structure to help maintain political support.

[79]P. 15 Lyons, Blythe J. United States-China Cooperation on Nuclear Power: An Opportunity for Fostering Sustainable Energy Security. Atlantic Council. http://www.acus.org/files/publication_pdfs/65/AtlanticCouncil-USChinaNuclearPower.pdf

[80]Simon, Stephanie. Even Bolder Finds It Isn't Easy Being Green. The Wall Street Journal. http://online.wsj.com/article/SB10001424052748704320104575015920992845334.html

[81]The Third Way organization has made a proposal for a Clean Energy Bank. Please see: Bennett, Matt, Josh Freed, and Jeremy Ershow. Breaking the Nuclear Financing Barrier. Third Way. http://content.thirdway.org/publications/265/Third_Way_Idea_Brief_-_Breaking_the_Nuclear_Financing_Barrier.pdf

[82] The Potential Gas Committee estimates that the US has over 100 years supply of natural gas with 2000 trillion cubic feet of domestic natural gas.

[83]The US-EU Energy Council was created in November 2009 to "provide a new framework for deepening the transatlantic dialogue on strategic energy issues such as security of supply or policies to move towards low carbon energy sources while strengthening the ongoing scientific collaboration on energy technologies." The European Union is represented by the EU Commissioners for External Relations, for Energy, and for Science and Research, as well as the EU Presidency. Their counterparts from the US are the Secretaries of Energy and State. The Energy Council is scheduled to meet annually and alternate between the US and EU, and will allow for working groups of senior officials to focus on three vital areas: global energy security and markets, energy policies, and energy technologies research cooperation ( New EU-US Energy Council to boost transatlantic energy cooperation. Europa.com. http://europa.eu/rapid/pressReleasesAction.do?reference=IP/09/1674).