The 10-50 Solution: Options for a Low-Carbon Future

Addressing the challenge of global climate change will require a significant reduction in annual greenhouse gas (GHG) emissions in the United States and throughout the world by 2050. This will necessitate a fundamental shift from an economy predominantly based on fossil fuels to one based on efficiently managed low-carbon energy sources and technologies that capture and store carbon from fossil fuels. Such a transition could also have other benefits, including increasing energy security, improving public health, and promoting economic development. But the transition will not be easy, as significant technological challenges, social and economic concerns, and political constraints exist.

Achievement of this transition depends on both near-term and long-term actions. In the near term, it is essential to take advantage of current technologies and opportunities, and also to make substantial investments in the technologies of the future. But most of all, the United States needs a clearly enunciated policy. Without such a policy, businesses, consumers, and citizens are missing opportunities for cost-effective GHG reductions and investment for the future. Too often the debate over GHG emission reductions pits near-term actions against long-term investments in technology, when in fact both are necessary and are each more effective if undertaken together. A variety of policies, public and private leadership, and broad societal engagement will be needed to bring low-carbon technologies into the market. Because of the long-lived nature of most energy infrastructure, it is critical that action begin now to promote the development and use of low-carbon energy technologies. This "In Brief" addresses possible technological solutions to enable a low-carbon future in the next 50 years and identifies policy options for the next 10 years to help push and pull these technologies into the market.

The Challenge of a Low-Carbon Future

In order to address climate change, a commonly stated goal is to stabilize the atmospheric concentration of carbon dioxide (CO_2) at twice its pre-industrial level.[1] To meet such a goal in the context of growing global demand for energy, an increase of roughly 100 to 300 percent of present-day worldwide "primary power" consumption would need to come from non-CO_2-emitting sources such as renewables, nuclear, and the use of fossil fuels with carbon capture and sequestration.[2] In addition to low-carbon primary energy sources, a future low-carbon economy will require widespread use of lower-carbon fuels and energy carriers such as hydrogen, and significant improvements in the efficiencies of energy production, distribution, and end-use technologies.[3] The transition to a low-carbon economy could have other benefits, such as increasing energy security, improving public health, and promoting economic development, but it will take several decades and will not be easy. Achieving this transition will require near-term and long-term actions. In the near term, it will be necessary to take advantage of current technologies and opportunities, and to make substantial investments in the technologies of the future.

It will be especially difficult to meet the technological challenges inherent in developing and deploying a suite of low-carbon energy technologies while achieving the traditional goals of U.S. energy policy (i.e., providing extensive energy services at low cost and through secure supply to a growing population and economy). Furthermore, low-carbon energy technologies that compete with entrenched conventional (and usually high-GHG-emitting) technologies are likely to encounter market, political, and societal barriers to deployment.

Accordingly, there is a clear need to initiate and sustain policies to push and pull low-carbon technologies into the market. Without such policies, businesses, consumers, and citizens are missing opportunities for cost-effective GHG reductions and investment for the future. A variety of policies, public and private leadership, and broad societal engagement will be needed. Characteristics of the energy sector—long capital investment cycles,[4] a high degree of system inertia, and the tendency for past developments to strongly influence current technology choices—highlight the need to begin now to promote technological change and enable far-reaching deployment over the next 50 years.

Background on the "10-50 Solution"

Considering the long-term nature of the climate challenge, the Pew Center on Global Climate Change and the National Commission on Energy Policy (NCEP) hosted a workshop entitled "The 10-50 Solution: Technologies and Policies for a Low-Carbon Future" in March 2004.[5] The overall goal was to articulate a long-term vision of the technologies and industrial process changes that would have to be in place 50 years from now to address climate change effectively, as well as the policies that would have to be initiated in the short, medium, and long term to achieve this vision. More specifically, the workshop aimed to achieve three goals:

- **analyze the strengths, weaknesses, barriers, and opportunities for technological options that could enable a low-carbon future;**
- **develop plausible time frames for when various low-GHG technologies and strategies might start to generate significant GHG reductions; and**
- **identify policies and investments that could facilitate the development and deployment of these technologies.**

In preparation for the workshop, the Pew Center and NCEP commissioned new analyses in five key technology areas with the potential to play a significant role in a low-carbon economy: efficiency, hydrogen, carbon sequestration/coal gasification, advanced nuclear power generation, and renewables. This is not an exhaustive list of future low-carbon energy technologies. Although many other technologies and solutions such as the use of biofuels, terrestrial sequestration, and land use changes[6] will likely play a role in the transition to a low-carbon future, the workshop restricted its focus to only five of the critical low-carbon technology options due to time and resource constraints. In addition, lessons drawn from analyses of these technologies should inform policy-making that could promote other low-carbon energy technologies as well. Multiple papers were commissioned in each of these technological areas to provide alternative views of the likely technological path forward in the short, medium, and long term. These papers also examined relevant challenges and policy considerations for each technology area.

In addition, workshop panels and speakers addressed other relevant topics including opportunities for greenhouse gas reductions in industry and the role of natural gas in the transition to a low-carbon future. Finally, keynote speakers shared their perspectives on relevant topics including an update on the implementation of the United Kingdom's plan to reduce GHG emissions by 60 percent over the next 50 years,[7] opportunities for addressing climate change and energy security concerns simultaneously, and examples of how forward-thinking states and businesses are taking action on the issue of climate change and energy policy in the absence of federal leadership.

More than 100 policy-makers, business leaders, NGO representatives, and leading experts participated in the workshop.[8] Starting with the background papers and presentations, participants worked to identify options for promoting low-carbon energy technologies and industrial processes in the near, medium, and long term. Technological uncertainty, policy uncertainty, and uncertainty regarding the responsiveness of technological change to policy prevented many participants from offering many recommendations beyond the near term. Thus, most workshop discussions focused on the policies needed within the next decade or two to enable these technologies to be widely deployed over the next 50 years and beyond. This overview summarizes the papers and identifies key points brought out in the conference.[9]

Several common themes and cross-cutting and technology-specific policy recommendations emerged from the workshop and the background papers. A brief discussion of these themes and policy recommendations is below.

Common Themes and Policy Recommendations

- **Clear and consistent policy signals are urgently needed.** Both broad (economy-wide) and technology-specific policies are essential. There is also a need to balance policy flexibility with reasonable policy certainty. A sustained carbon price signal—through policies such as cap-and-trade or carbon taxes—was identified as the most important cross-cutting policy driver by a number of participants. While such a program is being developed, an important first step would be mandatory GHG emission reporting—an essential tool for identifying and stimulating reductions. The effect of inconsistent policy signals on the deployment of low-carbon energy technologies is highlighted in Figures 1 and 2 (on page 5).
- **A portfolio of technologies and policies will be needed to drive the absolute reductions of GHG emissions necessary to address climate change.** No single technology or policy will be sufficient to enable a low-carbon future by 2050. All of the technologies studied have the potential to enable significant GHG reductions, yet increased and revamped research, development and deployment (RD&D) is necessary in all of them. Efficiency will provide the greatest opportunity in the near term and will remain important over the long term as well. In addition, natural gas can play a key role in the transition to a low-carbon future, subject to price and supply constraints. While specific technologies are likely to be important players, it is important to avoid the temptation to pick "winners." The challenge is to design policies that are neutral enough to promote the development and deployment of a suite of low-carbon technologies, yet also tailored enough to push and pull some specific technologies that might not enter the market under a broad

policy mechanism. Finally, cooperative international efforts can reduce the burden on all countries of developing low-carbon energy technologies.

- **A low-carbon technology revolution will require both leadership and broad engagement throughout society.** Policies should address climate change in the context of other societal goals (e.g., clean air, energy security) thereby taking advantage of co-benefits and creating public/private partnerships and non-traditional alliances. Leadership is needed in both the public and private sectors, and clear and unambiguous targets set by corporate leaders and governments can have a significant positive effect on achieving GHG reductions. Consumers and citizens must be involved in the transition to a low-carbon economy, and a greater focus on critical energy challenges (both in terms of resources and innovative capacity) is needed from U.S. universities and private-sector research laboratories.

- **It is essential to start now.** Finally, there was broad consensus that it is imperative to begin now with clear statements of policy and both cross-cutting and technology-specific policies and investments in order to be well into a transition to a low-carbon economy by 2050.

Technology-Specific Policies

In addition to the widespread support among workshop participants for broad national policies and investments, there was also recognition of the need for "husbandry" of certain key technologies.

Energy Efficiency. The technological potential for energy efficiency improvements now and in the future is significant, yet this potential is not likely to be realized through market forces alone. Accordingly, policies that address the technical, cost, and societal hurdles facing widespread improvements in energy efficiency are needed. In addition to price signals and reporting, certain standards, incentives, and RD&D programs can increase the use of efficient technologies. These options include:

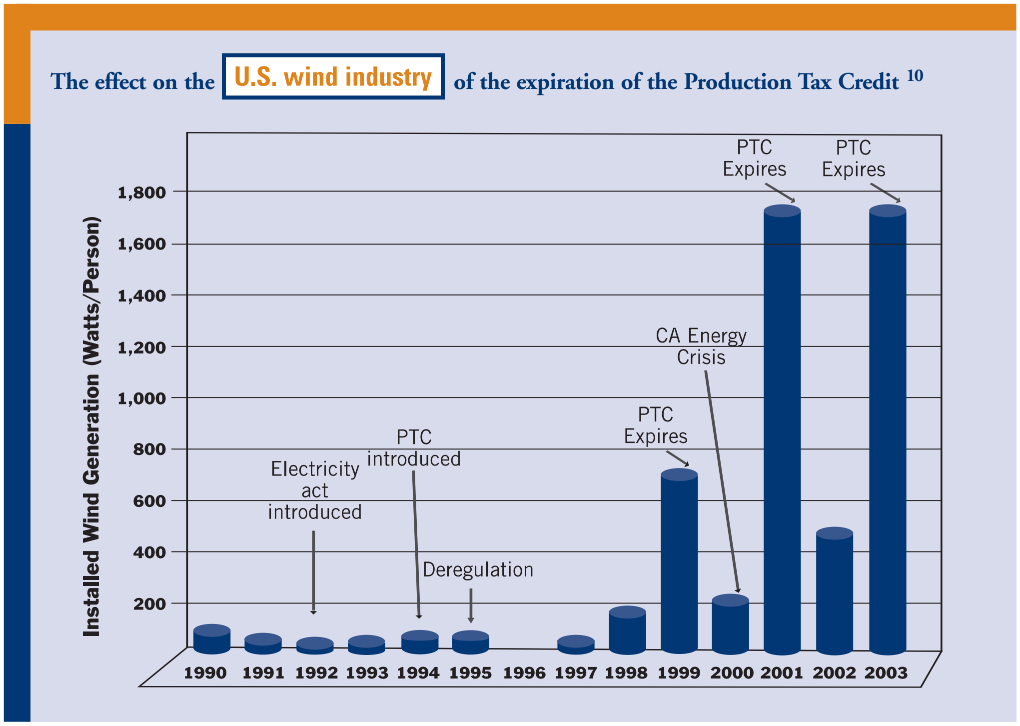
- **adoption and promotion of codes and standards focused on maximizing GHG reductions (e.g., for buildings, vehicles, and appliances);**
- **increases in public RD&D in innovative energy efficiency technologies; and**
- **incentives for the private and public procurement of highly efficient technologies.**

Hydrogen in Transportation. Specific policies are needed to address the major challenges to hydrogen becoming the low-carbon transportation fuel of the future (probably after 2025). Near-term policy options identified to enable future widespread deployment of hydrogen and other potentially low-carbon transportation technologies include:

- **continued and increased federal support for hydrogen-related R&D in targeted areas (e.g., low-carbon hydrogen production, storage, and fuel cells);**
- **national and international harmonization of hydrogen codes and standards;**
- **continued federal and state government support for, and participation in, public/private partnerships;**
- **incentives to increase the development and deployment of lower-GHG transportation technologies (e.g., hybrids), many of which are part of an evolutionary path toward the use of hydrogen and fuel cells; and**
- **increased consumer and public education regarding transportation, energy use, and GHG emissions.**

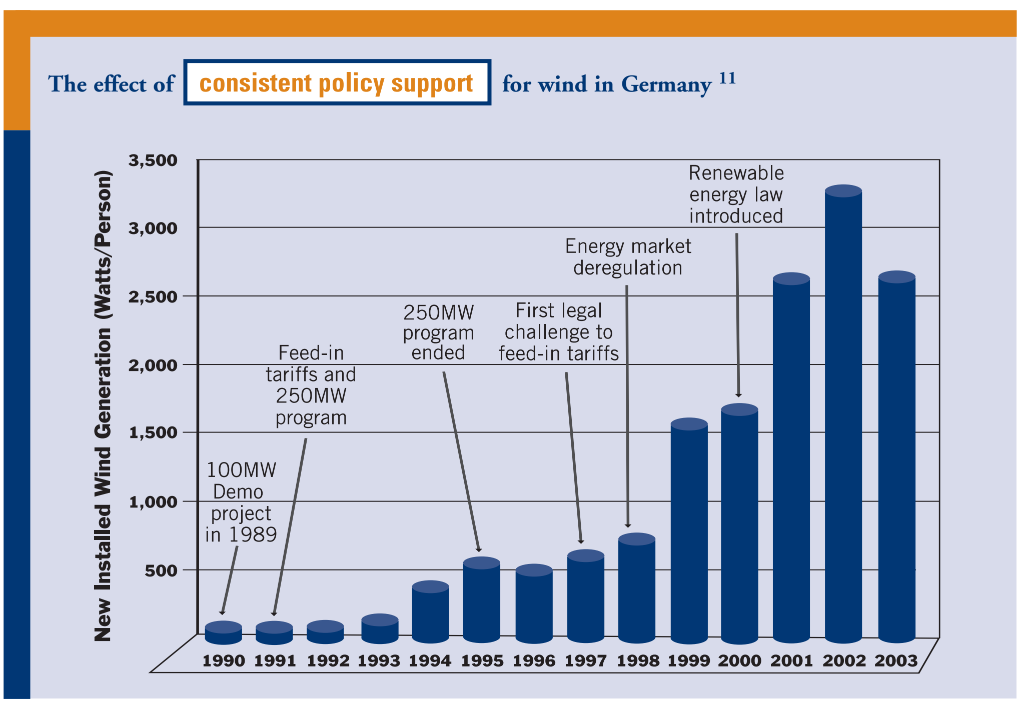
Some of the challenges, complexities and uncertainties of a transition to hydrogen are shown in Figure 3 (on page 6).

Figure 1



Source: BTM Consult ApS and Vestas Wind Systems

Figure 2



Source: BTM Consult ApS and Vestas Wind Systems

Figures 1 and 2 illustrate the importance of sustained policies in order to foster market confidence and maintain market growth over a reasonable period of time.

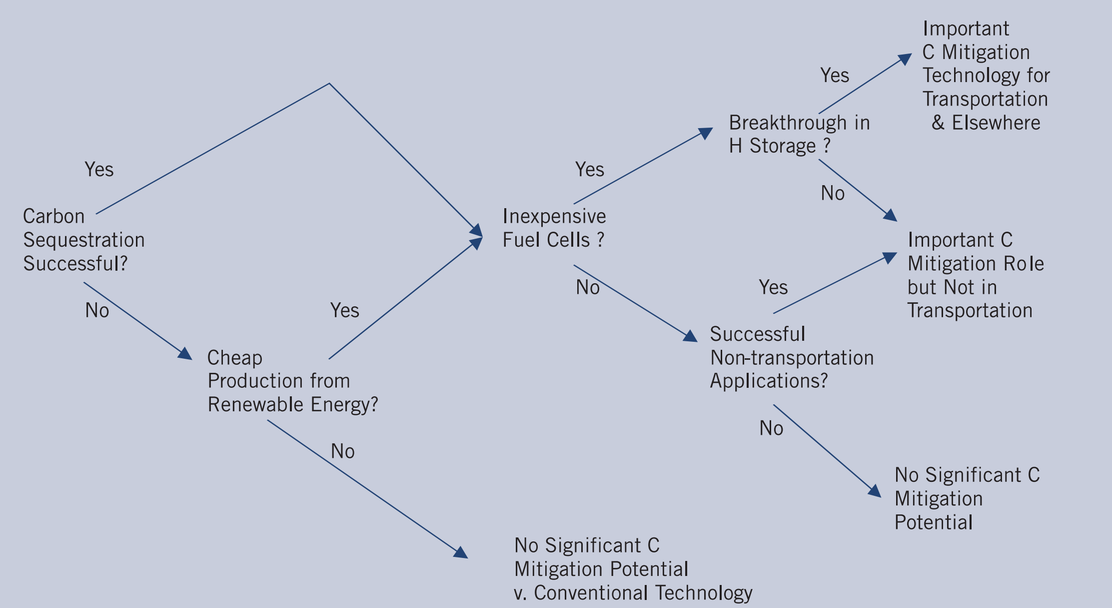
Carbon Sequestration/Coal Gasification. In order to answer critical R&D questions and to commercialize carbon capture and storage by 2025, significant effort must be made over the next 10 to 15 years. Near-term steps include:

- **a coordinated international effort to deploy coal gasification with carbon capture and sequestration (CCS) through trial projects that focus on remaining technical issues (e.g., four to six international projects);**
- **establishment of carbon sequestration trial projects in the United States to validate the integrity of geologic storage (e.g., four such projects);**
- **removal of policy disincentives to shutting down old coal plants;**
- **beginning to establish a regulatory framework for underground carbon dioxide (CO_2) storage;**
- **conducting R&D to reduce the cost of separation and capture technologies; and**
- **increasing education efforts to inform citizens about the use of fossil fuels combined with geologic carbon sequestration.**

Advanced Nuclear Power Generation. The ability of nuclear power to play a significant role in reducing GHG emissions over the next half-century depends upon what happens in the next 10 to 15 years. The question is whether, in that time frame, the nuclear industry can overcome serious

Figure 3

"Decision analysis" of Hydrogen Energy as a Carbon Dioxide Mitigation Strategy for Transportation[12]



Source: Greene, David L. 2004. Climate Change Policy for Transportation While Waiting for Hydrogen.

Figure 3 highlights the challenge of designing policies under technological uncertainty and the possible need for societal choices at some point in the future. This chart shows many of the potential technology breakthroughs involved in a transition to hydrogen over the next few decades, and highlights the need for policy flexibility.

obstacles, including economic concerns, waste, and safety, and launch a major deployment of nuclear power plants. Near-term policy options identified through the 10-50 Workshop to address these barriers include:

- **re-ordering of the priorities of the U.S. Department of Energy (DOE) nuclear fuel cycle R&D to focus on the "once-through" (i.e., without fuel reprocessing) fuel cycle;**
- **electricity production tax credits for "first mover" nuclear plants;**
- **significant expansion in size and scope of the U.S. DOE's nuclear waste management R&D;**
- **strengthening and reorienting of the current international non-proliferation regime; and**
- **public dialogue and education regarding the costs and benefits of nuclear power, especially in the context of climate change.**

Renewables. Despite the significant potential for growth of renewables, these sources currently provide only a small fraction of commercial energy in the United States and around the world. Closing the gap between the current low level of renewables deployment and their high potential will require significant and sustained policies. Near-term policy options include:

- **establishment of a national Renewable Portfolio Standard with set-asides for specific generation technologies and with tradable renewable energy credits;**
- **a major RD&D effort by the U.S. DOE focused on the use of renewables beyond niche markets;**
- **national test beds for new electricity grid systems that enable a broader set of power supply options, including intermittent and distributed energy and combined heat and power;**
- **increased research on expanding energy storage options;**
- **pollution fees for polluting energy sources; and**
- **continued and consistent support (e.g., through tax credits) to help renewables become competitive with fossil fuels for electricity generation.**

Conclusions

Using a portfolio of energy technologies and policies, the United States can be well into a transition to a low-carbon future by 2050. However, achieving such a future necessitates a significant, explicit, and comprehensive commitment to climate-friendly policy and investment. In addition to economy-wide policies that establish a carbon price, technology-specific policies would stimulate further improvements in key technologies. An effective policy portfolio should work to both push and pull a wide variety of low-carbon energy technologies into the market. More, better-managed, and stable funding of RD&D is needed over the short, medium, and long term as well. Public and private leadership, consumer and citizen involvement, engagement of the research community, and international cooperation will also be key to such a transition. Most importantly, it is critical to start now on all fronts—policy and education, and research, demonstration, and deployment—to spur the investments necessary to provide for a low-carbon future both domestically and internationally by 2050.

For a more detailed discussion of this subject, see Workshop Proceedings, "The 10-50 Solution: Technologies and Policies for a Low-Carbon Future," Washington, DC, 25 and 26 March 2004. The Pew Center on Global Climate Change and the National Commission on Energy Policy, available at: http://www.pewclimate.org

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[1] 550 parts per million (ppm) or less.

[2] Global primary energy demand is currently approximately 12 terawatts (TW). See Hoffert, Martin I. 2004. Renewable Energy Options—An Overview, in Workshop Proceedings, "The 10-50 Solution: Technologies and Policies for a Low-Carbon Future," Washington, DC, 25 and 26 March 2004. The Pew Center on Global Climate Change and the National Commission on Energy Policy. Available at: http://www.pewclimate.org; and Hoffert, M.I., K. Caldeira, G. Benford, et al. 2002. Advanced Technology Paths to Global Climate Stability: Energy for a Greenhouse Planet. *Science* 298: 981–987.

[3] Although the largest potential for reducing GHG emissions lies in the reduction of CO_2 associated with fossil-fuel energy production and consumption, carbon sequestration and the reduction of non-CO_2 GHGs also offer opportunities for reducing GHG concentrations in the atmosphere. See Reilly, J.M., H.D. Jacoby, and R.G. Prinn. 2003. *Multi-gas Contributors to Global Climate Change: Climate Impacts and Mitigation Costs of Non-CO_2 Gases.* Pew Center on Global Climate Change, Arlington, VA.

[4] See Lempert, Robert J., Steven W. Popper, Susan A. Resetar, and Stuart L. Hart. 2002. *Capital Cycles and the Timing of Climate Change Policy,* Pew Center on Global Climate Change, Arlington, VA. See also Mintzer, Irving M., J. Amber Leonard, and Peter Schwarz. 2003. *U.S. Energy Scenarios for the 21st Century*. Pew Center on Global Climate Change, Arlington, VA.

[5] The Pew Center/NCEP Workshop on The 10-50 Solution: Technologies and Policies for a Low-Carbon Future held at the St. Regis Hotel in Washington, D.C., March 25–26, 2004. A summary of the workshop, and full workshop proceedings can be found at: http://www.pewclimate.org/global-warming-in-depth/workshops_and_conferences/tenfifty/proceedings.cfm.

[6] Other important components of a GHG-friendly energy future that were not explicitly examined during the workshop may include coalbed methane, geothermal energy, nanotechnology, ocean wave energy, information technologies, sensors, materials, and biotechnology.

[7] See Department of Trade and Industry. 2003. *Energy White Paper: Our energy future—creating a low carbon economy.* The Stationary Office, London, UK (February). See http://www.dti.gov.uk/energy/whitepaper/index.shtml.

[8] A complete list of workshop attendees is available at http://www.pewclimate.org/global-warming-in-depth/workshops_and_conferences/tenfifty/index.cfm.

[9] This overview by the staff of the Pew Center on Global Climate Change aims to summarize some of the main points and common themes from the workshop papers and the discussions at the workshop. It may not represent the views of the NCEP, of all the authors of 10-50 Workshop background papers, or of all of the 10-50 Workshop participants.

[10] The explanatory arrows on this graph refer to policy actions that occurred during one year (bar) on the graph, but which had an effect on the next year (bar). For example, the Production Tax Credit (PTC) expired in 1999 during a capacity "boom" in the industry, which was subsequently followed by a "bust" in 2000. The California energy crisis (and renewal of the PTC in 2000) was followed by another "boom" in 2001. Source: BTM Consult ApS (2004) International Wind Power Development World Market Update 2003: Forecast 2004–2008. BTM Consult ApS, Ringkøbing, Denmark, and Vestas Wind Systems. "International Context." Presentation at the Ontario Wind Policy Summit. Canadian Wind Energy Association. February 24, 2004. See http://www.canwea.ca/downloads/en/PDFS/Context_-_Session_1.pdf.

[11] Feed-in laws guarantee independent power producers (e.g., wind generators) a certain price for the electricity they provide to the grid. These prices are set by statute, and rate-payers pay the difference between the "feed-in" price and the average cost of electricity. See http://www.windworks.org/articles/fl_ElectricityFeedLaws.html. Source BTM Consult ApS (2004) and Vestas Wind Systems.

[12] The figure is drawn from Greene, David L. 2004. Climate Change Policy for Transportation While Waiting for Hydrogen, in Workshop Proceedings, "The 10-50 Solution: Technologies and Policies for a Low-Carbon Future," Washington, DC, 25 and 26 March 2004. The Pew Center on Global Climate Change and the National Commission on Energy Policy. Available at: http://www.pewclimate.org.

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