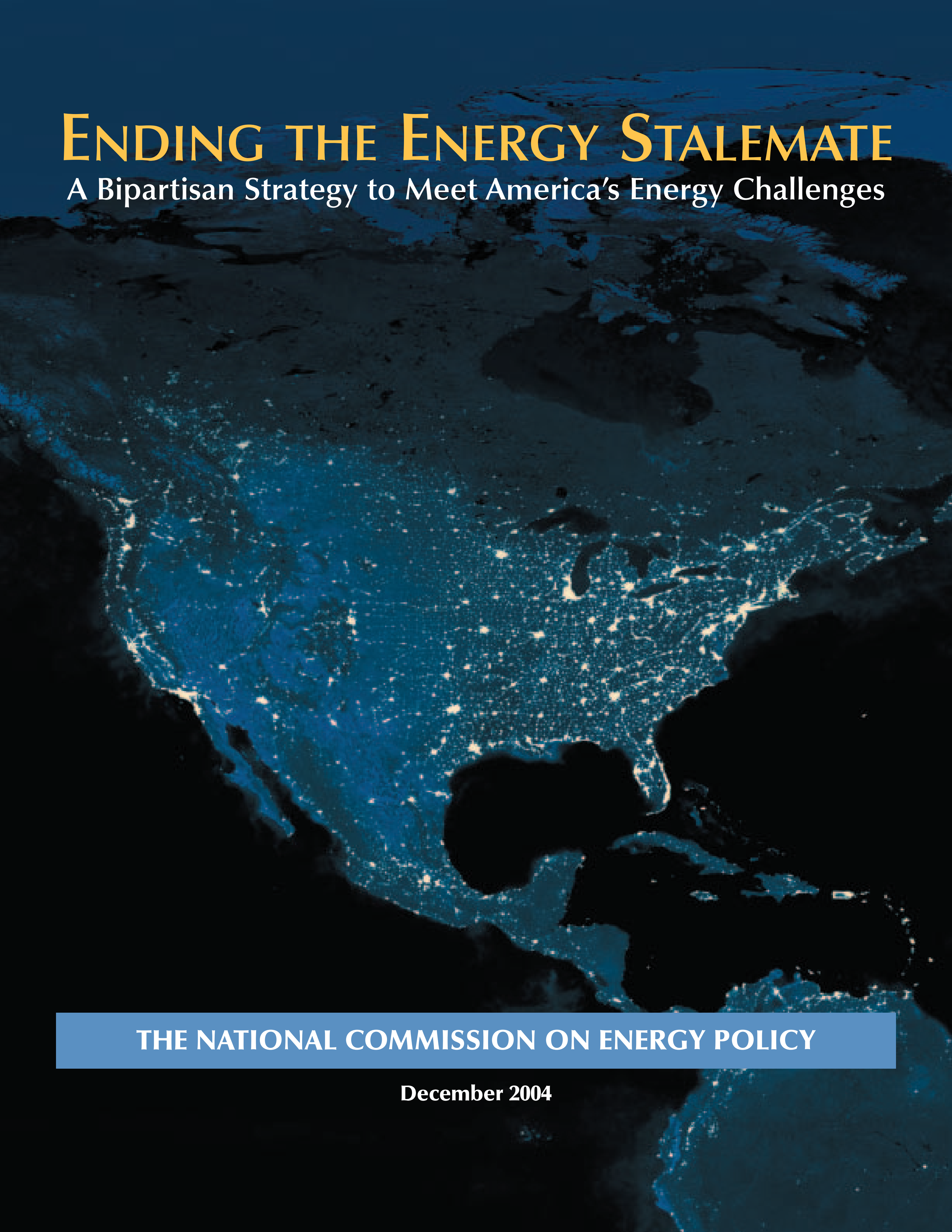
ENDING THE ENERGY STALEMATE

A Bipartisan Strategy to Meet America's Energy Challenges



THE NATIONAL COMMISSION ON ENERGY POLICY

December 2004

Cover: U.S. Government Satellite Images: Western Hemisphere at Night

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National Commission on Energy Policy

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PREAMBLE

This report is a product of a bipartisan Commission of 16 members of diverse expertise and affiliations, addressing many complex and contentious topics. It is inevitable that arriving at a consensus document in these circumstances entailed innumerable compromises. Accordingly, it should not be assumed that every member is entirely satisfied with every formulation in the report, or even that all of us would agree with any given recommendation if it were taken in isolation. Rather, we have reached consensus on the report and its recommendations *as a package,* which taken as a whole offers a balanced and comprehensive approach to the economic, national security, and environmental challenges that the energy issue presents to our nation.

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Key Recommendations

1. ENHANCING OIL SECURITY

- **Increase and diversify world oil production and expand global network of strategic petroleum reserves.**
- **Reform and significantly strengthen vehicle efficiency standards.**
- **Provide $3 billion over ten years in manufacturer and consumer incentives for domestic production and purchase of efficient hybrid-electric and advanced diesel vehicles.**

2. REDUCING RISKS FROM CLIMATE CHANGE

- **Establish a mandatory, economy-wide tradable-permits program to limit greenhouse gas emissions while capping initial costs at $7 per metric ton of CO_2-equivalent reduction.**
- **Link further U.S. action to developed and developing nation commitments.**

3. INCREASING ENERGY EFFICIENCY

- **Update and expand efficiency standards for new appliances, equipment, and buildings to capture additional cost-effective energy-saving opportunities.**
- **Integrate improvements in efficiency standards with targeted technology incentives, R&D, consumer information, and programs sponsored by electric and gas utilities.**
- **Pursue cost-effective efficiency improvements in the industrial sector.**

4. ENSURING AFFORDABLE, RELIABLE ENERGY SUPPLIES

- **Natural Gas: expand and diversify supplies of this critical resource**
  - **Adopt effective public incentives for the construction of an Alaska natural gas pipeline.**
  - **Encourage the siting and construction of liquefied natural gas (LNG) infrastructure.**
- **Advanced Coal Technologies: ensure a future for the nation's most plentiful energy resource**
  - **Provide $4 billion over ten years in public incentives for integrated gasification combined cycle (IGCC) coal technology and for carbon capture and sequestration.**
  - **Provide $3 billion over ten years in public incentives to demonstrate commercial-scale carbon capture and geologic sequestration at a variety of sites.**
- **Nuclear Energy: address the obstacles**
  - **Fulfill existing federal commitments on nuclear waste management.**
  - **Provide $2 billion over ten years from federal energy research, development, demonstration, and deployment budgets for demonstration of one to two new advanced nuclear facilities.**
  - **Significantly strengthen the international non-proliferation regime.**

- **Renewable Energy Sources: tap America's technological potential**
  - **Increase federal R&D funding for renewable electricity technologies by $360 million annually.**
  - **Expand and extend from 2006 through 2009 the federal tax credit for electricity production from non-carbon energy resources.**
  - **Support efforts by the Federal Energy Regulatory Commission (FERC) to address the need for better integration of intermittent renewable resources (such as wind and solar power) into the interstate grid system.**
  - **Establish a $1.5 billion program over ten years to increase domestic production of non-petroleum renewable transportation fuels.**

5. STRENGTHENING ESSENTIAL ENERGY SYSTEMS

- **Reduce barriers to the siting of critical energy infrastructure.**
- **Protect critical infrastructure from accidental failure and terrorist threats.**
- **Support a variety of generation resources — including both large-scale power plants, small-scale "distributed" and/or renewable generation — and demand reduction (for both electricity and natural gas) to ensure affordable and reliable energy service for consumers.**
- **Encourage increased transmission investment and deployment of new technologies to enhance the availability and reliability of the grid, in part by clarifying rules for cost-recovery.**
- **Enhance consumer protections in the electricity sector and establish an integrated, multi-pollutant program to reduce power plant emissions.**

6. DEVELOPING ENERGY TECHNOLOGIES FOR THE FUTURE

- **Double federal government funding for energy research and development, while improving the management of these efforts and promoting effective public-private partnerships.**
- **Increase incentives for private sector energy research, development, demonstration, and early deployment (ERD^3).**
- **Expand investment in cooperative international ERD^3 initiatives and improve coordination among relevant federal agencies.**
- **Provide incentives for early deployment of (1) coal gasification and carbon sequestration; (2) domestically produced efficient vehicles; (3) domestically produced alternative transportation fuels; and (4) advanced nuclear reactors.**

Introduction and Summary of Recommendations

This report recommends a revenue-neutral package of measures designed to ensure affordable and reliable supplies of energy for the twenty-first century while responding to growing concern about energy security and the risks of global climate change driven by energy-related greenhouse gas emissions. Through these recommendations and associated analysis, the Commission seeks to establish a constructive center in the often polarized debate over national energy policy.

This report presents key findings from an intensive, three-year effort to develop consensus recommendations for future U.S. energy policy. Bringing together a diverse and bi-partisan group of leaders from business, government, academia, and the non-profit community, the National Commission on Energy Policy has sought to establish a constructive center in the often polarized debate about energy and to advance a coherent strategy for meeting the energy challenges of the 21st century that has the economic, environmental, and political integrity to overcome the current stalemate in national energy policy.

KEY CHALLENGES

The challenges that must be addressed are at once familiar and new. Long-standing anxieties about the nation's underlying energy security have resurfaced at a time of record high oil and gas prices and in the wake of the largest cascading power outage in U.S. history. Recent developments in world oil markets, including rapid growth in global demand and the emergence of terrorist threats to oil facilities, are bringing new urgency to perennial concerns about the nation's exposure to oil price shocks and supply disruptions. Similar price and supply concerns increasingly apply to natural gas markets where sustained price increases and extreme volatility have begun to signal a steadily widening gap between domestic supply and demand for this economically and environmentally valuable fuel. At the same time, the uncertain state of restructuring efforts in the nation's electric industry is prompting urgent questions about the prospects for needed investment in an infrastructure that is essential to nearly every facet of modern life.

All of these issues present formidable challenges in their own right, even as the inability of the 108th Congress to pass comprehensive energy legislation in 2003 and 2004 demonstrated the political difficulty of addressing them. Meanwhile, the overall picture is vastly complicated by the inescapable linkages between energy production and use and the environment. In particular, the risk of global climate change from emissions released by fossil fuel combustion will exert a profound influence on the world's energy options and choices over the decades ahead. In this context, the old notion of energy security acquires new dimensions. Reliable access to the energy resources needed to support a healthy economy remains the core imperative, but in the 21st century energy security also means reducing the macroeconomic and terrorism-related vulnerabilities inherent in the current geopolitical distribution of oil supply and demand and coming to grips with the environmental impacts of the current energy system.

GOALS

The pages that follow set forth the Commission's specific recommendations for addressing these linked objectives, beginning with oil security and climate change risks — arguably two of the most difficult issues for U.S. energy policy. Thus, the first chapter of this report describes a package of measures designed to ***improve U.S. oil security*** by increasing global oil supply and reducing growth in domestic demand. The next chapter proposes a mandatory, economy-wide tradable-permits system for ***limiting emissions of carbon dioxide and***

other greenhouse gases. The third and fourth chapters describe a set of complementary proposals for, on the one hand, substantially ***improving energy efficiency*** throughout the economy (i.e., in buildings, equipment, industry, and transportation) and, at the same time, ***promoting energy supply*** options that advance a number of cross-cutting policy objectives, from reducing the nation's exposure to resource constraints and supply disruptions to reducing climate change risks.

Specifically, Chapter IV recommends a number of policies to help ***ensure adequate supplies of natural gas and to promote the expanded deployment of low-carbon energy alternatives*** — including advanced coal technologies with carbon sequestration, next-generation nuclear technology, and renewable sources for electricity production and transportation fuels. Recognizing that a robust and resilient energy infrastructure and healthy markets provide the necessary foundation for ensuring continued access to needed energy resources, Chapter V addresses the need to ***site critical infrastructure, protect key energy facilities from terrorist attack, and improve the performance and reliability of the nation's electricity system.*** Finally, the Commission recognizes that continued technological advances are essential to ensure that clean, secure, and affordable energy will be available in the quantities required to sustain long-term economic growth for the United States and the world. In Chapter VI, the Commission therefore recommends that the federal government promote technology innovation in both the public and private sectors by ***significantly expanding and refocusing federal energy research and development programs.***

POLICIES THAT WORK TOGETHER

It is important to emphasize that the Commission's various recommendations were designed to be mutually reinforcing and are intended to function as a package. Each component of that package is the product of extensive discussions and rigorous analysis, informed by many of the nation's top energy experts. The resulting consensus is a product of detailed technical exploration, substantive debate, and principled compromise. Early on, Commissioners agreed that a strong economy, affordable energy, and adequate energy supplies were essential prerequisites for tackling all other policy objectives; that markets — appropriately regulated — should be relied upon wherever possible to produce the most efficient solutions; that policies must be designed and implemented with great care and due appreciation for the law of unintended consequences; and that gradual adjustments are generally preferable to dramatic interventions.

REJECTING MYTHS ON THE LEFT AND RIGHT

Equally important, Commissioners found common ground in rejecting certain persistent myths — on the left and on the right — that have often served to polarize and paralyze the national energy debate. These include, for example, the notion that energy independence can be readily achieved through conservation measures and renewable energy sources alone, or that limiting greenhouse gas emissions is either costless or so costly as to wreck the economy if it were tried at all. Most of all, Commissioners rejected the proposition that uncertainty justifies inaction in the face of significant risks.

Given current trends, the consequences of inaction are all too clear. Under business-as-usual assumptions, the United States will consume 43 percent more oil and emit 42 percent more greenhouse gas emissions by 2025.[1] At the global level, oil consumption and emissions will grow 57 and 55 percent respectively over the same timeframe[2] and the Earth will be heading rapidly — perhaps inexorably — past a doubling and toward a tripling of atmospheric greenhouse gas concentrations. In the Commission's view, this is not a scenario that should inspire complacency, nor is it consistent with the goal of reducing the nation's exposure to potentially serious economic, environmental, and security risks.

POLICY CRITERIA

In choosing among a large number of potential policy options, the Commission applied several general criteria, including: economic efficiency; cost-effectiveness and consumer impacts; ability to provide appropriate incentives for future action; flexibility for adjustment in response to further experience, new information, and changed conditions; equity; political viability; and ease of implementation, monitoring, and measurement.

REVENUE NEUTRALITY

Another important consideration was impact on the U.S. Treasury. Here the Commission sought to ensure that, as a package, its proposed policies achieved revenue neutrality; that is, they are expected to roughly pay for themselves (see Table 1).[3] Commission estimates suggest that implementing these recommendations will require additional federal outlays of approximately $36 billion over ten years. To cover those outlays, the Commission outlines proposals that would raise about the same amount between 2010 and 2020 from the sale of a small portion of emission allowances under the proposed tradable-permits system for greenhouse gases.

Taken together, the Commission's recommendations aim to achieve a gradual but nevertheless decisive shift in the nation's energy policy. Their near-term impacts, by design, will be modest, and some will undoubtedly find them grossly inadequate to the challenges at hand. Others will criticize the same recommendations for going too far, precisely because they initiate a process of long-term change with consequences that no one can fully predict. These refrains are familiar. They characterize the stalemate in views that has too long resulted either in outright gridlock or in a piecemeal, special interest-driven approach to energy policy. These outcomes are no longer acceptable. It is time for the stalemate to end.

Notes:

1. United States Department of Energy, Energy Information Administration, *Annual Energy Outlook 2004 with Projections to 2025* DOE/EIA-0383 (Washington, DC: Energy Information Administration, 2004), 8, 95, http://www.eia.doe.gov/oiaf/aeo/index.html.

2. United States Department of Energy, Energy Information Administration, *International Energy Outlook 2004* DOE/EIA-0484 (Washington, DC: Energy Information Administration, 2004), 28, 137, Fig. 72, http://www.eia.doe.gov/oiaf/ieo/index.html.

3. Expected auction revenue over the first decade of program implementation (i.e., from the begining of 2010 to the begining of 2020) amounts to a discounted and annualized value of $2.6 billion per year. Expected safety valve revenues contribute an additional $1.0 billion per year. Over ten years, the total revenue generated is projected to equal roughly $36 billion.

Summary of Key Recommendations

IMPROVING OIL SECURITY

To enhance the nation's energy security and reduce its vulnerability to oil supply disruptions and price shocks, the Commission recommends:

- Increasing and diversifying world oil production while expanding the global network of strategic petroleum reserves.
- Significantly raising federal fuel economy standards for cars and light trucks while reforming the 30-year-old Corporate Average Fuel Economy (CAFE) program to allow more flexibility and reduce compliance costs. New standards should be phased in over a five-year period beginning no later than 2010.
- Providing $3 billion over ten years in manufacturer and consumer incentives to encourage domestic production and boost sales of efficient hybrid and advanced diesel vehicles.

Today's combination of tight oil supplies and high and volatile prices is likely to continue, given trends in global consumption (expected to grow by more than 50 percent over the next two decades), continuing instability in the Middle East and other major oil-producing regions, and a global decline in spare production capacity.

Oil production in the United States peaked in the 1970s and has been flat or declining since. Although highly important to the nation's economy and energy security, it cannot compensate for anticipated growth in domestic demand, which is expected to reach 29 million barrels per day by 2025 — a more than 40 percent increase over current consumption levels.

Improving the nation's energy security and reducing its vulnerability to high oil prices and supply disruptions are more meaningful and ultimately achievable policy goals than a misplaced focus on energy independence *per se*. Achieving these goals requires focusing in equal measure on expanding and diversifying oil supplies and improving efficiency, especially in the transportation sector. Additional Commission recommendations aim to expand transportation fuel supplies by enabling production of unconventional oil and alternative fuels.

The Commission's recommendations for improving passenger vehicle fuel economy, increasing the contribution from alternative fuels, and improving the efficiency of the heavy-duty truck fleet and passenger vehicle replacement tires, could reduce U.S. oil consumption in 2025 by 10–15 percent or 3–5 million barrels per day. These demand reductions, in concert with increased oil production, would significantly improve domestic oil security.

REDUCING RISKS FROM CLIMATE CHANGE

To address the risks of climate change resulting from energy-related greenhouse gas emissions, without disrupting the nation's economy, the Commission recommends:

- Implementing in 2010 a mandatory, economy-wide tradable-permits system designed to curb future growth in the nation's emissions of greenhouse gases while capping initial costs to the U.S. economy at $7 per metric ton of carbon dioxide-equivalent.
- Linking subsequent action to reduce U.S. emissions with comparable efforts by other developed and developing nations to achieve emissions reductions via a review of program efficacy and international progress in 2015.

The Commission believes the United States must take responsibility for addressing its contribution to the risks of climate change, but must do so in a manner that recognizes the global nature of this challenge and does not harm the competitive position of U.S. businesses internationally.

The Commission proposes a flexible, market-based strategy designed to slow projected growth in domestic greenhouse gas emissions as a first step toward later stabilizing and ultimately reversing current emissions trends if comparable actions by other countries are forthcoming and as scientific understanding warrants.

Under the Commission's proposal, the U.S. government in 2010 would begin issuing permits for greenhouse gas emissions based on an annual emissions target that reflects a 2.4 percent per year reduction in the average greenhouse gas emissions intensity of the economy (where intensity is measured in tons of emissions per dollar of GDP).

Most permits would be issued at no cost to existing emitters, but a small pool, 5 percent at the outset, would be auctioned to accommodate new entrants, stimulate the market in emission permits, and fund research and development of new technologies. Starting in 2013, the amount of permits auctioned would increase by one-half of one percent each year (i.e., to 5.5 percent in 2013; 6 percent in 2014, and so on) up to a limit of 10 percent of the total permit pool.

The Commission's proposal also includes a safety valve mechanism that allows additional permits to be purchased from the government at an initial price of $7 per metric ton of carbon dioxide (CO_2)-equivalent. The safety valve price would increase by 5 percent per year in nominal terms to generate a gradually stronger market signal for reducing emissions without prematurely displacing existing energy infrastructure.

In 2015, and every five years thereafter, Congress would review the tradable-permits program and evaluate whether emissions control progress by major trading partners and competitors (including developing countries such as China and India) supports its continuation. If not, the United States would suspend further escalation of program requirements. Conversely, international progress, together with relevant environmental, scientific, or technological considerations, could lead Congress to strengthen U.S. efforts.

Absent policy action, annual U.S. greenhouse gas emissions are expected to grow from 7.8 billion metric tons of CO_2-equivalent in 2010 to 9.1 billion metric tons by 2020 — a roughly 1.3 billion metric ton increase. Modeling analyses suggest that the Commission's proposal would reduce emissions in 2020 by approximately 540 million metric tons. If the technological innovations and efficiency initiatives proposed elsewhere in this report further reduce abatement costs, then fewer permits will be purchased under the safety valve mechanism and actual reductions could roughly double to as much as 1.0 billion metric tons in 2020, and prices could fall below the $7 safety valve level.

The impact of the Commission's proposed greenhouse gas tradeable-permits program on future energy prices would be modest. Modeling indicates that relative to business-as-usual projections for 2020, average electricity prices would be expected to rise by 5–8 percent (or half a cent per kilowatt-hour); natural gas prices would rise by about 7 percent (or $0.40 per mmBtu); and gasoline prices would increase 4 percent (or 6 cents per gallon). Coal use would decline by 9 percent below current forecasts, yet would still increase in absolute terms by 16 percent relative to today's levels, while renewable energy production would grow more substantially; natural gas use and overall energy consumption, meanwhile, would change only minimally (1.5 percent or less) relative to business-as-usual projections.

Overall, the Commission's greenhouse gas recommendations are estimated to cost the typical U.S. household the welfare equivalent of $33 per year in 2020 (2004 dollars) and to result in a slight reduction in expected GDP growth, from 63.5 percent to 63.2 percent, between 2005 and 2020.

IMPROVING ENERGY EFFICIENCY

To improve the energy efficiency of the U.S. economy, the Commission — in addition to an increase in vehicle fuel economy standards — recommends:

- Updating and expanding efficiency standards for new appliances, equipment, and buildings to capture additional cost-effective energy-saving opportunities.
- Integrating improvements in efficiency standards with targeted technology incentives, R&D, consumer information, and programs sponsored by electric and gas utilities.[1]
- Pursuing cost-effective efficiency improvements in the industrial sector.

In addition, efforts should be made to address efficiency opportunities in the heavy-duty truck fleet, which is responsible for roughly 20 percent of transportation energy consumption, but is not subject to fuel economy regulation, and in the existing vehicle fleet where a substantial opportunity exists to improve efficiency by, for example, mandating that replacement tires have rolling-resistance characteristics equivalent to the original equipment tires used on new vehicles.

In updating and implementing efficiency standards, policy makers should seek to exploit potentially productive synergies with targeted technology incentives, research and development initiatives, information programs (such as the federal ENERGY STAR label), and efficiency programs sponsored by both electricity and natural gas utilities.

Energy efficiency advances all of the critical policy objectives identified elsewhere in this report and is therefore essential to successfully managing the nation's, and the world's, short- and long-term energy challenges. Absent substantial gains in the energy efficiency of motor vehicles, buildings, appliances, and equipment, it becomes difficult to construct credible scenarios in which secure, low-carbon energy supplies can keep pace with increased demand. As a nation that consumes more energy than any other in the world, improving domestic energy efficiency can have a notable effect on global energy demand.

EXPANDING ENERGY SUPPLIES

The United States and the world will require substantially increased quantities of electricity, natural gas, and transportation fuels over the next 20 years. In addition to the measures discussed previously for improving oil security, the Commission's recommendations for assuring ample, secure, clean, and affordable supplies of energy address established fuels and technologies (such as natural gas and nuclear power), as well as not-yet-commercialized options, such as coal gasification and advanced biomass (including waste-derived) alternative transportation fuels.

Natural Gas:

To diversify and expand the nation's access to natural gas supplies, the Commission recommends:

- Adopting effective public incentives for the construction of an Alaska natural gas pipeline.
- Addressing obstacles to the siting and construction of infrastructure needed to support increased imports of liquefied natural gas (LNG).

Other Commission recommendations aim to: (1) improve the ability of agencies like the Bureau of Land Management to evaluate and manage access to natural gas resources on public lands and (2) increase R&D efforts to develop technologies for tapping non-conventional natural gas supplies, such as natural gas hydrates, which hold tremendous promise.

The above recommendations are intended to address growing stresses on North American natural gas markets that have already resulted in sharply higher and more volatile gas prices, and created substantial costs for consumers and gas-intensive industries. Construction of a pipeline would provide access to significant natural gas resources in Alaska's already-developed oilfields (potentially lowering gas prices by at least 10 percent over the pipeline's first decade). Support for a pipeline in the form of loan guarantees, accelerated depreciation, and tax credits was included in legislation passed by Congress late in 2004, but the Commission believes that additional incentives are likely to be necessary given the high cost, lengthy construction period, uncertainty about future gas prices, and other siting and financing hurdles associated with the project.

In addition to the Alaska pipeline, expanded LNG infrastructure would further increase the nation's ability to access abundant global supplies of natural gas, providing important benefits in terms of lower and less volatile gas prices and more reliable supplies for electricity generators and for other gas-intensive industries. Accordingly, the Commission recommends concerted efforts to overcome current siting obstacles, including improved federal-state cooperation in reviewing and approving new LNG facilities and efforts to educate the public regarding related safety issues.

Advanced Coal Technologies:

To enable the nation to continue to rely upon secure, domestic supplies of coal to meet future energy needs while addressing the risks of global climate change due to energy-related greenhouse gas emissions, the Commission recommends:

- Providing $4 billion over ten years in early deployment incentives for integrated gasification combined cycle (IGCC) coal technology.
- Providing $3 billion over ten years in public incentives to demonstrate commercial-scale carbon capture and geologic sequestration at a variety of sites.

Coal is an abundant and relatively inexpensive fuel that is widely used to produce electricity in the United States and around the world. Finding ways to use coal in a manner that is both cost-effective and compatible with sound environmental stewardship is imperative to ensure a continued role for this important resource.

IGCC technology — in which coal is first gasified using a chemical process and the resulting synthetic gas is used to fuel a combustion turbine — has the potential to be significantly cleaner and more efficient than today's conventional steam boilers. Moreover, it can assist in effectively controling pollutants such as mercury and can open the door to economic carbon capture and storage. The gasification process itself is already commonly used in the manufacture of chemicals, but — with the exception of a handful of demonstration facilities — has not yet been widely applied to producing power on a commercial scale.

Nuclear Power:

To help enable nuclear power to continue to play a meaningful role in meeting future energy needs, the Commission recommends:

- Fulfilling existing federal commitments on nuclear waste management
- Providing $2 billion over ten years from federal research, development, demonstration, and deployment (RDD&D) budgets for the demonstration of one to two new advanced nuclear power plants.
- Significantly strengthening the international non-proliferation regime.

Worldwide, some 440 nuclear power plants account for about one-sixth of total electricity supplies and about half of all non-carbon electricity generation. In the United States, 103 operating nuclear power plants supply about 20 percent of the nation's electricity and almost 70 percent of its non-carbon electricity. The contribution of nuclear energy to the nation's power needs will decline in the future absent concerted efforts to address concerns about cost, susceptibility to accidents and terrorist attacks, management of radioactive wastes, and proliferation risks.

Government intervention to address these issues and to improve prospects for an expanded, rather than diminished, role for nuclear energy is warranted by several important policy objectives, including reducing greenhouse gas emissions, enhancing energy security, and alleviating pressure on natural gas supplies from the electric-generation sector.

Renewable Energy:

To expand the contribution of clean, domestic, renewable energy sources to meeting future energy needs, the Commission recommends:

- Increasing federal funding for renewable technology research and development by $360 million annually. Federal efforts should be targeted at overcoming key hurdles in cost competitiveness and early deployment.
- Extending the federal production tax credit for a further four years (i.e., from 2006 through 2009), and expanding eligibility to all non-carbon energy sources, including solar, geothermal, new hydro-power generation, next generation nuclear, and advanced fossil fuel generation with carbon capture and sequestration. (This is in addition to the exten-sion recently passed by Congress for 2004-2005.)

- Supporting ongoing efforts by the Federal Energy Regulatory Commission (FERC) to promote market-based approaches to integrating intermittent resources into the interstate grid system, while ensuring that costs are allocated appropriately and arbitrary penalties for over- and under-production are eliminated.
- Establishing a $1.5 billion program over ten years to increase domestic production of advanced non-petroleum transportation fuels from biomass (including waste).

Renewable energy already plays an important role in the nation's energy supply, primarily in the form of hydropower for electricity production and corn-based ethanol as a transportation fuel. Other renewable options — including wind, solar, and advanced biomass technologies for power generation together with alternative transportation fuels from woody or fibrous (cellulosic) biomass and organic wastes — have made considerable progress in recent years, but still face substantial cost or technology hurdles as well as, in some cases, siting challenges.

The Commission's recommendations aim to improve the performance and cost-competitiveness of renewable energy technologies while also addressing deployment hurdles by providing more planning certainty in terms of federal tax credits, boosting R&D investments, and addressing issues related to the integration of renewable resources with the interstate transmission grid.

STRENGTHENING ENERGY SUPPLY INFRASTRUCTURE

To sustain access to the essential energy supplies and services on which the economy depends, the Commission recommends:

- Reducing barriers to the siting of critical energy infrastructure.
- Protecting critical infrastructure from accidental failure and terrorist threats.
- Supporting a variety of generation resources — including both large scale power plants and small scale "distributed" and/or renewable generation — and demand reduction (for both electricity and natural gas), to ensure affordable and reliable energy service for consumers.
- Encouraging increased transmission investment and deployment of new technologies to enhance the availability and reliability of the grid, in part by clarifying rules for cost-recovery.
- Enhancing consumer protections in the electricity sector and establishing an integrated, multi-pollutant program to reduce power plant emissions.

The Commission believes there is a national imperative to strengthen the systems that deliver secure, reliable, and affordable energy. Priorities include: siting reforms to enable the expansion and construction of needed energy facilities; greater efforts to protect the nation's energy systems from terrorist attack; and reforms to improve the reliability and performance of the electricity sector.

DEVELOPING ENERGY TECHNOLOGIES FOR THE FUTURE

To ensure that technologies capable of providing clean, secure, and affordable energy become available in the timeframe and on the scale needed, the Commission recommends:

- Doubling federal government funding for energy research and development, while improving the management of these efforts and promoting effective public-private partnerships.
- Increasing incentives for private sector energy research, development, demonstration, and early deployment (ERD^3).
- Expanding investment in cooperative international ERD^3 initiatives and improving coordination among relevant federal agencies.
- Providing incentives for early deployment of (1) coal gasification and carbon sequestration; (2) domestically-produced efficient vehicles; (3) domestically-produced alternative transportation fuels; and (4) advanced nuclear reactors.

Overcoming the energy challenges faced by the United States and the rest of the world requires technologies superior to those available today. To accelerate the development of these technologies, the federal government must increase its collaboration with the private sector, with states, and with other nations to develop and deploy technologies that will not be pursued absent greater federal support.

Investments by both the private and public sectors in energy research, development, demonstration, and early deployment have been falling short of what is likely to be needed to meet the energy challenges confronting the nation and the world in the 21st century. This insufficiency of investment is compounded by shortcomings in the government's management of its energy-technology-innovation portfolio and in the coordination and cooperation among relevant efforts in state and federal government, industry, and academia.

The Commission proposes that the nation devote the resources generated by the sale of greenhouse gas emissions permits to enhance the development and deployment of improved energy technologies. The approximately $36 billion that Commission analysis indicates will be generated over ten years by the proposed greenhouse gas tradeable-permits program — most of which will come from auctioning a small portion of the overall permit pool — will offset the specific additional public investments summarized below.

Table 1

A Revenue Neutral Strategy for Investing in Energy Technology Development

The Commission proposes to double current federal spending on energy innovation, substantially expand early deployment efforts for advanced energy technologies, and triple investment in cooperative international energy research. To offset additional costs to the Treasury, the Commission proposes that the federal government each year auction a small percentage of greenhouse gas emissions permits.

Additional Expenditures		**Annual**	**10 Year Total**
RD&D	Double current investment	$1.7 billion	$17 billion
Incentives for Early Deployment	Coal IGCC, biofuels, advanced nuclear, non-carbon production tax credit (PTC), manufacturer and consumer auto efficiency incentives, Alaska pipeline	$1.4 billion	$14 billion
International Cooperation	Triple Current Investment	$500 million	$5 billion
Total			**$36 billion**
Additional Revenues			
Greenhouse Gas Permit Sales	• 5 percent permit auction in 2010 with 0.5 percent annual increase starting in 2013 • Revenue from expected permit sales under the safety valve		$26 billion $10 billion
Total			**$36 billion**

Notes:

1. See, e.g., the constructive joint proposal on these issues to the National Association of Regulatory Utility Commissioners by the American Gas Association and the Natural Resources Defense Council (July 2004); available at www.aga.org.

I. Enhancing Oil Security

The United States should adopt a package of policies to (1) enable greater foreign investment in nations with significant oil reserves; (2) expand the global network of strategic petroleum reserves; (3) significantly strengthen passenger vehicle fuel economy standards beginning in 2010, while simultaneously reforming the existing Corporate Average Fuel Economy (CAFE) program to reduce compliance costs and provide cost-certainty for manufacturers and consumers; and (4) invest $3 billion over a ten-year timeframe to accelerate the domestic production and sale of highly efficient hybrid-electric and advanced diesel passenger vehicles. Together with measures described elsewhere in this report to accelerate the development and early deployment of domestically-produced transportation fuels derived from biomass and organic wastes, these recommendations are designed to increase global oil production and diminish the nation's vulnerability to high oil prices and supply disruptions.

A. UNDERSTANDING THE PROBLEM

Adequacy of Global Oil Supply

Over the next two decades, global oil consumption is projected to increase more than 50 percent, from 78 million barrels per day (MBD) in 2002 to 118 MBD in 2025, according to the federal Energy Information Administration (EIA). (More recent projections by the International Energy Agency (IEA) suggest somewhat lower growth, with world oil consumption estimated to reach 112 MBD by 2025). On the current trajectory, EIA projects that U.S. consumption will increase from 20 MBD to 29 MBD over the same timeframe.[1] The Commission does not embrace the view that world oil production has peaked — in the past, new discoveries and improved technology have allowed estimates of recoverable world oil reserves to continue to grow along with consumption. (For example, proven global reserves in 1971 were estimated at 612 billion barrels while world consumption since that time has totaled 767 billion barrels — yet current global reserves are estimated at 1,028 billion barrels.[2]) At present, however, the global oil system is under considerable strain with virtually no spare capacity to quickly increase production.

"Expanding global oil production must be a priority"

Moreover, a substantial share of the world's oil is concentrated in regions that are today unstable, experiencing armed conflict, or being targeted by terrorist attacks — while in other countries political and legal conditions are creating substantial business uncertainty. Examples here are not limited to the Middle East: recent developments in Nigeria, Russia, Venezuela, and other important oil-producing nations have further exacerbated the challenge of assuring a steady and reasonably priced supply of oil.

In this context, the Commission believes it is reasonable to expect that a 34–40 MBD increase in global oil demand will be accompanied by higher oil prices and the potential for more serious and frequent supply disruptions. If so, the consequences for the United States could be significant given already high and growing levels of oil consumption and the near-total reliance of the U.S. transport sector on petroleum fuels. Meanwhile, despite significant tax incentives, U.S. oil production has been in gradual decline since 1970 and the EIA projects this trend will continue.[3]

Given the importance of oil to the U.S. and global economy, expanding and diversifying worldwide oil production must therefore be a priority for national energy policy. To that end, the Commission supports diplomatic efforts to address barriers to energy-related investment in foreign markets and a review of U.S. sanctions in cases where unilaterally imposed sanctions

Oil Production and Consumption

Supply: The United States is the world's third largest oil producer after Saudi Arabia and Russia. Oil production operations extend into 29 states and oil extraction alone employs about 125,000 Americans. Even marginal "stripper" wells contributed some $370 million to 23 states' treasuries in 2003. Total employment for the domestic oil and natural gas sectors is about 1.5 million, and these workers earn wages that are well above U.S. averages. Measured purely in social and economic terms, there is an obvious national interest in maintaining a robust domestic oil industry.

Other major producing nations include China, Iran, and Mexico, which together with the United States and Saudi Arabia account for just under half of world oil production. Saudi Arabia, in addition to being the world's largest oil exporter, has played a crucial role in world oil markets because of its willingness and capacity to significantly increase production at times of global shortage. To meet future demand growth, EIA predicts significantly expanded production from the Caspian region, the Middle East, and Africa, and from unconventional oil resources in North America. Middle Eastern nations in the Organization of the Petroleum Exporting Countries (OPEC) are expected to account for the bulk of new production (19 MBD by 2025). If the world price of oil stays over $35/barrel, more expensive non-OPEC production will likely be higher than current forecasts indicate. Given that 45 percent of the world's proven reserves of conventional oil are located within the territorial boundaries of Saudi Arabia, Iraq, and Iran, however, a growing percentage of global oil demand will inevitably be met using resources from the Middle East.

Demand: The United States is now the world's largest oil consumer by a considerable margin, using four times more oil in absolute terms than any other nation. Relative to economic output, the United States consumes 7.5 gallons of oil per $1,000 GDP — more than other industrialized countries such as Japan, the United Kingdom, and Germany, but less than other large oil-producing nations such as Russia and Canada. In 2003, oil imports accounted for 55 percent of total U.S. consumption with 60 percent of U.S. imports coming from four countries: Canada, Saudi Arabia, Mexico, and Venezuela. Global patterns of oil demand are likely to shift in the future. From 2002 to 2025, EIA predicts that the highest rates of demand growth will occur in three developing nations — China, India, and Mexico. In absolute terms, developing nations are predicted to require an additional 22 MBD by 2025, while the industrialized nations are expected to require an additional 14 MBD, of which 9 MBD is due to expected growth in U.S. demand. Another 4 MBD of additional demand is expected to come from nations in the former Soviet Union and Eastern Europe. Meanwhile, China's rapidly growing demand in particular — oil consumption in China grew by 18 percent during the first quarter of 2004 after rising by 11 percent in 2003 — has already begun to strain global production capacity and contributed to a rise in crude oil prices to more than $50 per barrel during 2004.

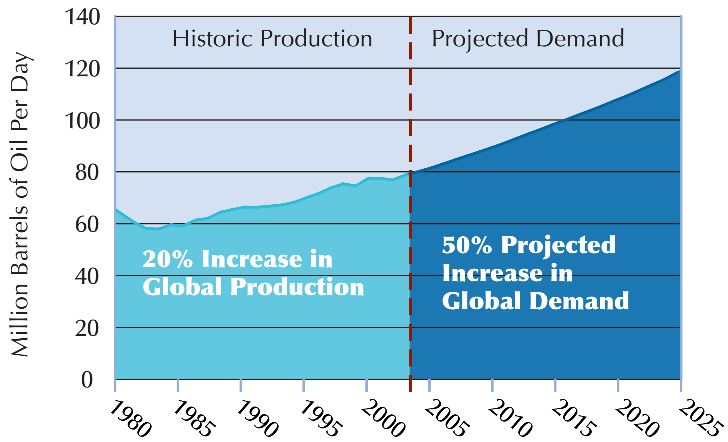
are likely to constrain world oil production.

A balanced and effective program to enhance U.S. oil security must also, however, place equal emphasis on reducing domestic oil demand. Using oil more efficiently and developing alternative transportation fuels relieves pressure on future production while simultaneously helping to insulate the U.S. economy from the negative consequences of oil price shocks and reducing its vulnerability to events in other parts of the world. Accordingly, the Commission believes that significant increases in vehicle fuel economy must accompany efforts to promote increased global oil production. As detailed later in this report, the Commission estimates that passenger vehicle and heavy-truck fuel economy improvements offer the potential to reduce U.S. oil consumption by 10–15 percent or 3–5 MBD oil by 2025, depending on how much fuel economy standards are raised. Over the same time period, Commission analysis suggests that alternative fuels from corn, agricultural and animal wastes, and energy crops can displace another 0.5 MBD, thus beginning the gradual process of diversifying the fuels available for use in the transportation sector (see discussion in Section E of Chapter IV).

Figure 1-1

Trends in Global Oil Production and Future Demand

Future demand for oil is projected to grow at more than double the historical rate since 1980.



Data Source: Energy Information Administration, 2004

Risk of Oil Supply Disruptions

Over the last 30 years, the United States has sought to improve oil security by promoting a greater diversity of world oil suppliers,[4] reducing domestic consumption through a substantial increase in new passenger vehicle fuel economy between 1975 and 1987, and creating the largest dedicated strategic petroleum reserve in the world.[5] Due to these policies and as a result of structural shifts, the U.S. economy today is less oil-intensive and therefore less vulnerable to oil price shocks than it was in 1970. The fact that oil imports have nonetheless steadily increased since that time suggests that calls for energy independence — while rhetorically seductive — represent the wrong focus for U.S. energy policy.

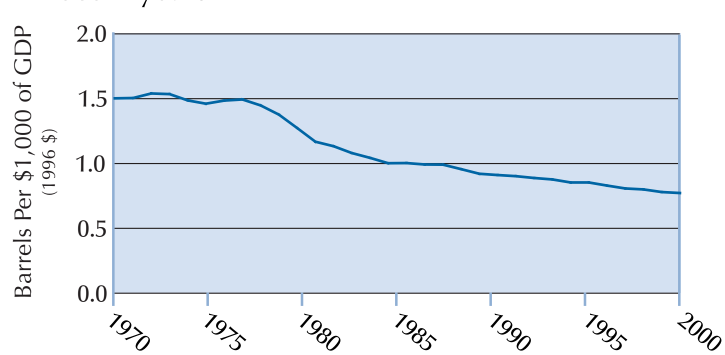
Oil is a global commodity traded in a global marketplace. As long as market forces prevail, the price of U.S. and world oil will be the same.[6] Therefore, a supply disruption anywhere in the world affects oil consumers everywhere in the world. Although domestic oil production is important to the U.S. economy, reduces financial transfers to foreign nations, and is less vulnerable to deliberate or accidental interruption, U.S. exposure to world oil price shocks is a function of the amount of oil it consumes and is not significantly affected by the ratio of domestic to imported product.[7]

Today, despite past progress, U.S. policies no longer provide adequate safeguards against the risk of oil supply disruptions and consequent price spikes. The ability of Saudi Arabia to increase production to offset world oil shortages has declined significantly since the 1990s. In 1990, when Iraq invaded Kuwait, OPEC had roughly 5.5 MBD of spare capacity, enough to replace the oil from those two countries and to supply about 8 percent of global demand. Today, OPEC's spare capacity stands at a slender 2 percent of world demand with 90 percent of this capacity under the control of Saudi Arabia.[8] The fact that spare capacity is both extremely limited and concentrated in one region

Figure 1-2

Oil and the Economy

The ability of the U.S. economy to weather oil price shocks improves as oil's share of GDP decreases. This share has declined over the past several decades, although the rate of decline has slowed in recent years.



Resources for the Future, 2004

leaves world oil markets extremely vulnerable to short-term disruptions, driving prices upward and increasing general volatility. Further, global economic vulnerability to domestic conditions in the Middle East — where long-term stability is threatened by a potent mixture of militant extremism, terrorist threats, and pressures for political reform — is likely to grow over the next two decades as the share of world oil supplies coming from this politically volatile region increases.

Except for significant progress in filling the U.S. Strategic Petroleum Reserve (SPR), efforts to buffer the U.S. economy from oil price shocks have faded. Since the late 1980s, U.S. passenger vehicle fuel economy has stagnated and alternative fuel use remains at just 2 percent of total transportation fuel consumption.[9] The Commission believes that a significant course correction is needed to dampen future growth in oil consumption and lessen the economic impacts of future oil price shocks. Policies aimed at achieving these objectives will also have the important benefit of reducing emissions that contribute to the risk of global climate change.

B. POLICY RECOMMENDATIONS

1. Increase Global Oil Production & Strategic Petroleum Reserves

Oil provides more energy to the world than any other energy source and because the geographic distribution of global oil resources does not match patterns of demand, the United States and other key oil consuming countries can expect their reliance on oil imports to continue to grow. In fact, it seems certain that global oil demand will continue to rise over the next 20 years regardless of the success of global efforts to increase transportation efficiency and develop non-petroleum fuels.

To satisfy this growing demand and lessen the impact of supply disruptions in any one nation or region of the globe, the United States must continue and expand efforts to increase oil production from the world's conventional and unconventional resources and work to strengthen global strategic petroleum reserves. The Bush Administration's 2001 National Energy Policy (NEP) presented a comprehensive discussion on this topic.[10] Specifically, the Commission recommends the following measures:

- The U.S. government should apply diplomatic pressure to encourage nations with significant but underdeveloped oil reserves to allow foreign investment in their energy sectors to increase global oil production. To the extent that unilaterally imposed U.S. economic sanctions may be limiting investment in foreign energy markets and constraining world oil supply, the oil security implications of these sanctions should be carefully considered.

- The U.S. government should support research and development efforts to advance technologies that mitigate the environmental impacts of developing unconventional oil resources.

- The U.S. government should fill the Strategic Petroleum Reserve to capacity and encourage other nations, particularly those with growing oil consumption, to establish publicly owned strategic reserves. In concert with other nations and the International Energy Agency, the United States should seek to expand the global network of strategic reserves to keep pace with global demand.

As a complement to these recommendations and in order to provide the knowledge base needed for sound energy policy decision-making in the future, the Commission further recommends that a detailed inventory of domestic petroleum resources be undertaken as part of a regular, comprehensive assessment of the nation's known and potential energy resources. The Commission's proposal for such an integrated assessment is described in more detail at page 43 of Chapter IV in this report.

Domestic production met 45% of U.S. oil demand in 2003.
Off Louisiana coast, Gulf of Mexico

DISCUSSION

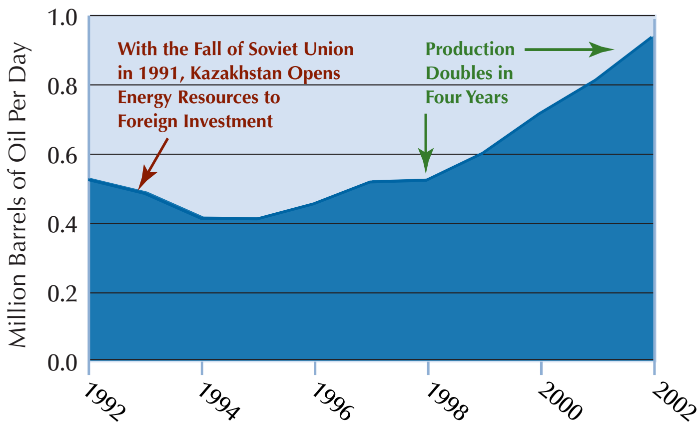
Foreign Oil Production — Opportunities for investment in and development of overseas energy resources have increased substantially in the past decade. Many nations previously closed to foreign investment have enacted laws or established policies to attract new capital and technology. These policies include lower tax rates on foreign corporations, guarantees against expropriation without compensation and the right to repatriate profits, joint ventures with local companies, and production sharing agreements that establish a legal structure for foreign companies to spend resources on exploratory drilling in exchange for a portion of the revenues if oil is discovered. Surging oil production in areas of the former Soviet Union and Nigeria, along with several energy projects launched in the Middle East in recent years, provide compelling examples of the benefits of liberalized investment policies. Kazakhstan, for instance, had opened its oil resources to significant levels of foreign investment by the mid-1990s, with companies such as ExxonMobil, ChevronTexaco, and a number of European operators at the fore. Although production dipped somewhat in the turmoil immediately following the collapse of the Soviet Union, production rates more than doubled between 1996 and 2002.[11] Current expectations are that Kazakhstan's oil output will reach 2 MBD in the next five to ten years, and will peak at 4 MBD.[12] For all these recent successes, however, challenges remain — as has recently been demonstrated by the problems of Yukos, a major Russian oil company.[13] Closer to home, resources in Mexico are largely off-limits to equity investment by foreign firms, and are likely to remain so despite Mexico's urgent need for energy. Thus, efforts must continue to promote the investment needed to expand the world's supply of oil, particularly from sources outside the Middle East.

In addition, U.S.-imposed economic sanctions can limit investment in foreign energy markets and thus constrain world supply. Experts disagree on the effectiveness particularly of unilateral sanctions, with critics arguing that they have not deterred countries from engaging in, or sponsoring, terrorist activities.[14] While there are many factors that influence U.S. decisions to impose unilateral sanctions against other nations, impacts on world oil markets should be among the factors considered.

Figure 1-3

Impact of Foreign Investment on Oil Production

Kazakhstan opened its energy resources to foreign investment in the early 1990s and witnessed a rapid increase in oil production over the next decade.



Data Source: Energy Information Administration, 2004

About 1 MBD of unconventional oil is currently extracted in Canada from facilities like this Steam Assisted Gravity Drainage oil sands facility. *Alberta, Canada*

Domestic Oil Production — Domestic oil production, which was running at 5.6 MBD in May of 2004,[15] is supported by several major tax incentives, including: (1) excess of percentage over cost depletion, (2) expensing of exploration and development costs, (3) oil and gas exception from passive loss limitation, and (4) credit for enhanced oil recovery costs. The combined value of these subsidies in 2004 has been estimated to range from $890 million to $1.54 billion; their cumulative cost to the federal Treasury up to the year 2000 has been assessed at somewhere between $134 billion and $149 billion.[16] The EIA has questioned the effectiveness of these programs, finding that "programs that offer small subsidies for products for which there are huge existing markets tend to function mostly as transfer programs; that is, their market impacts are negligible, and for the most part they simply redistribute funds."[17] The Commission recommends the redeployment of existing tax incentives for oil production, with a focus on results rather than expenditure. Whether the objective is more oil production or more efficient oil use, the same philosophy should guide the tax code: provide performance-based incentives that reward those who deliver the most at the lowest cost to the federal taxpayer.

Unconventional Oil — Canada has an estimated 170 billion barrels of unconventional oil in tar sands,[18] while Venezuela's unconventional heavy oil reserves are believed to top 230 billion barrels. If at some point these resources can be economically recovered in an environmentally acceptable fashion, the Western Hemisphere's share of world oil reserves would nearly triple from 13 percent to 36 percent. About 1 MBD of unconventional oils from tar sands are currently extracted in Canada; by 2015 it is likely that Canada and Venezuela together will produce nearly 3.5 MBD of unconventional crude.[19] At present, the extraction of unconventional oil often results in greater air and water pollution than the extraction of conventional oil.[20] In addition, total greenhouse gas emissions associated with these resources are two and a half times higher than for conventional oil production.[21] The Commission recommends a $300 million increase in federal funding over ten years to improve the environmental performance of technologies and practices used to produce unconventional oil resources.

Strategic Petroleum Reserve — The Strategic Petroleum Reserve (SPR) is a government-owned complex of four facilities in deep underground salt caverns along the Texas and Louisiana Gulf Coast that hold emergency supplies of crude oil. It is the largest strategic oil reserve of its kind anywhere in the world. The SPR was authorized in late 1975 to protect the nation against a repetition of the supply disruptions caused by the 1973–74 oil embargo. The Commission's view is that its use should continue to be reserved for genuine supply disruptions.

It is generally believed that the existence of a large, operational reserve of crude oil deters future oil cut-offs and discourages the use of oil as a tool for economic blackmail. According to the U.S. Department of Energy (DOE), total investment in the SPR to date is more than $21 billion.[22] As of September 2004, the SPR was filled to about 92 percent of capacity and held the equivalent of 53 days of oil import protection or nearly 669 million barrels.[23] Combined with private stocks (which total about 1 billion barrels of crude oil and various refined products), the SPR provides the United States with enough spare capacity to cover the loss of all oil imports for approximately 150 days or a partial disruption for much longer.

"...new vehicle fuel economy is now no higher than it was in 1981, but vehicle weight has increased by 24 percent and horsepower has increased by 93 percent."

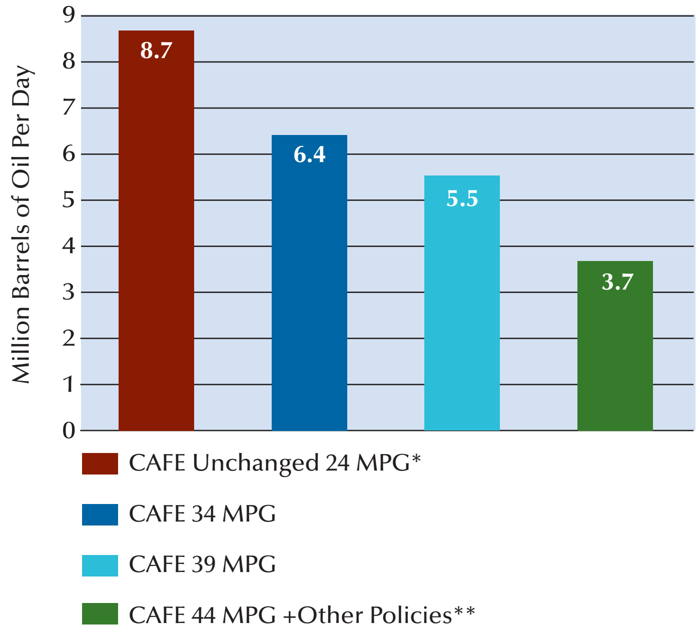
To improve global and domestic oil security, the United States should work with other major oil-consuming nations to strengthen the IEA's oil security system by encouraging other nations to increase their public reserves and participate in the global network of strategic reserves. Many of these countries now rely to a large extent on oil held in private inventories. Established after the 1972 embargo, the IEA system requires participating nations (such as the United States) to maintain national emergency oil reserves and implement coordinated stock drawdowns during genuine supply disruptions. In 2000, the IEA system contained public and private stocks to replace import losses for 110 days, which is well above the system's 90-day requirement but substantially below the historic high of 1986 when stocks were adequate to replace 160 days of imports. Currently, the three largest public storage systems belong to the United States, Japan, and Germany, which jointly account for more than 90 percent of total public IEA stocks.

In a 2001 report on oil supply security, the IEA states: "The last decade has seen IEA countries' dependence on oil imported from non-OECD [Organization for Economic Cooperation and Development] countries rise back toward the highs of the 1970s. IEA stocks as a proportion of imports have fallen steeply since the 1980s."[24] Should IEA countries decide to maintain the same ratio of stocks to net imports in the future as they did in the late 1990s, stocks would need to increase by as much as 50 percent over the next two decades. The Commission notes that China, which is not part of the IEA system but is now the second largest oil consumer in the world, and India have announced plans to establish public strategic petroleum reserves; this trend should be encouraged.

Figure 1-4

Projected Growth in Daily U.S. Oil Demand by 2025 Under Various Fuel Economy Scenarios

New passenger vehicle fuel economy standards will help reduce projected growth in U.S. petroleum demand.



* Combined car/light truck fuel economy level.
**Other policies include standards for heavy-duty tractor-trailer trucks, replacement tires and renewable fuel deployment policies.

Data Source: NCEP NEMS Modeling

POLICY RECOMMENDATIONS

2. Reduce U.S. Oil Consumption through Increased Vehicle Efficiency and Production of Alternative Fuels

Reducing U.S. oil consumption is a critical complement to the measures described in previous sections for expanding and diversifying global supplies of oil. A key to slowing continued growth in U.S. oil consumption — which is otherwise projected to increase by more than 40 percent over the next two decades — is breaking the current political stalemate on changing Corporate Average Fuel Economy (CAFE) standards for new motor vehicles. Although recommendations in later chapters of this report — notably those aimed at promoting the development of alternative transportation fuels — will also help to reduce oil demand, improving passenger vehicle fuel economy is by far the most significant oil demand reduction measure proposed by the Commission.

The Commission's approach to vehicle efficiency builds on three decades of experience with fuel economy regulation and a record of impressive technological advances by the automobile manufacturing industry. As a result of CAFE standards introduced in the 1970s and high gasoline prices in the late 1970s and early 1980s, the average fuel economy of new light-duty vehicles improved from 15 miles per gallon (mpg) in 1975 to a peak of 26 mpg in 1987, a 73 percent increase over a time period that also saw substantial progress in improved vehicle performance and safety. The trend toward greater fuel economy, however, did not continue. Passenger car CAFE standards peaked in 1985 at 27.5 mpg and have not changed since. Light-duty truck standards were recently raised by 1.5 mpg to a new standard of 22.2 mpg which will go into effect in 2005 — prior to this increase they had remained essentially unchanged since 1987. Thus, for most of the last two decades overall fleet fuel economy has stagnated and continued technology gains — such as port fuel injection, front-wheel drive, valve technology, and transmission improvements — have been applied to increase vehicle size and power, rather than fuel economy. In fact, at 24 mpg on average, new vehicle fuel economy is now no higher than it was in 1981, but vehicle weight has increased by 24 percent and horsepower has increased by 93 percent.[25]

The Commission believes that three factors are largely responsible for the current CAFE stalemate: (1) uncertainty over the future costs of fuel-saving technologies; (2) fear that more stringent standards will lead to smaller, lighter vehicles and increased traffic fatalities; and (3) concerns that higher fuel-economy standards will put the U.S. auto industry and auto workers at a competitive disadvantage.

With respect to the first of these factors — cost and technology potential — numerous recent analyses by the National Academy of Sciences and others have concluded that significant improvements in the fuel economy of conventional gasoline vehicles are achievable and cost-effective, in the sense that fuel savings over the life of the vehicle would more than offset incremental technology costs. Estimates of cost-effectiveness do not, however, account for — and thus cannot by themselves resolve — potential trade-offs in terms of vehicle performance, safety, and impacts on jobs and competitiveness. Given these complexities, the Commission was unable to agree on a numerical fuel-economy standard.

The recommendations that follow nevertheless reflect the Commission's conclusion that a combination of improved conventional gasoline technologies and advanced hybrid-electric and diesel technologies presents an opportunity to significantly increase fuel economy without sacrificing size, power, safety, and other attributes that consumers value. Note that the Commission defines "advanced diesel" in this context as a diesel passenger vehicle that meets stringent new federal air polution control requirements — or so-called "Tier 2" standards — that are being phased in from 2004 to 2008 (no currently available passenger diesel vehicles meet these standards). Ultimately, the Commission believes that a combination of higher standards, CAFE reforms, and complementary incentive programs will allow the nation to capitalize on potentially "game-changing" technologies such as hybrids and advanced diesels in a manner that greatly enhances its ability to achieve oil security and environmental goals, as well as its ability to sustain the future competitiveness of the U.S. automobile industry.

Specifically, the Commission recommends:

- ***Raising Passenger Vehicle Fuel Economy Standards***[26] **—** Congress should instruct the National Highway Traffic Safety Administration (NHTSA) to significantly strengthen federal fuel economy standards for passenger vehicles to take full advantage of the efficiency opportunities provided by currently available technologies and emerging hybrid and advanced diesel technologies. Consistent with existing statutory requirements, NHTSA should — in developing new standards — give due consideration to vehicle performance, safety, job impacts, and competitiveness concerns. To allow manufacturers sufficient time to adjust, new standards should be phased-in over a five-year period beginning no later than 2010.

- ***Reforming CAFE* —** To facilitate compliance with higher standards, Congress should modify CAFE to increase program flexibility by allowing manufacturers to trade fuel economy credits with each other and across the light truck and passenger vehicle fleets. In addition, Congress should authorize NHTSA to consider additional mechanisms that could further simplify the program, increase flexibility, and reduce compliance costs. One such mechanism is a compliance "safety valve" that would permit manufacturers to purchase CAFE credits from the government at a pre-determined price. Such a mechanism would effectively cap costs to consumers and manufacturers should fuel-saving technologies not mature as expected or prove more expensive than anticipated.

- ***Providing Economic Incentives for Hybrids and Advanced Diesels* —** Congress should establish a five- to ten-year, $3 billion tax incentive program for manufacturers and consumers to encourage the domestic production and purchase of hybrid-electric and advanced diesel vehicles that achieve superior fuel economy.

DISCUSSION

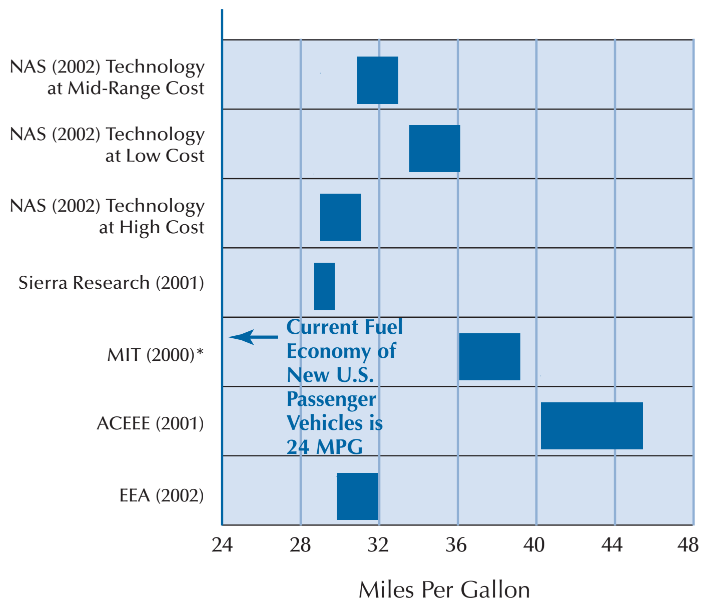
I. Raising Passenger Vehicle Fuel Economy Standards

***Oil Savings Potential* —** Figure 1-4 illustrates the range of oil savings that would be associated with various levels of fuel-economy improvement by 2025. To generate these estimates, Commission staff employed DOE's National Energy Modeling System (NEMS) and assumed that higher CAFE standards would be phased in between 2010 and 2015. (The Commission has employed NEMS to provide detailed analysis of policies considered throughout this report. For a fuller discussion of the Commission's modeling results, see the Economic Analysis in the Technical Appendix.) The figure is intended to be illustrative of the potential for reducing future oil demand growth, recognizing that a 20 mpg increase in CAFE standards (the high end of the range shown) may not be practical within the 2010–2015 timeframe given the re-tooling of automobile manufacturer and supplier production facilities required to achieve an improvement of this magnitude. The results of the NEMS analysis show that improving fleet-wide (i.e., car and light truck) passenger vehicle fuel-economy standards by 10, 15, and 20 mpg by 2015 would result, by 2025, in estimated fuel

Figure 1-5

Cost-Effective Fuel Economy Levels

Bars show range of cost-effectiveness with gasoline prices at $1.50 and $2.00 per gallon.



*MIT only examined passenger cars. To provide a useful comparison to other studies which examined cars and light trucks, the Commission weighted the MIT car estimate with the NAS mid-range estimate for light trucks.

Data Sources: National Academy of Sciences 2002, Sierra Research 2001, Massachusetts Institute of Technology 2000, American Council for an Energy Efficient Economy 2001, Energy and Environmental Analysis Inc. 2002

International Context

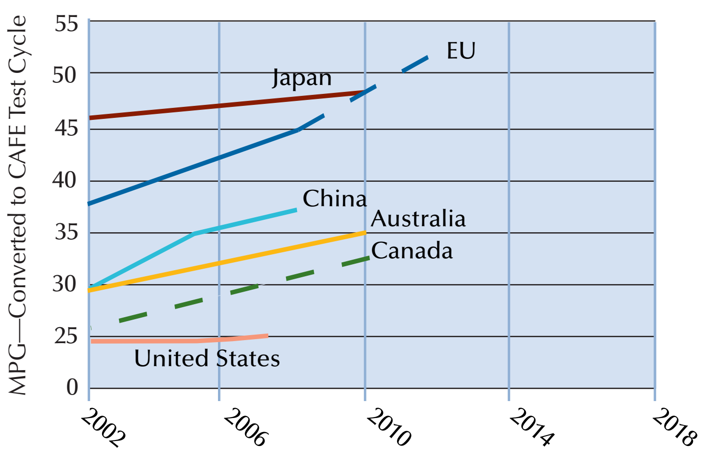
Over the last decade, many developed and some developing nations have established or strengthened domestic policies aimed at improving motor vehicle fuel economy. In many of these countries, higher fuel taxes and less stringent vehicle emission requirements (which have allowed diesel vehicles to gain a larger market share) have played a role in enabling superior fuel economy. The higher average fuel economy of vehicle fleets in other countries is also due in significant part to differences in vehicle mix — and in particular, to the fact that the market share of trucks in most other countries is smaller than in the United States.

In the United States, a recent increase in light truck fuel economy standards is expected to result in a 3 percent improvement in overall new passenger vehicle fuel economy to 25 mpg (from the current 24 mpg) by 2005. European Union policies are designed to improve new vehicle fuel economy to 44 mpg by 2008 from the current 37 mpg. At 45 mpg, Japan's fuel economy requirements are already the most stringent in the world; nevertheless, they are set to increase to 48 mpg by 2010. As part of its plan to meet national climate change commitments, Canada is considering a proposal to increase passenger vehicle fuel economy to 32 mpg by 2010 from the current level of 25 mpg. In the developing world, China — which has the world's fastest growing automobile fleet and is experiencing rapid growth in oil consumption — recently adopted standards aimed at increasing new passenger vehicle fuel economy to 37 mpg by 2008 from the current average of 29 mpg. Finally, the State of California has recently promulgated greenhouse gas emission standards for passenger vehicles that will have the collateral benefit of improving new passenger vehicle fuel economy to 36 mpg by 2015.[28]

Figure 1-6

Comparison of Projected Fuel Economy Levels

The fuel economy of the U.S. automobile fleet—both historically and projected based on current policies—lags behind most other nations.[29]



* Dashed lines represent proposed standards

Adapted by permission from An and Sauer, Pew Center on Global Climate Change, forthcoming

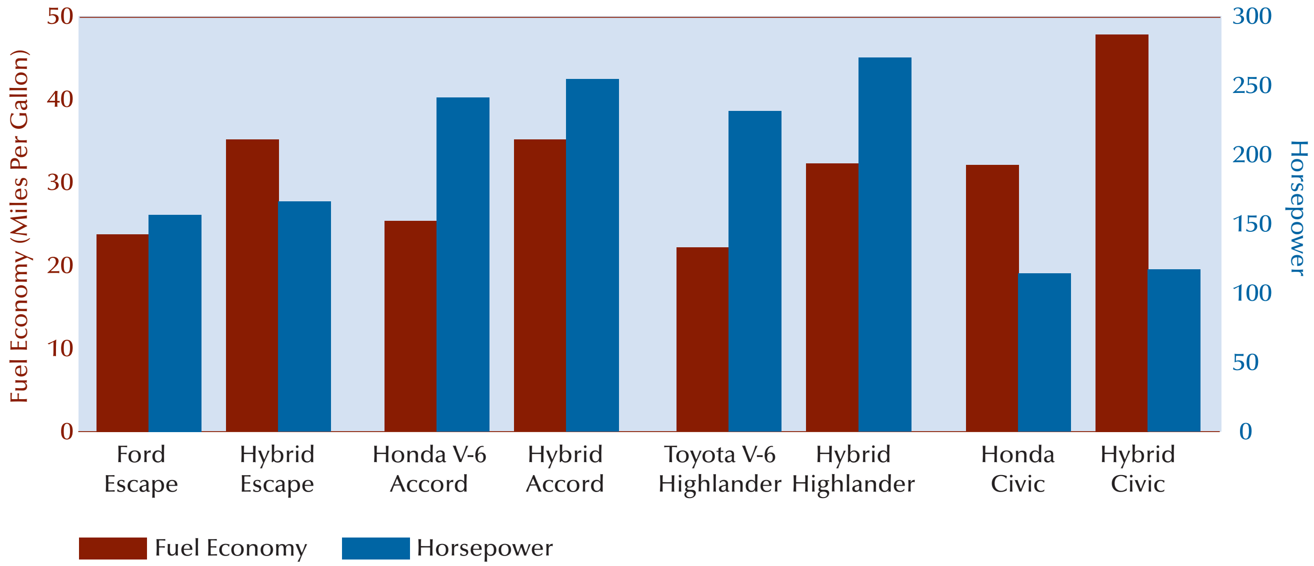
savings of approximately 2, 3, and 3.5 MBD respectively.[27] These savings reflect a 25–40 percent reduction in the additional U.S. oil consumption that is otherwise projected to occur over the same timeframe absent policy intervention. Complementary measures discussed later in this report (including improvements in heavy-duty truck efficiency, low rolling-resistance replacement tires for vehicles already on the road, and biomass-based fuels) could contribute another 1.7 MBD of oil savings by 2025.

Efficiency Technology Benefits and Costs **—** The Commission's proposal for a significant strengthening of new vehicle fuel economy standards is based upon a variety of studies of technology potential and cost-effectiveness completed since 2000. These studies are summarized in Figure 1-5. To allow for a comparison of results across the various studies, the Commission has applied a consistent set of cost-effectiveness assumptions (e.g., 8 percent discount rate; 150,000 miles traveled over the life of a vehicle) to the technology cost and benefit data from each analysis. In most cases, the studies seek to determine the degree of CAFE improvement possible using technologies that would pay for themselves in fuel savings over the life of the vehicle. (For further discussion of how cost-effectiveness is

Figure 1-7

Why Hybrids Change the Game

Hybrids can increase fuel economy and horsepower.



Note: The popular Toyota Prius hybrid is not included here because it does not have a conventional vehicle counterpart.

Data Sources: NewCars.com 2004, American Honda Motor Co. 2004, AIC Autosite 2004

defined and calculated in many of these studies, see Chapter III at page 34.) The range of findings reflects varying expectations about the future costs and benefits of the technologies examined. This range is wide, but if high and low estimates are excluded, it narrows considerably to between 30 mpg (midpoint of the High-Cost Technology Case in the 2002 National Academy of Sciences (NAS) study) to 37 mpg (midpoint of the 2000 Massachusetts Institute of Technology (MIT) study). This range reflects an increase of 6–13 mpg over today's combined car and light-truck average of 24 mpg.

"a significant course correction is needed to dampen growth in oil consumption"

In addition to the above fuel economy studies, a detailed study completed in 2004 by two automotive engineering firms (Martec and AVL) examined the potential to reduce greenhouse gas emissions from the light-duty vehicle fleet.[30] This study concludes that new passenger vehicle greenhouse gas emissions can be cost-effectively reduced by up to 47 percent. Achieving this substantial reduction would require a significant increase in the market share of hybrid-electric vehicles. Relying solely on technology improvements to conventional gasoline-power vehicles, the study finds that a 30 percent reduction in greenhouse gas emissions is cost-effective. Importantly, none of the emissions-reducing technology combinations considered in this study included reductions in vehicle size, weight, or performance. Converting the Martec/AVL estimates of achievable greenhouse gas reductions to vehicle efficiency improvements suggests that average new-vehicle fuel economy could be cost-effectively increased by 10–20 mpg.[31] (For more details of the Martec/AVL results, see further discussion at page 33 of Chapter III). Based on its review of recent fuel economy studies, the Commission finds that the cost-effective efficiency potential of passenger vehicles is substantial and merits serious attention from policymakers.

Safety Issues — A paramount concern when seeking to improve vehicle fuel economy is ensuring no reduction in overall vehicle safety. The concern is often expressed that mandating higher fuel economy will require production of less safe, lighter vehicles and compromise vehicle performance. While the relationship between vehicle weight and safety is clearly important, it is far from straightforward. The 2002 NAS study, for example, found that down-weighting and down-sizing of the passenger vehicle fleet in the late 1970s and early 1980s could be linked to reductions in fleet safety.[32] On the other hand, NHTSA recently cited both the 2002 NAS study and its own more recent review of safety issues in noting that down-weighting — if concentrated among the heaviest vehicles in the light-truck category — could produce a small, fleet-wide safety benefit.[33] Recent government data, moreover, suggest that sport utility vehicles are less safe overall than lighter passenger vehicles when the greater propensity of sport utility vehicles to roll over is taken into account.[34]

Figure 1-7 illustrates the game changing potential of already-available hybrid-electric technologies to boost fuel economy while maintaining vehicle size and performance. The Ford Escape, Honda Civic hybrid, the forthcoming Honda Accord hybrid, and the Toyota Highlander hybrid, all achieve substantial fuel economy improvements *while maintaining or increasing* horsepower (by as much as 17 percent) compared to their conventional counterparts, and without reductions in weight or size. These vehicles clearly demonstrate that substantial fuel economy improvements can be achieved using already-available technologies and without compromising vehicle performance and safety. In addition, some argue that advances in light but very strong composite materials will allow for significant weight reductions to be achieved in concert with ongoing safety improvements, although cost issues remain.

In light of the complexity and potential trade-offs associated with significantly increasing vehicle fuel economy, the Commission believes it is appropriate for Congress to instruct NHTSA to determine the optimal standard and programmatic details for future changes to CAFE. Given the importance of this decision and its ramifications for the nation and the auto industry, the Commission also urges Congress to ensure that NHTSA has the necessary resources and authority to significantly strengthen and reform the CAFE program.

II. Reforming CAFE

Provide Greater Efficiency through Market Mechanisms — A variety of possible reforms could substantially improve the flexibility of the CAFE program, reduce compliance costs, and thus allow for a greater increase in standards than might otherwise be economically and politically acceptable.

Specifically, the Commission recommends that Congress alter CAFE to enable manufacturers to trade fuel economy credits with one another and across their car and light truck fleets. Currently, the program requires each individual manufacturer to meet applicable fuel economy standards within its own car and light truck fleets. Manufacturers can gather credits for excess compliance and bank these credits to offset possible future compliance shortfalls. This offset system, however, is currently limited in several important ways. First, credits must be used within three years or they expire. Second, credits earned in the passenger car segment of the market cannot be used to offset fuel economy requirements for a manufacturer's light truck fleet, and vice versa. Since most carmakers produce both types of vehicles, this restriction is significant. The Congressional Budget Office has estimated that simply allowing

"...a variety of possible reforms could substantially improve the flexibility of the CAFE program, reduce compliance costs, and thus allow for a greater increase in standards..."

manufacturers to trade credits with each other would reduce the cost of the CAFE program by about 17 percent.

Consider Establishing Cost Certainty for the Vehicle Industry — Contentious debates about the costs associated with improving fuel economy and, by extension, the costs of complying with higher CAFE standards, have stymied past efforts to improve vehicle fuel economy. As these disagreements center upon inherently uncertain projections of future technology development, they are nearly impossible to resolve and often result in stalemate.[35] The Commission believes that providing the automobile industry and consumers with greater cost-certainty by capping future compliance costs could hold promise for moving beyond this stalemate. Cost estimates used to justify fuel economy and emission standards in the context of regulatory rulemakings are almost always considered understated by industry and overstated by environmental advocates. Combining significantly improved standards with an appropriate cost cap or "safety-valve" would protect automakers and consumers if regulatory estimates understate true costs. At the same time, it would assure that the benefits associated with higher standards will be achieved if government assumptions are either accurate or overstate true costs. A similar mechanism is included in the Commission's proposal for a tradable-permits program to limit greenhouse gas emissions and is discussed at some length in the next chapter.

Photo courtesy of Toyota Motor Company

Photo courtesy of American Honda Motor Corporation

Photo courtesy of Ford Motor Company

A growing variety of hybrid vehicles are currently available in American showrooms.

Arguably, the CAFE program already contains a safety valve in the form of a monetary penalty for noncompliance. Currently, manufacturers are penalized $55 for every mpg that their average fleet fuel economy falls short of applicable CAFE standards, multiplied by the number of vehicles sold. (The penalty was originally set at $50 per mpg per vehicle in 1978 and was updated to $55 in 1997.) Some smaller-volume foreign manufacturers (e.g., BMW, Jaguar) have paid this penalty rather than alter their U.S. market strategy by selling more fuel-efficient vehicles. Domestic manufacturers have not, however, availed themselves of this compliance option in part due to concerns that intentional violation of CAFE standards could provide a basis for shareholder lawsuits. Thus, the existing monetary penalty has not functioned as a cost-capping mechanism for domestic full-line manufacturers. To ensure that tradable credits or a safety valve function as intended, Congress would need to make clear that purchasing CAFE credits from other manufacturers or the government is a legitimate compliance option.

If, in concert with a significant increase in standards, the CAFE program is modified by the addition of a cost-capping safety valve, it will be critically important to set the cost cap at the right level. If the safety valve price is set too low, manufacturers will buy compliance credits from the government and under-invest in fuel-saving technologies relative to what is cost-effective in terms of achievable fuel economy improvements. If, on the other hand, the CAFE safety valve is set too high, manufacturers will need to make technology investments and/or purchase compliance credits beyond the point justified by the benefits associated with achieving CAFE requirements. To determine the appropriate price for the safety valve, federal agencies could consider the marginal costs that are assumed for fuel-saving technologies in justifying a revised standard and the benefits of avoided gasoline consumption considering reasonable externalities. Preliminary analysis by the Commission taking these factors into account suggests that the price level needed to ensure that the safety valve functions as intended would be higher than the current $55/mpg CAFE non-compliance penalty.

Address Potential for Adverse Job Impacts through Economic Incentives for Hybrids and Advanced Diesels — The concern that higher fuel-economy requirements would adversely affect the competitive position of U.S. manufacturers relative to foreign manufacturers has always played a prominent role in the long-running debate about raising CAFE standards. At present there is a roughly 3 mpg gap between the average fleet-wide fuel economy of the major American auto makers and their main European and Japanese competitors. As a result, domestic manufacturers — in large part because their fleet mix contains a higher proportion of light trucks and sport utility vehicles —start at some disadvantage in producing vehicles that can meet a higher target average. The current gap, however, is smaller than the 8 mpg fuel economy gap that existed between domestic and foreign manufacturers in 1975 when Congress first established the CAFE program. While some believe that the CAFE standards gave importers an advantage that allowed them to enter the larger and more profitable market segments, others believe that the standards proved salutary for the industry precisely because they prompted technological innovation that ultimately helped U.S. companies keep pace with their foreign rivals.

Increased compliance flexibility and innovative reforms like the cost-capping safety valve discussed previously are clearly two important means of addressing the legitimate concerns about competitiveness and job impacts that inevitably arise in considering new CAFE standards. In addition, the Commission believes that targeted incentives for consumers and manufacturers can play an important role in addressing these concerns, particularly with respect to the disadvantage domestic manufacturers currently face in producing hybrid-electric and advanced diesel vehicles. Though these types of vehicles currently account for significantly less than 1 percent of total U.S. vehicle sales, several major automobile manufacturers have begun making substantial investments in hybrid and diesel technologies with the expectation that the market for these technologies, both domestically and overseas, is likely to expand rapidly in coming years. The fact that Asian and European manufacturers are currently better positioned to produce both types of vehicles therefore presents an important competitive challenge for U.S. manufacturers.

To help the domestic industry meet that challenge in concert with achieving higher fuel economy standards the Commission recommends a ten-year package of incentives to increase consumer demand for highly efficient hybrid and advanced diesel vehicles and to encourage manufacturers and major suppliers to locate their production at existing facilities in the United States.

Consumer Tax Incentive — A tax deduction of up to $2,000 (worth between $400 and $600 to the average taxpayer) is currently provided to consumers who purchase a new hybrid-electric vehicle. This tax incentive starts phasing out in 2004 and expires after 2006. The Commission supports extending the tax incentive for five years (2007 to 2011), altering the mechanism from a simple deduction to a variable credit of up to $3,000 based on vehicle fuel economy, and expanding the scope of the program to include advanced diesel passenger vehicles. The goal here is to increase consumer demand for highly efficient vehicles, thereby reducing costs through increased production volumes. In order to cap overall costs and ensure that all vehicle manufacturers have access to the incentives, the Commission believes that the maximum number of incentives available to any one manufacturer should be limited. Legislation before Congress in 2004 included provisions limiting the total incentive to 80,000 vehicles per manufacturer. The estimated cost of the program is $1.5 billion over five years.

Auto Manufacturer and Supplier Tax Incentive — Despite the growing market share of imported vehicles, most of the new vehicles and automotive components sold in the United States are manufactured domestically (70 percent in dollar value). Auto industry and labor leaders have expressed concern that promoting advanced hybrid and diesel vehicles will encourage more overseas production at the expense of U.S. jobs. The Commission worked collaboratively with the United Auto Workers and the University of Michigan to examine this issue and concluded that these concerns are well-founded in the case of hybrids and light-duty advanced diesels.[36] Currently, European facilities are better positioned to produce diesel components and vehicles and Asian firms have better technical know-how and facilities to produce hybrid technologies. (For example, a majority of components for the Ford Escape hybrid come from suppliers based in Europe and Japan.)

To address potential adverse job impacts associated with an increase in the market share of hybrids and advanced diesels the Commission recommends providing tax incentives for U.S. manufacturing facilities to retool existing factories to produce hybrid-electric and advanced diesel passenger vehicles with superior fuel economy. The incentive would be available to domestic and foreign companies with U.S. facilities, including both assembly plants and parts suppliers. Based upon independent review, the Commission believes that this approach would be consistent with U.S. obligations under international trade agreements.[37] The recommended subsidy level would total $1.5 billion over ten years with the amount of the credit set to reflect up to two-thirds of the capital investment associated with the production of vehicles or vehicle components. The Commission's analysis finds that these federal expenditures would pay for themselves over a four- to five-year period through the increased tax receipts resulting from maintaining domestic manufacturing jobs.

Specific estimates of the range of costs and benefits associated with the proposed manufacturer tax credit are summarized in Table 1-1.[38] The analysis starts with three estimates of the size of the U.S. market for hybrids and advanced diesels in 2009. As noted previously, hybrid and advanced diesel vehicles now account for less than 1 percent of annual U.S. sales. Based on publicly announced production plans, the baseline growth scenario assumes that these vehicles will reach 3 percent of the U.S. passenger vehicle

Table 1-1

Costs and Benefits of Manufacturer Capital Investment Tax Credit

Scenarios	Hybrid & Diesel Share of U.S. Passenger Vehicle Market	Private Sector Capital Investment in U.S. Auto Plants* (Millions)	Cost to U.S. Treasury (Millions)	Jobs Gained
Baseline	3%	$348	$233	14,978
Moderate Growth	7%	$971	$651	39,057
High Growth	11%	$1,599	$1,072	59,459

*Assumes 50% of projected overseas production will be relocated to the U.S. due to the proposed capital investment tax incentive.
Note that the baseline estimates shown in the above table are independent of any assumptions about a future increase in CAFE standards.

Data Source: University of Michigan, 2004 market by 2009. The moderate- and high-growth scenarios assume that consumer preference, sustained high gasoline prices, an extension and increase in consumer tax incentives, and potential increases in fuel economy standards result in hybrid and advanced diesel vehicles capturing higher market shares of 7 and 11 percent respectively. At the 7 percent market share assumed under the moderate growth scenario, capital investment in the necessary retooling of assembly plants and component production facilities would cost the private sector close to $1 billion. If an investment tax credit compensates manufacturers for two-thirds of their capital investment costs, the cost to the U.S. Treasury would be about $650 million over a period of ten years. Resulting employment gains over the same time period would total almost 39,000 jobs. Importantly, this analysis also shows that the federal investment to encourage domestic production of these fuel-efficient vehicles would pay for itself several times over as a result of the tax revenues associated with increased domestic production. In the moderate growth scenario, for example, the increase in tax revenues would total more than $1.6 billion.

Notes:

1. United States Department of Energy, Energy Information Administration, *Annual Energy Outlook 2004 with Projections to 2025* DOE/EIA-0383 (Washington, DC: Energy Information Administration, 2004), 161, Table A21, http://www.eia.doe.gov/oiaf/aeo/index.html; International Energy Agency, *World Energy Outlook 2004* (Paris: Organization for Economic Cooperation and Development/International Energy Agency, 2004), 32, http://library.iea.org/dbtw-wpd/textbase/npsum/WEO2004SUM.pdf.

2. M.A. Adelman, "The Real Oil Problem," *Regulation* 27, No. 1 (2003): 18.

3. United States Department of Energy, Energy Information Administration, *Annual Energy Outlook 2004 With Projection to 2025* DOE/EIA-0383 (Washington, DC: Energy Information Administration, 2004), 93-95, Figs. 95-98, http://www.eia.doe.gov/oiaf/aeo/index.html.

4. Ibid., 95. See also: BP, *Energy In Focus: BP Statistical Review of World Energy 2004* (London: BP, 2004), 6-19, http://www.bp.com/statisticalreview2004/. Eighteen nations — many non-OPEC — experienced significant growth in petroleum production over the 5-year period between 1996 and 2001.

5. *Energy Policy and Conservation Act,* Public Law 94-163, 94th Cong., 1st sess., 1975.

6. National Energy Policy Development Group (NEPDG), *National Energy Policy* (Washington, DC: Executive Office of the President, 2001), 8-3.

7. M.A. Adelman, "The Real Oil Problem," 16-21.

8. Amy Myers Jaffe, "United States and the Middle East: Policies and Dilemmas," 8–9, in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

9. Stacy C. Davis and Susan W. Diegel, *Transportation Energy Data Book: Edition 23* ORNL-6970 (Washington, DC: United States Department of Energy, 2003), 2-1.

10. NEPDG, *National Energy Policy,* 2001.

11. United States Department of Energy, Energy Information Agency, *International Energy Annual 2002* (Washington, DC: Energy Information Agency, 2004), Table G.2, http://www.eia.doe.gov/emeu/iea.

12. "Kazakhstan Keen to Crash Kashagan Party," *International Petroleum Finance*, July 6, 2004: 1.

13. Robert Ebel, "Russian Oil: Boom or Bust," (Paper, Center for Strategic and International Studies, 2004), http://www.csis.org/energy/ebel010820.htm.

14. Gary Clyde Hufbauer, Jeffrey J. Schott, Kimberly Ann Elliott, *Economic Sanctions Reconsidered, Second Edition, Revised* (Washington, DC: Institute for International Economics, 1990), Executive Summary.

15. United States Department of Energy, Energy Information Administration, *Monthly Energy Review,* August 2004 DOE/EIA-0035 (Washington, DC: Energy Information Administration, 2004), 46, http://tonto.eia.doe.gov/FTPROOT/multifuel/mer/00350408.pdf.

16. Ecos Consulting, "Federal Oil Subsidies: How Can They Best Be Targeted?" 4–7, in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

17. United States Department of Energy, Energy Information Administration, *Federal Financial Interventions and Subsidies in Energy Markets 1999: Primary Energy* SR/OIAF/99-03 (Washington, DC: Energy Information Administration, 1999), viii, http://www.eia.doe.gov/oiaf/servicerpt/subsidy/pdf/sroiaf(99)03.pdf.

18. Marilyn Radler, "Worldwide Reserves Grow; Oil Production Climbs in 2003," *Oil and Gas Journal* 101, no. 49 (2003): 43.

19. United States Department of Energy, Energy Information Administration, *International Energy Outlook 2004* DOE/EIA-0484 (Washington, DC: Energy Information Administration, 2004), 44, http://www.eia.doe.gov/oiaf/ieo/index.html; and Canada National Energy Board, *Canada's Oil Sands: Opportunities and Challenges to 2015* (Calgary, AB: National Energy Board, 2004), 27.

20. Ibid., 61-72.

21. Bob Williams, "Heavy Hydrocarbons Playing Key Role in Peak-oil Debate, Future Energy Supply," *Oil and Gas Journal* 101, No. 29 (2003): 20; Alberta Chamber of Resources, *Oil Sands Technology Roadmap: Unlocking the Potential* (Edmonton, AB: Alberta Chamber of Resources, 2004), 63.

22. United States Department of Energy, Office of Fossil Energy, "Strategic Petroleum Reserve – Quick Facts and Frequently Asked Questions," August 3, 2004, http://fossil.energy.gov/programs/reserves/spr/spr-facts.html.

23. Ibid.

24. International Energy Agency, *Oil Supply Security: The Emergency Response Potential of IEA Countries in 2000* (Paris: Organization for Economic Cooperation and Development/International Energy Agency, 2001), 3.

25. K. Hellman and R. Heavenrich, *Light-Duty Automotive Technology and Fuel Economy Trends: 1975 Through 2003* (Washington, DC: United States Environmental Protection Agency, 2003), V.

26. In general, the Commission prefers market mechanisms over regulatory approaches. However, the Commission's analysis of the impacts of gasoline taxes as an alternative to regulating fuel-economy demonstrates that taxes, although more cost effective under certain conditions, would need to be increased to levels likely to be deemed politically unacceptable before they would begin to have a meaningful impact on fleet fuel economy or driving habits. Dan Meszler, Meszler Engineering Services, "Transportation Policy Options Policy Definitions and Discussion," 8, in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

27. In modeling these fuel economy gains, the current vehicle mix — in terms of cars vs. light trucks — was assumed to stay constant and the average fuel economy for each fleet was raised by the same amount. For example, to model a fleet-wide 10 mpg increase, it was assumed that the CAFE standard for light trucks and the CAFE standard for cars were each raised by 10 mpg.

28. Feng An and Amanda Sauer, "Comparison of Automobile Fuel Efficiency and GHG Emission Standards Around the World" (Draft Report, Pew Center on Climate Change, forthcoming), 18; and Mike Walsh, "Auto Ramblings: Global Trends in Transportation," in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

29. For purposes of comparison, GHG emission standards are translated into the equivalent fuel economy levels needed to achieve the standard.

30. AVL Powertrain, The Martec Group, and Meszler Engineering Services, *Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles* (Boston, MA: Northeast States Center for a Clean Air Future, 2004), also in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

31. Dan Meszler, Meszler Engineering Services, “Estimates of Cost-Effective Fuel Economy Potential for Passenger Vehicles Based Upon Relevant Data and Analyses Found in Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles,” in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004). The Commission sought input from Tom Austin of Sierra Research who reviewed the 2004 AVL Powertrain, The Martec Group, and Meszler Engineering study on behalf of the automobile industry. Mr. Austin's “Presentation to the National Commission on Energy Policy Regarding the NESCCAF Report on Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles,” can be found in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

32. National Research Council, Transportation Safety Board, *Effectiveness and Impact of Corporate Average Fuel Economy Standards* (Washington, DC: National Academy Press, 2002), 24–29.

33. United States Department of Transportation, National Highway Traffic Safety Administration, “Reforming the Automobile Fuel Economy Standards Program,” Advance Notice of Proposed Rulemaking, Docket Number 2003-16128 (2003), 9, http://www.nhtsa.dot.gov/cars/rules/cafe/rulemaking.htm.

34. United States Department of Transportation, National Highway Traffic Safety Administration, National Center for Statistics and Analysis, *Motor Vehicle Traffic Crash Fatality and Injury Estimates for 2003* DOT HS 809 755 (Washington, DC: Department of Transportation, 2004), 55, 86, 87. See also: Danny Hakim, “Safety Gap Grows Wider Between S.U.V.'s and Cars,” *The New York Times*, August 17, 2004.

35. A record of automobile industry concerns regarding cost and technology assumptions in the 2002 National Academy of Sciences study (National Research Council, *Effectiveness and Impact of Corporate Average Fuel Economy Standards)* is available at http://www.nhtsa.dot.gov/cars/rules/CAFE/docs/239572_web.pdf.

36. University of Michigan Transportation Research Institute and Michigan Manufacturing Technology Center, “Fuel Saving Technologies and Facility Conversion: Costs, Benefits, and Incentives,” 25–30, in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

37. Robert R. Nordhaus and Kyle W. Danish, Van Ness Feldman, “Manufacturer Facility Conversion Credit—International Trade Law Issues,” in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

38. University of Michigan, “Fuel Saving Technologies,” 35–39.

II. Reducing Risks From Climate Change

The United States should adopt a mandatory, economy-wide, tradable-permits system for limiting greenhouse gas emissions, with a safety valve designed to cap costs. The proposed program aims to accelerate progress in reducing the greenhouse gas intensity of the U.S. economy. The policy explicitly links the long-term pathway for U.S. reductions to mitigation efforts from developed and developing countries. To ensure continued access to affordable and reliable energy supplies, the Commission's proposal for limiting greenhouse gas emissions is supported by recommendations throughout this report that promote the development and early deployment of low- and non-carbon energy resources.

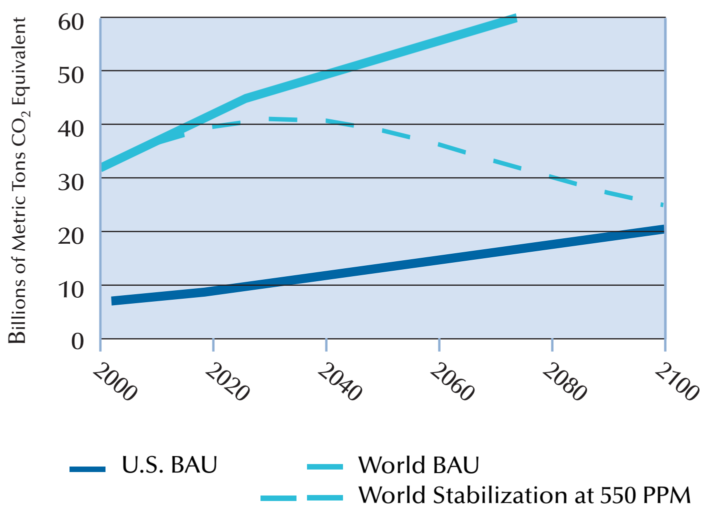
Climate change caused by energy-related greenhouse gas emissions is a century-scale, global issue that presents clear risks but is also characterized by significant uncertainties about both the costs and benefits of mitigation. The Commission seeks to establish a robust policy architecture for addressing these risks that can evolve along with scientific understanding, the range of possible solutions, and the prospects for collaboration with other nations. The Commission firmly believes that the United States must take a first step domestically, but must not do so to the competitive detriment of U.S. businesses internationally. Thus, the nation's initial actions must be sensitive to economic costs and must be framed as part of a global effort in which all major emitting nations assume a comparable level of commitment to reducing their contribution to climate risks.

This chapter describes a tradable-permits program that would begin to limit greenhouse gas emissions and create the market signals needed to stimulate long-term investment in climate-friendly energy alternatives. Recognizing that both U.S. and world emissions would have to decline substantially from current levels to stabilize greenhouse gas concentrations in the atmosphere, this proposal should be understood as an initial domestic step in the long-term effort to first slow, then stop, and ultimately reverse current emission trends. In its structure and stringency, the Commission's proposal is designed to encourage the timely initiation of what will necessarily be a phased process. The Commission believes that this approach is more pragmatic and ultimately more effective than years of further legislative stalemate in pursuit of a more aggressive initial goal.

Figure 2-1

Projected Global and U.S. Greenhouse Gas Emissions Trajectories

Stabilizing atmospheric concentrations of greenhouse gases will require significant global and domestic action.



Wigley, Richels, and Edmonds, 1996; NCEP projection

Regardless of initial stringency, the long-term success of any climate proposal to reduce greenhouse gas emissions depends upon the introduction of low-carbon energy sources in the quantities and in the timeframe needed to ensure substantial emission reductions and continued access to adequate and affordable energy.

Accordingly, the next chapters of this report describe a suite of policies to directly promote the development and early deployment of a variety of energy efficiency technologies and low-carbon energy resources.

A. ESSENTIAL CONTEXT: UNDERSTANDING THE RISKS OF CLIMATE CHANGE

Over the last decade, there has been growing scientific consensus that greenhouse gases are accumulating in the Earth's atmosphere as a result of human activity; that the resulting change in atmospheric composition is causing average temperatures to rise at a rate outside the range of natural variability; and that the resulting alterations in climatic conditions will continue and grow through the 21st century and beyond. Considerable uncertainty surrounds specific forecasts of future consequences, however, as well as estimates of the likely costs and benefits of alternate policy interventions.

Based on observations, paleoclimatological indicators of past climate change and its consequences, and computer models of the ocean-atmosphere system, the effects to be expected from greenhouse-gas-induced global warming are likely to include sea-level rise, altered patterns of atmospheric and oceanic circulation, and increased frequency and severity of floods and droughts. While increased concentrations of carbon dioxide in the atmosphere may entail near-term benefits for agriculture and forestry in some regions, broader climate change consequences over the mid- to long-term pose substantial risks to these same economic activities (agriculture and forestry) as well as to infrastructure investments (coastal facilities, heating and cooling capacity, and water supply), public health (increased disease vectors), and plant and animal habitat. Some regions are expected to experience climactic changes outside the uncertainty range for global-average values, with the potential for correspondingly larger impacts on well-being.

Satellites provide scientific data on meteorology, the ionosphere and the global climate.

Clearly, continued progress is needed in understanding the underlying climate science as well as the costs and benefits of various strategies for mitigation and adaptation. But current understanding of greenhouse gas-related climate risks is sufficient reason to accelerate, starting now, the search for a mix of affordable technical and policy measures aimed at: (a) reducing aggregate greenhouse gas emissions substantially from the business-as-usual trajectory over a relevant time frame, and (b) adapting to the degree of climate change that cannot be avoided without incurring unreasonable costs. This is not the only major challenge in fashioning a sensible energy policy for the United States, but it is a challenge that no sensible energy policy can ignore.

Many countries agree with this conclusion. In January 2005, the European Union will initiate an emissions trading system for carbon dioxide that covers more than 10,000 sources in 25 countries. Japan, which is already the most energy-efficient major economy in the world, subsidizes renewable energy both directly and through a national renewable portfolio standard, and is contemplating an emissions tax or cap-and-trade program to achieve further reductions. Canada is currently developing a domestic emissions trading program. Even some key developing countries have begun reducing their emissions below forecast levels as they pursue enhanced energy security, energy efficiency, conventional pollution control, and market reform. The proposal outlined below is designed to return the United States to a position of international leadership while protecting the nation's economy and global competitiveness.

B. POLICY RECOMMENDATION

for Limiting U.S. Greenhouse Gas Emissions through a Tradable-Permits Program

Key elements of the Commission's proposal for limiting U.S. greenhouse gas emissions include:

- ***Mandatory, economy-wide, tradable-permits system.*** The United States should implement a mandatory, economy-wide, tradable-permits system for limiting greenhouse-gas emissions. The permit system should go into effect in 2010 to allow adequate lead-time for businesses and to prepare for program implementation. In addition to carbon dioxide (CO_2), emissions covered by this program should include methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.

- ***Environmental target based upon annual reductions in emission intensity.*** Between 2010 and 2019, the target should be set to reflect a 2.4 percent annual reduction in greenhouse gas emissions per dollar of gross domestic product (GDP). Meeting this target would slow emissions growth from the currently projected rate of 1.5 percent per year to 0.4 percent per year.

- ***Cost cap.*** To limit possible costs to the economy, the government would sell additional permits at an initial price of $7 per metric ton of CO_2-equivalent ($MTCO_2e$). The price for additional permits (or so-called "safety valve" price) would increase by 5 percent each year in nominal terms. This annual increase is designed to modestly exceed inflation, resulting in a gradual escalation of the safety valve price in real terms.

- ***Permit allocation.*** The total volume of permits for a given year would be calculated and distributed well in advance based on available GDP forecasts. The Commission recommends that 95 percent of initial permits be issued at no cost to emitting sources. Beginning in 2010, 5 percent of permits would be auctioned to provide for new entrants and to finance advanced energy technology research, development, and early deployment. In 2013, the Commission recommends gradually increasing the quantity of permits auctioned by one-half of one percent per year (i.e., to 5.5 percent of the total target allocation in 2013, 6 percent in 2014, and so on) up to a limit of 10 percent of the total permit pool.

- ***Congressional review in 2015 and every five years thereafter.*** If major U.S. trading partners and competitors (including Canada, Europe, Japan, Russia, and such developing countries as China, India, Mexico, and Brazil) fail to implement comparable emission-control programs, escalation of the safety valve price and permit auction should be halted. Conversely, if the combination of international progress, technological advances, and scientific considerations warrant more aggressive U.S. action, Congress should strengthen program requirements.

- ***Long-term emission reduction pathway.*** Absent Congressional adjustment, targeted greenhouse gas intensity reductions should increase to 2.8 percent per year beginning in 2020. Meeting this target would amount to stopping further emissions growth. The Commission recognizes that emissions will ultimately need to be reduced substantially below current levels in order to stabilize atmospheric greenhouse gas concentrations, but has not sought to describe a global policy framework that could achieve reductions of this magnitude.

C. THE COMMISSION'S PROPOSAL

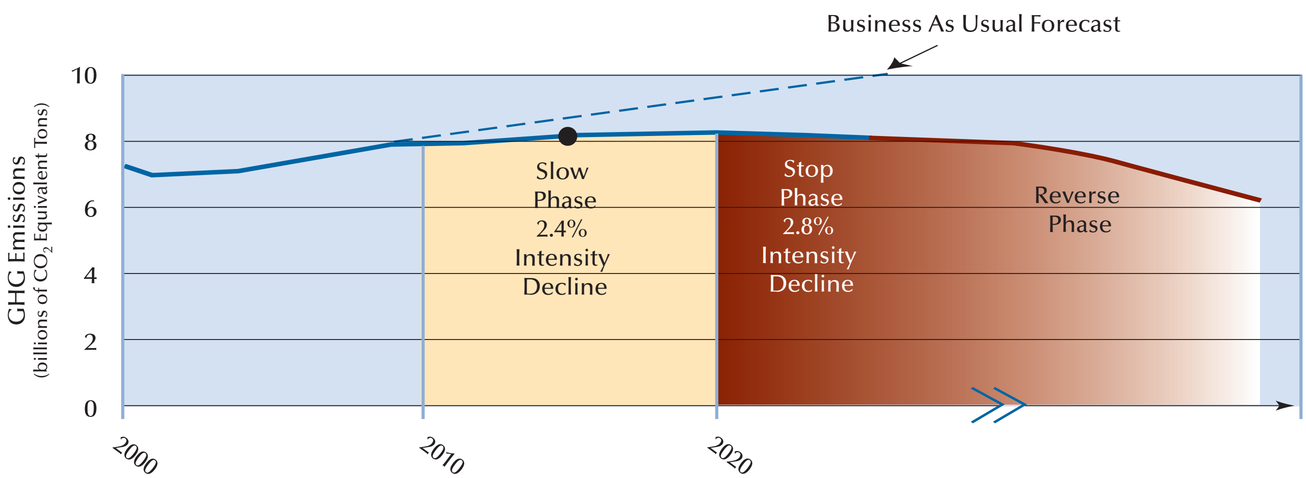
1. Policy Context for the Commission Proposal

The Commission's proposal for a tradable-permits program for greenhouse gases incorporates a number of important principles advanced over the last dozen years by successive presidential administrations. As a signatory to the original 1992 Framework Convention on Climate Change, the first Bush Administration recognized the concept of common but differentiated responsibilities among developed and developing nations. The Clinton Administration, in turn, emphasized a flexible policy response designed to elicit the most economical, environmentally equivalent emissions reductions regardless of when, or where, they are achieved. Most recently, the current Bush Administration has focused on the importance of technology development and has advanced an intensity-based approach to setting emission reduction goals. Finally, the

Figure 2-2

Commission Climate Proposal Timeline

The Commission recommendation is to slow, stop, and eventually reverse emissions growth, through an intensity-based target, contingent on action by other countries.



● Determination that major U.S. trading partners and competitors have implemented measurable and effective climate policies

NCEP

Commission's climate recommendations are informed by the conviction that the nation's environmental objectives can only be achieved if they are carefully integrated into a broader energy policy which is equally focused on supply and security imperatives. In particular, to the extent that policies addressing climate change reduce energy production, policies must be put in place to assure that replacement energy supplies become available at the same time. The proposal that follows, therefore, must be understood as fundamentally linked to all the other energy policy recommendations advanced in this report.

2. Emissions Target under the Commission Proposal

Under business-as-usual assumptions, national greenhouse gas emissions are expected to grow from 7.8 billion metric tons of CO_2 equivalent ($MTCO_2e$) in 2010 to 9.1 billion $MTCO_2e$ in 2020.[1] Excluding additional permits sales via the safety valve, the Commission's proposal would result in emissions of 8.1 billion $MTCO_2e$ in 2020, roughly 11 percent or 1 billion tons below business-as-usual levels.[2] Commission modeling indicates that the government will begin selling additional permits in 2015 via the safety valve such that actual reductions by 2020 (assuming no change in the program as a result of the first five-year review in 2015) would be closer to 540 million metric tons (6 percent) below business-as-usual projections. It is important to note that the latter figure represents a conservative estimate of likely program benefits. To the extent that available energy-economy models underestimate the technological innovation that will result once carbon reductions have real market value, sales of additional permits under the safety valve will be less than estimated and resulting emissions reductions will be greater, relative to business-as-usual expectations. If, after the first ten years of program implementation, the target rate of intensity reductions is increased to 2.8 percent per year, the domestic emissions budget would be reduced below 8.1 billion $MTCO_2e$ starting in 2020, or roughly the projected business-as-usual level in 2012.

3. Cost–Certainty: The Safety Valve

Although the effort to reduce greenhouse gas emissions is rooted in environmental concerns, the Commission believes that any such program must also address concerns over potential impacts on energy costs, economic growth, and competitiveness. Ultimately, addressing the threat of climate change will require global agreement about an ecologically sustainable emission limit and an equitable sharing of reduction burdens. Achieving the long-term environmental objective will likely require that fixed emission limits eventually replace cost-based policies. However, the Commission strongly believes that reducing uncertainty and likely opposition by explicitly capping program costs and impacts is the best path toward timely action. Hence, a key feature of the Commission's proposal is the inclusion of a safety valve, which effectively guarantees that the costs of emission reduction will not increase above the specified price — in this case, $7 per metric ton of CO_2-equivalent emissions beginning in 2010 and rising 5 percent annually. Unlike policies with a fixed emissions cap, where compliance costs are uncertain and can vary based on a host of factors ranging from the weather to economic growth and technology developments, policies with a safety valve limit costs and allow emissions to adjust in the face of adverse events. The level of the safety valve in the Commission's proposal reflects a judgment about the political feasibility of establishing a federal framework for reducing greenhouse gas emissions in the near term. It also falls within the range of benefits associated with climate change mitigation according to a number of recent studies, which have estimated those benefits at anywhere from $3 – $19 per metric ton of CO_2-equivalent.[3]

International allowance trading, credits for project-based emission reductions, and carbon sequestration in forests and soils will be important components of global greenhouse gas emissions reduction efforts. The Commission proposal does not incorporate these options at this time. The Commission recognizes, however, that such flexibility mechanisms — provided they are carefully designed and implemented —could augment its proposal by enabling further reductions, lowering costs, and helping developing countries to improve their energy infrastructure.

By choosing cost certainty over environmental certainty, the Commission's proposal explicitly caps costs while at the same time producing significant annual emission reductions. Depending on assumptions concerning future technological change, the proposed program would produce annual estimated emissions reductions ranging from 540 million to 1.0 billion $MTCO_2e$ below business-as-usual levels by 2020 and could lead to permit prices and costs below the safety valve level. The range of estimated reductions reflects the inherent uncertainty in forecasting the effects of increased research and development spending, enhanced early deployment programs, building and equipment standards, and other Commission proposals that are likely to reduce compliance costs and increase program benefits. With advance knowledge of future emissions budgets and safety valve levels, the Commission expects *immediate* effects on investment decisions concerning long-lived capital assets. The cumulative effect of the Commission's proposals to increase investment in energy technology, enhance efficiency standards, and affect near-term investment decisions suggests that overall program benefits will approach the upper end of the projected range of likely emissions reductions.

> ***"the Commission's proposal explicitly caps costs while at the same time producing significant emissions reductions"***

4. Impacts on Businesses and Households

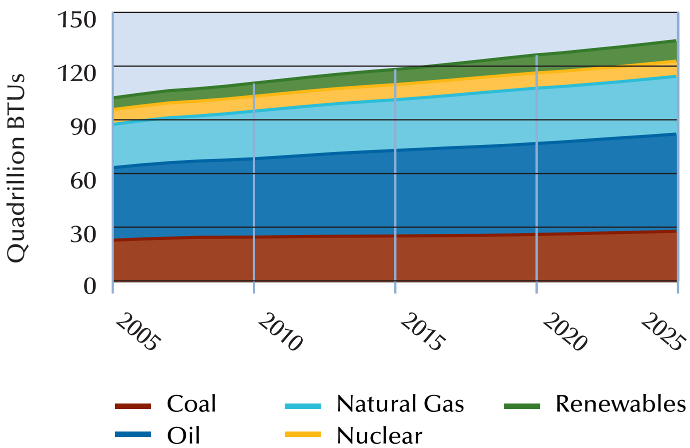
In modeling the economic impacts of its greenhouse gas tradeable-permits proposal, the Commission focused on consequences for energy markets, industrial activity, and individual households. The models reveal that half of the estimated 540 million $MTCO_2e$ emissions reduction achieved in 2020 under

Figure 2-3

Projected Energy Consumption under Commission Plan

Under the Commission's greenhouse gas proposal from 2004-2020:

- coal use increases 16%
- renewables increase 60%
- oil use increases 30%
- nuclear increases 5%
- natural gas use increases 30%



Data Source: NCEP NEMS Modeling

standard modeling assumptions comes from reductions in greenhouse gases other than CO_2 — in particular, from industrial gases such as hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. As a result, projected energy-related emissions fall by only 3.7 percent relative to business-as-usual assumptions, even as total emissions fall 5.9 percent. Further, total energy consumption declines by only 1 percent relative to forecasted levels by 2020, while growing 14 percent in absolute terms between 2010 and 2020.

According to the Commission's modeling analysis, the largest relative changes under the proposed tradable-permits program are seen in coal and renewable energy production. Projected coal consumption in 2020 grows by 16 percent compared to current (2004) consumption, but falls roughly 9 percent compared to business-as-usual projections. In contrast, renewable energy production grows 60 percent above current levels, compared to only 32 percent in the reference case. Natural gas prices rise by about 7 percent above business-as-usual levels by 2020 but consumption remains roughly the same. Most of these changes occur in the electric sector where new renewable energy plants displace new coal-fired generation and prices rise by 5–8 percent. Specifically, the Commission's modeling predicts that an additional 42 gigawatts (GW)[4] of renewable capacity are built by 2020 under the proposed policy, while an additional 0.7 GW of existing coal capacity are retired over the same timeframe.

In the transportation sector, gasoline prices are projected to increase under the trading program by 4–6 cents per gallon relative to current forecasts (see Figure 2-4). As a result, this policy alone would be expected to produce very little improvement in the fuel efficiency of passenger cars and very little reduction in vehicle-miles traveled. Coupled with the fuel economy recommendations in Chapter I, however, the Commission expects average new vehicle fuel economy to rise significantly in the 2010–2015 timeframe.

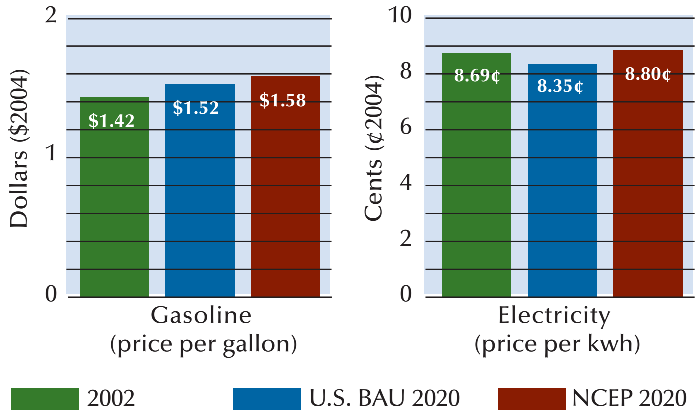
In addition to estimating the impact of its proposal on energy markets, the Commission analyzed aggregate impacts on the economy, households, and specific industrial sectors.[5] Charles River Associates estimate that the Commission's climate recommendations would cost the typical U.S. household the welfare equivalent of $33 in 2020 (2004

Energy intensive industries continue to play a vital role to the U.S. economy.

Figure 2-4

Household Energy Prices

Residential energy prices rise 4% to 5% in 2020 under the Commission proposal.



Data Source: NCEP NEMS Modeling

dollars) and result in a slight reduction in expected GDP growth, from 63.5 percent to 63.2 percent between 2005 and 2020.

5. Equity and Competitiveness Considerations

The Commission's recommended policy is designed to protect the U.S. economy from competitive disadvantage if other nations fail to limit greenhouse gas emissions. The proposal is explicitly phased and attempts first to slow emissions growth before seeking to stop emissions growth. If other countries with significant emissions and/or trade with the United States do not take comparable action to limit emissions by 2015, five years from the commencement of the U.S. program, further increases in the safety valve price should be immediately suspended. Depending on international progress, the United States could also opt not to introduce a more ambitious target rate of emissions intensity improvement in 2020 and make other adjustments to its domestic program; conversely it could decide to move forward more aggressively in the second decade of program implementation than the Commission is proposing.

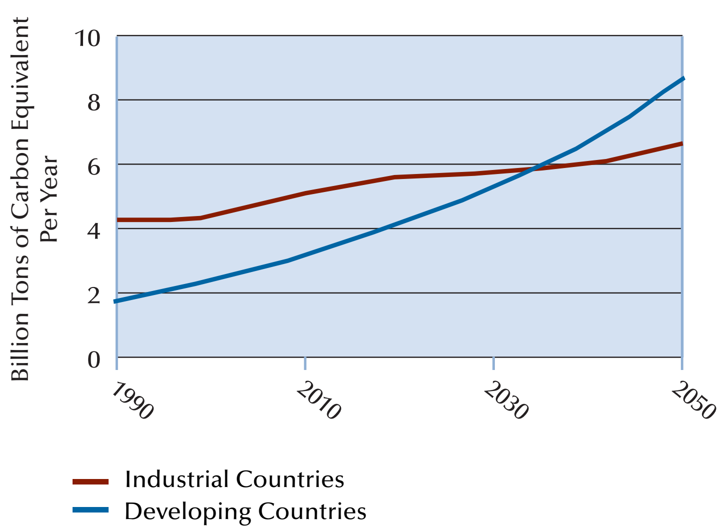
To encourage emissions mitigation efforts by major developing nations, the United States should continue and expand its current bilateral negotiations with such nations as China, India, and Brazil. In addition, the United States should consider providing incentives to promote technology transfer and to encourage U.S. companies and organizations to form international partnerships for implementing clean energy projects in developing nations.

While anticipated emissions reductions under the Commission's proposal are nowhere near those required for the United States under the Kyoto Protocol (which envisioned a 30 percent reduction below business-as-usual levels by 2012), they do represent an important first step toward limiting the nation's greenhouse gas emissions. The recommended safety valve price in the first phase of the Commission's proposed program is roughly half the current $11 per ton CO_2-equivalent forward price for permits that purchasers expect to use in the European Union's Emissions Trading Scheme starting in January 2005.

Figure 2-5

Global GHG Emissions

If current trends continue, developing world emissions will surpass those of the industrialized nations in the next several decades.



Manne and Richels, 2004

Though differing in timing, the projected 0.5 to 1.0 billion $MTCO_2e$ reductions achieved under the Commission's proposal in 2020 are similar in magnitude to the reductions envisioned under domestic climate proposals developed by the Clinton and current Bush Administrations, as well as the McCain-Lieberman Climate Stewardship Act (see text box). The Bush Administration's climate initiative seeks to achieve some 400 million metric tons of voluntary domestic reductions by 2012. Recent analysis of the proposed McCain-Lieberman Climate Stewardship Act, as amended, predicts domestic reductions of up to 1.5 billion metric tons per year relative to business-as-usual levels by 2020, and a permit price as low as $9 per ton of CO_2-equivalent emissions in 2010.[6]

Table 2-1

Comparison of Commission GHG Proposal to Other Domestic Climate Change Policies[a]

		Commission Proposal	Bush Climate Initiative	McCain Lieberman Bill[b]	Kyoto Protocol[c]
Mandatory / Voluntary		mandatory	voluntary	mandatory	mandatory
Target type		emission intensity	emission intensity	absolute emissions	absolute emissions
Cost limit		yes	N/A	no	no
2010	Expected domestic emission reductions	200 million tons	300 million tons (goal)	550 million tons	1.2 billion tons
2010	Permit price ($/ton CO_2 equivalent)	$5[d]	N/A	$9–$16	$51
2010	Estimated Cost in 2010	$500 million	N/A	$2.5–$4.3 billion	$31 billion
2020	Expected domestic emission reductions	0.5-1 billion tons[e]	850 million tons (extrapolated goal)	1.5 billion tons	1.7 billion tons
2020	Permit price ($/ton CO_2)	$7	N/A	$15–$36	$44
2020	Estimated Cost in 2020	$2-4 billion	N/A	$11–$27 billion	$37 billion

Notes:

a All prices and costs are in constant 2004 dollars; tons are CO_2-equivalent. Cost for each policy is computed for domestic emission reductions only, based on an average cost equal to one-half the permit price.

b The low permit price estimates are from S. Paltsev, et al. *"Emissions Trading to Reduce Greenhouse Gas Emissions in the United States: The McCain-Lieberman Proposal,"* 2003 (Table 5, Scenario 12). The domestic emission estimates and higher prices are from, Energy Information Administration (EIA), *"Analysis of Senate Amendment 2028, the Climate Stewardship Act of 2003,"* Table B20.

c The reduction and price estimates under the Kyoto Protocol are based on the "1990+9%", or "moderate international activities" scenario contained in EIA's, *"Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity."* (Washington, DC: Energy Information Administration, 1998): Tables ES-1 and ES-2.

d Commission modeling predicts that the cost of a permit in 2010 under the Commission's proposal will be $5 per ton of CO2-equivalent, lower than the safety valve price of $7 per ton.

e The low end of the emission reduction range corresponds to the greenhouse gas (GHG) Trading Scenario included in the Commission's economic analysis and described in the Technical Appendix to this report. Modeling results for this Scenario project additional permit sales under the safety valve mechanism starting in 2015. The upper end of the emissions reduction range corresponds to a scenario in which permit prices and costs are lower than expected based on technological advances prompted, in part, by the Commission's research, development, and deployment recommendations (see, for example, the Advanced Technology + GHG Trading Scenario modeled by the Commission). In this case the marginal cost of emissions reductions remains below the safety valve price and total emissions stay within the limit set by the intensity-based reduction target.

COMPARISON OF COMMISSION PROPOSAL TO OTHER DOMESTIC AND INTERNATIONAL POLICIES

Several policies have been proposed that attempt to address the U.S. contribution to global climate change risks by establishing quantitative targets for national greenhouse gas emissions. These domestic proposals are summarized below:

- The Bush Administration in 2002 announced a national goal of reducing greenhouse gas emissions intensity — that is, emissions per dollar of real GDP —by 18 percent from 2002 to 2012. The primary mechanism for achieving this goal has been voluntary efforts by major emitting industrial sectors.

- Senators McCain and Lieberman in 2003 proposed a mandatory cap and trade program for the U.S. that would aim to return emissions to 2000 levels by 2010–2015. The legislation would have permitted regulated entities to satisfy 15 percent of their obligation through international offsets or sequestration projects. As a result, the actual domestic emissions limit under this program is roughly equal to projected 2010 emissions (i.e., 2000 levels plus 15 percent).

- The Kyoto Protocol would have required the United States to reduce its emissions to 7 percent below 1990 levels — or a projected reduction of 2.1 billion tons in 2010. It was assumed that many of these reductions would be met through the purchase of project-based offsets or allowances under the flexible mechanisms incorporated in the Protocol. (A central estimate by EIA predicted that roughly half of the required reductions would be achieved domestically.) With the Russian Federation's recent ratification, the Kyoto Protocol will enter into force in early 2005, absent U.S. participation.

The Commission believes the U.S. should focus on achieving domestic emissions reductions while intensifying bi-lateral negotiations with major developing nations that have no emission reduction obligations under Kyoto. At the same time, the Commission recognizes that a number of countries that have ratified the Kyoto Protocol have begun taking meaningful steps to address their contribution to global greenhouse gas emissions, even as it is becoming evident that actually meeting the original Kyoto goals will be quite challenging. Recent efforts by the European Union, Japan, and Canada, in particular, provide useful context for the Commission's recommendation:

- The European Union (EU) is furthest along in developing policies to meet its Kyoto obligation and plans to initiate an EU-wide emissions trading program in 2005. Following a warm-up phase from 2005 to 2007, the program is expected to be fully effective by the Kyoto start date of 2008. The trading program is designed to cover the majority of stationary sources in the EU and will account for approximately half of the continent's CO_2 emissions, making it the largest emissions trading program in the world. Trading in advance of the program suggests an allowance price of between $5 and $10 per metric ton of CO_2. Trading has recently accelerated following Russia's announced ratification of the Kyoto Protocol.

- Canada in 2003 released a plan to achieve three-quarters of its emissions reduction obligation under the Kyoto Protocol through a combination of voluntary efforts and traditional regulation, including an emissions trading program for so-called "large final emitters." The trading program requires a reduction in emissions intensity of roughly 15 percent below projected levels for 2010 and caps costs through a safety valve mechanism similar to the Commission's proposal. The proposed Canadian safety valve is currently set at a price equivalent to approximately U.S. $12 per metric ton of CO_2. At present, however, the status of Canada's plan is uncertain, given a recent change in government and a lack of implementing legislation. Both the government and business interests are concerned about Kyoto's impact on the competitiveness of the Canadian manufacturing sector, given that approximately 85 percent of national exports are to the United States.

- To date, Japan's strategy for meeting its Kyoto obligations has centered on a series of voluntary commitments by 40 industry sectors. These commitments are intended to return Japan's emissions to 1990 levels by 2010, with sequestration and reductions of other gases estimated to bring the country close to achieving its Kyoto target of reducing emissions by 6 percent *below* 1990 levels. With government encouragement, Japanese companies have become the largest buyers of international emission credits, responsible for some 41 percent of international credit purchases in 2003. Japan has committed to review its climate policies in 2004 and 2007 and to consider whether additional action will be required to achieve its Kyoto target. It is not clear at this time whether Japan will implement a domestic cap and trade program

6. Allocation & Point of Regulation

Allowance Auctions — Most economists favor auctioning allowances and using the resulting revenues to offset taxes on investment or income. While this approach is theoretically most cost-effective from a macro-economic standpoint because the revenues raised from the auction can be used to offset distortionary taxes, it suffers from several political liabilities. First, a substantial auction significantly increases the costs imposed on carbon-intensive industries. Second, this approach raises distributional issues depending on how auction revenues are recycled. Finally, many express discomfort with the idea of the government collecting and then re-allocating tens of billions of dollars in annual auction revenue.

In light of these and other concerns, emissions trading programs in the United States and other countries have to date allocated the vast majority of permits freely to emitters while setting aside a small pool of permits to be auctioned — primarily as a means of ensuring market access for new entrants. Recent cap-and-trade proposals, including the Bush Administration's original Clear Skies Initiative for reducing power sector air pollution emissions and the European Union's National Allocation Plans have also used this approach. The Commission recommends that Congress follow these precedents. Specifically, the Commission proposes an initial auction of 5 percent of total permits for the first three years that the program is in effect (i.e., from 2010 through 2012), growing thereafter at a rate of 0.5 percent per year up to a limit of 10 percent of the total permit pool. The purpose of the auction is to accommodate new entrants and provide funds for energy technology research and early deployment. Over the course of a decade, the Commission's analysis indicates that this auction would generate $26 billion in revenue.

Allocation Approaches — Emission allowances represent a valuable asset for which a variety of competing interests that may be adversely affected — for example, fossil fuel producers, energy-intensive industries, miners, state and local communities, and advocates for the poor — will claim a share. Once the decision has been made to distribute allowances to emitters, the manner in which allowances are allocated among various claimants will have little impact on overall societal costs or benefits because the price signal created by a tradable-permits program in competitive markets should be the same under any allocation approach. (An exception to this general rule may occur in the case of electricity markets where utilities — to the extent they are still regulated — may not be able to pass all or any implied allowance costs through to consumers if permits have been grandfathered. This would lead to a smaller electricity price signal than in the case where the utility must purchase permits.)

"a policy designed to protect the U.S. economy from competitive disadvantage if other nations fail to limit greenhouse gas emissions"

Allocation decisions will, however, have important distributive impacts and as such may bear heavily on the perceived fairness and political viability of greenhouse gas mitigation policies. The Commission has not sought to develop specific formulae for allocating allowances. However, the Commission recommends that Congress allocate permits in a manner that recognizes the disparate burdens created by greenhouse gas regulation. The Commission also recommends that specific attention be directed toward addressing impacts on low-income

Glacier Bay National Park and Preserve, Alaska.

and minority households.[7] A recent study conducted for the Commission by the Congressional Black Caucus, for example, found that African-American households dedicate a roughly 25 percent greater share of income to energy and energy-related goods than the average U.S. household.[8] The study also concluded, however, that the impacts of climate change itself — if unaddressed — could worsen existing inequities in the United States, while policies intended to limit greenhouse gases could generate large health and economic benefits for African Americans, or could impose additional costs, depending on how they are structured.

Point of Regulation — A final design issue that Congress must address is where in the economic chain to impose the requirement to hold emissions permits. That requirement could in theory be imposed "downstream" on individual consumers, "upstream" on fossil fuel producers, or at any of several points in between. A primary argument for regulating greenhouse gas emissions upstream is administrative simplicity. Using an upstream approach, it is possible to capture virtually all carbon emissions in the economy by regulating a relatively small number of entities. Advocates for upstream approaches also argue that they are more efficient because they place the regulatory burden at the earliest point in the energy supply chain, thus enabling the widest array of responses. Critics of upstream regulation, however, contend that emission limits should be imposed closer to the point of end-use consumption where behavioral changes are needed to reduce greenhouse gas emissions. Finally, there is concern in the refining industry that refiners cannot fully recover the costs imposed by upstream emission limits.

As in the case of permit allocations, decisions about the point of regulation will be hotly contested and the outcome will bear heavily upon the likelihood of program adoption. The Commission believes, however, that these decisions are fundamentally political and do not affect the overall societal costs or benefits of the proposed climate change program. Therefore, the Commission believes that these decisions are best explored and resolved in the political arena.

Notes:

1. United States Department of Energy, Energy Information Administration, *Annual Energy Outlook 2004 with Projections to 2025* DOE/EIA-0383 (Washington, DC: Energy Information Administration, 2004), 62, Table 19, http://www.eia.doe.gov/oiaf/aeo/index.html.

2. While the program could be weakened or strengthened as a result of the first 5-year review, the modeling presented here assumes that that the 2.4 percent annual intensity reduction target and the 5 percent annual nominal increase in safety-valve price continue from 2010 through 2019.

3. See Intergovernmental Panel on Climate Change, Working Group III, *Climate Change 2001: Mitigation* (Cambridge, UK: Cambridge University Press, 2001), Chapter 6; and Intergovernmental Panel on Climate Change, Working Group II, *Climate Change 2001: Impacts, Adaptation, and Vulnerability* (Cambridge: Cambridge University Press, 2001), Chapter 19; Kenneth Gillingham, Richard Newell, and Karen Palmer, Resources for the Future, "Retrospective Examination of Demand-side Energy Efficiency Policies", Table 13, in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

4. One gigawatt equals 1,000 megawatts or 1 million kilowatts.

5. Note that the economy-wide cost analysis only includes the impacts of the greenhouse gas tradeable-permits program.

6. Sergey Paltsev, John M. Reilly, Henry D. Jacoby, A. Denny Ellerman, and Kok Hou Tay, *Emissions Trading to Reduce Greenhouse Gas Emissions in the United States: The McCain-Lieberman Proposal* Report 97 (Cambridge, MA: Massachusetts Institute of Technology Joint Program on the Science and Policy of Global Change, 2003), Table 5, Scenario 12.

7. An important existing program in this regard is the federal Low Income Home Energy Assistance Program (LIHEAP), which provides grants to low-income households for weatherization and energy-related home repairs, as well as to help pay fuel and utility bills. The LIHEAP program has been in existence since 1981 and annual funding levels have generally fluctuated between $1 and $2 billion since that time. Past funding has not, however, been adequate to assist more than a fraction of eligible households (an estimated 15 percent in 2001, for example).

8. Congressional Black Caucus Foundation, Inc., and Redefining Progress, *African Americans and Climate Change: An Unequal Burden* (Washington, DC: Congressional Black Caucus Foundation, Inc., 2004), 4, also in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

III. Improving Energy Efficiency

Energy efficiency has a vital role to play in the transition to a more prosperous, secure, and environmentally sustainable energy future. Over the last 30 years, efficiency standards, building codes, technology incentives, informational programs, and other policies have proved effective at countering pervasive market failures that would otherwise lead to systematic under-investment in energy efficiency. To capture the potential for additional efficiency gains, the Commission recommends updating and expanding efficiency standards for new appliances, equipment, and buildings; integrating improvements in efficiency standards with targeted technology incentives, R&D, consumer information, and programs sponsored by electric and gas utilities; and pursuing further efficiency opportunities in the industrial sector, and the passenger car and heavy-duty truck fleets.

A. OVERVIEW

Energy efficiency advances all of the critical policy objectives identified elsewhere in this report and must therefore feature prominently in the larger portfolio of strategies required to successfully manage the nation's, and the world's, short and long-term energy challenges. Credible projections suggest that world energy demand will increase by 34–75 percent between 2001 and 2025 as developing nations modernize and developed nations continue to expand their economic output.[1] If one assumes growth at the high end of the range (75 percent) it becomes challenging to construct a scenario in which secure, low-carbon energy supplies can keep pace with increased demand. In these high-growth scenarios, the world is presented with untenable choices between diminished prosperity, security, and environmental quality.

"evidence indicates that consumers and business managers routinely forego efficiency opportunities with payback times as short as 6 months"

Increasing the rate of improvement in domestic and global energy efficiency is therefore critical as a complement to developing new energy supply options and expanding the contribution from low-carbon technologies. Because the United States consumes more energy than any other nation in the world, increasing domestic energy efficiency can have a notable effect on global energy demand. Equally important, developing and exporting advanced efficiency technologies can boost the U.S. economy while helping other nations find a more sustainable pathway toward prosperity. Here and elsewhere, by 'energy efficiency' the Commission means doing more with less, as opposed to suffering hardships or closing businesses. The aim is not to dictate lifestyle choices, but to help households and businesses get equivalent or better service from less energy.

Unfortunately, however, market forces alone are unlikely to deliver the full potential of energy savings given a host of market failures that tend to discourage efficiency investments even when they are highly cost-effective. Informational barriers, split incentives, distortions in capital markets, and failures in rental and equipment resale markets are among the many underlying structural problems that provide a justification for government intervention to promote efficiency in buildings and equipment. For example, split incentives occur when purchasing decisions for energy-using equipment are made by people who will not be responsible for paying energy bills, such as landlords, developers, and industrial buyers. Many buildings are occupied by a succession of temporary owners or renters, each unwilling to make long-term improvements that would mostly reward subsequent users. Sometimes what looks like apathy about energy use merely reflects inadequate information or time to explore more efficient alternatives, as anyone knows who has rushed to replace a broken water heater, furnace, or refrigerator. In the specific and particularly consequential case of commercial building design, architects and consulting engineers are generally paid as a percentage of job cost and have little incentive to take extra time to design more energy-efficient buildings, given that doing so would earn little if any extra compensation (because efficiency features add little, if anything, to the cost of the building itself, from which the designer's fee is calculated).

In the case of passenger vehicles, consumers obviously consider a wide array of attributes when making purchasing decisions. Fuel economy is one of those attributes, and it appears clear that consumers do not calculate lifetime fuel savings when choosing a vehicle. Although this might seem rational at first glance, given that most purchasers of a new vehicle probably do not expect to keep the vehicle for its full useful life, it does not explain why longer-term fuel savings would not be factored into the re-sale value of the vehicle and thus be appropriately valued at the time of initial purchase. In fact, surveys conducted by the auto industry suggest that, on average, car buyers value potential fuel savings over three years when purchasing a product that, on average, lasts for thirteen years. Various theories have been proposed to account for this apparent undervaluation of fuel savings in both new- and used-car markets and there is strong disagreement over whether consumers' purchasing behavior with respect to vehicle efficiency characteristics is indicative of a market failure.[2] Still, it is clear that technologies exist to significantly increase vehicle fuel economy that will more than pay for themselves through fuel savings.

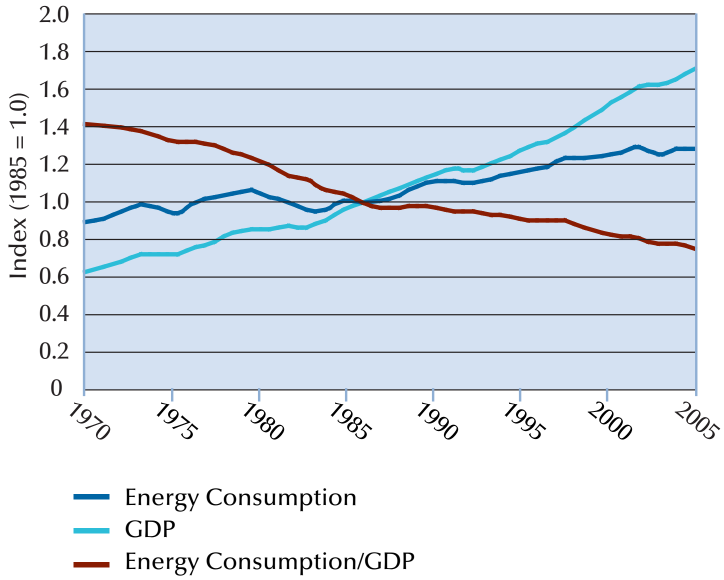
Benefits of Past Efficiency Programs

For the variety of reasons discussed above, private investment in energy efficiency tends to fall far short of socially optimal and economically justified levels. Indeed, considerable empirical evidence indicates that consumers and business managers routinely forego efficiency opportunities with payback times as short as 6 months to three years — effectively demanding annual rates of return on efficiency investments in excess of

Figure 3-1

Energy Intensity of the U.S. Economy

Due to increased efficiency, the energy required to support economic growth has steadily declined over the past 30 years.



Data Source: Energy Information Administration, 2004

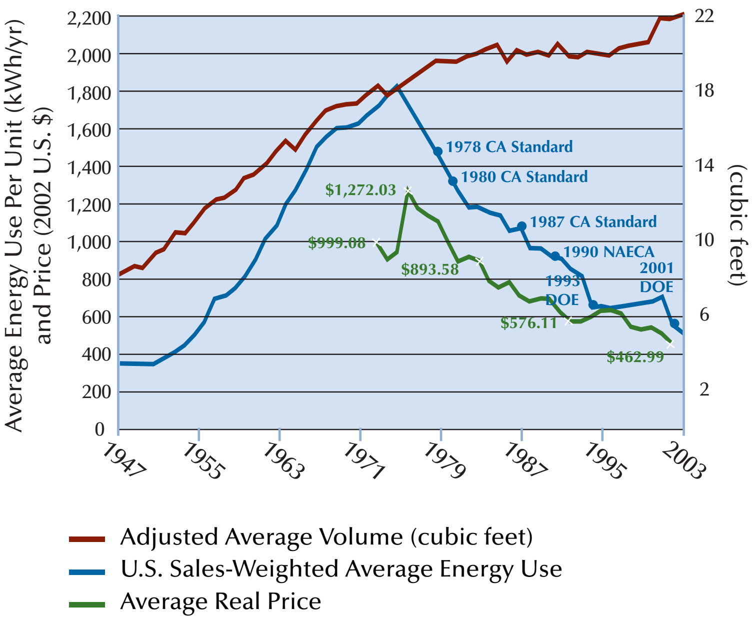
40–100 percent. Energy-related equipment standards and building codes, which were first introduced in the 1970s, represent one important strategy for addressing this phenomenon: an analysis conducted for the Commission by Resources for the Future estimates that national energy savings from appliance standards alone totaled approximately 1.2 quadrillion British thermal units (quads)[3] in 2000, or about 3 percent of overall buildings-related energy use. These savings were achieved at a cost of approximately $2.8 billion per quad — far less than the average cost of non-transportation energy at $6.1 billion per quad in 2000.

Meanwhile, on the transportation side, fuel economy standards for passenger vehicles were enacted in 1975; together with substantially higher gasoline prices in the late 1970s and early 1980s, these standards increased the fuel economy of new passenger vehicles by 75 percent over the next decade. A 2002 report by the National Academy of Sciences (NAS) estimated that vehicle fuel economy standards saved the nation 2.8

Figure 3-2

U.S. Refrigerator Energy Use Over Time

A concerted government and industry effort since the 1970s has led to significant energy savings from refrigerators without sacrificing size or price.



Geller and Goldstein, 1999

million barrels of oil per day in 2000, or 15 percent of that year's oil consumption.

Prospects for Future Energy Savings

Together, the residential, commercial, and transportation sectors account for roughly 66 percent of total U.S. energy consumption. Merging results from available analyses of efficiency opportunities in each of these sectors, the Commission concludes that it is possible to cost-effectively reduce the nation's annual energy consumption by at least 16 quads per year in 2025 in these three sectors using known efficiency technologies.[5] Additional energy savings are possible in the industrial sector as well.

Buildings, Equipment, Manufacturing, and Industrial Processes — Substantial additional energy and cost-savings could be achieved over the 2010–2030 timeframe by updating and expanding existing building codes and appliance and equipment standards with respect to a wide range of residential and commercial end-uses, and industrial equipment. Specifically, a separate study conducted for the Commission by researchers at Lawrence Berkeley National Laboratory (LBL) finds that upgraded codes and standards could produce cumulative energy savings of 14.2 quads in

Consider the Refrigerator

Over the quarter century following World War II, this household appliance became the largest single energy user in most American homes. It more than doubled in size, added steadily larger and colder freezer units, and acquired automatic defrosting. Manufacturers also cut production costs in ways that degraded operating efficiencies, so that even the small manual-defrost refrigerator of the 1970s used 70 percent more energy than its 1940s counterpart.

These trends, coupled with steady growth in the number of households, drove energy consumption by U.S. refrigerators up by almost 10 percent per year between 1946 and 1974. By then, refrigerators alone consumed an amount of electricity equivalent to the combined output of more than 30 large coal-fired power plants; if the postwar rate of growth had persisted for another three decades, that figure would have swelled more than ten-fold. And to make matters worse, refrigerator manufacturers had to shed ozone-depleting chlorofluorocarbons during the 1990s, an adjustment that most experts had considered impossible without significant additional increases in energy use.

Remarkably enough, today's average refrigerator uses less than one-fourth the electricity of its 1970s counterpart, despite continued gains in amenity. What once was an energy guzzler is now the equivalent of a 50-watt light bulb, and the resulting cost and energy savings are measured in the tens of billions of dollars and the tens of thousands of megawatts.[4]

The refrigerator story is one of industry and government cooperation, based on effective coordination of federal and private sector research budgets, utility-financed incentives for customers to purchase efficient models, and government efficiency standards at both state and federal levels. Its results demonstrate that better energy services do not necessarily require more energy use.

Cost effective fuel economy improvements could be achieved in heavy-duty trucks through a variety of existing and emerging technologies. *Mojave Desert, Southern Nevada*

residential buildings and 16.8 quads in commercial buildings over the 2010–2030 timeframe. Energy savings of this magnitude would offset approximately 25 percent of the cumulative increase in residential and commercial building energy consumption projected to occur between 2010 and 2030.[6] According to LBL, the most substantial additional efficiency opportunities involve electric water heating, miscellaneous electronics, motors, and lighting in residential buildings and refrigeration, lighting, air conditioning, and office equipment in commercial buildings. To this list, the Commission would add residential air conditioning and distribution transformers for the commercial, industrial, and electricity sectors. Estimated lifecycle costs of conserved energy for efficiency improvements among all the end-uses considered in the LBL study range from 1–5 cents per kilowatt-hour.

A promising example in the case of building codes is the new "E-Benchmark" standard for commercial buildings from the New Buildings Institute, which aims to reduce energy needs typical of current practice by at least 30–50 percent while meeting rigorous tests of cost-effectiveness.[7] At all levels of government, recurrent failures to fund the timely analysis, development, and adjustment of standards present patently false economies. In addition, the nation's utilities have a proven capacity to provide leadership and financial support in promoting code compliance; the relatively modest investments involved will yield extremely inexpensive reductions in generation and capacity needs.

The industrial sector has made greater improvements in energy efficiency than most others, but significant opportunities remain. A recent review of 11 industrial sector efficiency surveys found median estimates for untapped, cost-effective savings of more than 20 percent for electricity and nearly 10 percent for natural gas.[8] To cite just one example, the U.S. Department of Energy's (DOE's) Best Practices Program has a well-documented track record of developing tools that help plant managers identify energy-efficiency improvements in their operations. However, the need for these and other tools far exceeds the resources of the program, at a time when the international competitiveness of the nation's industrial base is being challenged, particularly in its most energy-intensive industries.

Passenger Vehicles **—** Passenger vehicles and heavy-duty trucks accounted for 80 percent of energy consumed by the transportation sector in 2002.[9] The previously mentioned 2002 NAS study found that passenger vehicle fuel economy could be improved from today's level of 24 mpg to 31 mpg by 2012-2017, using conventional technologies that would pay for themselves in fuel savings over the life of the vehicle.[10] The study did not examine other technologies with considerable fuel-saving potential (i.e., hybrids and diesels) because, at the time, hybrids were just coming into the market at prices heavily subsidized by the manufacturers and there were questions about whether diesel-powered passenger vehicle would be able to meet emission standards. Since the NAS completed its work, there is mounting evidence of solid consumer interest and manufacturer commitment to hybrids, and notable progress in diesel emission control technologies.

In recognition of the further technological advances that have occurred since the NAS study, the 2004 analysis of potential vehicle greenhouse gas reductions by Martec and AVL (first discussed at page 11 of this report) employed a sophisticated simulation model to examine the potential savings of various vehicle

Table 3-1

Evaluation Parameters from Recent Fuel Economy Studies

Study	Fuel Price (per gallon)	Discount Rate (%)	Payback Period	Vehicle Mileage	**Cost-Effective Fuel Economy**
NAS 2002	$1.50	0	3	15,600 first year, 4.5% annual decline	**25 mpg**
		12	14		**31 mpg**
Sierra 1999	$1.20	10	10	MOBILE5-based, values unspecified	**28 mpg**
EEA 2001	$1.50	8	4	unspecified	**31 mpg**
			15		**34 mpg**
MIT 2000	$1.37 ±0.31	unspecified	15	12,427 miles/year	**not estimated**
ACEEE 2001	$1.35	5	12	12,000 miles/year	**41 mpg**

Data Sources: National Academy of Sciences 2002, Sierra Research 1999, Energy and Environmental Analysis 2002, Massachusetts Institute of Technology 2000, American Council for an Energy Efficient Economy 2001

technology packages including hybrids and diesels.[11] The results indicated that average vehicle fuel economy could be cost-effectively increased to between 32 and 44 mpg by 2016, or a roughly 35–80 percent increase over current levels of fuel economy.[12] The "low end" 32 mpg estimate represents the cost-effective efficiency potential using conventional technologies and assuming a gasoline price of $1.58 per gallon; the "high end" 44 mpg estimate is based on penetration of full hybrid technology into most of the fleet and assumes $2.00 per gallon gasoline. These estimates are based on detailed modeling of five major vehicle classes (small car, large car, small truck, large truck, and minivan) and are consistent with the fuel-economy ratings achieved by a number of hybrid and diesel vehicles that are already on the market (e.g., the Honda Insight achieves 56 mpg; the Toyota Prius, 55 mpg; the Honda Civic Hybrid, 48 mpg; the Volkswagon Diesel Golf, 41 mpg; and the Ford Escape Hybrid, 34 mpg).[13] It is important to note that weight reduction was excluded in the Martec/AVL analysis as a possible strategy in order to minimize safety concerns related to down-weighting.

In addition to reviewing recent fuel economy studies, the Commission employed the Energy Information Administration's National Energy Modeling System (NEMS) to obtain additional information about the potential benefits and impacts of higher levels of new vehicle fuel economy. Specifically, the Commission modeled a 10, 15, and 20 mpg increase above the current combined car and light truck fuel-economy level of 24 mpg. These three fuel-economy scenarios were phased in over a five-year period starting in 2010; however, the Commission recognizes that the 20 mpg-increase scenario would likely require a longer lead time. As discussed in Chapter I, fuel-economy improvements of this magnitude would reduce projected oil consumption by between 2 and 3.5 million barrels per day, and diminish carbon dioxide emissions by 250 and 400 million

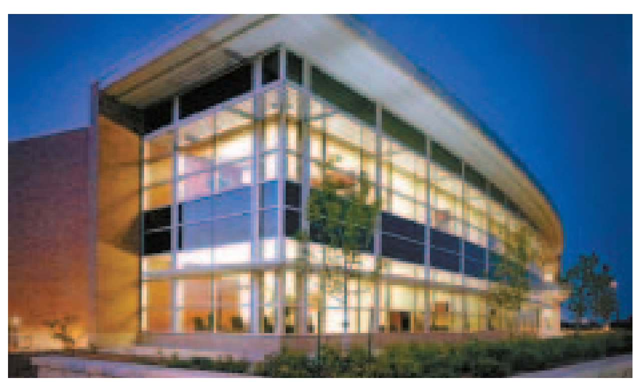


Photo courtesy of the Energy Center of Wisconsin

Additional energy and cost-savings could be achieved by updating and expanding existing building codes in the next two decades. *Energy efficient building, Appleton, Wisconsin* metric tons per year, respectively.

In addition, NEMS can be used to estimate how various fuel-saving technologies (e.g., 6-speed transmission, cylinder deactivation) will be deployed to meet new fuel-economy requirements. One of the most significant efficiency options currently available in the model is the gasoline-electric hybrid vehicle. Under the 10 mpg scenario, NEMS predicts that sales of hybrid-electric vehicles will double by 2025 from 5 percent to 10 percent of new vehicle sales, while under the more aggressive CAFE scenarios (i.e., CAFE increases of 15 mpg and 20 mpg) hybrids reach one-quarter of new vehicle sales in the same timeframe (see Figure 3-3).

NEMS can also be used to estimate the impact of higher fuel-economy levels on retail vehicle prices based on the model's assumptions about future technology costs. From a consumer perspective, the average NEMS-predicted price of a new passenger vehicle is projected to increase by 3 percent (or about $900 relative to a vehicle that would otherwise cost $28,000) as a result of a 10 mpg increase in CAFE. CAFE increases of 15 mpg and 20 mpg, by contrast, are projected by NEMS to correspond with vehicle price increases of 6 percent and 12 percent respectively. As noted in the foregoing discussion, discounted fuel savings over the life of the vehicle are nevertheless expected to fully offset these vehicle price increases under each scenario. (A full description of the NEMS analysis can be found in the Technical Appendix to this report.)

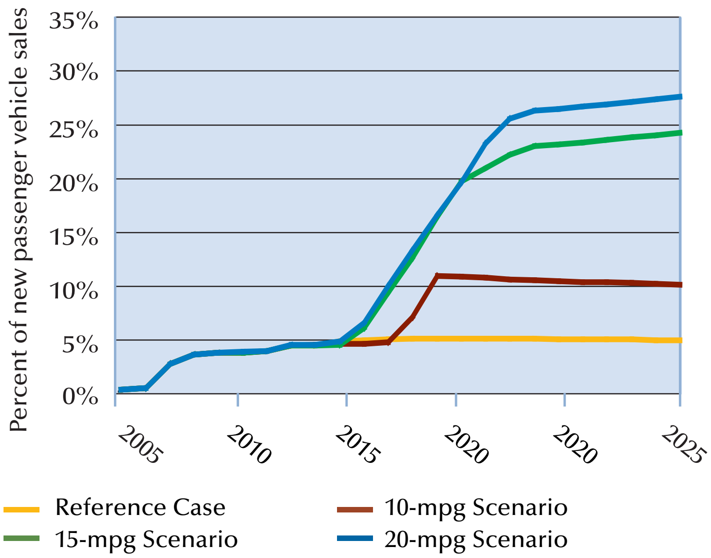
Heavy-Duty Trucks — Heavy-duty trucks account for roughly 20 percent of total transportation sector energy use. Tractor-trailer trucks consume almost 70 percent of all diesel fuel, or 1.5 million barrels of diesel per day. At present, there are no efficiency standards or federal test procedures for this class of vehicles. The lack of focus on heavy-duty vehicles is based on an assumption that the sensitivity of truck operators to fuel costs provides an effective incentive for engine and vehicle manufacturers to increase truck fuel economy. Yet, Commission-sponsored research has found that substantial, cost-effective fuel economy improvements could be achieved in heavy trucks through a variety of existing and emerging technologies, including engine improvements, auxiliary load reductions, and advances in aerodynamics. This finding is based on technical studies by DOE's 21st Century Truck Program and by Argonne National Laboratory, which suggest that average fuel economy for new tractor-trailers could be raised by 30–60 percent by 2015, depending on the required payback period. A 30 percent improvement, achieving payback in three years, is estimated to increase the purchase price of a new tractor-trailer by $7,000 and to save $11,000 in fuel costs over the life of the vehicle, while a 60 percent gain in fuel economy is estimated to result in a 14-year payback, raise the purchase price by $15,000, and produce $35,000 in lifetime (present value) fuel cost savings. The fact that large trucking companies typically turnover tractor-trailer trucks after two or three years may play a role in their apparent undervaluation of fuel economy.

In-Use Vehicles — Often overlooked in the debate about efficiency policies for the transport sector are potential fuel savings in the 200 million passenger vehicles already on U.S. roadways. Better vehicle maintenance, including regular oil changes and proper tire inflation, could generate significant savings. While encouraged in all owners' manuals, actual practice varies

Figure 3-3

Market Share of Gasoline-Electric Hybrid Vehicles

Sales of hybrid vehicles are expected to grow dramatically if fuel economy standards are increased.



Data Source: NCEP NEMS Modeling

considerably. The fuel economy of in-use vehicles, however, could be improved significantly by requiring replacement tires to be of the same quality as those sold on new vehicles.

Auto manufacturers typically place high-quality, low rolling resistance tires on new cars to help meet federal fuel economy standards. Because low rolling resistance tires are slightly more expensive (i.e., they may cost $1.00–$2.50 more per tire), equivalent tires are usually not available in the replacement tire market. Higher quality replacement tires improve fuel economy by 1.5–4.5 percent, depending in large part on how a vehicle is driven. For the added cost of about $10–$20 for two sets of higher quality replacement tires, a driver can expect to save from $87–$260 in fuel costs. These figures indicate that the payback period of low rolling resistance tires is about one year.[14]

"benefits of past efficiency policies have substantially outweighed their costs"

Legislation to address the issue of less efficient replacement tires was passed in California in 2003. As a result, the California Energy Commission is developing regulations for replacement tires that are to be adopted in July 2007 and will go into effect by July 2008.[15]

Energy efficiency has a vital role to play in the transition to a more prosperous, secure, and environmentally sustainable energy future. Efficiency standards for appliances, buildings and equipment, and passenger vehicles have proved over the last 30 years to be an effective antidote to pervasive market failures that would otherwise lead to systematic under-investment in energy efficiency. While the potential for efficiency standards in the industrial sector is more modest, substantial energy can be saved through expanded collaborative research activities and technical assistance, particularly for small- and medium-sized firms that lack the internal resources of large companies. Available evidence indicates that the benefits of past efficiency policies have substantially outweighed their costs and that considerable additional benefits could be achieved through ongoing efforts to update and in some cases expand existing standards. The evolution of refrigerator technology since 1970 (see text box) provides compelling anecdotal evidence for the efficacy of policy approaches that combine industry and government cooperation, effective coordination of R&D efforts, and direct incentives with government efficiency standards at both the state and federal levels.

Going forward, policy-makers should seek to exploit such synergies wherever possible, while also making efforts to address underlying market failures directly by, for example, addressing informational and regulatory barriers, and using pricing mechanisms to capture externalities. For example, one existing widely recognized effort to address informational barriers and promote consumer awareness of product efficiency characteristics is the federal ENERGY STAR labeling program. Under this voluntary program, which is administered by the U.S. Environmental Protection Agency (EPA) and DOE, partner manufacturers are allowed to display the ENERGY STAR logo on products that meet energy efficiency guidelines set by the two federal agencies. To ensure that the ENERGY STAR designation continues to reflect the most efficient equipment available at a given time, these guidelines must be updated on a timely and regular basis, as recommended below. In addition, more accurate and timely price signals for regulated energy commodities will encourage consumers to reduce use when costs are highest, which is itself a proven way to cut those costs.[16]

Finally, to help ensure that the federal government has and can provide accurate, up-to-date, and well-integrated information on all domestic energy resources, including untapped energy efficiency opportunities, the Commission recommends publishing a comprehensive inventory every 5 years, which would synthesize and, where necessary, augment ongoing government assessments. The inventory is discussed in Chapter IV at page 43.

B. POLICY RECOMMENDATIONS

With respect to building, equipment, and industrial efficiency, the Commission recommends that states and the federal government:

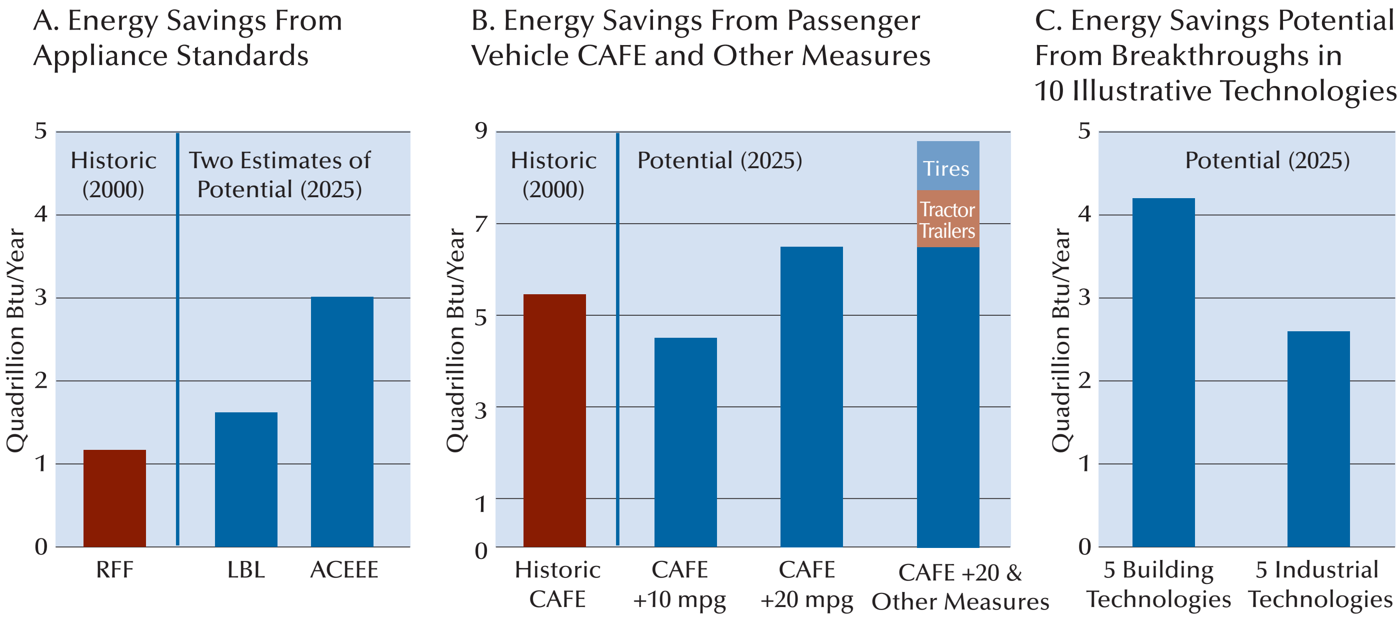
- Update and expand, where appropriate, efficiency standards for appliances and equipment.
- Provide for timely, regular revisions — on a category-by-category basis — to the efficiency specifications used to qualify products for the federal ENERGY STAR labeling program.
- Update building codes to capture cost-effective energy efficiency opportunities in new residential and commercial construction. Within a decade at most, these codes should require levels of performance at or above those exemplified today by ENERGY STAR and E-Benchmark standards for residential and commercial buildings.
- Give increased attention to educating consumers and building designers, and — in the case of building codes — facilitating improved compliance.
- Expand federally funded collaborative research on new efficiency technologies and practices with energy partners, along with development of energy analysis tools and technical assistance to industrial plant managers.
- Strive wherever possible to exploit potentially productive synergies between standards and codes and targeted technology incentives, R&D initiatives, and efforts to address informational barriers and other underlying market failures.[17]
- Devise procurement policies to aggressively exploit the most cost-effective, efficient technologies, based on Energy Star and similar criteria, for purchases and construction projects.

With respect to vehicle efficiency, the Commission recommends—in addition to a significant increase in CAFE standards for new cars and light trucks, as described in Chapter 1—that the federal government:

- Establish federal test procedures for heavy-duty tractor-trailer trucks and begin testing of new vehicles in anticipation of Congressional consideration of whether to set fuel economy standards for this class of vehicle.
- Adopt requirements for passenger vehicle replacement tires to meet the same fuel economy performance levels as original equipment manufacturer tires. This initiative should be coupled with a tire efficiency labeling and education program to inform the public about the fuel saving benefits of properly inflated tires.

Figure 3-4

Energy Savings from Appliance Standards; Energy Savings from Buildings; Energy Savings Potential from Breakthrough Technologies



Data Sources: Resources for the Future 2004, Lawrence Berkeley National Laboratory 2004, Oak Ridge National Laboratory 2004, American Council for an Energy Efficient Economy 2004, California Energy Commission 2003, NCEP NEMS Modeling

Notes on Figure 3-4

Figures 3-4A and 3-4B show energy savings from efficiency standards for appliances and equipment and for light-duty passenger vehicles. In both cases, current savings as a result of past policies are contrasted with estimates of potential future savings if standards are strengthened over time to capture cost-effective opportunities for further efficiency improvement. In the buildings sector, which accounts for approximately 39 percent of total U.S. energy consumption (or about 38 quads per year), existing national appliance and equipment standards have yielded approximately 1.2 quads per year of energy savings. As shown in Figure 3-4A, various estimates suggest that continued updating of appliance and equipment standards could yield additional cost-effective savings equal to or greater than those that have already been achieved. Future savings from more stringent building codes are not shown in Figure 3-4 but are estimated to range from 0.4 to 1.5 quads per year by 2025.

Past and potential future energy savings associated with light-duty vehicle fuel economy standards are even larger. As shown in Figure 3-4B, existing standards were estimated to be producing energy savings on the order of 5.5 quads per year in 2000. Figure 3-4B also shows the additional energy savings that would be associated with a 10 and 20 mile-per-gallon (mpg) increase in the combined efficiency of the light truck and car fleets, as well as — in the rightmost column of the figure — an estimate of potential savings from a 50 percent improvement in the fuel economy of heavy-duty tractor-trailer trucks and lower rolling resistance replacement tires for the existing passenger vehicle fleet.

Continued technological advances are likely, of course, to expand the scope of cost-effective efficiency opportunities in the future — perhaps dramatically. This point is illustrated by Figure 3-4C which depicts potential energy savings associated with a set of specific breakthrough technologies in the buildings and industrial sectors, such as solid state lighting, equipment integration, and operations technologies for buildings and advances in casting, motor systems, co-generation, and membrane and gasification technologies in the industrial sector. The estimates shown here were developed by LBL and Oak Ridge National Laboratory: each selected five not yet cost-effective technologies and examined their energy-saving potential if they were to be commercialized and widely deployed over the next two decades. Potential national-level savings for some of these individual technologies ranged as high as 1 quad per year. These estimates are meant to be illustrative — they do not attempt to capture the full potential associated with further technological advances across the whole range of efficiency opportunities in the buildings and industrial sectors.

Overview of Existing and Emerging Vehicle Technologies

Hybrids

The best hybrids achieve fuel economy gains of 30–80 percent with no reduction in weight or size. The on-board energy storage device, usually a battery, increases efficiency in several ways. It allows "regenerative braking"— recapturing energy that is normally lost when the car is braking. It also allows the internal combustion engine to be shut down when the car is idling or decelerating. At the same time, key components, such as the air-conditioning unit, can run off the battery. Finally, because the internal combustion engine of a hybrid can be smaller than that of a comparable conventional vehicle (with a boost provided by the electric motor for peak power needs) it becomes possible for the engine to operate more of the time in its zone of greatest efficiency.

The chief barrier to hybrids is their incremental cost which typically ranges from $2,000–$3,000 depending on the level of hybridization. Initial consumer reaction to early hybrid models has been largely positive, but the market is still young. With a larger battery pack, it may be possible in the future to extend the all-electric range of hybrid-electric vehicles and provide consumers with the option of recharging the battery using the electric grid. "Plug-in" hybrid technology, because it could make use of grid-provided electricity, could help further diversify the energy mix used in the transportation sector. For further discussion of plug-in hybrids, see Chapter IV, Section F.

Diesels

Diesel engines are nearly always used in big trucks and construction equipment because of their efficiency, durability, and high torque (the force that produces wheel rotation and hauling power) at low speed. Modern diesel engines are quite different from the smoky and noisy engines of the 1970s and 1980s, with advances such as electronic controls, high-pressure fuel injection, variable injection timing, improved combustion chamber design, and turbo-charging. Although they represent less than 1 percent of car and light truck sales in United States, diesels are becoming the car of choice in Europe, where gasoline prices are much higher, where fuel taxes favor diesel use, and where tailpipe emissions standards are less stringent. Diesel vehicles are typically 20–30 percent more fuel-efficient than their gasoline counterparts.

While diesel engines currently have higher emissions of particulates and oxides of nitrogen, steady progress is being made in reducing diesel emissions. Many believe that with the large amounts of R&D funding currently being focused on diesel technology, diesel engines with after-treatment of the exhaust stream will be able to meet the same emission standards as gasoline engines in the near future — though probably at a price premium. A new global warming concern relevant to diesel technologies involves their tendency to emit high levels of very small (less than 1 micron) particles of black carbon. The key to the success of diesel technology as a long-term greenhouse gas reduction strategy will be alternative (i.e., non-petroleum) forms of diesel that have far lower net carbon emissions than current diesel fuels, possibly coupled with advanced particulate controls. This could include advanced diesels made from biomass (including, potentially, a wide variety of organic wastes) or a synthetic diesel fuel made from coal using a process that includes sequestration of carbon dioxide. Cost is also a barrier as diesel engines now add about $1,500 to the price of a passenger vehicle.

Heavy-Duty Diesel

The heaviest trucks (i.e., those weighing more than 26,000 pounds) dominate truck energy use, accounting for 81 percent of total fuel consumption by this group of vehicles. Heavy trucks therefore represent an important opportunity to achieve energy savings through improved fuel economy. Technologies to improve the fuel economy of heavy-duty tractor trailer trucks include engine, aerodynamics, auxiliary load, and transmission improvements, as well as mass reduction. Noteworthy examples include:

***Electric and fuel-cell auxiliaries* —** Compressors, pumps and fans that normally run off the engine could instead be operated electrically, through an integrated starter-generator or by diesel fuel cell. A fuel cell could also operate auxiliary systems at rest stops, reducing idling time.

***Thermal management, etc.* —** This technology category encompasses reduction of waste heat through, for example, increasing the efficiency of turbocharging.

***Pneumatic blowing* —** Aerodynamics can be improved by blowing air through points on the vehicle exterior, a technique already applied to aircraft.

***Hybridization* —** Hybridization improves the efficiency of stop-and-go driving more than the efficiency of highway driving; thus heavy-duty delivery trucks that operate in urban areas are ideal candidates for this technology.

Notes:

1. United States Department of Energy, Energy Information Administration, *International Energy Outlook 2004* DOE/EIA-0484 (Washington, DC: Energy Information Administration, 2004), Fig, 24, Fig. Data, http://www.eia.doe.gov/oiaf/ieo/index.html.

2. Another partial explanation for consumer behavior might be that consumers are uncertain what price to assume for future fuel use.

3. A Btu is a measure of heat content. One quad is equal to 10^{15} British thermal units (Btu). There are approximately 5.8 million Btu in one barrel of oil.

4. Measured in terms of total system needs for generating capacity, the difference between 150 million U.S. refrigerators and freezers consuming electricity at 1974 and 2001 average efficiency levels, respectively, is more than 40,000 Megawatts. A. Rosenfeld, "Sustainable Development, Step 1" (Presentation, International Conference for Enhanced Building Operations, Berkeley, CA, October 13-15, 2003), 4.

5. To provide a reasonable approximation of the cumulative efficiency opportunity in these sectors, the Commission has merged and adapted the results from several detailed analyses to yield results in quads of potential energy savings: 1.) AVL Powertrain, The Martec Group, and Meszler Engineering Services, *Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles* (Boston, MA: Northeast States Center for a Clean Air Future, 2004), also in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004); to translate findings from reductions in greenhouse gas emissions to improvements in fuel economy, the Commission relied on "Estimates of Cost-Effective Fuel Economy Potential for Passenger Vehicles Based Upon Relevant Data and Analyses Found in *Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles*," in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004); 2.) American Council for an Energy Efficient Economy, "Energy Savings Through Increased Fuel Economy for Heavy-Duty Trucks," 9, in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004); 3.) Chris Calwell et al., Ecos Consulting, *California State Fuel-Efficient Tire Report,* vol. II, *Consultant Report* (Sacramento, CA: California Energy Commission, 2003), http://www.energy.ca.gov/reports/2003-01-31_600-03-001CRVOL2.PDF, also in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004); 4.) Dan Meszler, Meszler Engineering Services, "Transportation Policy Options Policy Definitions and Discussion," 8, in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004); 5.) Greg Rosenquist, Michael McNeil, Maithili Iyer, Steve Meyers, and Jim McMahon, Lawrence Berkeley National Laboratory, "Energy Efficiency Standards for Buildings and Equipment: Additional Opportunities,"in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004); 6.) Steve Nadel, American Council for an Energy Efficient Economy, "Supplementary Information on Energy Efficiency for the National Commission on Energy Policy," in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

6. See United States Department of Energy, Energy Information Administration, *Annual Energy Outlook 2004 With Projections to 2025* DOE/EIA-0383 (Washington, DC: Energy Information Administration, 2004), 71-73, Reference Case Projections, http://www.eia.doe.gov/oiaf/aeo/index.html.

7. Advanced Buildings, *E Benchmark: Energy Benchmark for High Performance Buildings* (White Salmon, WA: New Buildings Institute, Inc., 2003), http://www.poweryourdesign.com/benchmark.htm.

8. Steve Nadel, Anna Shipley, and R. Neal Elliott, American Council for an Energy Efficient Economy, *The Technical, Economic, and Achievable Potential for Energy Efficiency in the U.S.: A Meta-Analysis of Recent Studies* (Washington, DC: American Council for an Energy Efficient Economy, 2004), 5-6.

9. Energy Information Administration, *Annual Energy Outlook 2004,* 144.

10. National Research Council, Transportation Safety Board, *Effectiveness and Impact of Corporate Average Fuel Economy Standards* (Washington, DC: National Academy Press, 2002), 67.

11. AVL Powertrain, The Martec Group, and Meszler Engineering Services, *Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles,* 2-1 – 2-22.

12. Efficiency technologies were considered cost-effective if fuel savings over the life of the vehicle matched or exceeded the added cost of the technologies required to achieve those fuel savings.

13. United States Department of Energy, Energy Efficiency and Renewable Energy, "www.fueleconomy.gov," http://www.fueleconomy.gov/.

14. Chris Calwell, et al, *California State Fuel Efficient Tires Report,* vol. II, 13-15, 43.

15. California State Assembly, *Replacement Tire Efficiency Program,* AB 844, 2003-2004 sess., 2003.

16. United States Government Accountability Office, *Electricity Markets: Consumers Could Benefit From Demand Programs, But Challenges Remain* GAO-04-844 (Washington, DC: Government Accountability Office, 2004), 4-5.

17. National Research Council, *Energy Research at DOE: Was It Worth It?* (Washington, DC: National Academy Press, 2001), 24-30.

IV. Expanding Energy Supplies

To provide the ample, secure, clean, and affordable energy supplies the nation and the world require — now and in the future — the Commission recommends policies to: (1) expand and diversify available supplies of natural gas; (2) support other existing low and non-carbon options, including nuclear energy, hydropower, and wind power; and (3) supplement the modest price signal created by the Commission's proposed tradable-permits system for greenhouse gas emissions with direct investment in not-yet-commercialized technologies such as coal gasification with carbon capture and sequestration, next-generation nuclear power, bio-fuels, and other renewable resources. These energy supply options have the potential to advance a number of cross-cutting policy objectives, from mitigating the nation's vulnerability to energy price shocks and supply disruptions to reducing emissions of greenhouse gases, improving air quality, and promoting domestic energy resources.

INTRODUCTION

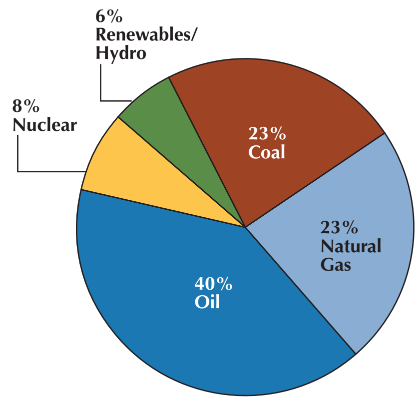
America's need for abundant and reliable supplies of energy to fuel its expanding economy will continue to grow in the coming decades. In that context, recent trends in some key energy markets are troubling. Rapidly rising oil prices have drawn considerable attention over the last year, yet prices for natural gas have also roughly tripled over the last five years. Higher energy costs have in turn imposed hardships on gas-intensive industries and individual consumers and are thought to be slowing economic growth. Even with the efficiency measures proposed in the previous section, the United States will require substantially increased quantities of electricity, natural gas, and transportation fuels over the next 20 years. The challenge of providing for continued demand growth is complicated by the need to expand the nation's production and use of energy in a manner compatible with emerging environmental and national security imperatives.

The Commission recognizes that no single technology, resource, or policy can solve all energy problems or meet all energy policy objectives. Rather, meeting those objectives will require a portfolio of responses, some of them not yet developed or perhaps even known. For now, it is essential to preserve and explore potentially viable technologies that may help to provide the ample, secure, clean, and affordable energy the nation and the world will require in coming decades. Improving oil security and stabilizing atmospheric levels of greenhouse gases, for example,

Figure 4-1

Total Domestic Energy Use by Source

The U.S. relies upon fossil fuels to meet over 85% of its total energy needs (2003).



Data Source: Energy Information Administration, 2004

will take many decades and require substantial technological leaps. To make near-term progress toward these goals while maintaining economic growth the Commission recommends policies to: (1) expand and diversify available supplies of natural gas, a fuel that is critically important to the nation's energy supply and that is likely to play a substantial role in the transition to a lower-carbon energy future; (2) support other existing low- and non-carbon options,[1] including nuclear energy, hydropower, and wind power; and (3) supplement the modest price signal created by the Commission's proposed tradable-permits system for greenhouse gas emissions with direct investment in not-yet-commercialized technologies such as coal gasification with carbon capture and sequestration, next-generation nuclear, bio-fuels, and other renewable resources.

"the United States will require substantially increased quantities of electricity, natural gas, and transportation fuels over the next twenty years"

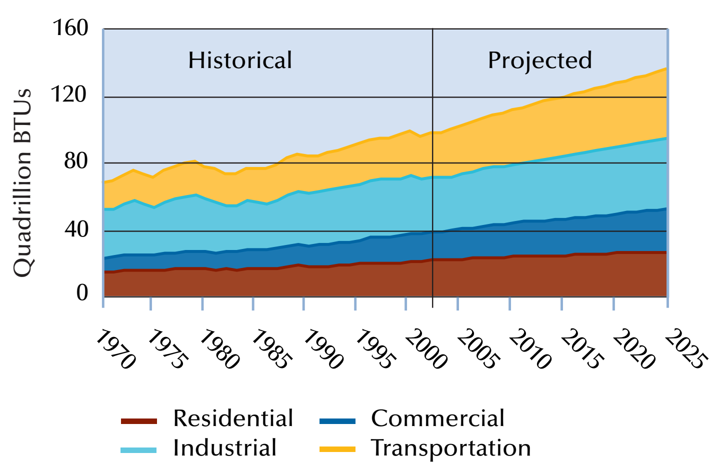
Like the efficiency measures described in the previous chapter, the energy supply options discussed here have the potential to advance a number of cross-cutting policy objectives, from mitigating the nation's vulnerability to energy price shocks and supply disruptions to reducing emissions of greenhouse gases and air pollutants, and promoting domestic energy resources. In each case, the Commission has determined through careful analysis that market forces alone, even in the presence of a modest price signal for avoided carbon emissions, will be insufficient in the near-term to adequately expand the supply of existing low-carbon resources or to create opportunities for demonstrating the commercial potential of advanced technologies such as next-generation nuclear power and coal gasification. To overcome current barriers, the Commission proposes a variety of different incentive mechanisms and policy approaches designed to reflect the stages of development characteristic of different technologies and the unique deployment challenges they face.

At the same time, however, it is important to emphasize the Commission's view that public support for any particular technology or set of technologies should not be open-ended nor should it be indiscriminate. In the allocation of scarce public resources, as in the marketplace, all options should compete on their merits and policy makers should aim to design programs that reward outcomes rather than picking winners. Thus, to encourage competition among technologies, the

Figure 4-2

Total Energy Consumption by Sector

Under BAU conditions, domestic energy consumption is expected to grow steadily over the next several decades. The U.S. consumed roughly 98 quads of energy in 2003.



Data Source: Energy Information Administration, 2004

Commission proposes to expand eligibility for federal production tax credits to all new non-carbon sources. Where the Commission recommends additional, direct support for a particular technology, that support is intended to elicit first-of-a-kind demonstrations of commercial-scale feasibility and reliability; it is not intended to result in enduring subsidies or preferential treatment for any particular technology.

As a starting point for making sound choices among various energy options, the Commission recommends that a comprehensive inventory be published every five years that catalogs all the nation's domestic energy resources, including fossil fuel resources located on- and off-shore, as well as potential energy efficiency and renewable energy resources. This inventory would coordinate and build on regular, ongoing assessments that the federal government conducts. Current federal data collection efforts are significant but scattered across multiple agencies. For example, the U.S. Energy Information Administration (EIA) publishes data on various energy supply sources. The U.S. Geological Survey (USGS) prepares regular assessments of undiscovered, technically recoverable oil and gas resources beneath federal lands, while the Minerals Management Service assesses offshore resources. The federal government also conducts regular assessments of energy efficiency potential for particular sectors and end-uses as part of existing programs, including the Environmental Protection Agency's (EPA's) and Department of Energy's (DOE's) ENERGY STAR program as well as DOE's appliance efficiency standards and Industries for the Future programs, among others. Finally, the federal government has recently expanded its assessments to include renewable energy resources.

The Commission's proposal would synthesize existing resource assessments into a comprehensive inventory of the nation's energy resources while highlighting current information gaps, such as the lack of reliable estimates of resources located in current moratoria areas of the Outer Continental Shelf (the Commission believes these areas should be included in an overall national assessment). A principal goal of the Commission's recommendation is to create the knowledge base needed to enable an informed discussion about how best to manage the nation's potential energy resources. The Commission is not recommending changes to existing moratoria, or to the current statutory requirements governing off-limits areas onshore such as national parks, national monuments, or designated wilderness areas.

A. Natural Gas

OVERVIEW

The Commission is greatly concerned about recent adverse trends in natural gas markets and accords high priority to recommendations outlined in this section that aim to expand the nation's access to natural gas supplies through construction of an Alaska natural gas pipeline, increased capacity for importing liquefied natural gas (LNG), and other measures.

"natural gas production from traditional North American sources will satisfy only 75 percent of domestic demand by 2025"

Historically, domestic resources have largely met U.S. demand for natural gas, with some imports from Canada and a small fraction imported in the form of LNG. Future U.S. demand for natural gas is expected to grow — driven in part by the addition of over 150 gigawatts (GW) of gas-fired power generation since 1999 — even as production from traditional North American sources has begun to plateau. Indeed, an assessment of domestic gas production over the latter half of the last decade reveals negligible growth despite increases in drilling. Notwithstanding recently added production from deepwater sources in the Gulf of Mexico and from unconventional sources in the Rockies, the National Petroleum Council (NPC) now predicts that natural gas production from traditional North American sources will remain flat and will be able to satisfy only 75 percent of domestic demand by 2025, with the result that future demand growth will need to be met through imports and Alaskan gas.[2]

Natural gas markets have responded to the emerging gap between projected demand and currently accessible domestic supply with a series of severe price shocks and sustained price volatility, along with a dramatic rise in average prices for natural gas. These trends are already adversely affecting those portions of the nation's industrial sector that are heavily dependent on natural gas. Failure to address the mounting imbalance between the nation's appetite for natural gas and a declining ability to produce it could have significant environmental as well as economic consequences.

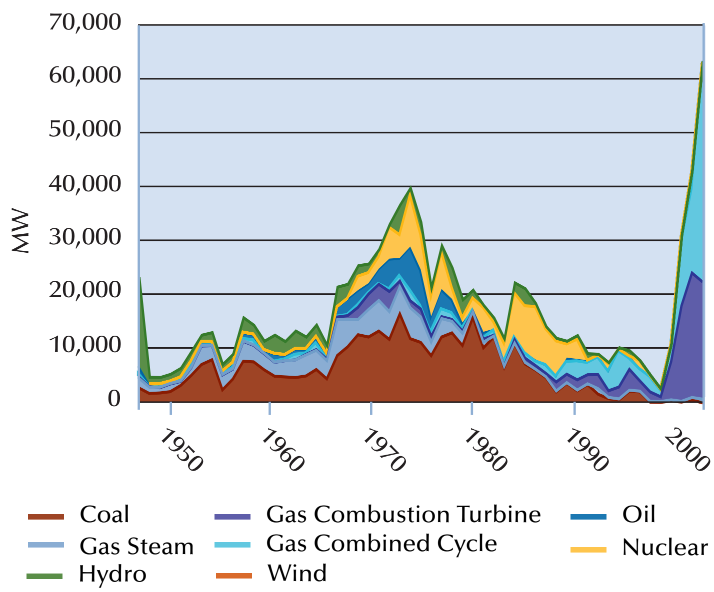
Already, rising natural gas prices have begun to undermine the pace at which the United States is reducing the carbon intensity of its economy. As a result, forecasts by EIA have been revised to reflect higher coal consumption and increased greenhouse gas emissions based on the changing fundamentals of natural gas markets.

Given the critical importance of good data to

Figure 4-3

Investments in Electric Sector Generating Capacity

Unprecedented investment in natural gas-fired electric capacity in recent years will drive future natural gas demand.



Energy and Environmental Analysis, Inc., 2004

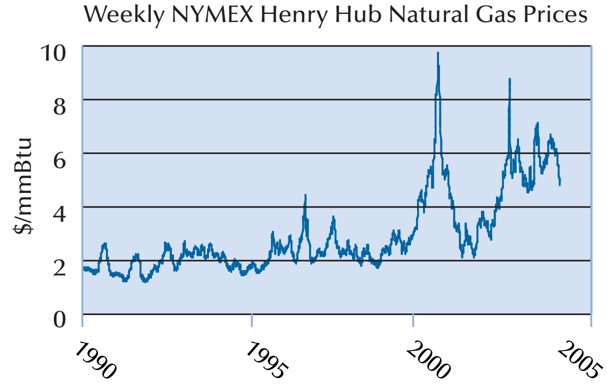
Natural Gas Drilling Rig. *San Joaquin Valley, California*

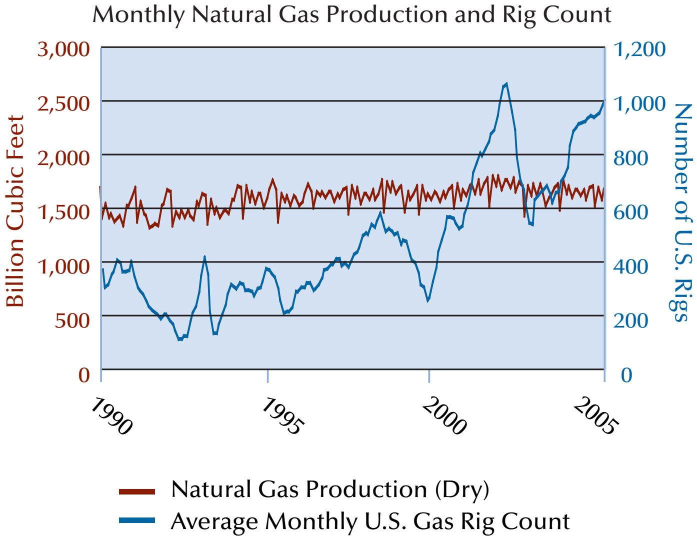
inform sound energy policy decisions, the Commission vigorously endorses efforts currently underway to enhance EIA's ability to track developments in natural gas markets. EIA's traditional, voluntary system of collecting data on natural gas is out of date and no longer adequate for today's information needs. Although EIA has long recognized the need to update its data collection efforts as the market structures of various energy industries evolve, an overhaul of the current system has become particularly urgent for the gas industry where a lack of dependable, current, and detailed information from both government and private sources has stymied efforts to better understand market events and analyze potential policy options for addressing consumer needs. Specifically, the Commission supports DOE's recent proposal for a refined, mandatory survey to improve data collection and urges the Department to ensure that adequate resources are made available for this and other information-gathering initiatives.

Figure 4-4

Natural Gas Prices and Domestic Production

Natural gas prices have risen dramatically and sustained significant volatility over the past five years. Although domestic drilling has more than doubled (as measured by the number of rigs) in response to high prices, gas production has remained roughly constant.





Data Source: Energy Information Administration, 2004

POLICY RECOMMENDATIONS

The Commission strongly supports policies to ensure continued access to reliable, affordable natural gas resources. No single measure can accomplish this; rather, the Commission believes a variety of steps must be taken to diversify and increase the supplies of natural gas available to meet U.S. demand. As indicated at the outset of this section, the Commission's priority recommendations are to encourage construction of a gas pipeline from Alaska and facilitate a significant expansion of LNG infrastructure. In addition to these two priorities, the Commission is making a series of other recommendations. Two that are relevant to current concerns regarding the adequacy of domestic natural gas supplies are described at the end of this section: the first aims to improve the ability of public land managers to make timely and well-informed land-use decisions; the second concerns the development of techniques for better characterizing and utilizing the nation's vast unconventional reserves of methane hydrates. Additional measures that can help ameliorate current stresses on natural gas markets including support for cost-effective, near-term demand-side efficiency improvements; fostering research, development, and early deployment of clean coal technologies that produce synthetic gas (which can be used like natural gas); and promoting more effective risk-hedging by gas distribution companies by encouraging long- as well as short-term supply contracts.

To assure future access to adequate and reliable supplies of natural gas, the Commission recommends that policymakers:

- Provide effective public incentives for the construction of an Alaska natural gas pipeline.
- Address hurdles to the siting and construction of liquefied natural gas (LNG) terminals.
- Increase resources for key public land management agencies to allow for improved land-use planning and permitting processes and to promote more efficient resource extraction while maintaining environmental protections.
- Increase federal support for research and development into methane hydrates.

1. ALASKA NATURAL GAS PIPELINE

The Alaskan North Slope holds significant natural gas resources. Approximately 35 trillion cubic feet (tcf) have been discovered to date, equivalent to roughly 20 percent of U.S. proved reserves. Estimates of the total resource base likely to exist in this area range from 200 to 300 tcf. (By comparison, U.S. consumption of natural gas totaled 22 tcf in 2003).[3] Currently, natural gas in Alaska is being re-injected to support oil production because there is no infrastructure to deliver it to the lower 48 states (in addition, a very small amount of natural gas is exported in the form of LNG from Alaska to Japan).

Numerous barriers have thus far prevented construction of a pipeline to deliver natural gas from already-developed oilfields on the North Slope of Alaska. First and foremost among those barriers are the high cost ($20 billion) and lengthy construction period (10 years) required to complete this project.[4] These challenges are exacerbated by siting and permitting uncertainties, uncertainty regarding royalty payments, the pipeline's geographic commitment to North American markets, and the decline in recent years of long-term gas contracts which, in the past, would have been relied upon to help manage investment risks. Finally, the very size of the project and its potential to lower gas prices may create a further deterrent: when complete, the pipeline could deliver roughly 4 billion cubic feet of natural gas per day (or nearly 1.5 tcf per year) — an amount that could lower gas prices nationally by up to 50 cents per mmBtu.[5] While good for the nation, the possibility of significantly lower prices and lower profits in the initial years of operation is an additional barrier for investors.

RECOMMENDATION

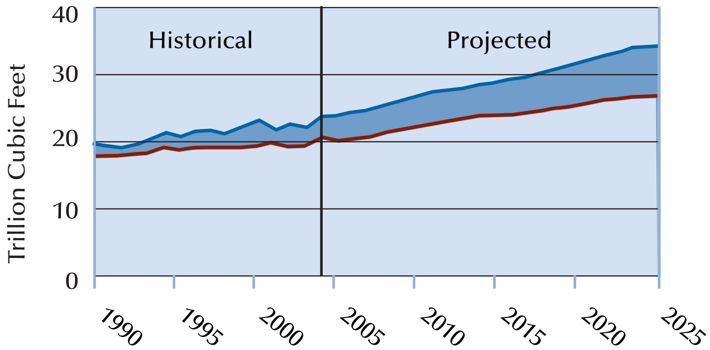
The Commission supports recent action by Congress to provide loan guarantees, accelerated depreciation, and tax credits to diminish the investment risks associated with a project of the magnitude of the Alaska gas pipeline. These measures are meaningful and necessary to facilitate pipeline construction. The

Commission remains concerned, however, that uncertainty about likely natural gas prices nearly a decade in the future may continue to forestall actual pipeline construction. Given the critical importance of gaining access to Alaskan gas, the Commission recommends that Congress address this remaining hurdle by enacting additional policies that partially shield investors from the risks of extreme low-price contingencies, while ensuring that taxpayers will be fully compensated for any outlays should natural gas prices subsequently rise to higher levels. Commission analysis indicates that the likely economic benefits of such a policy — if it succeeds in clearing the way for pipeline construction — would substantially outweigh the costs. These economic benefits include not only lower gas prices, but reduced gas price volatility given that the resource base in Alaska is large enough to support a long-lasting expansion of overall North American supplies.

Figure 4-5

U.S. Natural Gas Supply

Even with construction of the Alaska pipeline, the United States will need more natural gas imports in the years to come.



Data Source: Energy Information Administration, 2004

2. LIQUEFIED NATURAL GAS

In liquefied form, natural gas can be transported long distances by ocean vessel. Increasing the nation's capacity to import LNG therefore provides a means of accessing vast global natural gas supplies, particularly as recent substantial cost declines in liquefaction and shipping have made it economic to develop LNG projects that target the U.S. market. Currently LNG plays only a small role in augmenting domestic supplies: it accounted for just 2 percent (500 billion cubic feet) of national consumption in 2003.[6] Though a variety of factors — including the evolution of global LNG markets and the development of liquefaction capacity to provide LNG for U.S. markets — will determine how much and how quickly LNG can contribute to meeting future gas demand, expanded import capacity is clearly critical if LNG is to play a significant role in easing the tight supply situation and helping to dampen price increases and volatility in U.S. gas markets.

The primary obstacle to constructing new (or expanding existing) LNG receiving terminals in the United States is local opposition, compounded by regulatory and siting uncertainty in light of the fact that no new facilities have been constructed in this country for more than 20 years. Public opposition is largely motivated by safety concerns which have been heightened recently by increased awareness of terrorist threats. It is clear that the cryogenic nature of LNG, its flammability under certain conditions, and its dispersion tendencies do present a number of potential safety hazards during transport and handling. But the empirical evidence — based on the extensive track record of the

A single tanker can bring enough liquefied natural gas to this offshore receiving dock to meet the daily energy needs of more than 10 million homes. *Cove Point, Maryland* industry and the numerous safety precautions typically incorporated in LNG ship design and operation — indicates that these hazards can be adequately managed under normal operating conditions.[7] Based on current understanding, LNG does not appear to pose a greater societal safety hazard than other widely used sources of energy such as petroleum and its by-products.

The emergence of an ongoing terrorist threat in recent years has added a new and potentially more challenging dimension to existing concerns about the potential risks involved in importing large quantities of LNG. As a result, the specific vulnerability of LNG transportation and storage facilities to intentional acts must be thoroughly addressed before policymakers, insurers, investors, and the public consent to considerable expansion of the existing LNG infrastructure. Potential attacks on LNG vessels or storage facilities are, of course, likely to be most troublesome if they occur near a populated area. Some recent proposals would locate the off-loading process off shore. In such a scheme, LNG vessels need not approach the coastline but would instead off-load their cargo via a pipeline connection at sea. An off-shore receiving facility of this type, located 116 miles off the coast of Louisiana, recently received approval from the U.S. Coast Guard and others are under consideration. In some cases, however, locating re-gasification facilities off-shore may be quite costly. Meanwhile, government and industry are making considerable efforts to address terrorism-related LNG safety risks.

"priority recommendations are to encourage construction of a gas pipeline from Alaska and facilitate a significant expansion of LNG infrastructure"

RECOMMENDATION

The Commission recommends that concerted efforts be made to educate the public regarding LNG-related safety issues. The Commission believes that an effective way to address public concerns about LNG siting would be through objective, site-specific safety assessments. The federal government is the most logical entity to convene balanced sets of experts and coordinate these reviews; however, a variety of institutional arrangements are possible.

While supporting a strong federal role in the siting of LNG facilities, the Commission recognizes that "cooperative federalism" is necessary for effective implementation of LNG proposals. This framework recognizes that the Coast Guard has been delegated the authority for siting off-shore LNG terminals,[8] and that the Federal Energy Regulatory Commission (FERC) has authority for siting onshore LNG facilities. States that have been formally designated as adjacent coastal states also have an important role to play in the siting process for certain off-shore LNG facilities and generally through the exercise of a coastal state's responsibilities to carry out federal "consistency reviews" of on-shore and off-shore facilities proposed in coastal zones under the Coastal Zone Management Act (CZMA).

The Commission sees encouraging evidence that this cooperative model is emerging in practice. While federal law gives FERC the last word on the construction and siting of onshore LNG import terminals, states' substantial interests in environmental protection, land use, and other issues are being accommodated through a variety of means. A prominent example is the joint preparation of environmental reviews of proposed LNG facilities by FERC and state agencies responsible for the issuance of permits under the Clean Water Act, the Clean Air Act, and the CZMA. Also, applicants for LNG facilities often must comply with local requirements concerning property acquisition since there is no eminent domain authority for such facilities under applicable federal law. The Director of FERC's Office of Energy Projects recently noted that "[a]lthough FERC has jurisdiction over proposed LNG import projects, certain permits, approvals and licenses are the responsibilities of other federal agencies and state and local authorities," and "[t]here is nothing unusual about an energy project simultaneously being subject to various regulatory requirements promulgated by other federal, state and local authorities."[9]

While the Commission concurs with FERC's

Chair that "[a]t the end of the day…it is the [FERC] that must approve and condition onshore LNG facilities,"[10] the Commission also commends FERC for its recognition of the important role that the states and other stakeholders have in the siting process. Finally, the Commission believes that regulators should take into account the nation's need for new natural gas supplies so that siting and permitting decisions can reflect this important national interest goal.

3. LAND-USE PLANNING AND PERMITTING

Substantial natural gas reserves exist on public lands managed either by the Department of Interior's Bureau of Land Management (BLM) — which is responsible for 262 million acres, primarily in the 12 western states including Alaska — or by the U.S. Forest Service (USFS), which is responsible for an additional 191 million acres. The Rocky Mountain region, in particular, currently accounts for 18 percent of domestic natural gas production and recent projections indicate that natural gas production in this region could increase 50 percent by 2020.[11] The National Petroleum Council (NPC) estimates that the Rocky Mountains have substantial technically recoverable reserves — as much as 284 tcf — with a large undiscovered potential, 80 percent of which is in the form of unconventional resources (e.g., coal bed methane, tight gas).[12] The same area is, of course, also known for its spectacular beauty, wildlife habitat, recreational opportunities, and other values. In the Rocky Mountains and elsewhere, public land managers play a pivotal role in protecting these values and managing access to potential energy resources.

The basis for these management decisions is a land-use planning process designed to evaluate natural and cultural resources, as well as the impacts of energy development activities, and intended to provide a foundation upon which BLM can make sound, factually supported leasing and permitting decisions. Starting in 2001, Congress significantly increased BLM's land-use planning funds and BLM has since focused attention on updating and completing its 162 land-use plans. The Commission welcomes this trend toward improved planning, while noting that many of BLM's plans are still out-of-date and leasing decisions are sometimes made without adequate information. In some offices, a shortage of personnel with the requisite expertise contributes to the problem. Despite recent positive trends, the current situation is still considered — on all sides — to be problematic: the lack of underlying, up-to-date land-use plans may result in overly restrictive lease and permit decisions, or it may lead to exploration and development in areas that are, or have become, environmentally sensitive. In fact, most stakeholders — from industry groups to hunters and anglers — agree that BLM and USFS require increased resources and more personnel to effectively carry out their land management responsibilities.

The Bureau of Land Management's multiple use mission includes protecting wildlife habitat. *Pronghorn antelope, BLM land, Wyoming*

The agencies' overall land management responsibilities also include the timely processing of lease and permit applications, as well as the ongoing research and monitoring of species and habitat that are necessary to evaluate the impacts of specific energy development activities as they are proposed. At BLM, these interrelated activities are funded through several budget items. Some of these categories have increased in recent years. For example, funding for "Oil and Gas Management" has increased almost 40 percent since 2001; other categories, such as "Wilderness Management" and "Wildlife Management," have declined or stayed relatively steady.

RECOMMENDATION

The Commission supports the recent trend toward increased funding for BLM permitting and land management activities. In light of remaining widespread concern about existing planning efforts, permitting delays, and inadequate monitoring,[13] the Commission recommends that BLM and USFS be given sufficient additional funding to effectively perform their essential land management functions. Specifically, the Commission recommends an increase in the range of 10–20 percent in the funding available for updating and completing land-use plans, improving monitoring and data collection, and achieving reasonable processing periods for lease and permit applications. In addition, the Commission agrees with a recent report by the NPC which calls for further work to develop more consistent assessments of the extent to which government and other restrictions (e.g., lease stipulations, permit conditions of approval) are creating either explicit or *de facto* impediments to accessing Rocky Mountain gas.[14] Several recent studies have arrived at different conclusions about this issue; a more consistent assessment would be useful for future resource and land-use planning purposes.[15]

4. METHANE HYDRATES

Methane hydrates hold tremendous potential to provide abundant future supplies of domestic natural gas. Globally, more energy potential is stored in methane hydrates than in all other known fossil fuel reserves combined.[16] Hydrates are ice-like solid structures consisting of water and gases (most commonly methane) compressed to greater than normal densities. These deposits exist within a narrow set of circumstances defined by cold temperatures and high pressures.

While detailed information on the global resource base is scarce and figures vary widely, it appears that the United States may be endowed with over one-quarter of total worldwide methane hydrate deposits. Estimates indicate a U.S. resource base containing up to 200,000 tcf of methane in a variety of structures both on-shore, in Alaskan permafrost, and off-shore, on much of the nation's deep continental shelf.[17] (By comparison, a consensus estimate for the global resource base, published by EIA, is approximately 742,000 tcf.)[18] If even 1 percent of the estimated domestic resource base proves commercially viable, it would roughly double the nation's technically recoverable natural gas reserves,[19] which are currently estimated at 1,280 tcf.[20] (As noted earlier in this chapter, the United States annually consumes roughly 22 tcf of natural gas.)[21] Unfortunately, substantial uncertainties exist regarding the nature of these deposits and, in particular, how best to extract the enormous quantity of natural gas they contain in an economic and environmentally sensitive manner. In addition, not all non-conventional natural gas extraction technologies are mature, raising technical challenges for accessing these resources. Nevertheless, while hydrates are unlikely to provide commercially viable natural gas supplies within the next 20 years, their long-term potential to contribute domestically sourced natural gas to meet U.S. demand is considerable.[22]

RECOMMENDATION

The Commission believes that a focused research and development program is necessary to answer remaining questions about methane hydrate characteristics (such as accessibility and distribution), to develop commercially viable extraction techniques, and to better understand the potential environmental impacts of resource extraction and utilization, including the role of hydrates in balancing the global carbon cycle. To date, Japan has been the international leader in hydrate research,[23] having committed over $40 million to research and field testing on a resource base thought to be on the order of 261 tcf.[24] The Commission recommends that federal research and development funding for methane hydrates be increased roughly five-fold, from $9 million in 2004 to $50 million annually.

B. ADVANCED COAL TECHNOLOGIES

OVERVIEW

Coal is an abundant and relatively inexpensive fuel that is widely used for the production of electricity in the United States and around the world. In fact, coal's share of overall electricity production is 40 percent worldwide, more than 50 percent in the United States, and 75 percent in China and India.[25] High natural gas prices have recently prompted resurgent interest in new coal plant construction in the United States. Meanwhile, rapid growth in coal-fired generating capacity is also expected to occur in key developing countries.

Unfortunately, coal's high carbon content relative to other fossil fuels also means that its use in conventional steam-electric power plants releases significant quantities of carbon. At present, coal combustion accounts for more than a third of global carbon emissions.[26] Thus, conventional new pulverized-coal steam-electric plants are likely to undermine, or perhaps become stranded assets under, a future carbon management regime. In this context, cost-effective technologies that would allow for continued utilization of coal with substantially lower greenhouse gas emissions could represent a significant breakthrough — one that would make policy responses to the risk of climate change compatible with a new era of expansion for the coal industry.

Coal-based integrated gasification combined cycle (IGCC) technology, which — besides having lower pollutant emissions of all kinds — can open the door to economic carbon capture and storage, holds great

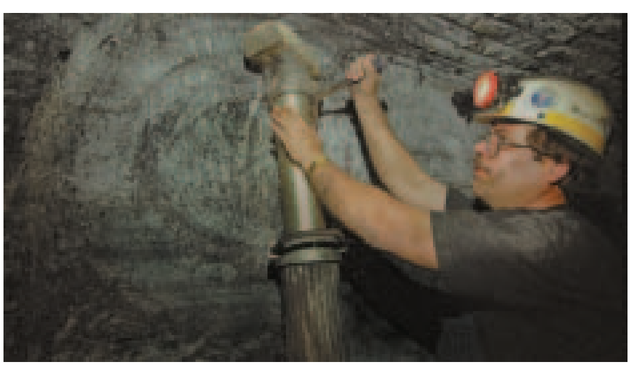
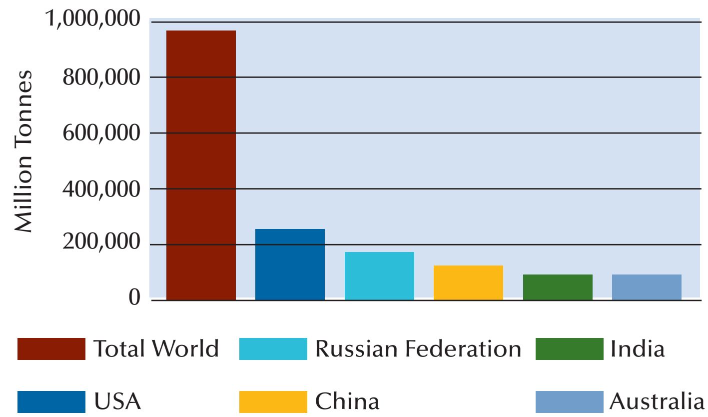

Coal miner sets hydraulic roof support. *West Virginia*

Figure 4-6

Proved Coal Reserves

The United States has the largest proved coal reserves of any nation in the world (the top five nations are shown here).



Data Source: BP, 2004

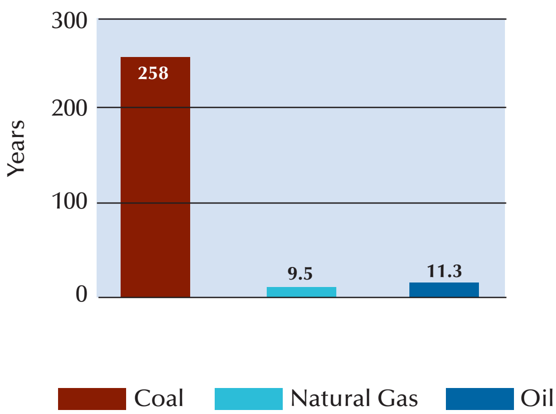
promise for advancing national as well as global economic, environmental, and energy security goals. The future of coal and the success of greenhouse gas mitigation policies may well hinge to a large extent on whether this technology can be successfully commercialized and deployed over the next 20 years.

IGCC technology involves first gasifying coal using a chemical process (rather than combustion) to generate a synthetic gas or "syngas" that is mostly composed of hydrogen and carbon monoxide. The syngas is then used to fuel a combustion turbine and the exhaust heat is employed to produce steam for both further power generation and gasification. This process has the potential to be both cleaner and more efficient than burning coal in a steam boiler to make electricity, which generates considerable waste heat and leads to the release of myriad undesirable emissions. By contrast, the gasification process offers the potential for cost-effectively isolating and collecting nearly all impurities — including mercury and other pollutants, as well as a large portion of the carbon — before combustion. Moreover,

Figure 4-7

U.S Fossil Fuel Reserve/Production Ratios

At current production levels U.S. proved coal reserves would last over 250 years



Data Source: BP, 2004

because the same gasification process can theoretically be applied to any low-quality carbonaceous feedstock, progress in developing this technology also raises interesting possibilities with respect to the future use of biomass — alone or in combination with coal — for electricity production.

Coal gasification with carbon capture and sequestration also holds promise for producing clean, low-carbon liquid fuels suitable for use in the transportation sector. In fact, the most economic configurations might involve utilizing the basic IGCC electricity generating platform (which typically has a spare gasifier built-in for reliability purposes) and developing a system for co-producing other high-value products in addition to electricity. This so-called polygeneration based on gasification of residual fuels is well established in the petroleum refining industry. Super-clean, coal-derived designer fuels such as Fischer-Tropsch diesel and dimethyl ether (DME), for example, represent a potential domestic resource for reducing reliance on petroleum fuels in the transportation sector and thereby improving the nation's energy security.[27]

"IGCC technology holds great promise for advancing national as well as global economic, environmental, and energy security goals."

Coal gasification technology *per se* is well-developed and is already being widely used in the global manufacture of chemicals. A handful of facilities now utilize this technology for power generation, however; these plants are generally below 300 MW.[28] Thus, at present the electric industry remains largely unfamiliar with the chemical processes involved. Meanwhile, the primary technical hurdle concerns reliability: a high degree of availability (in the sense that IGCC plants are available to operate when called upon) is necessary to make these capital-intensive facilities cost-competitive. A reasonable goal for IGCC plants is to achieve availabilities in the range of 80–90 percent, but the few public/private IGCC demonstration projects that have gone forward to date have failed to consistently achieve this target. Recent technical and operational improvements, together with the proven performance of gasifiers at industrial facilities and refineries where personnel are experienced with the chemical processes involved, nevertheless provide cause for considerable optimism.[29]

Coal IGCC also faces significant economic challenges. The risk premiums imposed by the financial community on largely unproven equipment applications — especially in an investment environment that is currently characterized by a high degree of risk aversion — ensures that incumbent technologies will not be displaced absent large benefits or incentives. A recent decision by the Wisconsin Public Service Commission (PSC) to reject an application from Wisconsin Energy Corporation to build a 600 MW coal IGCC plant that would have gone on-line in 2011 is illustrative of the challenge. In its decision, the Wisconsin PSC specifically cited the high costs of the proposed IGCC plant (at $150 more per kW, the PSC estimated that the plant would cost $90 million more than two comparably sized pulverized coal plants that were being proposed at the same time) and technology concerns stemming from the lack of operating experience with an IGCC facility of this size.[30]

Operating improvements and cost reductions typical of maturing technologies are, of course, likely to make coal IGCC more competitive. Early public investments are still needed, however, to develop the field experience required to overcome current hurdles to IGCC adoption by the marketplace.

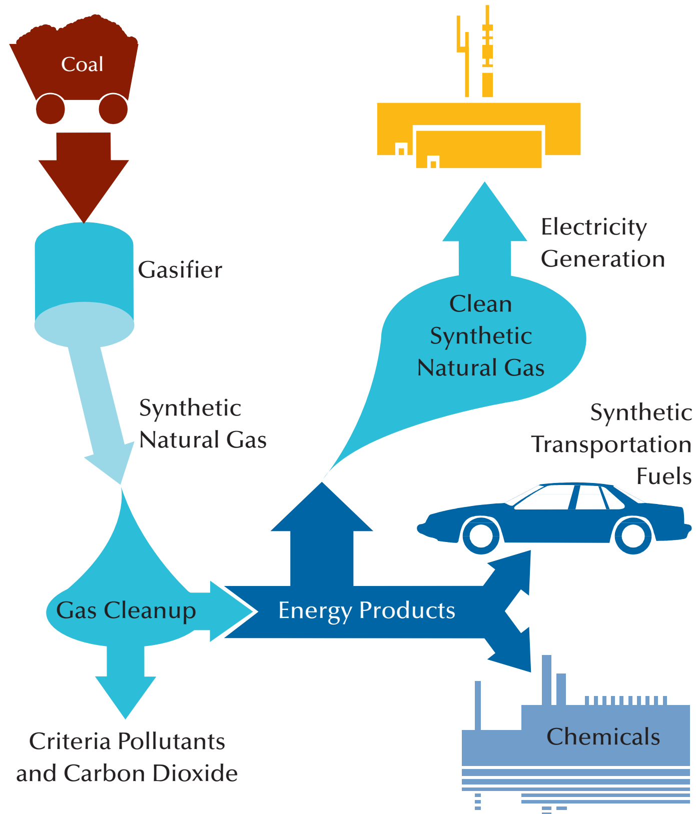
Meanwhile, the impact of higher natural gas prices on existing natural gas combined-cycle (NGCC) generating plants may also create interesting opportunities for facilitating IGCC deployment. Specifically, developers looking to convert existing NGCC assets into IGCC facilities could potentially acquire currently underutilized NGCC generation assets at discount prices. Accordingly, the Commission recommends that IGCC incentives be made available to developers of both new and retrofit facilities.

The implementation of a regulatory system that limits greenhouse gas emissions could potentially make IGCC more viable than coal-steam electricity at some point in the future. (As has already been noted, the Commission's proposal for a tradable-permits system for greenhouse gas emissions would not likely provide enough of a cost advantage — at least in its first phase — to overcome early barriers to entry for IGCC technology.) Some means for disposing of waste CO_2 will be necessary, however, if coal IGCC technology is to play a role in substantially reducing future greenhouse gas emissions. Currently, there is optimism that long-term carbon storage in geologic reservoirs is feasible and can be made cost-effective; all parts of this technology (including carbon capture and compression, transport, and injection) are already in commercial practice today, but at substantially smaller scales than would be necessary for widespread application. Determining the viability of carbon capture and storage is thus essential and will likely require substantial research, as well as several large-scale demonstration projects during the next 10 to 15 years to develop commercial experience.

Figure 4-8

Integrated Gasification Technology

Integrated gasification combined cycle (IGCC) technology has the potential for significantly cleaner use of coal.



NCEP

Photo courtesy of U.S. Department of Energy

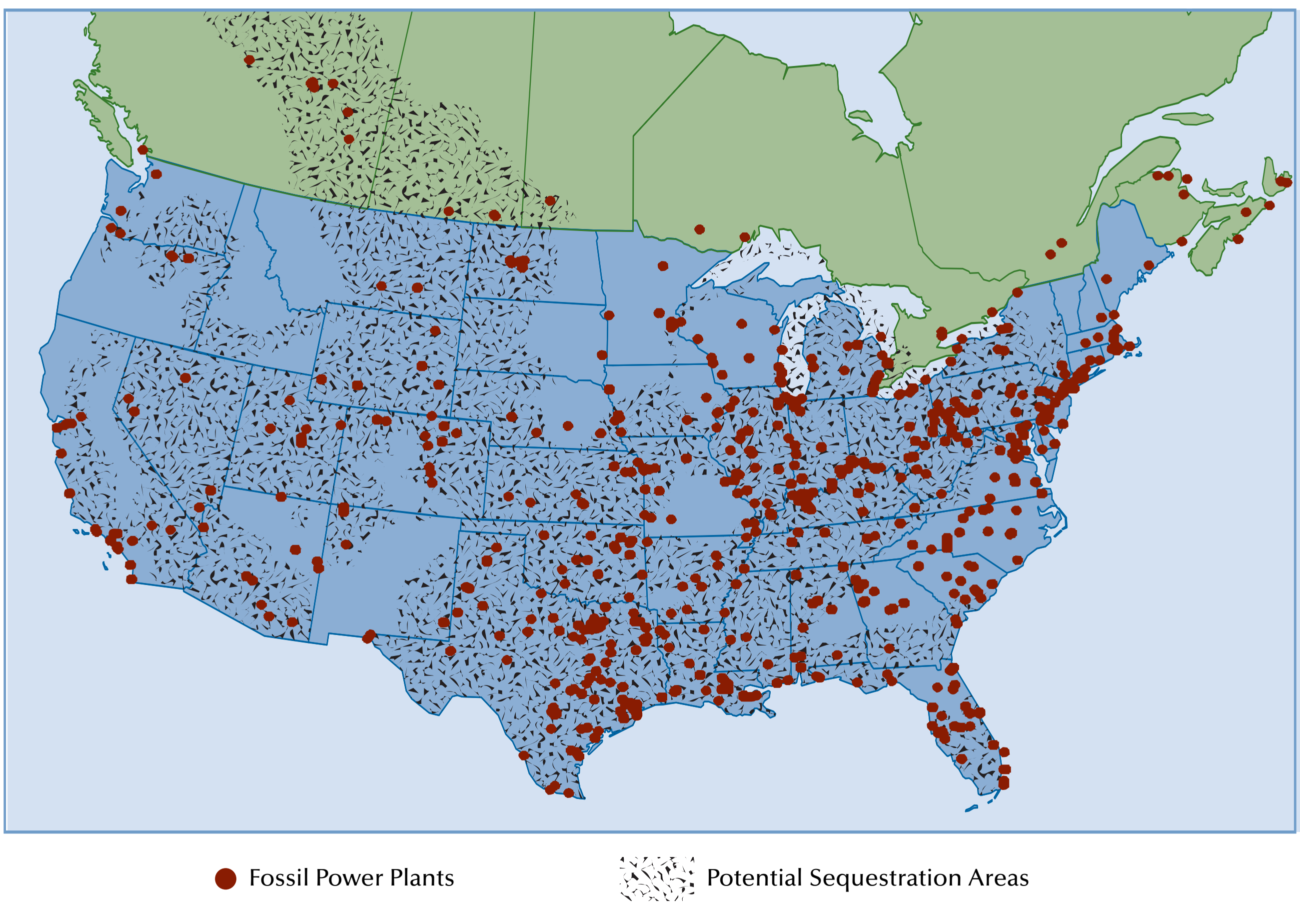
250 megawatt Integrated Coal Gasification Combined Cycle power facility. *Polk, Florida*

Figure 4-9

Potential Sites for Geologic Carbon Sequestration

Capturing and permanently sequestering carbon in geologic formations offers a means to prevent emissions released by fossil fuel use from reaching the atmosphere and thus may play an important role in the array of strategies used to mitigate climate change risks in the future. Carbon capture and sequestration is most likely to be feasible and cost-effective at large industrial facilities or electric power plants where CO_2 can be collected before it is released to the atmosphere and then compressed and transported via pipeline to a geologic repository. Potential repositories include depleted oil and gas fields, unmineable deep coal seams, or deep saline formations. Current estimates suggest that in the United States, deep saline formations alone can potentially hold up to 3 trillion tons of CO_2 or roughly 600 times current annual U.S. emissions. Given that many of these formations have safely stored hydrocarbons for millennia, there is considerable optimism that they can reliably retain injected CO_2. As noted in the text, all aspects of the technology required for carbon capture and sequestration are developed and in use today — primarily to support the use of CO_2 injection for oil recovery — but not at the scale that would be required to offset a substantial portion of current energy-related carbon emissions. Cost estimates described in the technical appendix to this report and used to develop the Commission's recommendation for federal funding to support large-scale carbon capture and sequestration projects, suggest that the cost of capturing 90 percent of carbon emissions at a large (500 MW) coal IGCC facility range from $12.40–$18.70 per MWh, while the costs of sequestration are on the order of $2.93 per metric ton of CO_2.

The map below details potentially promising sequestration sites in (1) depleted gas fields, (2) depleted oil fields, (3) unmineable coal seams, (4) deep saline formations, and (5) basalts. Each geologic formation presents a unique set of characteristics, storage capacities, and challenges that must be carefully understood before large scale sequestration occurs. On the whole, however, potential sites are numerous and are, for the most part, close to much of the existing fossil fuel-based electric industry infrastructure.



Adapted from Battelle, 2004

POLICY RECOMMENDATIONS
Advanced Coal Technologies

The Commission believes that support for first-mover sequestration-capable IGCC facilities is appropriate given this technology's potential for simultaneously addressing economic, environmental and energy security concerns. Thus, the Commission recommends that the federal government:

- Provide up to $4 billion over ten years to support the early deployment of roughly 10 GW of sequestration-ready IGCC plants.
- Provide support for the commercial-scale demonstration of geologic carbon storage at a variety of sites with an investment of $3 billion over ten years.

Carbon capture and sequestration would address one of the most important environmental issues associated with a significant expansion of coal use in combination with new technologies such as IGCC. But such an expansion would also have other potentially significant environmental, economic, and industrial implications, particularly with respect to the "upstream" impacts of extracting, transporting, and processing coal for use in IGCC facilities. To examine these implications, the Commission sponsored a study to explore what challenges and opportunities might be associated with a doubling of U.S. coal production over the next 25 years. The study, titled *"Coal: Planning Its Future and Its Legacy,"* concludes that with continued improvement in coal production technologies and methods, and careful planning, increased coal use in the future can be achieved in a manner that advances both local and national interests.[31]

As the basic technological elements for IGCC with carbon capture and storage are commercially available, public support should be focused on early deployment. Several proven mechanisms for facilitating deployment include loan guarantees (where the government commits to pay part or all of the loan required to build a facility if the borrower defaults);[32] production tax credits (where a specified financial benefit is provided for each unit of electricity produced — in this case the facility is financed entirely by private capital and the subsidy works to make operation more economical); and direct capital grants (where an up-front, lump-sum subsidy payment is made to the builder of a qualifying facility). Other potentially viable subsidy mechanisms include power purchase agreements and insurance pools to manage the risks of investment in largely unproven technologies. [33]

Recognizing the diverse attributes and needs of potential market participants, the Commission believes that a single incentive mechanism may not be optimal in all situations. For example, production tax credits do not work for public developers and may not work for certain large generators. Other mechanisms, such as loan guarantees may be more appropriate for traditional regulated public utility developers. Accordingly, the Commission recommends that early deployment programs be designed to accomodate a variety of approaches for providing subsidies of equivalent value, with all forms of incentive allocated through some form of reverse auction or similar competitive mechanism. Competitive financial instruments are also critical as they can adjust to changes in market conditions — such as natural gas and coal prices — that will have large impacts on program costs.

To be eligible for government support, IGCC or other advanced coal-fueled power plant technology should be required to meet prescribed criteria in terms of minimum coal heat input (e.g., at least 50 percent on an annual basis), providing a technical pathway for both carbon separation (i.e., eligible technologies should be sequestration ready) and co-production of a hydrogen slip-stream, and meeting stringent emissions standards for sulfur dioxide, nitrogen oxides, particulate matter, and mercury. To maximize fuel diversity and regional economic benefits, incentive programs should also be designed to maintain a role for sub-bituminous coal (which would otherwise be less likely to be used as an input fuel for IGCC applications because of its higher moisture content), as well as bituminous coal.

Drawing on available estimates of coal IGCC costs compared to costs for mature natural gas combined cycle and pulverized coal generation technologies, the Commission has estimated that roughly $4 billion of public support would be needed to overcome current cost differentials and facilitate the early deployment of roughly 10 GW of new IGCC capacity. The analysis, which is described in detail in a memorandum in the Technical Appendix to this report, assumes a $4.70/mmbtu baseline price for natural gas and assigns a marginal cost consistent with the Commission's greenhouse gas proposal for any additional emissions associated with a coal IGCC plant compared to a natural gas combined cycle plant (the assumption here is that carbon emissions from first-mover IGCC facilities would not, in this early deployment phase, necessarily be sequestered).

In addition, the Commission has separately estimated the costs of several demonstration projects to explore the feasibility of large-scale carbon capture and storage in combination with IGCC technology. This analysis suggests that $1.5 billion would be adequate — based on current estimates of cost for carbon capture and geologic sequestration — to demonstrate 50 percent carbon capture and sequestration at two 500 MW coal IGCC plants and 90 percent carbon capture and sequestration at an additional two 500 MW plants. Again, for consistency with the Commission's greenhouse gas proposal, the analysis assigns a value to carbon emissions avoided through capture and sequestration. This credit reduces estimated net costs for the proposed demonstration program by 20–30 percent depending whether high or low cost assumptions for carbon capture and sequestration are used.[34] To explore the feasibility of carbon capture and sequestration at a variety of locations and with diverse types of potential repositories, the Commission proposes an additional $1.5 billion for additional demonstration projects not necessarily in conjunction with IGCC facilities. Thus, the total funding recommended for demonstrating carbon capture and sequestration is $3 billion. As with other initiatives described in this chapter, the Commission recommends that this amount — in addition to the $4 billion in early deployment incentives described above for demonstrating IGCC technology — be made available over a ten-year period.

Another prominent proposal for promoting early IGCC deployment involves a risk-sharing partnership between federal government, a state utility rate-setting body, and an equity investor wherein the federal government provides high-quality credit, state regulators provide an assured revenue stream through regulated utility rates, and the plant owner provides equity and management or operational expertise. Proponents argue that this particular approach could be highly cost-effective from a federal perspective: because repayment of the loan would be tied to a revenue stream that has been secured by state regulatory determinations, the cost to the federal government of guaranteeing such a loan would be relatively low.[35] The fact that this proposal relies on the regulated utility rate base, however, may also limit its feasibility in practice, especially in areas where retail electricity competition has been introduced or is being contemplated. The Commission believes that such a risk-sharing approach — if it can win acceptance from regulators and ratepayers — could enable a small number of IGCC plants (perhaps three to five) to be built.

C. Nuclear Energy

OVERVIEW

As this is written, the 103 commercial nuclear power plants operating in the United States are generating about 20 percent of the country's electricity. This nuclear contribution also amounts to nearly 70 percent of the non-carbon part of U.S. electricity generation.[36] But no new nuclear plants have been ordered in this country since 1978, and no plant ordered since 1973 has been completed. Unless electric utilities and the public embrace a new round of nuclear-power-plant construction, the contribution of nuclear energy to U.S. electricity supply will actually decline over the next 30 years as older plants are retired.

Worldwide, some 440 nuclear power reactors account for about a sixth of world electricity supply and for about half of the carbon-free part of electricity generation. Nuclear energy worldwide has been growing more slowly than electricity generation as a whole over the past decade, so its share of world generation has fallen even as its absolute contribution has grown.[37] Nuclear generation has leveled off for now in Europe and Russia as well as in the United States, and the near-term prospects for further growth are mainly in Asia.

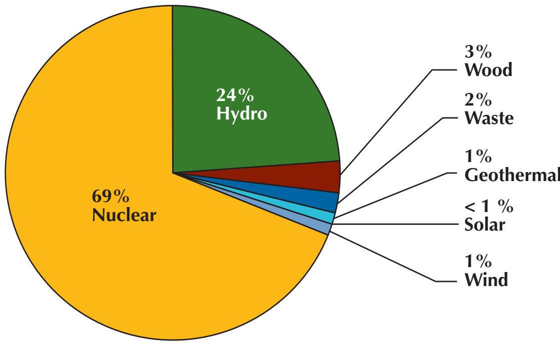
Expanding nuclear energy's shares of U.S. and world electricity generation in the decades immediately ahead, rather than allowing these shares to shrink, would offer a number of benefits:

- The crucial challenge of capping and ultimately reducing U.S. and world greenhouse gas emissions would be considerably more difficult without the contribution that expanding nuclear electricity generation could make to this task.
- Uranium to fuel an increased number of reactors is abundant and relatively inexpensive, both in the United States and worldwide. The uranium-supply situation is such that the availability and cost of this fuel are not likely to fall prey to cartels, embargoes, political instability, or terrorist acts.
- Expanded use of nuclear energy would alleviate pressure from the electric-generation sector on natural-gas supplies, helping to constrain increases

Figure 4-10

Percentage of Non-Carbon Electricity Generation Energy by Source (2003)

In 2003, nuclear power accounted for roughly 70% of the nation's non-carbon electricity generation.

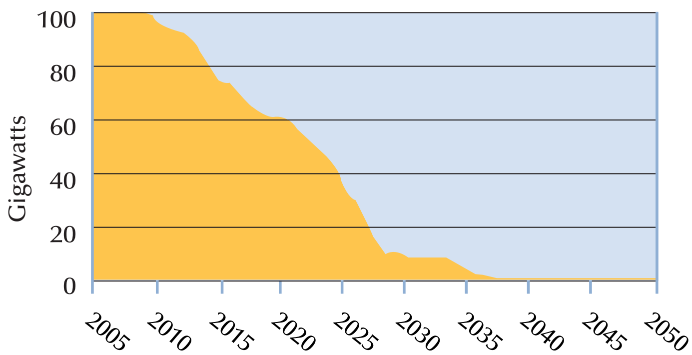


Data Source: Energy Information Administration, 2004

Figure 4-11

Total U.S. Nuclear Power Plant Capacity (by License Expiration Date)

Today's existing nuclear fleet will gradually be retired over the next 50 years – if current licenses expire – depriving the nation of one of its key non-carbon electricity sources.



Data Source: Energy Information Administration, 2003

in natural-gas prices and freeing up gas for non-electric applications, with benefits in terms of conventional pollution, greenhouse-gas emissions, and energy security.

- Experience with nuclear power plants over the past decade and more, in the United States and elsewhere, has demonstrated that these plants can be operated with high degrees of reliability and safety and extremely low exposures of workers and the public to radiation.

These are important reasons for seeking to make possible a substantial expansion in the use of nuclear energy both in the United States and abroad. Achieving that result will not be easy, however. It will require surmounting four substantial challenges:

1. Cost. One reason for the dearth of new nuclear power-plant orders in the United States and in some other countries has been the expectation that the cost of electricity from new nuclear plants would be higher than that from gas-fired and coal-fired power plants where gas and coal are available and inexpensive. The competitiveness of nuclear energy has now improved with the increase in the price of natural gas and a concomitant increase in the price of coal.[38] Nuclear energy's position will improve further if a price is placed on greenhouse gas emissions, if production credits or portfolio standards are provided for non-carbon sources, or if coal plants are required to add costly equipment to control mercury emissions. But another key to closing the cost gap would be standardized and simplified nuclear-power-plant designs that could routinely be constructed in five years or less.

2. Accidents and terrorist attacks. Nuclear power reactors of contemporary design have compiled an excellent safety record. If the number of nuclear reactors in the United States is to double or triple over the next 30 to 50 years, however, and the number worldwide is to grow ten-fold — as would be needed to have a large impact on greenhouse gas emissions — one would want the probability of a major release of radioactivity, measured per reactor per year, to fall a further ten-fold or more.[39] This means improved defenses against terrorist attack as well as against malfunction and human error. The desired improvements can probably be achieved, in part through advanced reactor designs that rely more heavily than those of the past on passive mechanisms for heat removal, in the event of accident or sabotage, than on "active" sensors, pumps, and valves. The biggest challenge will be to achieve these improvements while simultaneously reducing rather than increasing the costs of reactor construction and operation.

3. Radioactive wastes. Even with success in the cost and safety challenges, a new generation of nuclear reactors is unlikely to be built in the United States unless and until nuclear plant owners (largely electric utilities) and the public are persuaded that the government is able to meet its obligation, under existing law, to take possession of and adequately sequester the highly radioactive spent fuel from reactor operations. In principle, this criterion could be achieved in the relatively near term by overcoming the current obstacles to certifying, licensing, and beginning to operate the geologic repository at Yucca Mountain, Nevada. No effort should be spared in trying to do that, in compliance with applicable law. But the difficulties remaining on that path — and the importance of the issue — demand a multi-pronged approach. The government should also be moving ahead on the parallel path of constructing centralized, engineered (dry-cask) spent-fuel-storage facilities at multiple locations (at very least, one east of and one west of the Mississippi) to reduce spent-fuel-transport burdens. This is a proven, safe, inexpensive waste-sequestering technology that would be good for 100 years or more, providing an interim, back-up solution against the possibility that Yucca Mountain is further delayed or derailed — or cannot be adequately expanded before a further geologic repository can be ready.[40]

"nuclear amounts to nearly 70% of non-carbon U.S. electricity generation. But no new nuclear plants have been ordered since 1978"

4. Proliferation risks. The principal technical limitation restricting the ability of countries and subnational groups to make nuclear weapons is lack of access to the needed highly enriched uranium (HEU) or plutonium.[41] Dedicated military programs have been the main sources of these materials in the countries that have developed nuclear weapons to date — and probably remain today the most likely targets of criminal attempts to steal these materials, if not the weapons themselves. But a country whose commercial nuclear-energy program includes a uranium-enrichment plant has the potential to use it to produce HEU for weapons, and a country that reprocesses spent nuclear fuel in order to recycle plutonium in its power reactors has the option of diverting that plutonium into a weapons program — as well as running the risk that the separated plutonium will be stolen by or for proliferation-prone countries or terrorists. It is important that expanded use of nuclear energy in the United States and abroad be accomplished in a way that minimizes these potential contributions of nuclear-weapon proliferation, not only because of the immense dangers to national and international security that such proliferation would pose, but also because a nuclear explosion anywhere in the world based on material produced in a civil nuclear-energy program would jeopardize the future of nuclear energy everywhere. These considerations dictate that the United States do everything it can to minimize access to uranium-enrichment and fuel-reprocessing technologies by countries other than the five de jure nuclear-weapon states; that it defer — at least for the next few decades — plutonium separation in its own commercial nuclear-energy operations (as an example to others and to avoid the risk of theft of such plutonium from its own civil stocks); that it cooperate with other countries that possess separated civil plutonium to build up the barriers against theft of this material; that it work with the community of nations to strengthen the International Atomic Energy Agency (IAEA) in its capacities for early detection of diversion of civil nuclear facilities and materials to weapon purposes; and that it increase R&D on advanced nuclear fuel cycles that might increase the energy yield from uranium and reduce waste-management burdens while avoiding storing and circulating weapon-usable plutonium.

Slightly more than 100 nuclear power plants currently operate in the U.S. James A. Fitzpatrick Nuclear Power Plant. *Oswego, New York*

The section on recommendations that follows provides more specifics about the array of government efforts that the Commission believes warranted in order to maximize the chance that nuclear energy will be able to play an expanding role in U.S. and world energy supplies.

POLICY RECOMMENDATIONS

Nuclear Energy

Government policies to improve the prospects for expansion of nuclear energy are warranted by the interests of society as a whole — going beyond the private interests that are reflected in the marketplace — in abating climate-change risks by expanding the share of no-carbon and low-carbon energy options in the electricity-generating mix; in reducing other fossil-fuel pollution from the electricity sector; in reducing pressure from the electric sector on natural-gas markets; and in decreasing the fraction of electricity generation that depends on fuels subject to large price fluctuations. The policies the Commission judges to be warranted at this time are similar in many respects to those of the recent MIT study of the future of nuclear energy;[42] they relate to (A) cost and safety/security (considered together), (B) radioactive-waste management, and (C) proliferation risks.

A. SAFETY, SECURITY, AND COST

- License extensions for existing plants and the issuance of licenses for new plants should be contingent on the Nuclear Regulatory Commission's (NRC's) affirmative judgment that the plants meet not only the usual safety criteria but also are adequately resistant to terrorist attack. The latter consideration should reflect the findings of the post-9/11 studies of the terrorist threat to nuclear facilities by the NRC, DOE, the National Academy complex, and the nuclear industry.
- In the foregoing aspects of licensing as well as other aspects, the licensing process should be managed to benefit from — and reward with accelerated review — the use of standardized designs (for which the non-site-specific aspects of the review of safety and security analysis do not need to be repeated for each replica).

- Provide $2 billion over ten years from the federal energy research, development, and deployment budget (see Chapter VI) for the demonstration of one or two first mover advanced nuclear pwer plants.

- The federal government should also recognize and reward the non-carbon nature of nuclear energy by treating new nuclear generation on a par with renewable energy sources in the event that portfolio standards are adopted, subject to an overall cap on cost.

B. RADIOACTIVE WASTES

- The Administration and the Congress should act immediately and in concert to reform the budget treatment of the Nuclear Waste Fund. Much of the $20 billion that has been paid into the fund by nuclear-power-plant operators or accrued as interest on this money has been diverted to other government programs in past years when receipts to the fund exceeded expenditures. Progress in the government's waste-management effort is now threatened because the spending requirements are growing and the money deposited in the fund for this purpose is no longer there. Congressional action is required to restore past diversions from the Nuclear Waste Fund to the extent necessary to fully fund the program now and in the years ahead. And new ground-rules should be imposed under which spending from the Nuclear Waste Fund is not scored for Federal budget purposes, though it should remain subject to the annual Congressional appropriations process.

- In compliance with applicable law, DOE should proceed with all deliberate speed to complete its license application for operating the Yucca Mountain geologic repository, currently scheduled to be submitted to the NRC in December 2004, and the Nuclear Regulatory Commission should make available all needed resources to complete a rigorous and transparent review of that application within the four years thereafter allowed for this process by applicable federal law.

- In parallel with the NRC's review of the Yucca Mountain license, DOE should move expeditiously to develop its report on the need for an additional geologic repository (required by applicable law to be completed in the period between 2007 and 2010). Its analysis of this question should include careful review of the technical possibilities for expanding the capacity of the Yucca Mountain repository beyond the current statutory limit of 70,000 metric tons of high-level waste.

- Also in parallel with the NRC's review of the Yucca Mountain license application, DOE should renew its offer to the State of Nevada to enter into negotiations on a benefits package for the State as allowed under the 1987 Nuclear Waste Policy Amendments Act.

- DOE should continue to engage other stakeholders on issues related to the waste-management program, particularly on transport. DOE expects to transport radioactive material through more than 40 states if Yucca Mountain is approved. Extensive outreach to state and local officials will be necessary to prevent or resolve additional legal and political challenges to the program related to waste transport.

- The Administration and the Congress should move expeditiously to establish a project for centralized, interim, engineered storage of spent fuel at no fewer than two U.S. locations, as a complement and interim back-up to the geologic repository program.

C. PROLIFERATION RISKS

- The nuclear-energy policy of the federal government should make explicit that measures to reduce the risks of the use civil nuclear-energy facilities or materials for weapons by proliferant states or terrorists are an absolutely essential part of the effort to enable expansion of the use of nuclear energy in the United States and in other countries.

- In this connection, the administration should reiterate its commitment to continue indefinitely the long-standing U.S. moratoria on commercial reprocessing of spent nuclear fuel and construction of commercial breeder reactors (which, with the current technology, require reprocessing for the separation and recycle of weapon-usable plutonium).

- In a manner consistent with the long-standing U.S. moratorium on commercial reprocessing (see previous bullet), the government should continue to support research and development, for potential future application, on advanced reactor and fuel-cycle concepts offering promise of lower costs, reduced waste-management burdens, and significantly higher barriers to theft and diversion of weapon-usable material than do the current reprocessing and breeding technologies.

- The U.S. government should continue its long-standing policy of discouraging the accumulation of separated plutonium in civil fuel cycles elsewhere but should pursue this aim more actively than it has done to date. The increased effort should include pressing (and where practicable offering incentives to) Russia, France, the United Kingdom, and Japan to declare moratoria on civil reprocessing, with some of the plutonium-fuel fabrication capacity that would otherwise be made surplus by this step then being turned to the task of fabricating fuel from surplus weapon plutonium.

- The U.S. government should actively work to prevent the deployment of uranium-enrichment and spent-fuel-reprocessing capacity in additional countries, exploring a range of approaches to this end including offering fresh low-enriched-uranium fuel and spent-fuel take-back on highly attractive terms to countries that refrain from deploying their own such facilities.

- The government should work with the international community to greatly upgrade the powers, procedures, and resources available to the IAEA for its missions relating to minimizing proliferation risks from civil nuclear energy. (The IAEA is hobbled by inadequate powers and stretched thin by inadequate resources; a major expansion of the global nuclear-energy system would overwhelm it unless these conditions were rectified.) Among the needed increased powers, the IAEA should be allowed to develop binding standards for the physical protection of weapon-usable materials in civil nuclear-energy programs and to monitor compliance with these standards.

D. Renewable Electricity Technologies

OVERVIEW

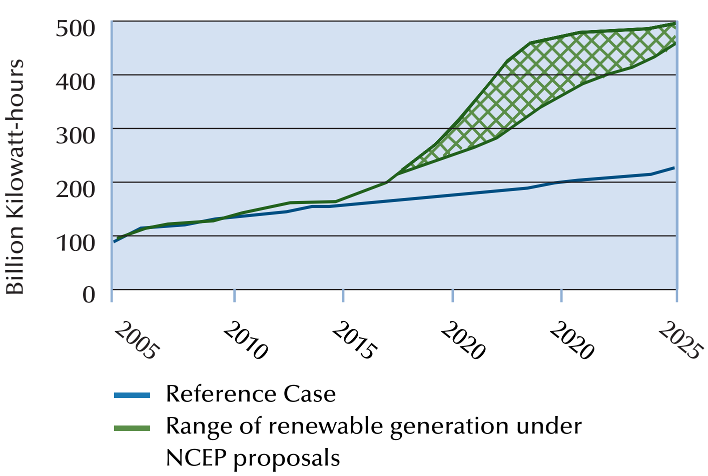
Clean, renewable energy plays an important role in the nation's energy supply, accounting for roughly 10 percent of U.S. electricity generation. At present, hydro-electric plants supply the bulk of this renewable generation. Other, non-hydro renewable sources — such as wind, solar, biomass, and geothermal — currently provide only 2 percent of the nation's power. Although the costs of these non-hydro renewable technologies have fallen dramatically over the last two decades, they are still generally more expensive than fossil-based electricity and face continuing technological and siting challenges.

Wind farm in wheatgrass field. *Dalles, Oregon*

Figure 4-12

Projected Renewable Electricity Generation

Non-hydro renewable electricity generation is expected to more than double in 2025 compared to forecasted business-as-usual levels as a result of the Commission's proposed greenhouse gas emissions trading program and other policy recommendations.



Data Source: NCEP NEMS Modeling

The Commission believes that further improvements in renewable energy technologies and increased deployment of these technologies are important components of a comprehensive strategy to assure adequate energy supplies and reduced greenhouse gas emissions. The Commission's greenhouse gas proposal will itself encourage further deployment, particularly of wind resources. In addition, the Commission recommends a substantial increase in federal funding for renewable energy research, development and early deployment; the inclusion of renewables in a systematic national inventory of domestic energy resources; and further extension and expansion of the federal production tax credit for renewable energy.

As noted in Chapter III, the Commission's economic analysis projects that the contribution of non-hydro renewable electricity resources will grow to as much as 10 percent of total generation by 2020 as a result of both the proposed greenhouse gas tradable-permits system and increased R&D funding (by comparison, current government forecasts project non-hydro renewables will reach 3 percent of total generation by 2020 under business-as-usual assumptions).

RENEWABLE ENERGY OPPORTUNITIES AND CHALLENGES

As context for the Commission's recommendations in this area, it is useful to begin with a short review of current technology status as well as key opportunities and challenges for each of the chief renewable electricity options. In addition to the issues summarized below, siting hurdles present an important cross-cutting challenge for the expanded deployment of most, if not all, renewable energy options and are discussed in general terms after this brief technology review. Additional Commission recommendations with respect to siting all types of energy infrastructure are discussed in the next chapter of this report (Chapter V).

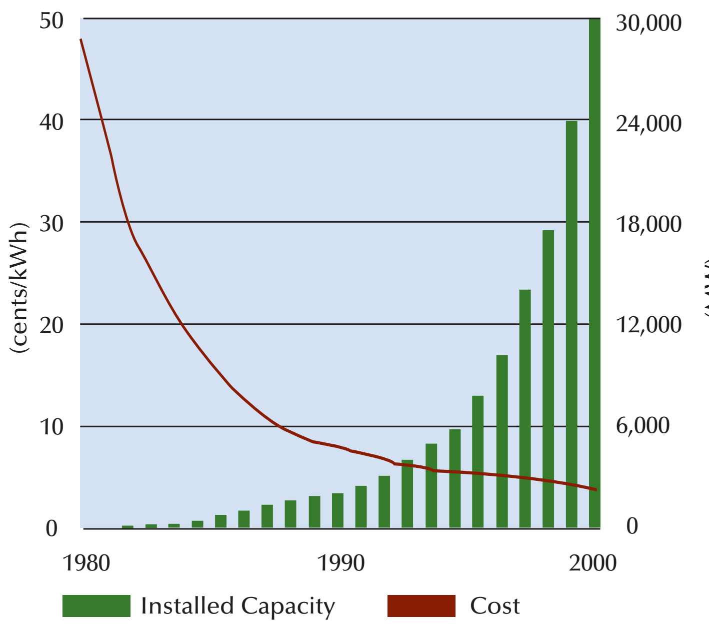
Wind **—** Over the past 30 years, the cost of wind power has declined over 80 percent and now ranges from 4–6 cents per kilowatt-hour.[43] Investments in wind power have grown rapidly in recent years, thanks not only to reduced costs but also to a federal production tax credit for renewable energy that was recently extended through 2005. Total wind capacity increased by 30 percent in 2003 alone. The 6,370 megawatts (MW) of wind capacity now in place nationally are expected to generate approximately 16.7 billion kilowatt-hours (kWh) in 2004.[44]

In spite of continued progress in reducing costs, the intermittent nature of the wind resource remains a serious drawback. Wind facilities have a relatively low capacity (or utilization) factor compared to other generation technologies and wind power often has less economic value than firm power that can be produced on demand from traditional generation facilities. In the near term there is also a need for expanded transmission capacity that could deliver wind power from remote rural and off-shore sites to major load centers and for improved technologies capable of cost-effectively exploiting lower-speed wind resources. Accordingly, storage technologies, transmission enhancements, and design improvements to improve compatibility with lower-speed resources deserve priority among competing early deployment and research and development initiatives.

Figure 4-13

Declining Costs of Wind Power

As experience grows and technology improves with more wind turbine installations, the costs of wind power have dramatically decreased over the past two decades.



The Energy Foundation, 2004

Solar **—** There are approximately 397 MW of grid-connected solar energy capacity in the United States, most of it provided by central station solar thermal-electric (STE) facilities in Southern California.[45] The range of solar energy options, however, encompasses several technologies including solar photovoltaics (PV), solar water heating (SWH), and passive solar design for buildings. Solar PV may be grid-connected — in the form of large, central-station installations or in customer-sited, net-metered applications — but is often also appropriate for stand-alone, off-grid applications. Indeed, the global market

Photo Courtesy of J. Johansson for allPOWER.com

This grid-tied, commercial-scale photovoltaic array helps shave peak building power demand. *Brooklyn, New York*

for stand-alone solar technologies, especially where grid infrastructure is lacking, has been growing rapidly.

In 2002, grid-connected PV and STE installations together provided about 0.6 billion kWh of electricity generation and accounted for about 0.02 percent of national generation. In addition, off-grid PV installations provide approximately 300 MW of electricity capacity nationally, primarily in remote locations and for powering traffic signs and communications equipment. Grid-connected solar power is significantly more expensive than other sources of grid-connected electricity — at least 20–25 cents per kWh. Stand-alone solar technologies are, however, often the least-cost source of power in remote locations distant from the electric grid. The key challenge for solar PV systems remains reducing costs through improvements in the materials used to manufacture PV modules. For solar thermal systems, technology improvements, increases in scale, and cost reductions resulting from higher production volumes are needed to accelerate deployment.

“costs of renewable technologies have fallen dramatically over the last two decades”

Geothermal — Geothermal power, which draws energy from underground reservoirs of water that have been heated by geological processes, is a well-established renewable energy technology. Although up-front costs are high, geothermal plants typically benefit from their reliability and high (typically over 90 percent) availability (i.e., they are usually available to supply power when called upon).[46] Reservoir depletion has reduced generation capacity at some existing geothermal plants, though water re-injection has in several cases helped to sustain production.

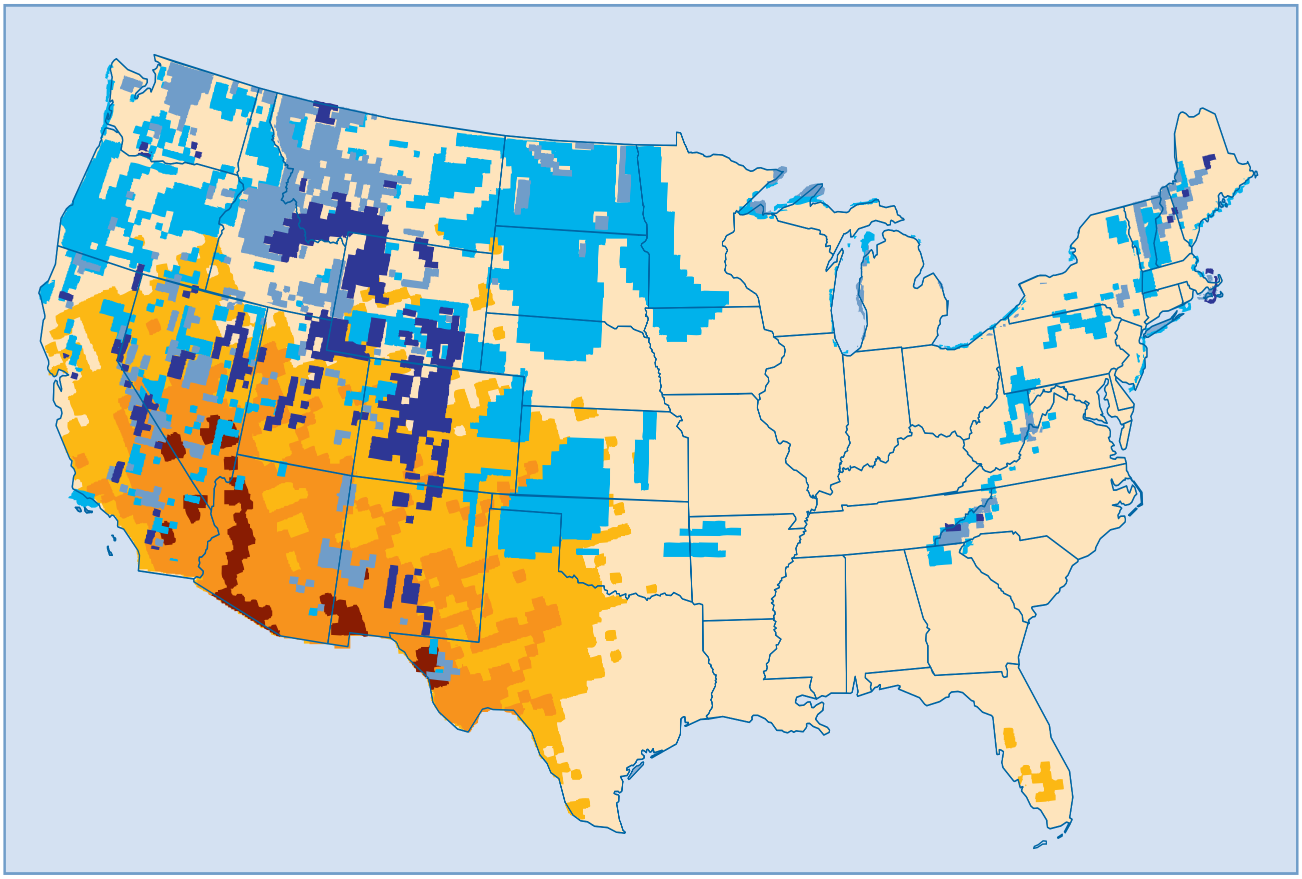
Approximately 2,300 MW of geothermal capacity is installed in the United States at present, of which most (about 1,875 MW) is located in California.[47] Other states with geothermal capacity include Nevada (196 MW today, 205 MW planned) and, to a small extent, Utah and Hawaii. DOE’s Geothermal Technologies Center estimates that 15,000 MW of new geothermal capacity will be developed over the next decade.[48] New geothermal plants are expected to operate at costs in the 4–6 cents per kWh range.[49] The outlook for this technology depends on at least three factors: availability of geothermal resources, costs for competing energy resources, and continued technology improvement. The latter requires focused research in the areas of exploration, drilling, and power-plant design, as well as to develop strategies for maximizing reservoir lifespans.

Besides grid-connected geothermal power plants, ground-source heat pumps — which exploit the differential between air temperature and below-ground temperature to provide space heating or cooling for buildings — represent an important, distributed application of geothermal energy. Some 900,000 ground-source heat pumps have been installed in the United States to date and current estimates are that this number could grow by 50,000 new installations per year over the next few years.[50] Selective water sorbents, lower-cost heat exchangers, and other advances could significantly improve the cost-effectiveness of this technology.

Figure 4-14

Wind and Solar Resource Potential is Large, Especially in the Western United States

The map below illustrates the distribution of wind and solar resources across the United States. While all 50 states have potentially significant resources, some of the best prospects for commercial-scale renewable electricity production are in the West. As noted in the text, successfully developing these resources will require further progress in addressing transmission constraints — particularly where resources are located far from population centers — and improving technology cost and performance.



Average Solar Radiation (kWh/m²/day)

5.5-6.0	6.0-6.5	6.5-7.0
Good	Better	Best

Wind Power Class

4	5	6
Good	Better	Best

Data Source: Adapted from National Renewable Energy Laboratory, 2004

***Hydroelectric* —** Moving water has long been an important source of energy for industry and commerce in the United States and elsewhere around the world. Total installed hydropower capacity in the United States is approximately 80,000 MW at this time, much of it concentrated in the Pacific Northwest.[51] Hydropower provides significant air quality and climate benefits relative to other forms of power but is often associated with other environmental concerns in terms of its potentially adverse impact on water quality, fish habitat (including interference with species migrations), and river flow. Given these concerns, high up-front capital costs for new installations, and resource limitations (most of the nation's significant hydropower resources have already been tapped), large-scale hydroelectric power is not likely to expand greatly in the future. Nevertheless, technology improvements that could increase the power output of existing hydro facilities while minimizing negative ecological impacts could further expand the contribution of this renewable resource.

Major research and development opportunities for hydropower include advanced turbine designs, including high-efficiency and fish friendly turbines that substantially reduce fish mortality. As the re-licensing of hydro facilities frequently results in lower capacity, advanced turbines and generators — which DOE estimates could help deliver up to 4,300 MW of new capacity in the future — will be necessary to maintain or increase the nation's hydroelectric resource base. Over the longer-term, alternative hydropower technologies, including micro-hydro facilities as well as systems that generate power using tidal flows and currents, may provide substantial new opportunities. Meanwhile, additional challenges for all forms of hydropower include their typically high up-front capital costs, environmental and siting concerns, and ensuring that impact mitigation projects (such as wetland reconstruction, fish ladders, water oxidation, and other measures) achieve desired objectives.

***Biomass* —** Biomass is the single largest existing source of non-hydro renewable electricity production, with approximately 9,799 megawatts (MW) of biomass generating capacity installed around the country as of 2003.[52] Biomass generation in 2003 totaled 37 billion KWh. Much of the biomass-based power production that occurs today comes from the use of wood and wood waste by the pulp and paper industry to generate steam and electricity. Biomass can also be burned simultaneously with coal in conventional steam boilers in a process known as co-firing. Currently, 96 power plants in the United States co-fire biomass with coal.[53] Other forms of biomass-based generation rely on municipal solid waste, gas from landfills or anaerobic digesters, and agricultural residues. In addition, advanced technology to gasify biomass — similar to IGCC technology for coal — is currently under development and may hold significant promise. Prospects for increasing the contribution of biomass-generated electricity will depend on technology improvements (including the potential for co-production of electricity and high-value industrial chemicals with biomass-based transportation fuels, as discussed in the next section of this chapter), maintaining reliable feedstocks at affordable prices, and reducing feedstock transportation costs

DEPLOYMENT PROGRAMS

At the national-level, renewable energy deployment is promoted primarily through a federal production tax credit (PTC). In the past, the PTC — which was designed to spur the deployment of technologies that are near economic competitiveness — has allowed wind and "closed-loop" biomass generators to receive an inflation-adjusted 1.5 cent/kWh federal tax credit for their electricity output over a ten-year period. (Inflation has since increased the credit amount to 1.8 cents per kWh). This incentive has been particularly effective in helping to boost the domestic wind power industry. Since it was introduced in 1992, installed wind capacity has grown more than 400 percent.

Though originally enacted with a 2001 expiration date, the PTC has been extended twice: in 2001 and again in 2004. On each occasion the extension

State Policies

Significant additional efforts to promote the deployment of renewable energy technologies are being undertaken at the state level
.

State Renewable Portfolio Standards (RPS) have been the most widely-used state-level mechanism for promoting increased renewable generation capacity and utilization. As of September 2004, 17 states had passed RPS requirements (the RPS in Illinois is a non-binding goal).[54] An RPS typically requires either a minimum percentage of electricity (anywhere from 1 percent to as much as 20 or even 30 percent in some states) to be generated from renewable sources. In a few cases, states have instead required that a certain amount of renewable capacity be installed within a defined timeframe.[55]

The premise of most state RPS policies is that renewable technologies, despite their generally strong resource-conservation and environmental advantages, are not yet directly cost-competitive with conventional generation technologies, but do provide benefits in terms of environmental quality, public health, and fuel diversity, while also stimulating local economies and thus belong in the generating mix. Since all eligible renewable technologies[56] can usually compete to meet RPS requirements, this mechanism has also been popular because it tends to promote the most cost-effective option(s) available. To date, that option has tended to be wind power, although there has been some regional variation in the mix of renewables used to meet RPS requirements. RPS eligibility requirements in different states often reflect regionally-available energy sources or may favor resources with unique regional advantages if they are not yet economically preferred: solar power in Arizona and Nevada, for instance.[57]

California Renewable Resources Account and Reverse Auction: In addition to an RPS, the State of California in 1996 launched a Renewable Energy Program that included a dedicated account to provide funds for renewable energy projects. The account is funded by a surcharge on electricity consumers collected through utility rates (the surcharge was originally authorized from 1998 through 2001 and was later extended to 2011). Funds from the account are distributed using a reverse-auction mechanism in which renewable energy developers submit bids for various incentive amounts per kWh of production, up to a limit of 1.5 cents per kWh for up to five years.[58] Auctions were held in 1998, 2000, and 2001. At the time of the first solicitation in 1998, the California Energy Commission observed that: "The bids came in with requested incentives well below the level that critics predicted would fail to stimulate development of a new market."[59]

After nearly a decade (from the late-1980s to the late-1990s) of virtually no growth in California's renewable energy market, some $162 million from the New Renewable Resources Account has been allocated to new wind, geothermal, landfill gas, biomass, digester gas, and small hydroelectric projects using the reverse auction mechanism. As a result, by June of 2004, 45 renewable projects totaling 429 MW of capacity had come on-line in California. An additional 26 projects have been selected through the auction mechanism but have yet to come on-line, though several wind projects are expected to begin operation in the near future with the recent reauthorization of the federal production tax credit.[60]

Public Benefits Funds: Many states maintain "public goods" or "system benefits" funds — typically collected through a small surcharge on consumer electricity bills — to support a variety of electricity-related policy objectives. Currently, 26 states maintain such funds and many dedicate a portion of their funds to siting or promoting renewable energy projects.[61] Oregon, for example, devotes about $8 million annually from its public benefits fund to renewable energy. One state, Maine, does not mandate a specific charge, but allows for private, voluntary contributions to fund renewable energy projects.[62]

State-Federal R&D Collaboration: States currently receive about $200 million in federal energy R&D grants, the bulk of which goes towards weatherization assistance programs for low-income households ($145 million in 2004) with the remainder divided between three energy R&D programs: State Energy Programs (SEP), SEP Special Projects, and the State Technology Advancement Collaborative (STAC). The SEP program provides funds to state energy offices for efforts aimed at improving energy reliability, national security, and U.S. competitiveness; the related Special Projects program requires a 50 percent cost share from the state and is designed to target high-priority deployment activities in buildings, industry, and transportation. The newest and smallest of collaborative state-federal energy programs is STAC, a 5-year pilot program specifically designed to broaden cooperation, leverage funding, and promote a diversity of projects by requiring a 50 percent cost-share and participation by state-chartered institutions (such as the state energy office or a state university) from at least two states. Most of the proposals funded to date under these state-federal programs have involved energy efficiency projects. Given that many states are actively trying to promote the deployment of renewable technologies, however, similar approaches — which, like the STAC program, stress cost-sharing and collaboration — may also provide opportunities for leveraging future federal spending on renewables R&D.

allowed an additional two years for new projects to qualify for ten years of production tax credits. These relatively brief extensions and more general uncertainty regarding future Congressional action have complicated investment planning for renewable energy developers and may be hindering projects with longer lead times. The most recent extension, for example, applies retroactively from the beginning of 2004 through the end of 2005; given the short timeframe, few if any additional projects are likely to qualify within this window. Greater certainty and sustained commitments are therefore important in promoting the continued growth and development of renewable power alternatives.

SITING AND INFRASTRUCTURE NEEDS FOR RENEWABLE TECHNOLOGIES

Renewable energy projects generally face many of the same siting challenges as more traditional energy plants. Local opposition and complex, open-ended siting processes can lead to long delays. Although most renewable technologies produce no air emissions, concerns are often raised regarding noise and visual impacts, land requirements, or effects on wildlife — especially in scenic or residential areas.

Moreover, renewable technologies often face additional siting and infrastructure challenges that are unique to the resources involved. First, these resources are often site-specific. Wind speeds or solar radiation can vary dramatically even across small areas, meaning not only that proposed projects cannot readily be moved, but that careful mapping and analysis is needed to identify and maximize the resource base.

Second, the site-specific nature of many renewable resources often gives rise to additional infrastructure needs. Wind, solar and geothermal projects must be sited were the resources are available. Biomass plants must also be sited near a ready fuel source to minimize feedstock transportation costs. Because many of the best renewable resources are not located near population centers, additional transmission lines must be built to transport power where it is needed. Given the intermittent nature of many of these resources, however, the cost to build additional transmission can be prohibitive and the generation itself must be carefully integrated with the rest of the electricity grid to ensure these resources are fully utilized while maintaining reliability.

POLICY RECOMMENDATIONS

Renewable Electricity Technologies

As noted in the introduction to this section, the Commission's proposal for a tradable-permits system to limit U.S. greenhouse gas emissions is projected to lead to a substantial increase in renewable technology deployment by 2020 relative to current business-as-usual expectations. As with other technologies described in this chapter, additional targeted measures are also warranted to overcome substantial deployment hurdles for new renewable resources and to further reduce technology cost and improve performance. With such advances, renewable energy technologies have the potential to make a significant contribution to the nation's long-term energy portfolio. Specifically, the Commission recommends:

- Increasing federal funding for renewable technology research and development by $360 million annually (for further discussion of the Commission's recommendations with respect to federal energy R&D, see Table 6-1 in Chapter VI at p. X). Federal efforts should be targeted at overcoming key hurdles to renewable energy cost-competitiveness and early deployment and should be leveraged where possible through collaboration and cost-sharing with states and other entities.

- Extending the federal PTC for a further four years (i.e., for 2006 through 2009), on top of the extension that was recently passed to the end of 2005, and expanding eligibility to all non-carbon energy sources, including solar, geothermal, and new hydropower generation, as well as new, next-generation nuclear and advanced fossil-fuel generation with carbon capture and sequestration. A full four-year extention would provide greater investment certainty than recent policy actions, which have typically extended the window for PTC eligibility by just two years at a time. In addition, the PTC should be offered on equal terms to all eligible sources, allowing these technologies to compete fairly with one another for limited federal resources, with total spending capped at $4 billion for the additional four-year extension. DOE should be designated the lead agency to determine which technologies qualify for the PTC.

- In addition, the Commission acknowledges and supports FERC's ongoing efforts to promote market-based approaches to integrating intermittent resources into the interstate grid system, while ensuring that costs are allocated appropriately among all involved and that arbitrary penalties for over- and under-production are eliminated. Grid operators must recognize that business rules written for conventional generation, when applied to intermittent generation, can make the intermittent resource uneconomic. Intermittent generators, in turn, must recognize that their facilities may impose additional costs on the grid for regulation, operating reserves and load-following services.

Finally, in the interests of providing a sound basis for future energy policy decision making the Commission recommends that a comprehensive assessment of the nation's renewable energy resource potential be included as part of the overall national energy resource assessment described in the introduction to this chapter. The National Renewable Energy Laboratory (NREL) should spearhead the renewables portion of this assessment in coordination with other lead government agencies.

E. Non-Petroleum Transportation Fuels

OVERVIEW

Since the late 1980s, the United States has pursued a policy of promoting alternatives to petroleum-based transportation fuels as a means of diminishing the nation's vulnerability to oil price shocks and supply disruptions and reducing emissions from passenger vehicles. Despite these efforts, the existing U.S. transportation system relies almost exclusively on petroleum-derived, liquid fuels. Gasoline and diesel accounted for over 98 percent of transportation motor fuels sold in 2004.[63] The 2 percent share of alternative fuels was comprised chiefly of corn-based ethanol,[64] with additional contributions from compressed natural gas (CNG), liquefied petroleum gas (LPG), bio-diesel, and electricity.[65]

The Commission seeks to encourage development of a suite of domestically produced transportation fuels that can collectively help to diminish U.S. vulnerability to high oil prices and oil supply disruptions while reducing the transportation sector's greenhouse gas emissions. The Commission does not seek to identify a single fuel or technology to displace petroleum in the transportation sector. Rather the Commission aims to promote a diversity of low-carbon alternative fuels that can be produced from a variety of domestic feedstocks. Efforts underway to develop a mix of low-carbon sources for producing electricity offer an appropriate analogy to the task at hand in that the availability of multiple sources of commercially competitive renewable electricity is in part premised on their ability to be successfully integrated into the existing electricity system. Similarly, those non-petroleum fuels that are compatible with existing infrastructure and vehicle technology enjoy a significant advantage over those that require a wholly new distribution system or vehicle fleet.

Among the variety of alternative fuel options potentially available for the light-duty vehicle fleet, the Commission believes that ethanol produced from cellulosic biomass (i.e. fibrous or woody plant materials) should be the focus of near-term federal research, development, and demonstration efforts. For reasons discussed later in this section, cellulosic ethanol offers substantial energy security, environmental, and long-term cost advantages compared to corn-based ethanol. Indeed, Commission-sponsored analysis indicates that with steady though unremarkable progress to reduce production costs and increase crop yields, cellulosic ethanol has the potential to make a meaningful contribution to the nation's transportation fuel supply over the next two to three decades.

Potential alternatives for the diesel fuel now used in most heavy-duty trucks, buses, and construction equipment, have been less extensively explored and are not as well-developed. A small market currently exists for biomass-derived diesel or "bio-diesel" which to date has generally consisted of transportation-grade fuel from oil-seed crops (e.g., soy, rapeseed) or waste oils (e.g., grease from restaurants). While they provide one alternative fuel option for the heavy-duty fleet, these types of bio-diesel have significant cost, resource, and — in the case of waste oil — environmental drawbacks; as a result their potential for substantially displacing conventional diesel is probably limited. Just as cellulosic ethanol represents a more promising long-term alternative to gasoline than corn-based ethanol, however, newer technologies are emerging that can produce clean, low-sulfur synthetic diesel fuels from biomass or other organic materials. The most promising of these technologies can utilize a wide variety of organic wastes as feedstocks. One process in particular, known as thermal depolymerization, is now being demonstrated on a commercial-scale to produce low-sulfur diesel fuel from wastes generated by a turkey-processing facility. This technology and other advanced bio-diesel options merit further research, development, and early deployment efforts.

Table 4-1

Summary of Renewable Fuel Options

The most promising renewable transportation fuel alternatives meet four criteria: (1) they can be produced from ample domestic feedstocks; (2) they have low or near-zero carbon emissions during production and use; (3) they work in existing vehicles and with existing infrastructure; and (4) they have the potential to become cost-competitive with petroleum fuels given sufficient time and resources dedicated to technology development.

	Hydrogen	Corn Ethanol	Cellulosic Ethanol	Bio-Diesel	Electricity
Ample, Domestic Resource	**Yes** Hydrogen can be produced from water through electrolysis or by separating hydrogen from fossil fuels. The U.S. has plentiful coal deposits and abundant water supplies to generate sufficient hydrogen to fuel the domestic transportation system.	**No** In 2003, roughly 7% of the U.S. corn crop was used to make ethanol. Corn ethanol production will continue to grow, but even use of 100% of the current crop would displace only 25% of current gasoline use on an energy-equivalent basis.	**Yes** Greater diversity of biomass and waste feed stocks means cellulosic ethanol is likely to be less limited by competing land uses for food and forest products. NCEP analysis suggests potential for substantial production w/o constraining food supply.	**Yes** Bio-diesel can potentially be made from a wide variety of organic materials, including animal and crop waste, vegetable oils, used grease, etc. Waste quantities generated in the U.S. could support significant production if new technologies for making bio-diesel prove cost-competitive and widely applicable.	**Yes** The diversity of fuels and technologies used to provide electricity is now much greater than the diversity of fuels used in the transportation sector. Moreover, nearly all electricity used in the U.S. is produced using domestic resources.
Low-Carbon	**It depends . . .** Three times more carbon intensive per mile than gasoline if produced using electri-city from existing pow-er plants. Use of natural gas, renewable, nuclear, or coal power with sequestration would make hydrogen low-carbon, but these technologies will provide greater benefits by directly displacing fossil-based electricity than by in-directly displacing gasoline.	**Yes** Corn ethanol is roughly 20% lower in greenhouse gas emissions than gasoline. Most emissions result from upstream energy inputs required for the cultivation, harvest, and processing of corn. CO_2 reductions from corn ethanol are modest compared to cellulosic ethanol.	**Yes** Unlike corn ethanol, has potential to achieve near-zero net carbon emissions. Cultivation of cellulosic feedstocks requires very low energy inputs and, if sustainably managed, the carbon released during fuel combustion is re-absorbed by the growth of new feedstocks.	**It Depends . . .** Provided it is produced from agricultural crops or wastes, bio-diesel would have very low carbon emissions (similar to cellulosic ethanol).	**It Depends . . .** Depends on the manner in which the electricity used was generated. The carbon intensity of future electricity production could be greatly reduced by more reliance on renewables and development of next-generation nuclear and fossil technologies with carbon sequestration.
Compatible with Existing Infrastructure	**No** As a gas, would require a new national distribution infrastructure estimated to cost hundreds of billions of dollars.	**It Depends . . .** Can be blended with gasoline at varying levels, but cannot now be transported by pipeline and must be moved by barge or truck.	**It Depends . . .** Infrastructure and vehicle compatibility issues are the same as for corn ethanol.	**Yes** New synthetic, waste-derived bio-diesels are compatible with existing diesel engines and infrastructure. Some existing vegetable oil bio-diesel can cause problems in older engines at blends greater than 20%.	**Yes** Assuming plug-in hybrids with short all-electric range, recharging could be done using the existing grid.
Potentially Competitive with Gasoline by 2020	**No** Substantial technological breakthroughs and dramatic cost reductions are required. National Academy of Sciences estimates 50-year time horizon to full development.	**No** Technology is mature, but still costs more than twice as much to produce as gasoline (~$1.40/gal). Current market for corn ethanol is supported by large public subsidies.	**Yes** Significant progress still needed, but costs have already declined by a factor of three since 1980. NCEP analysis suggests production cost below $0.80/gal. is attainable.	**It Depends . . .** Economics of early deployment depend heavily on feedstock costs. In the case of waste-derived fuels, avoided cost of waste disposal can in some instances help to make bio-diesel cost-competitive.	**It Depends . . .** Battery technology, not electricity itself, is main cost hurdle. Plug-in hybrids are more promising than all-electric vehicles.

Data Sources: National Academy of Sciences, 2004; Romm, 2004 (I); Lynd, Lave, and Greene, 2004; Lynd, Greene, and Sheehan, 2004; International Energy Agency, 2004; Energy Information Administration, 2004; Romm, 2004 (II).

Each year the U.S. produces over 100 million metric tons of corn stover, a potential source for renewable transportation fuels such as cellulosic ethanol.

OVERVIEW OF PROMINENT TRANSPORTATION FUEL ALTERNATIVES

Hydrogen — The prospect of a hydrogen economy and zero-emission hydrogen fuel cell vehicles has drawn considerable interest from government and industry. Realizing this vision, however, requires overcoming a number of significant technical challenges. The Commission supports continued research and development into hydrogen as a long-term (2050) solution. The Commission also concludes, however, that hydrogen offers little to no potential to improve oil security and reduce climate change risks in the next twenty years. Certainly, a low-carbon hydrogen fuel cycle, where hydrogen is produced using electricity generated from renewable, nuclear, or advanced fossil technologies with carbon sequestration would have potentially very significant benefits and is an appropriate target for basic research into hydrogen storage, infrastructure, and safety. While supportive of this basic research, however, the Commission believes that efforts to speed deployment of a hydrogen transportation system should not displace other activities that can deliver significant results in the next twenty years.

Electricity — Electric technologies for vehicles have improved dramatically over the last fifteen years as new types of batteries (nickel cadmium, nickel metal hydride, lithium ion) and new uses of battery technology (laptop computers, cell phones, hybrid-electric vehicles) have proliferated. Motor vehicles have also been developed that are capable of battery-only operation for short periods; however their limited range remains a significant barrier to broad-based consumer acceptance. Hybrid-electric vehicles solve the range problem, but today's versions are generally not capable of operating on grid-supplied electricity. "Plug-in" hybrids are a logical extension of the current technology. These vehicles would carry more robust battery packs and be capable of being charged using the electricity grid. Since most trips are relatively short, these vehicles could operate using grid-provided electricity much of the time, while retaining the flexibility consumers desire for being able to travel longer distances without the need to recharge. To the extent they would operate more often than conventional hybrids in a pure-electric mode, plug-in hybrids could provide additional oil security and fuel diversity benefits. Because most of the nation's electricity supply remains fossil-based, however, they would not offer substantial advantages in terms of their greenhouse gas emissions relative to conventional hybrids. Even with an increased reliance on renewable resources in the electricity sector, renewable electricity generation will have a greater positive impact on climate risks if it is used to displace carbon emissions from fossil-based electricity generation, rather than petroleum combustion in the transportation sector.

Corn Ethanol — Ethanol is the most successful domestically and internationally produced non-petroleum fuel in the market today — mainly due to large production volumes in the United States and Brazil. Global fuel ethanol production doubled between 1990 and 2003, and may double again by 2010.[66] Fuel ethanol produced from corn has been used as a transport fuel in the United States since the early 1980s; today it is most commonly used in a blend of modest proportions with gasoline. It is also possible, however, with minimum vehicle modifications, to use blends that are up to 90 percent ethanol. In 2003, roughly 2.8 billion gallons of domestic corn ethanol production displaced 2 percent of

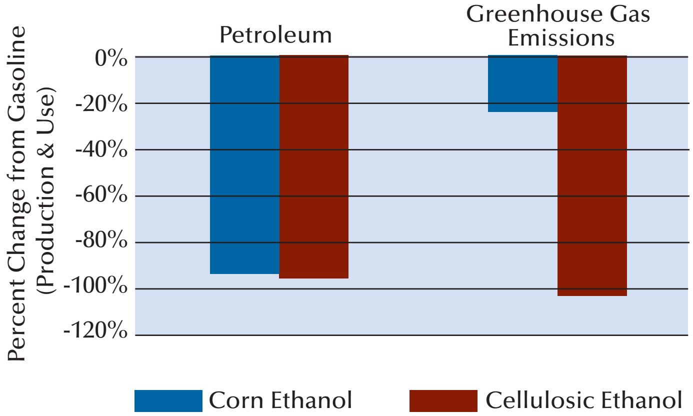
U.S. gasoline consumption (about 1.8 percent on an energy-equivalent basis). Over the next decade, ethanol's market-share in the United States is expected to increase as a result of the phase-out of the gasoline additive MTBE (for which the primary replacement at present is ethanol) and the possible adoption of a national Renewable Fuels Standard (RFS).[67] Current proposals for a national RFS would double renewable fuel production to 5 billion gallons per year (0.3 MBD) by 2012. The Commission recognizes the oil security, fuel diversity, and greenhouse gas reduction benefits that would accrue from an increase in ethanol production. Future legislative efforts to promote ethanol should be aimed at maximizing benefits in terms of these national interests, as opposed to the less certain local air quality benefits that are the basis of current ethanol requirements. Toward this end, the Commission believes that future RFS proposals should be designed such that the incentives they offer accurately reflect the relative benefits of traditional vs. cellulosic ethanol as discussed below.

Figure 4-15 contrasts the energy security and greenhouse gas reduction benefits of corn-based and cellulosic ethanol in terms of the percentage reductions they achieve on a per-mile basis compared to a vehicle operating on reformulated gasoline. The underlying calculations take into account upstream energy inputs for cultivating and harvesting feedstocks and converting them to fuel (in the case of ethanol) and refining petroleum (in the case of gasoline). Benefits are calculated in terms of direct petroleum use and greenhouse gas emissions. Figure 4-15 indicates that on a full fuel-cycle, per-mile basis, a vehicle operating on either corn-based or cellulosic ethanol uses 95 percent less petroleum than a vehicle operating on reformulated gasoline would. The greenhouse gas benefits associated with cellulosic ethanol, however, are considerably larger because the biomass feedstocks involved require less energy and fertilizer inputs and, in part, because the analysis assumes that cellulosic production facilities co-produce electricity, thereby displacing fossil-fuel generated electricity. Thus, whereas corn ethanol achieves reductions of roughly 20 percent relative to gasoline, the potential greenhouse gas reductions associated with cellulosic ethanol are much larger. In fact, Figure 4-15 shows greenhouse gas reductions for cellulosic ethanol greater than 100 percent, because the avoided emissions associated with co-producing electricity more than offset the modest energy-related greenhouse gas emissions that arise from feedstock cultivation, harvesting, and fuel production.

Figure 4-15

The Attributes of Corn Ethanol and Cellulosic Ethanol

While both corn and cellulosic ethanol are effective at offsetting petroleum consumption, cellulosic ethanol has the added benefit of substantially reduced greenhouse gas emissions.



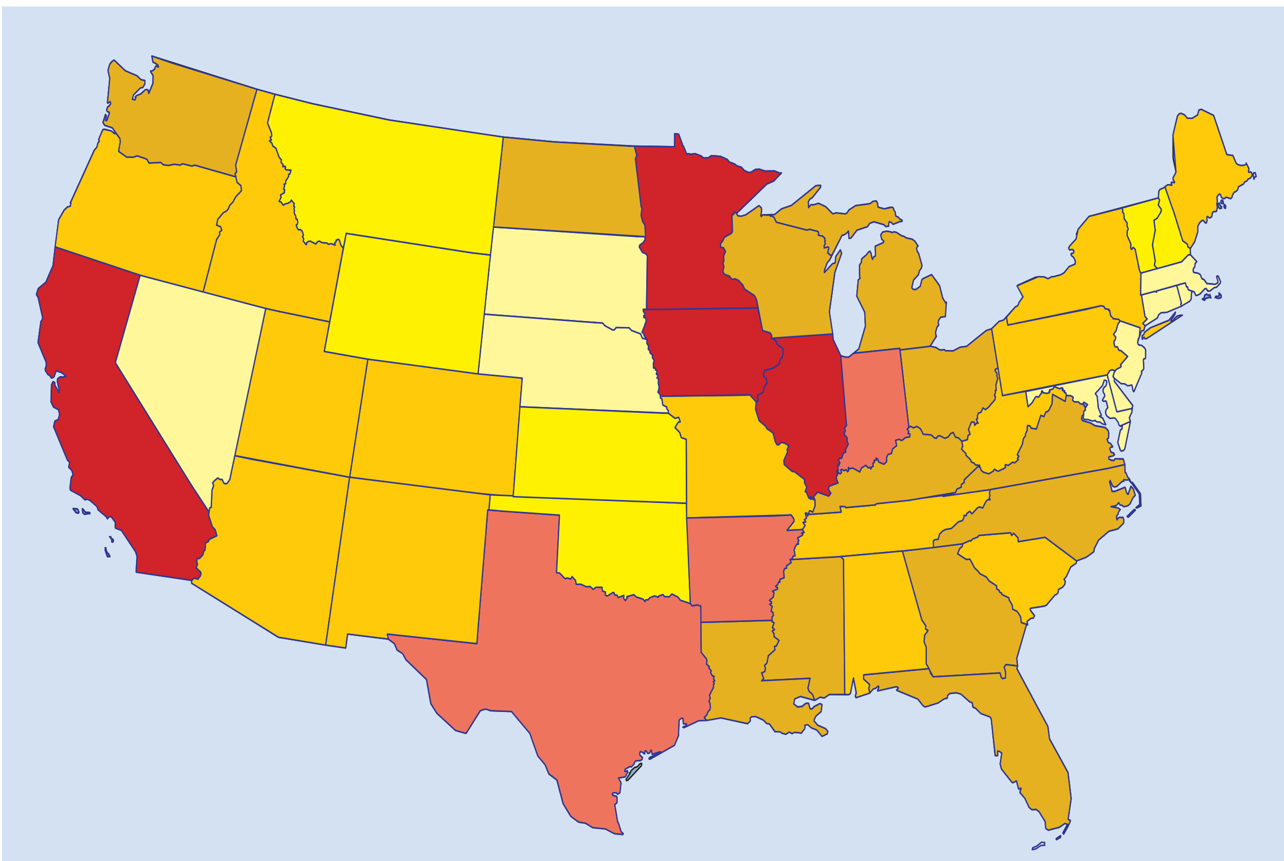
Data Source: Lynd, Greene, and Sheehan, 2004

Cellulosic Ethanol — Like corn-based ethanol, biomass ethanol from cellulosic (i.e., woody or fibrous) plant material represents a domestic, renewable fuel option; provides oil security benefits; and has the important virtue of being compatible with existing infrastructure and vehicle technology. In contrast to corn ethanol, as has already been noted above and in Figure 4-15, cellulosic ethanol offers significant additional benefits, both in terms of its substantially lower full fuel-cycle energy inputs and greenhouse gas emissions and in terms of its potential to become cost-competitive with gasoline at very large production scales.[68] The use of cellulosic ethanol is environmentally advantageous because cultivating cellulosic biomass feedstocks

Figure 4-16

Broad Geographic Distribution of Renewable Waste Resources

According to an analysis conducted for the Commission by Oak Ridge National Laboratory (ORNL), the United States annually generates over 250 million dry tons of forest, crop, and urban wood wastes that could potentially serve as feedstocks for biomass-based transportation fuels. ORNL estimates that this quantity of waste feedstocks could produce up to 1 million barrels per day of transportation-grade bio-fuels. Forest wastes include the tree tops and branches left after logging, as well as tree volumes in excess of historic levels that could be beneficially removed to reduce the risk of forest fires. Crop residues come primarily from the non-food portion of major crops (corn and wheat), while urban wood wastes include yard and tree trimmings, debris from construction and demolition, and other woody materials, such as pallets and containers. In assessing the magnitude and distribution of biomass waste feedstocks, ORNL excluded substantial quantities of waste on the basis of access constraints, equipment limitations, and environmental concerns. As illustrated in the map below, the resulting state-by-state estimates suggest a resource base that is broadly distributed across the nation, but most highly concentrated in the six states of California, Minnesota, Illinois, Iowa, Texas, and Indiana.



Million dry tons

< = 1 | 1 - 3 | 3 - 5 | 5 - 8 | 8 - 12 | 12 - 20

Perlack, 2004

requires low inputs of energy, fertilizer, pesticide, and herbicide, and is accompanied by less erosion and improved soil fertility. From a global climate perspective, the fact that it is also possible to co-produce electricity in the process of converting cellulosic material into fuel ethanol (as discussed above) provides an opportunity for offsetting any remaining greenhouse gas emissions related to harvesting and fuel production and for generating additional revenue streams through the sale of low-carbon power.

For biomass ethanol to succeed on a large scale, important concerns about land requirements and impacts must be overcome and production costs must be significantly reduced. A central challenge is to produce sufficient feedstocks without disrupting current production of food and forest products. Some cellulosic ethanol can be produced from currently-available waste materials, such as corn stalks, supplemented by energy crops grown on idle land. Given realistic land constraints, however, production scales on the order of millions of barrels per day would require improved high-yield energy crops, integration of ethanol production into existing farming activities, and improved process efficiency for converting cellulosic materials into ethanol. The increased research, development and demonstration funding the Commission is recommending for biomass fuels should be focused in these areas.

Another central challenge is reducing production costs for biomass ethanol to the point where they are competitive with those of conventional fuels. Despite substantial progress (research and development efforts have reduced costs by nearly a factor of three since 1980), cellulosic ethanol remains uncompetitive with gasoline at this time and is not currently being produced on a commercial scale anywhere in the world.[69] In the last ten years, several commercial ventures to produce cellulosic ethanol from waste products have stalled; nevertheless, new proposals continue to emerge. For example, Iogen, a Canadian company with backing from Shell Oil, is currently considering siting a $250 million cellulosic ethanol facility in Idaho to take advantage of the growing California market for ethanol and the availability of low-cost wheat straw in that area.

Photo courtesy of Changing World Technologies, Inc.

This commercial-scale waste-to-energy plant currently processes 200 tons per day of inedible turkey parts.
Carthage, Missouri

The Iogen proposal is premised on a loan guarantee to help defray some of the high capital costs associated with a first-of-a-kind production facility. Iogen expects to produce cellulosic ethanol for $1.30 per gallon. With the current, federal 51 cent per gallon ethanol subsidy, this target price is competitive with gasoline.[70]

In sum, further progress is needed, both with respect to the development of low-cost feedstocks and with respect to technologies for efficiently converting cellulose to ethanol. Fortunately, progress to date is such that the pathway to success is becoming clearer. NREL now estimates the post-2010 cost of biomass-based ethanol at $1.07 per gallon; a separate Commission-sponsored analysis has estimated costs for a fully mature and optimized cellulosic production process at 67–77 cents per gallon.[71]

***Bio-diesel* —** A small market for bio-diesel produced from rapeseed, soybean, and other vegetable oils — as well as, to a limited extent, from used cooking oil — already exists in Europe and the United States. These types of bio-diesel are unlikely to become economic on a large-scale, however, and may cause problems when used in blends higher than 20 percent in older diesel engines (in addition, waste oil is likely to contain impurities that give rise to undesirable emissions). All forms of bio-diesel are largely compatible with existing distribution infrastructure since bio-diesel mixes well with conventional diesel fuel and stays blended even in the

Biomass Potential

Do land constraints rule out a significant role for cellulosic ethanol? The Commission has examined the question of whether land constraints will prevent biomass fuels from playing a significant role in the nation's supply of transportation fuels (for purposes of this brief analysis, a significant role is defined as displacing at least half the gasoline used by the current U.S. passenger vehicle fleet). While existing low-cost waste streams such as corn stover, forest residue, and urban wood waste are likely to serve as primary feedstocks in the early stages of commercializing cellulosic bio-fuel production, dedicated energy crops would eventually be necessary to supplant a substantial fraction of domestic gasoline use. Commission-sponsored research concludes that reasonable progress in improving crop productivity, biomass-to-fuel conversion processes, and vehicle fuel economy would greatly reduce the land requirements associated with a significant expansion of bio-fuel production capacity. By integrating the cultivation of bio-fuels feedstocks with the production of animal feed through crops that can serve both purposes, it becomes possible to displace a substantial portion of petroleum fuel consumption by the U.S. passenger vehicle fleet while in no way constraining future food production.

Table 4-2 shows how advances in crop productivity, fuel conversion, vehicle efficiency, and co-production of animal feed could affect the land requirements associated with displacing 50 percent of current gasoline consumption through biomass fuels derived from energy crops. Starting with status quo assumptions, achieving this target would require approximately 180 million acres or roughly 40 percent of the land already under cultivation in the United States.[72] The table then lists several areas where substantial improvement is likely to be achievable with concerted research and effective policy interventions (i.e., energy crop yields, vehicle fuel economy, and biomass-to-fuels conversion processes). When all of these advances are combined, the estimated acreage required to fuel half the U.S. passenger fleet declines by more than 80 percent, from 180 million to 30 million acres.

- ***Improved Energy Crop Yields:*** Switchgrass is a leading candidate feedstock for bio-fuel production. At present, approximately 5 dry tons of switchgrass can be harvested per acre. With steady improvement in crop yields similar to the productivity gains that have been achieved for corn cultivation (over the last 60 years, corn yields have increased five- to six-fold, or about 3–4 percent per year, on average), switchgrass yields could double in less than 20 years.

- ***Conversion Efficiencies:*** Further research could improve the conversion efficiency of bio-fuels production processes by increase the portion of cellulose that is converted into ethanol. Conversion efficiency can be improved in several ways: through improved pre-treatment that makes more of the cellulose accessible to bacterial enzymes and through improved bacteria that are either capable of breaking cellulose down more rapidly (thereby reducing processing time) or are engineered to use less of the sugars for their own metabolism, making more available in the form of ethanol.

- ***Vehicle Fuel Economy:*** In Chapter I of this report, the Commission recommends a significant increase in vehicle fuel economy standards to capture the potential efficiency gains from conventional technologies as well as hybrid-electric and advanced diesel passenger vehicles.

Are 30 million additional acres of land available for energy crop cultivation in the United States?
To become economic on a large-scale, energy crop production would need to be integrated with existing agricultural and forestry production. For example, grasslands can produce both ethanol feedstocks and protein for animal feed; similarly forests can produce ethanol feedstocks (from the unused portions of trees), as well as pulp. A recent study by Oak Ridge National Laboratory (ORNL) identified 16.9 million acres of land in the Conservation Reserve Program (CRP) as being potentially available for bio-energy crop production. (The CRP as a whole includes some 30 million acres of land, but the ORNL estimate excludes climate-challenged and environmentally sensitive areas within the program.) Energy crop production is likely to be compatible with CRP lands because many energy crops can be grown and harvested without depleting the land. By gradually integrating the cultivation of energy crops with animal feed crops, the land requirements implied by the calculations described here can likely be met with a combination of CRP lands and lands already used for the production of animal feed (for example 70 million acres in the United States are currently dedicated to growing soybeans primarily for animal feed).

Table 4-2

Estimated Land Requirements for Producing Bio-fuels Sufficient to Fuel Half the Current U.S. Passenger Fleet

Cumulative Impacts ↓

Scenario	Biomass Production	Improved Conversion Efficiencies	Fleet MPG	Additional Land Required
1.Status quo	5 tons per acre	NO	20 mpg	180 million acres
2.Increase Yield of Energy Crops	10 tons per acre	NO	20 mpg	90 million acres
3. Improved Conversion Efficiency	10 tons per acre	YES	20 mpg	60 million acres
4. Higher Vehicle Fuel Economy	10 tons per acre	YES	40 mpg	30 million acres

Data Sources: Lynd, Greene, and Sheehan, 2004; Mann, 2004

presence of water. With the exception noted above in the case of older engines, modern diesel engines can operate well on neat (100 percent) bio-diesel, bio-diesel blends, and synthetic bio-diesel from organic wastes. Bio-diesel from yellow grease is closer to being cost-competitive with diesel fuel, but its potential volumes are limited. Unless soybean prices fall substantially, it is unlikely that bio-diesel from vegetable oils will become cost-competitive with diesel fuel.

Given these limitations, there is interest in finding additional ways to convert biomass and organic wastes to a high-quality, clean diesel fuel that could be readily integrated into the existing distribution infrastructure and would be compatible with a wide variety of existing heavy-duty vehicle and equipment technologies. Since 1999, a pilot plant in Philadelphia has been testing a new process known as thermal depolymerization (TDP) that has the potential to convert a wide variety of wastes (including animal offal, agricultural residues, municipal solid waste, sewage, and old tires) into clean fuels, fertilizers, and specialty chemicals. More recently, a $20 million commercial-scale facility using TDP technology has been constructed in Carthage, Missouri to convert wastes from a turkey processing facility into a variety of useful products, from fertilizer to low-sulfur diesel fuel. Engineering estimates from this facility suggest that the plant has the potential to convert 200 tons per day of turkey offal and waste into an annual output of about 100,000 barrels of diesel fuel (or 274 barrels per day) at an average cost of $30 per barrel (or about 72 cents per gallon).

"cellulosic ethanol has the potential to... make a meaningful contribution to the nation's transportation fuel supply over the next two to three decades"

Given the large variety of organic materials that could potentially serve as feedstocks, the energy potential associated with TDP technology could be quite significant. On average, for example, meat processing facilities discard 40 percent of the animal mass they handle.[73] Proponents of TDP estimate that this technology could be used to produce more than 2.7 MBD of diesel fuel from agricultural wastes.

Feedstock costs represent an important component of the overall calculation in terms of the cost-competitiveness of biomass-based, including waste-derived, fuels. Waste feedstocks may be particularly attractive where avoided disposal costs or "tipping fees" help to make fuel production economic. In other cases, of course, the expense of collecting biomass or waste feedstocks may represent a negative cost factor.

POLICY RECOMMENDATIONS

Non-Petroleum Transportation Fuels

Current federal programs directed toward reducing the cost of bio-fuels and cellulosic ethanol in particular are under-funded, intermittent, scattered among different agencies, and poorly targeted. The Commission proposes a ten-year, $1.5 billion effort to reduce the costs of biomass and waste-derived fuel production through a combination of targeted support for research and development and incentives for pioneer commercial production facilities. The primary goal of this proposal is to bring the cost of cellulosic ethanol below that of corn-based ethanol and within striking distance of gasoline over the next two decades. Even with this level of investment, however, the Commission recognizes that the technology for producing cellulosic ethanol at prices competitive with gasoline is at least a decade away. Moreover, it will likely take another decade to achieve large-scale commercialization, including building production plants and cultivating the necessary feedstocks.

More effective R&D — The Commission recommends increasing federal funding for bio-fuels R&D from $25 million (in 2004) to $150 million annually for five years (from 2006-2011) for a total of $750 million. These funds should be directed towards improving process efficiencies for converting plant material and wastes to ethanol and bio-diesel, and improving energy crop productivity. Funding solicitations should be channeled through existing mechanisms established by the Biomass Research and Development Act of 2000 which was first funded in the Farm Bill of 2002.[74] The current program involves open and competitive solicitations with awards made regularly based on expert peer review of proposals. The following criteria should be applied in the grant process:

- Results of funded projects should be made public.
- Innovation and basic applied R&D should not require a spending match.
- At least half of the reviewers for each area and type of R&D should be external experts drawn from outside the U.S. Department of Agriculture and DOE.

Building the first billion gallons of capacity — Although further technology progress and innovation are needed to cost-effectively and sustainably develop and deploy bio-fuels, commercial-scale technologies exist today that would provide a wealth of information about the prospects for integrated cellulosic ethanol and bio-diesel fuel systems. The Commission recommends that the federal government provide $750 million in early deployment incentives from 2008 through 2017 to encourage a diversity of pioneer projects relying on different feedstocks in different regions of the country. These incentives should be provided on a competitive basis to candidate fuels that not only meet U.S. fuel and emissions specifications, but can help diversify domestic transportation energy supplies while improving, or at least maintaining, air, water, soil, and habitat quality. Incentives should be distributed through a combination of federal loan guarantees for the construction of production facilities and supporting infrastructure and through a reverse auction mechanism to subsidize alternative fuel production. In a reverse auction, fuel providers would bid to receive a specific amount of federal assistance, on a per gallon basis, for producing alternative fuels. This approach has been successfully used in California to stimulate the deployment of renewable technologies for electricity generation and is described in Section E of this chapter (see text box at page 67).

Notes:

1. Note that few, if any, energy technologies are wholly "carbon-free" if one takes into account the energy inputs required to manufacture their structural components or, in some cases, to extract and process fuel. This report nevertheless applies the term "non-carbon" to technologies such as renewable and nuclear power to distinguish them from conventional technologies that directly generate much larger quantities of greenhouse gas emissions in the course of normal operation and that also incur upstream emissions for the manufacture of structural components and for the extraction, transport, and processing of fossil fuel inputs.

2. National Petroleum Council, Committee on Natural Gas, *Balancing Natural Gas Policy: Fueling the Demands of a Growing Economy*, vol. 1, *Summary of Findings and Recommendations* (Washington, DC: National Petroleum Council, 2003), 30, http://www.npc.org/reports/ng.html.

3. United States Department of Energy, Energy Information Administration, "U.S. Natural Gas Summary," http://tonto.eia.doe.gov/dnav/ng/ng_sum_lsum_dcu_nus_a.htm.

4. National Commission on Energy Policy, *Increasing U.S. Natural Gas Supplies: A Discussion Paper and Recommendations* (Washington, DC: National Commission on Energy Policy, 2003), 5, http://www.energycommission.org/ewebeditpro/items/O82F3270.pdf, also in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

5. Ibid., 7.

6. United States Department of Energy, Energy Information Administration, "U.S. Natural Gas Summary."

7. National Commission on Energy Policy, Staff et al. "The Safety of Liquefied Natural Gas," 2, in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

8. DOT is responsible for issuing the licenses for offshore LNG terminals, while the U.S. Coast Guard regulates LNG ships and marine terminals, and is the lead agency on the environmental review for siting applications.

9. J. Mark Robinson, Director of the Office of Energy Projects, Federal Energy Regulatory Commission, testimony on September 8, 2004, before the Texas House Committee on Energy Resources, 78th Leg., 4th Called Sess., 2004.

10. Pat Wood, FERC Chairman, testimony on June 22, 2004, before the Subcommittee on Energy Policy, Committee on Regulatory Reform, United States House of Representatives, 108th Cong., 2nd Sess.

11. National Petroleum Council, Committee on Natural Gas, *Balancing Natural Gas Policy: Fueling the Demands of a Growing Economy,* vol. 2, *Integrated Report* (Washington, DC: National Petroleum Council, 2003), 121, http://www.npc.org/reports/ng.html.

12. Ibid., 139-140.

13. See National Petroleum Council, *Balancing Natural Gas Policy,* 2003, and Terry Z. Riley, Theodore Roosevelt Conservation Partnership,"A Review of Energy Development in the West," in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

14. National Petroleum Council, *Balancing Natural Gas Policy,* vol. 1, 67.

15. United States Department of the Interior, United States Department of Agriculture, and United States Department of Energy, *Scientific Inventory of Onshore Federal Lands' Oil and Gas Resources and Reserves and the Extend and Nature of Restrictions or Impediments to Their Development* (Washington, DC: United States Departments of Interior, Agriculture and Energy, 2003), 3-5, http://www.doi.gov/epca/; developed in compliance with the Energy Policy and Conservation Act Amendments of 2003, found that out of 138 tcf total gas resources on federal lands, only 16 tcf, or 12 percent, were off limits, while National Petroleum Council, *Balancing Natural Gas Policy,* vol. 4, *Supply Task Group Report,* which for the first time examined post-leasing conditions of approval and increased costs along with lease stipulations, estimated that of the total gas resource in the Rockies, 125 tcf were subject to access restrictions (Chap. 6, Sec. 8) and 69 tcf, or 29 percent of the total technical resource base, was "effectively off limits" (Chap. 6, Sec. 1). As NPC's *Supply Group Task Report* points out, these different assessments result from evaluating different restrictions on different underlying acreages, making direct comparisons difficult.

16. William Dillon and Kent Kvenvolden, U.S. Geological Survey, Marine and Coastal Geology Program, "Gas Hydrates – A New Frontier," September 1992, http://marine.usgs.gov/fact-sheets/gas-hydrates/title.html.

17. United States Department of Energy, National Energy Technology Laboratory, "All About Hydrates: Natural Methane Hydrate," and "The Science of Natural Methane Hydrate," http://www.netl.doe.gov/scngo/Natural%20Gas/Hydrates/about-hydrates/about_hydrates.htm.

18. United States Department of Energy, Energy Information Administration, *Natural Gas 1998: Issues and Trends* DOE/EIA-0560 (Washington, DC: Energy Information Administration, 1999), 74, http://www.eia.doe.gov/oil_gas/natural_gas/analysis_publications/natural_gas_1998_issues_and_trends/it98.html.

19. United States Department of Energy, Office of Fossil Energy, *A Strategy for Methane Hydrates Research and Development* DOE/FE-0378 (Washington, DC: United States Department of Energy, 1998), 1, http://www.netl.doe.gov/scngo/Natural%20Gas/Hydrates/pdf/98hydratestrategy.pdf

20. United States Department of Energy, Energy Information Administration, *Annual Energy Outlook 2004 with Projections to 2025* DOE/EIA-0383 (Washington, DC: Energy Information Administration, 2004), 91, http://www.eia.doe.gov/oiaf/aeo/index.html.

21. United States Department of Energy, Energy Information Administration, "U.S. Natural Gas Summary."

22. Eloise Logan, "Methane Hydrates: Environmental Time Bomb or New Energy Source", *Energy Economist* 263 (September 2003): 21.

23. Nina M. Rach, "Japan Undertakes Ambitious Hydrate Drilling Program," *Oil and Gas Journal* 102, Issue 6 (2004): 9.

24. Eloise Logan, "Methane Hydrates," 21.

25. United States Department of Energy, Energy Information Administration, *International Energy Outlook 2004* DOE/EIA-0484 (Washington, DC: Energy Information Administration, 2004), 103, http://www.eia.doe.gov/oiaf/ieo/index.html.

26. Robert H. Williams, Princeton Environmental Institute, Princeton University, "IGCC: Next Step on the Path to Gasification Based Energy from Coal," in *NCEP Technical Appendix* (Washington, DC: National Commission in Energy Policy, 2004).

27. Robert H. Williams, Princeton Environmental Institute, Princeton University, "Toward Polygeneration of Fluid Fuels and Electricity via Gasification of Coal and Biomass," in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

28. Williams, "IGCC: Next Steps," 2.

29. A leading example of the promise of recent IGCC improvements is Tampa (FL) Electric Company's Polk Power Station IGCC unit. It is one of two IGCC power plants currently operating in the U.S.

30. Public Service Commission of Wisconsin, "Written Order Summary on Phase 2 of Power the Future Oak Creek: Docket 05-CE-130," November 10, 2003, http://psc.wi.gov/event/newsrel/nwsrel03/oakcreek5.htm.

31. J. Davitt McAteer, National Technology Transfer Center, "Coal: Planning Its Future and Its Legacy," in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

32. Note that federal law requires guaranteed loans to be scored for federal budget purposes. In other words, because funds need to be set aside to cover this obligation, loan guarantees compete with other budget requirements even though the government may never actually have to pay out any money.

33. William G. Rosenberg, Dwight Alpern, and Michael Walker, *Deploying IGCC Technology in this Decade with 3 Party Covenant Financing, vol. 1, Discussion Paper 2004-07* (Cambridge, MA: Belfer Center for Science and International Affairs, Kennedy School of Government, Harvard University, 2004), Fig. ES-6, also published in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

34. National Commission on Energy Policy Staff et al., "Technical Memorandum Documenting NCEP IGCC and CCS Recommendations," in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

35. Specifically, proponents estimate that $150 million in federal scoring for loan guarantees would yield 1,000 MW of IGCC deployed. Rosenberg et al., *Deploying IGCC Technology in This Decade,* 17.

36. Total U.S. net electricity generation (utility and non-utility) in 2003 was 3848 terawatt-hours (1 TWh = 1 billion kWh), of which nuclear energy contributed 764 TWh, hydro contributed 266 TWh, and non-hydro renewables contributed 84 TWh. Thus the nuclear contribution to total net generation was 764/3848 = 19.85 percent and the nuclear contribution to carbon-free generation was 764/(764 + 266 + 84) = 764/1114 = 68.58 percent. See United States Department of Energy, Energy Information Administration, *Monthly Energy Review, May 2004* (Washington, DC: Energy Information Administration, 2004), 96: Fig. 7.1, 98: Fig. 7.2, http://tonto.eia.doe.gov/FTPROOT/multifuel/mer/00350405.pdf

37. Worldwide, nuclear energy contributed about 2500 TWh in 2003, one sixth of the total net electricity generation of 15,000 TWh. The carbon-free portion of net electricity generation consisted of the 2500 TWh from nuclear and another 2500 TWh from hydro and non-hydro renewables. Nuclear electricity generation grew at 1.9 percent per year between 1993 and 2003, while total electricity generation grew at 2.8 percent per year. BP, *Energy In Focus: BP Statistical Review of World Energy 2004* (London: BP, 2004), 34-35, http://www.bp.com/statisticalreview2004/.

38. John Deutch and Ernest Moniz, Co-Chairs, *The Future of Nuclear Power: An Interdisciplinary MIT Study* (Cambridge, MA: Massachusetts Institute of Technology, 2003), http://web.mit.edu/nuclearpower, p. 42.

39. Ibid., p. 48.

40. Matthew Bunn, John P. Holdren, Allison MacFarlane, Susan E. Picket, Atsuyuki Suzuki, Tatsujiro Suzuki, and Jennifer Weeks, *Interim Storage of Spent Nuclear Fuel: A Safe, Flexible and Cost-Effective Near-Term Approach to Spent Fuel Management* (Cambridge, MA: Harvard University Project on Managing the Atom and University of Tokyo Project on Sociotechnics of Nuclear Energy, 2001), http://bcsia.ksg.harvard.edu/BCSIA_content/documents/spentfuel.pdf.

41. National Academy of Sciences, Committee on International Security and Arms Control, *Management and Disposition of Excess Weapon Plutonium* (Washington, DC: National Academy Press, 1994), p. 19.

42. Deutch and Moniz, *The Future of Nuclear Power*.

43. United States Department of Energy, Energy Efficiency and Renewable Energy, *Wind Power Today and Tomorrow: An Overview of the Wind and Hydropower Technologies Program* (Washington, DC: National Renewable Energy Laboratory, 2004), 2, http://www.nrel.gov/docs/fy04osti/34915.pdf.

44. American Council on Renewable Energy (ACORE), personal memorandum, October 12, 2004.

45. United States Department of Energy, Energy Information Administration, *Renewable Energy Trends 2003* (Washington, DC: Energy Information Administration, 2004), 9, http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/trends.pdf. See NCEP Technical Appendix for full report.

46. United States Department of Energy, Energy Efficiency and Renewable Energy, “Geothermal FAQs,” http://www.eere.energy.gov/geothermal/faqs.html.

47. United States Department of Energy, *Renewable Energy Trends 2003,* 9; capacity figure is U.S. Electric Net Summer Capacity.

48. United States Department of Energy, Energy Efficiency and Renewable Energy, “Geothermal Technologies Program,” http://www.eere.energy.gov/geothermal/powerplants.html.

49. Ibid.

50. ACORE, Untitled.

51. United States Department of Energy, *Renewable Energy Trends 2003,* 9; Capacity figure is U.S. Electric Net Summer Capacity.

52. Ibid., 9; Capacity figure is U.S. Electric Net Summer Capacity.

53. Ibid., 3.

54. North Carolina Solar Center, "Database of State Incentives for Renewable Energy," http://www.dsireusa.org/.

55. Ibid.

56. Eligibility is defined differently by different states, but often excludes existing hydropower.

57. North Carolina Solar Center, "Database of State Incentives for Renewable Energy."

68. California Energy Commission, *New Renewable Resources Account, Volume 2A, Sixth Edition* (Sacramento, CA: California Energy Commission, 2003), 3-14, http://www.energy.ca.gov/renewables/guidebooks/2004-01-23_500-01-014V2A.pdf.

59. Need cite for this quote.

60. California Energy Commission, *Renewable Energy Program: Quarterly Report to the Legislature, April 2004 through June 2004* (Sacramento, CA: California Energy Commission, 2003), 15, http://www.energy.ca.gov/reports/2004-08-03_500-04-050.pdf.

61. Martin Kushler, Dan York, and Patti Witte, *Five Years in: Examination of the First Half-Decade of Public Benefits in Energy Efficiency Policies* (Washington, DC: American Council for an Energy Efficient Economy, 2004), vi.

62. North Carolina Solar Center, "Database of State Incentives for Renewable Energy."

63. United States Department of Energy, Energy Information Administration, "Alternatives to Traditional Transportation Fuels 2003: Estimated Data," Table 10, http://eia.doe.gov/cneaf/alternate/page/datatables/atf1-13_03.html.

64. Ibid.

65. Ibid. While still less than 2 percent of the overall market for transportation fuels, the contribution from corn-derived ethanol and CNG has increased by 50 percent over the last decade.

66. International Energy Agency, *Biofuels for Transport: An International Perspective* (Paris: Organization for Economic Cooperation and Development/International Energy Agency, 2004), 28: Fig 1.1, 167: Fig. 1.2.

67. As states proceed to ban the additive MTBE over concerns about groundwater contamination, ethanol will be used in greater quantities both to satisfy Clean Air Act requirements that effectively require the addition of either MTBE or ethanol to gasoline and to compensate for a reduction in octane that would otherwise occur as MTBE, a high-octane component, is phased-out.

68. At the point of end-use, all biomass fuels are carbon-neutral (provided their feedstocks are sustainably managed) because the carbon released during combustion is reabsorbed by the growth of replacement feedstocks. Thus, the different greenhouse gas emissions characteristics of biomass fuels depend on upstream energy inputs for growing, harvesting, and processing the biomass into fuel. Besides offering the potential for lower upstream emissions, some potential feedstocks for cellulosic ethanol could provide additional climate benefits by promoting long-term carbon sequestration. The replacement of row crops with perennial switchgrass, for example, would result in substantial net carbon uptake by below-ground root systems. Moreover, current evidence suggests that carbon would continue to be added to the soil (in the form of humus) for a considerable period of time before equilibrium is reached.

69. Cellulosic ethanol has been made during wartime and is currently produced in Canada on a limited demonstration-plant scale.

70. Maurice Hladik, Marketing Director, Iogen Corporation, personal communication, July 15, 2004.

71. Lee Lynd, Nathanael Green, and John Sheehan, Dartmouth College, Natural Resources Defense Council, and National Renewable Energy Laboratory, "The Role of Biomass in America's Energy Future," 78, in *NCEP Technical Appendix* (Washington, DC: National Commission in Energy Policy, 2004).

72. Calculation is as follows: VMT is ($2.5x10^{12}$ miles per year)*(1 gallon of gas/20 mi)*(0.0144 ton biomass/gallon gasoline equivalent)*(1 acre*year/5 ton) = 360 x 10^6 acres. Note calculation for ton biomass/gallon gasoline equivalent: (1.55 gallon ethanol/gallon gasoline)*(1 ton biomass/108 gallon ethanol) = 0.0144 ton/gallon gasoline equivalent. Similar values are obtained for other biomass-derived fuels.

73. B. Appel, "Comments for Proposed Rule to Implement Preferred Procurement of Biobased Products" (Memorandum, United States Department of Agriculture and Changing World Technologies, January 29, 2004), 10.

74. Lynd, Green, and Sheehan, "The Role of Biomass in America's Future," 78. The Farm Bill approved $75 million over 6 years ($5 million for the first year followed by $14 million a year for the following 5 years). These levels were exceeded in the last two years ($23 million was awarded in 2003, $25 million in 2004). The remaining funds will apparently be awarded in approximately two years.

V. Strengthening Energy-Supply Infrastructure

The Commission recommends siting reforms to enable the expansion and construction of needed energy facilities and further efforts to protect the nation's energy systems from terrorist attack. These measures are necessary to sustain access to the essential energy supplies and services on which the nation's economy depends. In addition, the Commission recommends specific reforms to improve the reliability and performance of the electricity sector.

A. INTRODUCTION

This chapter addresses three challenges that must be overcome to provide a foundation for secure, reliable, and affordable access to energy supplies and services — now and in the future: (1) siting critical energy infrastructure; (2) protecting energy facilities and delivery systems from terrorist attack; and (3) improving the reliability and performance of the nation's electricity sector. The difficulty of siting nearly all types of major energy infrastructure — from liquefied natural gas (LNG) terminals and high voltage transmission lines to large windfarms — presents a major cross-cutting challenge for expanding access to the energy supply options described in the previous chapter. At the same time, the emergence of new terrorist threats has added another, potentially more difficult dimension to the perennial challenge of designing reliable and robust energy systems: these systems must now be resilient, not only to simple operator error, equipment failure, and extreme weather, but also to the potential for malicious interference or attack. Finally, the Commission examines regulatory and market uncertainties that currently affect the nation's electricity system and offers a series of detailed recommendations to address the challenges now being faced by this critical industry.

"Virtually every region has looming energy infrastructure needs"

B. SITE CRITICAL ENERGY INFRASTRUCTURE

Overview

Virtually all primary energy sources require complex infrastructure to transform them into the right forms and deliver them to the right locations. Oil must be extracted, shipped, refined, and transported before it can be used as a transportation fuel. Natural gas, coal, and oil must also be extracted, processed and transported before they can be used in heating, industrial processes, and other end-use applications. These energy sources (and others, such as wind, geothermal and solar) must be converted at power plants (large and small) into electricity and instantaneously moved on interconnected transmission and distribution grids in order to light streets and houses, or run computers, appliances, and telecommunication and information networks.

A critical question for U.S. energy policy therefore relates to the adequacy of underlying energy system infrastructure, and to the question of how this infrastructure can be improved and expanded in a manner deemed acceptable on economic, environmental, and public interest grounds. For example, the August 2003 power system blackout in the United States and Canada revealed weaknesses in the hardware and procedures that comprise and govern operation of the electric transmission grid. Recent escalations in the price of natural gas not only reflect the maturity of the resource base in the lower-48 states, but also physical and economic limitations on the capacity to process and transport abundant supplies from distant domestic and international sources to gas-consuming regions.

The Commission recognizes that it will not be possible to ensure adequate and reliable supplies of energy, achieve desired reductions in greenhouse gas emissions, or diversify transportation fuels without simultaneously reducing the barriers that now hamper

Figure 5-1

Major National Energy Infrastructure Needs

Nearly every region of the United States will require new energy infrastructure over the next several decades as the national energy system expands and modernizes, adjusts to new challenges, and responds to shifting supply and demand patterns. The map below attempts to illustrate, in a purely schematic sense, the magnitude and distribution of major infrastructure financing and siting challenges the nation is likely to confront in the next ten to thirty years.

NCEP

the siting of new energy infrastructure. Though much-needed infrastructure has been added in certain regions in the past several years, critical constraints remain and there are numerous examples of abandoned projects, difficult and time-consuming infrastructure siting processes, and strong local opposition. These siting difficulties stem from the friction between a public that is increasingly unwilling to accept the construction of energy and other industrial infrastructure in its communities, and the growing need to add energy infrastructure to economically and reliably meet business and consumer demands. Virtually every region, and the country as a whole, has looming energy infrastructure needs that are, in some cases, being thwarted in the context of local or state siting processes. Examples include:

- Electricity transmission bottlenecks in the Northeast and elsewhere that have specific and well-documented cost and environmental impacts, and that threaten the reliability of regional electricity systems.
- Problems siting LNG import facilities that could help mitigate high natural gas prices and promote gas use, thereby reducing carbon emissions and other environmental impacts, while addressing the widening gap between U.S. natural gas consumption for heating, industrial processes and electricity generation, and the supply available from U.S. and Canadian sources.
- Impediments to the siting of large wind power projects despite clear greenhouse gas-reduction and other environmental benefits and the need to promote renewable power and electricity supply diversification.
- Delays in finding a suitable permanent repository or monitorable, retrievable interim storage for nuclear waste, despite the public health, environmental, security, and nuclear proliferation risks posed by the existence of a large and growing quantity of spent nuclear fuel and other high-level nuclear wastes dispersed throughout the country.

The need for critical energy infrastructure is primarily driven by regional or national interests, but approval of infrastructure proposals to meet these needs may be held up or rejected in significant part due to local considerations. This is particularly true in cases where the primary siting authority is the state (e.g., transmission lines, power plants), but it is also true that local opposition has delayed or blocked projects even when the primary siting authority is federal (e.g., LNG terminals, natural gas pipelines, nuclear waste). Large infrastructure projects can impose significant changes and burdens on the communities in which they are located. The Commission believes that these local impacts must be comprehensively reviewed and objectively addressed through processes that also recognize the importance of certain infrastructure projects to regional and national reliability, and for achieving economic, environmental and security goals. As the energy interdependence of all U.S. states and regions grows, so must the ability to incorporate regional and national perspectives and needs in the context of state and local siting procedures. In effect, the Commission believes it is necessary to promote a better understanding of the energy infrastructure issue as one of "common interests and equal burdens."

Although energy infrastructure needs exist across all fuel types and in all regions, the Commission believes the most urgent infrastructure needs that face

The U.S. electricity transmission system consists of over 150,000 miles of high-voltage transmission lines. *Arizona* difficult siting challenges are high-voltage electricity transmission lines (especially when these lines are interstate), new LNG facilities, and high-level nuclear waste storage. With respect to electricity transmission, recent analysis indicates that the nation's power grid is increasingly congested. Transmission capacity additions have declined in recent years and are projected to continue declining relative to the level of peak electrical demand.[1] Even where there is transmission investment, currently few proposals are moving forward with the exception of those related to local reinforcements or interconnections for new power generating facilities.[2] A May 2002 study by the Department of Energy (DOE) concluded that declining transmission system investments and deteriorating infrastructure, combined with growing electricity demand, were creating regional bottlenecks in transmission that significantly decrease reliability, impair wholesale electric competition, increase consumer prices, and increase system vulnerability.[3] As is discussed in some detail in the previous chapter, similar infrastructure siting and investment challenges apply with regard to expanding access to natural gas supplies (including LNG imports) and safely disposing of nuclear waste.

The next section outlines a number of broad recommendations concerning the siting of energy infrastructure. Additional recommendations specific to siting challenges for electricity transmission infrastructure, LNG terminals, and nuclear waste storage facilities are discussed elsewhere in this report.

POLICY RECOMMENDATIONS

In order to achieve the Commission's objectives of assuring an adequate, reliable and reasonably-priced supply of energy, reducing greenhouse gas emissions, diversifying fuels available for transportation-related energy use, and satisfying the nation's other energy supply objectives, it is essential to reduce the barriers that now hamper the siting of new, needed energy infrastructure. Such siting reforms include implementing, across the nation, the best practices which currently exist in some states' siting processes, including:

- Providing clear and accessible agency rules, timelines, siting criteria, other policies, and case precedents to facilitate the filing and administration of complete and viable siting proposals.

- Requiring up-front, pre-filing efforts by developers in the local affected communities, including contact with political and public interest groups, community education and flagging of key issues, to identify fatal flaws as well as information and education needs, and to reduce the time and cost of regulatory and administrative siting procedures.

- Focusing the siting approval process on the question of whether a specific infrastructure proposal at a particular place is acceptable. Applicants should provide information demonstrating not only environmental impacts, but also the process used to identify and consider other sites, as well as project configurations and technology choices that satisfy similar needs. These siting-related processes are to be distinguished from broader utility resource planning proceedings, in which there is a review of the various technology and fuel options available to satisfy the utility's needs. The siting of electricity transmission infrastructure, in particular, *should* include a comprehensive system-wide review of alternatives, although once that review process has validated the need for new transmission lines, the siting process for a specific line segment should not allow for a re-opening of broader system planning issues. The Commission's support for a comprehensive review of alternatives in the context of transmission proposals is specific to the electricity sector and is not intended to apply to other types of energy infrastructure, such as LNG facilities.

- Providing state and federal siting agencies with sufficient resources (personnel, expertise and funding) to efficiently guide proposals through the siting process, including educating developers on rules and potential pitfalls; assisting and educating the public and political representatives within host communities; facilitating meetings with relevant groups and officials and hosting public meetings; and posting complete and timely project and process information on agency websites.

C. PROTECT CRITICAL ENERGY INFRASTRUCTURE

Overview

The trauma the nation suffered on September 11, 2001 creates new urgency to ensure that critical energy infrastructure is protected against acts of terror. The Commission notes the significant efforts to assess infrastructure vulnerability undertaken by the National Academy of Sciences, DOE and the Department of Homeland Security, as well as non-governmental organizations. As the United States moves to revitalize its energy infrastructure, significant attention and resources must be devoted to understanding and guarding against risks from terrorism.

Even prior to the events of September 11, 2001, several public and private efforts were underway to examine the vulnerability of energy-sector infrastructure to accidents or terrorist attack. Some elements of that infrastructure are especially vulnerable and likely to be targeted on the basis of their visibility, difficulty of replacement, exposure to attack, and potential impact. Particular examples include nuclear plants, far-flung electricity transmission lines and transformer substations, natural gas pipelines and associated pumping stations (several areas of the country are dependent on a single major pipeline system), and oil refineries (currently operating at a combined 93 percent of capacity and heavily concentrated in Texas and Louisiana).

Recent and ongoing efforts to better protect the nation's major energy systems include:

- The Department of Homeland Security (DHS) has established information sharing and analysis centers (ISACs) for different sectors of the economy to help businesses share information and work together to address electronic threats and reduce information security vulnerabilities. The North American Electricity Reliability Council (NERC) fulfills ISAC duties for the electricity sector, while Energy ISAC, an independent organization, has been established specifically for the remainder of the energy sector.[4]
- DHS also oversees the Protected Critical Infrastructure Information Program, which is designed to encourage private industry and others with knowledge about critical infrastructure to share propriety or sensitive information with the government.[5]
- The National Infrastructure Advisory Council (NIAC)[6] provides the President with cyber security recommendations from experts across a variety of sectors. The Council is supported by DHS.
- The Partnership for Critical Infrastructure Security (PCIS),[7] a non-profit, industry engagement organization, provides for infrastructure information-sharing.
- Many private-sector groups have taken steps to address critical infrastructure threats, vulnerabilities, and protection. For instance, the American Petroleum Institute (API) and the National Petrochemical and Refiners Association (NPRA) have developed guidelines for risk assessment and preparedness, while the Electric Power Research Institute (EPRI) is working with government laboratories to analyze vulnerabilities at nuclear power plants. Other industry groups are also actively sharing information with their members.

In addition to the above efforts, the National Academy of Sciences, National Academy of Engineering, Institute of Medicine, and National Research Council in 2002 released a first-of-its-kind, comprehensive national study on the role of science and technology in countering terrorism.[8] This study assessed vulnerability to terrorist threats across all sectors of public and private sector activity; salient to the Commission's work are its findings with regard to the civilian nuclear power system, as well as to the electricity, natural gas, and oil sectors.

Of the many energy-sector vulnerabilities considered in the National Academies study, threats to nuclear reactors, possibly involving the use of aircraft, and threats to the electricity grid were considered to be among the most serious. In the case of nuclear plants, extensive security regulations already exist and further efforts to analyze threats and improve security are underway at Sandia National Laboratories and at EPRI. The U.S. Nuclear Regulatory Commission (NRC) is also undertaking a package performance study that will examine a variety of impact situations and will include a top-to-bottom review of potential vulnerabilities, including risks associated with the storage and transfer of spent nuclear fuel. Electricity transmission and distribution systems, meanwhile, represent a different kind of target, but may also be vulnerable for reasons of their geographical distribution; susceptibility to cyber or electromagnetic, as well as physical, attack; and highly integrated design (one vulnerability of a highly integrated design may be that the effects of a relatively localized failure can reverberate through the broader system). The nation's power grid not only presents a host of potential targets, recent market and regulatory trends have tended to reduce reserve capacity, system redundancy (including the stockpiling of spare parts), and utility investments in research and development, all of which have exacerbated these vulnerabilities

"new terrorist threats have added another, potentially more difficult dimension to the perennial challenge of designing reliable and robust energy systems"

A particular vulnerability of the current electricity system is its reliance on large, difficult-to-replace extra-high-voltage (EHV) transformers. These transformers exist throughout the transmission system; they are crucial to grid function and would be relatively easy to attack. Moreover, because they are very expensive, difficult to transport, typically designed for a particular site, and manufactured exclusively by a handful of overseas suppliers, only a very limited number of EHV transformers are available at any given time. Thus, a coordinated attack on several strategically located transformers could conceivably disrupt power to a large part of the country for an extended period of time. The risks are well-illustrated by a recent incident involving the loss (due to accidental fire) of a transformer that affected peak power availability to a large part of central Arizona; fixing this problem took over a month and involved the torturous 20-day transport — by barge and slow-moving, special-purpose tractor-trailer truck — of a 190-ton replacement transformer from Washington state to Arizona.

To address this source of vulnerability, the Commission strongly endorses recent efforts by DOE to explore the feasibility of developing a modular, universal EHV transformer that would be smaller, cheaper, more versatile, and more transportable than typical transformers.[9] This modular version would be designed to substitute for damaged single-application transformers and to allow the grid to continue limited functioning until a replacement could be installed; it would also need to be cheap enough so that several could be stockpiled in each power control area and ideally should be transportable by a regular 18-wheel truck. DOE's recent issuance of a solicitation for proposals to address the transformer issue suggests that progress is underway in this important area.[10] In addition, the Commission concurs with the National Academies report that particular attention must be paid to improving the security of supervisory control and data acquisition (SCADA) systems that play a vital role in managing not only the power grid, but thousands of miles of often remote and unprotected oil and natural gas pipelines.

POLICY RECOMMENDATIONS

Consistent with the findings of the 2002 National Academies report, the Commission recommends the following measures to improve the security of the nation's vital energy systems and infrastructure. Note that most of these recommendations apply to the nation's oil and gas systems as well as the electricity system.

- The industry should review, with the aim of improving security and reducing vulnerability to hacking or disruption, means of data transmission between control points and/or SCADA systems — including existing firewalls and procedures for detecting cyber-intrusions. Advances in cyber-security should be transferred to energy systems. Related systems and devices should be reviewed by appropriate standards-setting groups and vendors. DOE and DHS should coordinate.

- DHS should coordinate efforts to examine whether surveillance technologies developed for defense and intelligence purposes could be applied to widely distributed energy systems. Examples include drone aircraft, satellite surveillance, intelligent software analysis of surveillance images, change-detection sensors, and intrusion-detection cables.

- DOE should lead an effort by national laboratories to develop threat simulation design tools for analyzing prevention, response, and recovery from accidental or malicious interference in the functioning of major energy systems or facilities.

- Integrated multi-sensor warning systems should be developed to improve response, control and post-event analysis for important energy facilities. Such systems would recognize unanticipated activities and provide information to new, holistic operating models. In addition, tools for high-reliability system design, self-monitoring sensors to detect failure, and error-checking algorithms should be developed to improve monitoring reliability.

D. IMPROVE THE RELIABILITY AND PERFORMANCE OF THE ELECTRICITY SECTOR

Overview

Restructuring of the electric industry is at a crossroads. The failure of the California market in 2000 and 2001 and the implosion of Enron and much of the wholesale electricity trading business have caused some state regulators and utilities to question the viability of all competitive markets. Other states and the Federal Energy Regulatory Commission (FERC), pointing to the success of the PJM-operated markets,[11] press ahead, maintaining that consumers have benefited and will continue to benefit from wholesale and, in some cases, retail electric competition. Still others seek a system that integrates retail regulation and wholesale competition.

As a consequence, three competing visions are being debated and implemented by federal and state regulators and utilities in different regions of the country. This often-acrimonious debate has contributed to unprecedented federal/state tension and investor uncertainty. The three models that have emerged from this debate may be summarized as follows:

- ***Traditional Regulated Monopoly* —** where traditional, vertically-integrated electric utilities implement resource acquisition decisions for retail customers in an exclusive retail franchise area, subject to after-the-fact prudence review and cost-of-service regulation by state regulators;
- ***Integrated Resource Management with Wholesale Competition* —** where distribution companies manage diverse resource portfolios for all or most

retail customers and meet their generation needs through procurement from competitive wholesale markets, relying on FERC to ensure nondiscriminatory transmission access and on state regulators or local public power boards to review and provide advance approval for recovery of prudently incurred resource acquisition costs;

- ***Market-Based Customer Choice with Regulated Default Service*** — where selected retail customers make the initial resource acquisition for themselves by purchasing power directly from competitive suppliers at a market price. Other customers (including all or most small retail customers) continue to receive a regulated default or "provider of last resort" service from the local distribution utility or from some other entities that own or procure resources from competitive markets. State regulators set the default service price using a variety of methods, including competitive procurement to secure the benefits of wholesale competition.

The Commission does not contend that there is a single "right" model and urges policymakers and regulators to respect the fact that the industry is evolving in different ways in different regions.

A further complicating factor in devising solutions is that federally owned, publicly owned and cooperatively owned utilities (many of which are essentially self-regulated and which by law have responsibilities beyond providing power) play a substantial role in providing electricity in some regions, while they are practically non-existent in others. Regional differences will have to be accommodated.

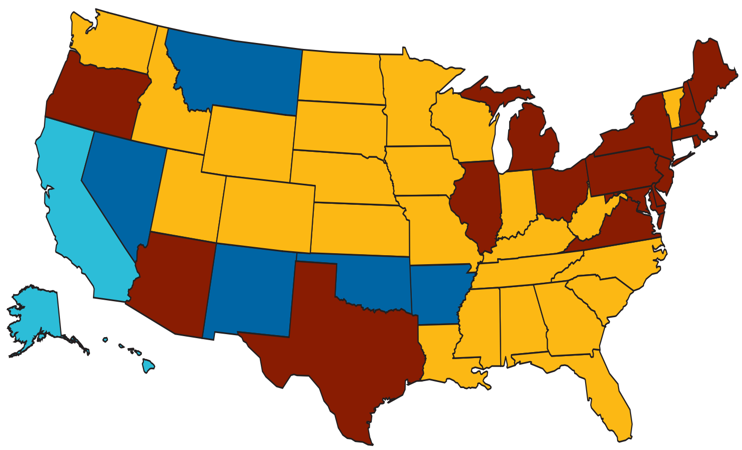
It is now too often unclear who is responsible for providing the economical and reliable electricity supplies that a healthy economy requires. Competitive models assume that decisions by market participants will replace resource planning by utilities or regulators. In practice, however, most competitive models have retained — whether in utilities, in regional transmission organizations or in the states themselves — some residual responsibility for ensuring that electricity supplies remain adequate. In some restructuring models, customers unwilling or unable to choose a supplier have been provided with default options that influence the evolution of the market. These "provider of last resort" options may fail to address either the real relationships between wholesale and retail markets or the complex issues involved in resource planning.

In states with traditional regulatory regimes, the regulated utilities that provide most resource

Figure 5-2

The State of Electricity Restructuring

Roughly half of the states in the United States have taken action on electricity restucturing, although several chose to suspend or delay retail competition as a result of the California power crisis in 2001. The remaining states have chosen instead to maintain traditional state-regulated monopolies.



Restructuring Active
Restructuring Suspended
Restructuring Delayed
Restructuring Not Active

Energy Information Administration, 2003

procurement and management services generally do so based on longstanding cost recovery principles, with abundant downside risk and little or no prospect of gain regardless of the quality of their performance. In states with retail competition, the competitive retail suppliers view long-term procurement by distribution companies as unfair competition, and the distribution companies face potential stranded cost problems or prudence reviews from regulators if they do make resource commitments. Yet failures to make such commitments may force expensive purchases in volatile short-term markets, which may result in adverse treatment by regulators.

The rules for supply obligations and cost responsibility and recovery must be clarified. For example, when and on what terms may distribution utilities enter into long-term contracts with generation service providers? How will distribution utility responsibilities interact with the opportunities created for competitive retail suppliers in states with retail competition? Who has the responsibility for identifying needed enhancements to the transmission network? How will they be paid for securing them, and who will pay?

Even in some states that do not have retail competition programs, the possibility of their introduction and stranded costs deters long-term commitments even though the alternative – reliance on short-term purchases – exposes consumers to more market volatility and deters investment in new generation and infrastructure. Utilities, regulators and wholesale suppliers alike are struggling with how states can regulate retail electric service provided by companies that operate in wholesale power markets. All parties are stuck between uncertain regulatory regimes—often with tension between state and federal policies—and with no assurance about the rules that will determine commercial survival and success.

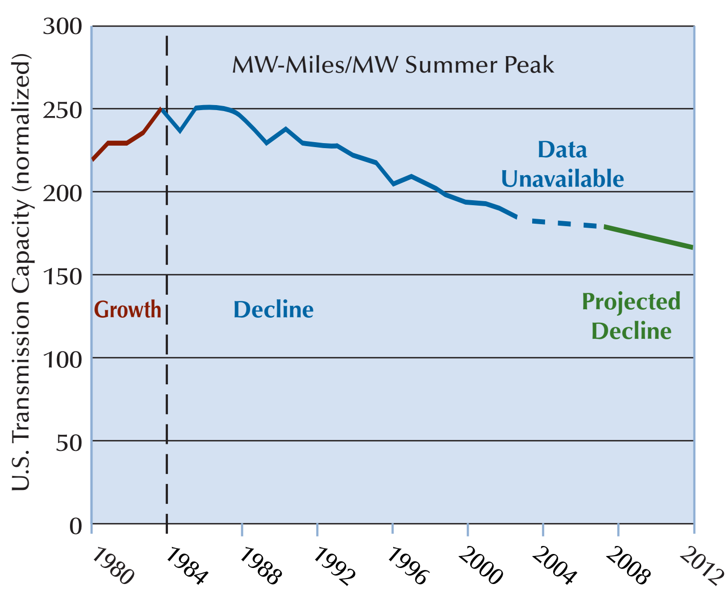
The electric industry's environmental footprint is significant. A wide range of technologies and technology vintages means widely varying emissions and other impacts from the competitors for generation and grid investments. While

"Inadequate investment in transmission infrastructure... costs consumers tens of billions of dollars a year in higher energy costs and lost productivity"

Figure 5-3

Transmission Capacity versus Peak Electricity Demand

U.S. transmission capacity per megawatt of summer peak demand has been steadily declining since the 1980s and is expected to continue to decline.



U.S. Transmission Capacity Normalized by Summer Peak Demand.

Hirst, 2004

there have been important reductions in emissions associated with power generation, the sector's greenhouse gas emissions have been increasing more rapidly than those of the rest of the economy. Some states are beginning to act on their own initiative to reduce these emissions. This continuing policy struggle and growing jurisdictional tension creates an additional source of uncertainty for the industry, with serious implications for different technology options, electricity service costs, and environmental effects of electricity production and transmission.

The Commission sees an urgent need to help resolve these issues. As the Commission's recommendations demonstrate in detail, both state and federal regulators have vital and complementary roles to play in providing consumers with the benefits of properly structured electricity markets.

No assessment of the nation's electricity challenges would be complete without attention to the system's vulnerability to terrorist attack. Much of the electricity infrastructure is in private hands, so protecting that infrastructure will require a strong government-private sector partnership. Although the grid is more resilient than many may appreciate, some equipment has long replacement lead-times and constant vigilance is essential to guard against potential disruption of the grid control systems. Attacks could be either cyber-based or physical, or some combination of the two. These issues deserve, and are getting sustained attention from, institutions including DHS, DOE, FERC, the National Academies, numerous state agencies, and NERC. The Commission's recommendations reflect and reinforce the vital work already underway.

Power Transformer Station. *South Carolina*

At the same time, although it was not a result of sabotage, the August 2003 blackout is a reminder that reliability concerns demand strong enforcement of mandatory reliability standards as a replacement for today's overburdened voluntary system; the Commission adds its voice to those who have been urging Congress to take immediate action here.

POLICY RECOMMENDATIONS

The Commission supports an energy policy that recognizes both the benefits of the quarter-century march toward increased competition in electric generation and wholesale markets as well as the value of traditional regulation. As the federal government and the states attempt to resolve the tensions inherent in promoting wholesale electricity competition while protecting retail customers, multiple paths may be found to widely shared energy, environmental and economic objectives. This section outlines the Commission's recommendations for reform.

FOR ALL DECISION-MAKERS

- Inadequate investment in transmission infrastructure in many regions of the country is a significant and growing national problem that costs consumers tens of billions of dollars a year in higher energy costs and lost productivity due to power outages, poor power quality and lack of access to potentially lower-cost power supplies from a diverse mix of resources. Transmission owners should be encouraged and challenged to identify and consider all potentially cost-effective solutions to increase the robustness of the grid, relieve congestion and assure reliability, including targeted demand reduction, replacement of existing facilities with new technology and upgrading or expanding transmission facilities. The Commission believes that all beneficiaries of transmission upgrades should pay their fair share of the costs.

- In recent years, electric industry participants and many states have begun to explore new mechanisms for resolving interstate disputes on transmission planning and facility siting. The Commission encourages continued interstate and state/federal cooperation in the siting of critical transmission infrastructure needed to support regional reliability and/or national security. Where state conflicts are causing transmission bottlenecks that undermine the national interest, new roles and responsibilities for the states and the federal government must be considered. Some have recommended that where a state does not act in a timely fashion, the federal government should have authority to approve facility construction upon making appropriate findings with regard to environmental impact, economic benefits and costs, and national interest. Recognizing the difficult tensions that exist between state and federal jurisdiction on transmission facility siting issues, the Commission recommends reaching this conclusion only as a last resort.

- Congress, FERC and state regulators should encourage interconnected electricity systems to undertake more regional resource and grid enhancement planning.

- Action is needed to increase the electricity sector's investments in research and development. The Commission favors supplementing the federal budgetary contribution with a combination of federal tax incentives and state-approved utility investments, recovered as a small part of electricity bills, similar to the funding mechanisms that have helped support EPRI over the past thirty years.

- To improve system security and reliability, serious attention is needed to the development of dispersed and secure stockpiles of critical equipment with long replacement lead-times. Standardization of such equipment should be explored by NERC and required for future investments wherever feasible. Priority attention also should be given to ensuring the security of SCADA systems. FERC and the states should work together to ensure that the prudently incurred costs of such reliability enhancements can be recovered fully by utilities.

FOR STATE REGULATORS AND BOARDS OF CONSUMER-OWNED UTILITIES

- The Commission recognizes that the states are pursuing a variety of approaches in reconciling wholesale competition with retail service. Some states continue to press for competitive retail markets, with varying degrees of success. Other states prefer to rely on utilities to create and manage resource portfolios for many or all retail customers. Regardless of approach, the Commission believes that state and local regulators are in the best position to make determinations about and oversee retail distribution and supply frameworks, and to assure that retail customers enjoy reliable and cost-effective service. The Commission strongly believes that where states require that local distribution companies manage electric energy resource portfolios to provide this service, the portfolio should be a mix of short, medium and long-term commitments, with long-term commitments held at or below the fraction of the system load at lowest risk of migration to retail competition. Assuming that a resource has been presented for regulators' review and has secured their approval, any associated long-term investments must not later be disallowed based on subsequent changes in electricity prices. Similarly, where states require that local distribution companies participate in a state sanctioned auction or request for proposal (RFP) process to secure such service, the local distribution company should be assured recovery of all prudently incurred costs of procuring the service or conducting and/or backstopping the process, including particularly any costs incurred as a result of supplier default.

- In states that follow a portfolio management approach, regulators should adopt performance-based incentives for good electric-resource portfolio management (by which the Commission means assembling a diversified mix of short- and long-term resource commitments and other risk management tools, in order to provide the economical and reliable electricity services that a healthy economy requires). Reliable load reductions should be eligible along with generation for purposes of meeting portfolio management responsibilities.

- Regulators should not impose extended freezes or caps on electricity rates, which discourage utilities from making investments to improve reliability and provide access to lower cost supplies of power.

- The best of the emerging distributed generation technologies offer promise, but as grid enhancements, not grid replacements. These small-scale resources rely on the distribution grid itself to deliver much of their value, which centers on opportunities to displace more costly and cumbersome solutions to distribution systems' congestion and reliability problems by delivering electricity where and when most needed. State and local utility regulators should work with distribution utilities to design fair mechanisms for rewarding distribution company investment in cost-effective and environmentally sound distributed resources (either directly or through customer partnerships), by letting utilities share in any independently verified savings that such resources create when they displace more costly infrastructure investment.

- As additional consumer protection measures it will be important to: (1) ensure that the views of small customers are adequately represented in regulatory decision-making; (2) minimize adverse effects on residential customers and distribute benefits of regulatory changes proportionately among customer classes during any restructuring transition; (3) prevent private, non-regulated entities from shifting costs or risks to the regulated entities that serve consumers (conversely, regulated utility bills should not be used to pay for infrastructure that primarily serves proprietary interests); (4) especially in competitive markets, adopt disclosure rules to ensure that consumers have access to accurate information about the products and services that they buy; and (5) ensure that consumer interests are not abandoned during "transitions", which means — among other things — that consumers should not be subject to higher-than-warranted rates to encourage the entry of competitive suppliers.

FOR THE FEDERAL ENERGY REGULATORY COMMISSION

- FERC should assure that the costs involved in improving grid security are shared system-wide on a competitively neutral basis.

- The Commission supports FERC's efforts to ensure nondiscriminatory transmission operations and nondiscriminatory access to competitive wholesale markets, with appropriate deference to the needs of states that have not adopted retail competition.

- FERC should promulgate clear, fair rules that: (1) provide for recovery of costs associated with grid enhancements; and (2) assign responsibility for payment of these costs.

- In reviewing wholesale transactions that stem from state-sanctioned resource procurement processes of jurisdictional utilities, FERC should recognize and give weight to the policy frameworks and preferences offered by different states when it reviews whether those transactions are just and reasonable.

FOR THE CONGRESS

- Congress should promptly approve widely supported legislation to make currently non-binding reliability rules for the bulk power grid mandatory and enforceable.

- Congress should back FERC's efforts to ensure open, nondiscriminatory access to the transmission system. Congress should authorize the extension of nondiscriminatory open access requirements to all transmission regardless of ownership.

- Better coordination and greater certainty regarding targets and timetables for achieving long-term environmental objectives would substantially benefit consumers and the industry. Congress should establish an integrated multi-pollutant regulatory structure that: (1) establishes a firm multi-year schedule of phased emission reductions that accommodates both environmental and system reliability needs; and (2) uses market-based mechanisms to the maximum extent feasible to minimize compliance costs and encourage innovation.

Notes:

1. Eric Hirst, *U.S. Transmission Capacity: Current Status and Future Prospects* (Washington, DC: Edison Electric Institute and United States Department of Energy, 2004), v.

2. Ibid., 1.

3. United States Department of Energy, *National Transmission Grid Study* (Washington, DC: Department of Energy, 2002), 25, http://www.eh.doe.gov/ntgs/reports.html.

4. United States Department of Homeland Security, "Information Sharing and Analysis Centers," http://www.dhs.gov/dhspublic/display?theme=73&content=1375.

5. United States Department of Homeland Security, Information Analysis and Infrastructure Protection Directorate, "Protected Critical Infrastructure Information Program," http://www.dhs.gov/dhspublic/display?theme=92&content=3755.

6. United States Department of Homeland Security, National Infrastructure Advisory Council, http://www.dhs.gov/dhspublic/display?theme=9&content=3445; and Brett Lambo, National Infrastructure Advisory Council Staff, telephone communication, September, 2004.

7. Partnership for Critical Infrastructure Security, "About the Partnership for Critical Infrastructure Security", http://www.pcis.org dcontent.cfm?dcPg=1.

8. National Research Council, Committee on Science and Technology for Countering Terrorism, *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism* (Washington, DC: National Academy Press, 2002).

9. Lawrence Papay, personal conversation, April, 2004. Mr. Papay, currently with Science Applications International Corporation, served on the panel covering energy facilities for *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism* (National Research Council, 2002) and is a chief proponent of the modular, universal EHV transformer concept. Mr. Papay suggests that if one assumes a per transformer cost of roughly $10 million, the cost associated with an initial order of 10 to 20 transformers — which he estimates to be the minimum required to spur development of a universal, modular design — would be on the order of $100–$200 million.

10. United States Department of Energy, National Energy Technology Laboratory, "Rapidly Deployable Emergency Spare Transformers," Solicitation DE-RP26-04NT42193, Pre-Solicitation Notice, http://e-center.doe.gov. The goal of this project is to procure, store, and make preparations for the deployment of nine modular EHV transformers of two different voltage ratings: three single-phase autotransformers with a nominal 500/230 kV rating and six single-phase autotransformers with a nominal rating of 345/138 kV.

11. PJM Interconnection is the regional transmission organization (RTO) responsible for managing the transmission system and competitive wholesale electricity markets in all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia. http://www.pjm.com/index.jsp.

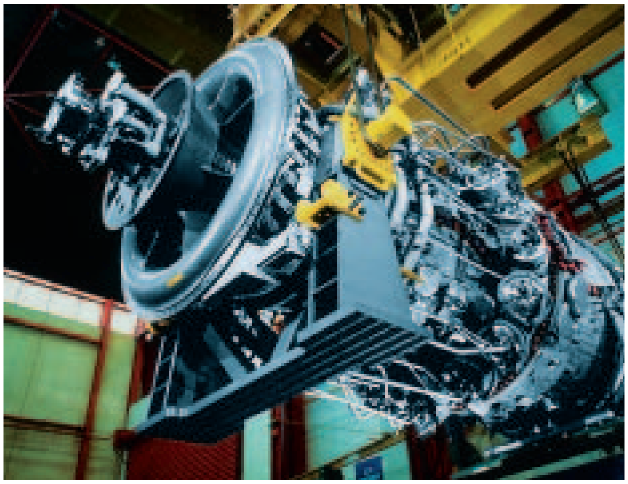
VI. Developing Better Energy Technologies for the Future

The energy challenges faced by the United States and the rest of the world in the 21st century can be alleviated by promoting increased use of the most cost-effective energy-supply and energy-end-use technologies currently available for the needed purposes, but actually surmounting those challenges in an affordable way will require development and deployment of energy technologies superior to those available today. Unfortunately, both private and public investments in research, development, demonstration, and early deployment of advanced energy technologies have been falling far short of what is likely to be needed to make these technologies available in the timeframes and on the scales required. Accordingly, the Commission here recommends (i) enhanced government incentives to the private sector to strengthen its programs of energy research, development, demonstration, and early deployment (ERD^3) for advanced supply and efficient-end-use technologies; (ii) better managed — but also substantially increased — publicly funded efforts in ERD^3, complementary to industry's efforts and coordinated with them through appropriate public-private partnerships; and (iii) increased investment in international cooperation on ERD^3, with improved coordination across the agencies of the federal government that engage in these efforts. The costs of these increased incentives for and investments in ERD^3 would be balanced by revenues to the U.S. Treasury generated by other measures recommended in this report, leaving the package revenue-neutral.

A. MOTIVATION

As argued at the beginning of this report, the overarching energy imperative is to maintain and expand the benefits to Americans and others around the world from reliable energy supplies and their productive application, while controlling and reducing energy's costs and risks in the economic, environmental, and international-security domains. The latter include, especially, the economic and security costs and risks of U.S. and world dependence on oil, the health impacts from combustion of fossil and biomass fuels, the proliferation risks from nuclear energy, and the impacts on global climate from the emissions of greenhouse gases from fossil-fuel use.

Two general approaches are available for maintaining and expanding energy's benefits while controlling and reducing its costs and risks: (1) making better use of the array of energy-supply and energy-end-use technologies that are already available (which may include measures to improve the operation of existing energy systems and energy markets); and (2) improving the characteristics of the available energy technologies, over time, through technological innovation. Inducing more effective use of the technologies already



Advanced turbines developed with public support have increased the efficiency of U.S. power generation.

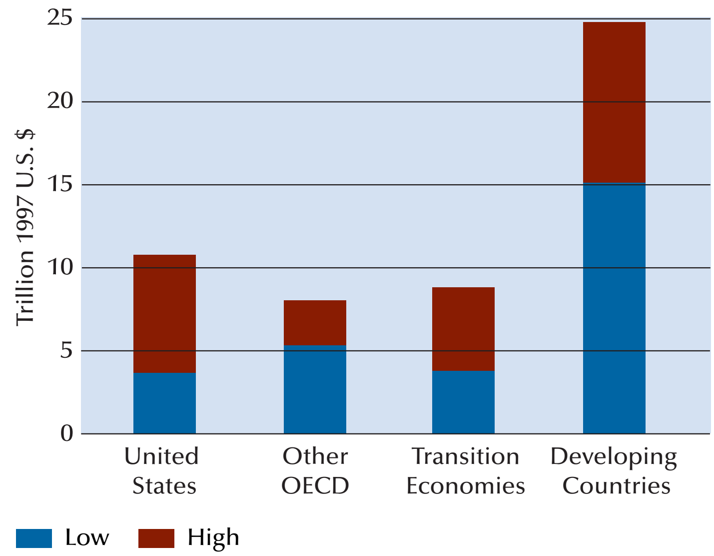
commercially available is very important — and many of the recommendations offered above will help to achieve this — but it will not be sufficient. The second approach cannot be neglected: better technologies for energy supply and efficient end-use will clearly be required if the immense challenges of the decades ahead are to be adequately addressed.

More specifically, improved technologies will make it easier to limit oil demand and reduce the fraction of it met from imports without incurring excessive economic or environmental costs; to improve urban air quality while meeting growing demand for automobiles; to use abundant U.S. and world coal resources without intolerable impacts on regional air quality and acid rain; to expand the use of nuclear energy while reducing related risks of accidents, sabotage, and proliferation; and to sustain and expand economic prosperity where it already exists — and achieve it elsewhere — without intolerable climatic disruption from greenhouse-gas emissions. U.S. investments in developing and demonstrating the advanced energy technologies that can address these challenges will be essential for maintaining this country's competitiveness in the immense (circa $400 billion per year) and rapidly growing global energy-technology market. (Figure 6-1 shows projected total investments in energy-supply technology to 2050 for the United States and the rest of the world.)

Successful development of an advanced technology does not necessarily lead to successful innovation (which is defined by success at the stage of widespread deployment), particularly in the energy field. New energy technologies generally must compete with mature, highly optimized, economically proven technologies for providing the same energy services; and if all else is equal, or even close to equal, firms and consumers will tend to stick with the proven technologies they already know. Without concerted efforts in the "demonstration" and "early deployment" categories to bring down costs and establish reliability, few of the advances that emerge from the development stage of R&D would be able to achieve commercial success.

Figure 6-1

Projected Investments in Energy-Supply Technology to 2050



President's Council of Advisors on Science and Technology, 1999

"the United States must maintain its competitiveness in the $400 billion per year rapidly growing global energy-technology market."

Firms in the energy business fund a significant amount of energy-technology innovation for purposes of improving productivity, besting the competition, and meeting environmental and other regulatory requirements. But industry ERD[3] is limited by risk aversion, free-rider concerns, and pressures on the short-term bottom line, as well as by the lack of market incentives to pursue public benefits (such as reduced vulnerability to oil-price shocks). In addition, privately funded ERD[3] tends to be heavily tilted toward near-term objectives.[1] As shaped by these factors, the magnitude and focus of the private sector's energy-technology-innovation efforts are suboptimal in relation to the interests of society as a whole. The divergence

The Nature of Energy-Technology Innovation and the Roles of the Public & Private Sectors

Energy-technology innovation may be characterized as comprising six interrelated stages, as follows:

1. fundamental research, which is aimed at improving understanding of physical, chemical, and biological materials and processes and may be germane to energy options insofar as the improved understanding provides the foundation for devising new types of energy technologies or improving existing types;

2. applied research, which seeks new understandings and the application of existing ones for the specific purpose of devising a new type of energy technology or improving an existing type;

3. development, which aims to embody the results of fundamental and applied research in a practical, operating device that establishes the potential for widespread application;

4. demonstration, which tests the most promising products of development at or near the unit size — and in the operating environment — for which large-scale application is envisioned;

5. early deployment at a scale larger than that of demonstration, which may occur with the help of subsidies or in niche markets or both, and which generally has the effect of "buying down" the unit costs of a demonstrated technology by virtue of the "learning" associated with building and operating increasing numbers of units; and

6. widespread deployment, which is generally determined in the marketplace based on characteristics and information generated in the previous stages and on cost and price signals in the market

In this report, the term ERD^3 is used to mean the combination of the first five steps — fundamental and applied energy research, development, demonstration, and early deployment — and ERD&D to mean energy research, development, and demonstration.

Oak Ridge National Laboratory. *Oak Ridge, Tennessee*

between private interests and the public's interests are the justification for public investments in energy-technology innovation to complement the private sector's efforts, as well as for as tax incentives and other inducements to increase and in some cases to redirect what the private-sector spends.

Complementarity of public-sector investments and incentives with the private sector's efforts means that the publicly supported efforts should be focused precisely on those ingredients of a societally optimal ERD^3 portfolio that industry would not be supporting on its own — avoiding the error of paying industry with public funds to do what it would otherwise be doing with its own money. Complementarity also means exploiting the complementary technology-innovation *capacities* of industry and publicly funded national laboratories and academic research centers. In many cases this should entail actual partnerships, in which industry's role will naturally increase as the innovation process in any particular case proceeds through the stages listed above: specifically, as a technology moves from applied research through development, demonstration, and early deployment, the insights about commercial products and the marketplace that are industry's forte become increasingly indispensable to success.

ADEQUACY OF CURRENT EFFORTS IN THE PUBLIC AND PRIVATE SECTORS

Energy is by far the least "R&D-intensive" high-technology sector in the U.S. economy, where R&D intensity is defined as the ratio of investments in R&D divided by the value of sales in the sector. While total energy sales in the United States were rising from $500 billion per year in 1990 to about $700 billion per year currently, private-sector investments in energy R&D appear to have fallen from about $4 billion per year in 1990 to about $2 billion per year today, hence from 0.8 percent of sales in 1990 to 0.3 percent of sales today.[2] Private-sector and federal funding combined appear to be under 1 percent of sales. For the most R&D-intensive component of the energy sector — electricity-generation equipment — private R&D investments are about 4 percent of sales. For comparison, private-sector investments in R&D are about 12 percent in the pharmaceuticals industry and about 15 percent in both the aircraft industry and the "office, accounting, and computing machinery" industry.[3]

> ***"public and private investments in energy research, development, and demonstration have fallen dramatically over the past quarter century."***

Deciding how much energy R&D is enough, however, requires looking not just at levels of expenditure ("inputs") and whether these are rising or falling in relation to the apparent magnitudes of the challenges at which the expenditures are directed, but also at the *outputs* of ERD^3 efforts (which depend not only on inputs but on the difficulty of the technical problems and the effectiveness of the efforts mounted to address them), both in absolute terms and in relation to the pace of technology improvement that meeting the challenges requires. It also requires looking at the promising *opportunities* for developing better energy technologies that are being neglected or under-exploited for lack of funds; the *likely costs* of better exploiting those opportunities, both in absolute terms and compared with the costs of obtaining equal or greater benefits (to the firm or to the society) by investing comparable resources elsewhere); and the *reductions in the cost of progress* that might be obtained from improved management and/or better exploitation of complementarities and partnerships across institutions, sectors, and countries.

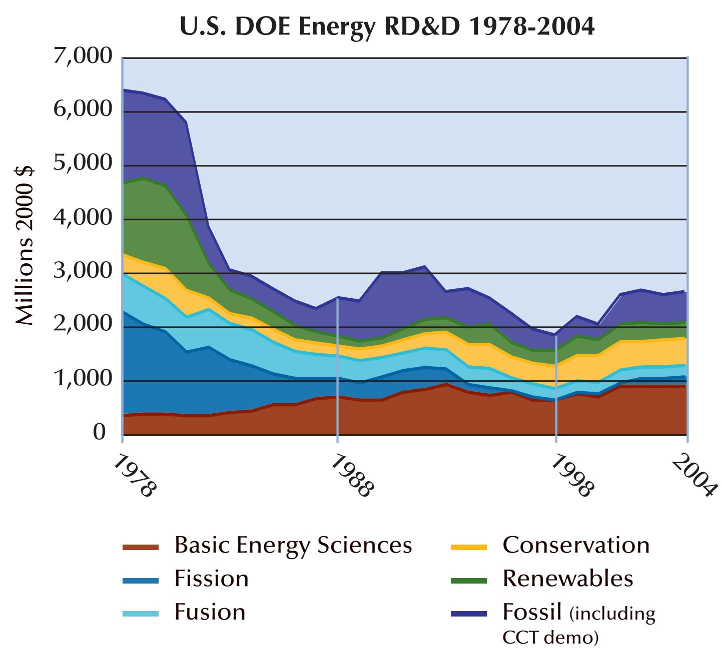
This is a large order, and no analysis done under real-world constraints of time, imperfect information, and imperfect methodology can fill it completely. But virtually every study in recent years that has attempted all or part of such an analysis of the costs and benefits of energy-technology innovation — whether in the context of the United States, the industrialized countries as a group, or the world as a whole — has concluded that current efforts in both the public and private sectors are not commensurate in scope, scale, or direction with the challenges, the oppor-tunities, and the stakes.[4]

Of course, if proposals to increase public funding for ERD^3 are to be persuasive, there should be evidence that past investments in these activities have yielded substantial returns, and there should be attention

Figure 6-2

Declining Public Support for ERD&D in the United States

Analysis of DOE data shows that, over the 25 years from FY1978 to FY2004, US government appropriations for ERD&D fell from $6.4 billion to $2.75 billion in constant year-2000 dollars, a nearly 60-percent reduction. The part of these appropriations devoted to applied-energy-technology RD&D fell from $6.08 billion to $1.80 billion.

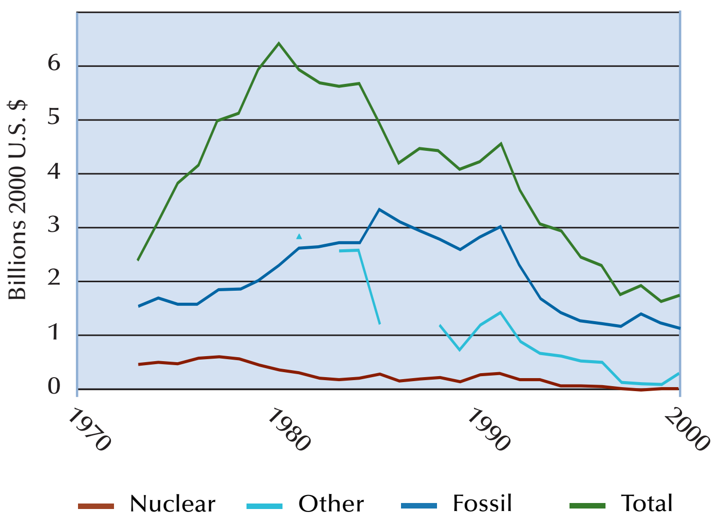


Gallagher and Sagar, 2004

Figure 6-3

U.S. Private Sector ERD&D

An analysis of less complete private-sector data indicates a drop by about a factor of three in private-sector funding for these purposes over the same period.



Dooley and Runci, 2004

to the potential for increasing the returns from existing levels of investment through improving the management of publicly funded ERD[3] efforts. Although it is commonplace for critics of public support of ERD[3] to cite conspicuous examples in which such efforts seemingly failed — the synfuels program pursued under the auspices of "Project Independence" in the 1970s and the Clinch River Breeder Reactor project are often mentioned — the success or failure of R&D efforts cannot properly be judged one project at a time or with too narrow a view of how, when, and where the benefits materialize. The fact is that suitably systematic and wide-ranging reviews of the benefits versus the costs of publicly funded ERD&D have invariably arrived at high ratios of benefits to costs, even if they also find that improvements in organization and management could increase these ratios further.[5]

A number of recent studies of the benefits to society to be expected from developing advanced technologies for non-carbon energy supply, in the event that society puts limits on carbon emissions, have concluded that these could run into the trillions of dollars — far larger than the costs of developing those technologies.[6] It should also be noted that any measures to internalize the cost of greenhouse gas emissions — such as the tradable-permits program recommended earlier in this report — will both increase the returns to private investment in developing low and non-carbon energy technologies and accelerate market penetration of advanced technologies of these types developed through private and public investments alike.[7] Clearly, technology-innovation investments and market-based incentives for carbon reduction are strongly complementary.

On the question of the gains to be had from better organization and management, studies that have looked closely at this dimension of energy R&D in the United States — and have offered quantitative estimates of the improvements that might be possible — have typically concluded that the effectiveness of current levels of investment might be increased in this way by 15 to 25 percent.[8] Such gains are very much worth pursuing, and the Commission offers its own recommendations for management improvements to achieve them below. But

Energy technologies developed in the U.S. can help modernize energy production systems in developing countries around the world. *Along the Yangtze River, China* such improvements are typically assumed and taken into account by analysts estimating what would be required to close the gap between current energy-technology-innovation efforts and those that would be required to address adequately the challenges and opportunities in this domain; the consistent conclusion is that the gains to be had from better organization and management are not nearly large enough to close that gap.

AN INNOVATION PROGRAM COMMENSURATE WITH ENERGY CHALLENGES & OPPORTUNITIES

The Commission agrees with other recent major studies in concluding that the gap between current efforts in energy-technology innovation and the level and quality of effort that will be required to meet extant and looming energy challenges is large. This applies to publicly funded and privately funded efforts combined, and it is true for the world, not just for the United States. But the United States — as the largest user of energy, the leading importer of oil, the largest emitter of greenhouse gases from fossil-fuel combustion, and the richest and most technologically advanced country in the world — has the interest, the obligation, and the capacity to lead in the global effort to close that gap in time; and the Commission believes that the "public goods" issues at stake in the outcome dictate that public policies show the way, both through expansion and restructuring of publicly funded activities in ERD^3 and through increased incentives to more effectively engage the private sector in rising to the challenge. The recommendations that follow are motivated by these convictions.

B. POLICY RECOMMENDATIONS

- The Commission recommends revising the energy-relevant provisions of the tax code to substantially increase private-sector incentives to invest in ERD^3.

- The Commission recommends doubling annual direct federal expenditures on ERD&D over the period 2005-2010 (corrected for inflation) — with increases emphasizing public-private partnerships, international cooperation, and energy-technologies offering high potential leverage against multiple challenges.

- The Commission recommends creation of a serious and systematic "early deployment" component to complement the increased RD&D activity with effective, accountable, and performance-oriented approaches to accelerating the attainment of market competitiveness by the most promising technologies successfully passing the demonstration phase.

- The Commission recommends expanding by at least three-fold, within the above-recommended increases in Federal ERD^3 efforts, the government's activities promoting and participating in international cooperation in this domain.

- The Commission recommends strengthening of the organization and management of the federal government's ERD^3 activities through continuation and expansion of the efforts already underway in the Department of Energy on improved communication, coordination, portfolio analysis, and peer review in DOE's ERD^3 programs and pursuing increased coherence and self-restraint in the Congressional "earmarking" process for ERD^3 appropriations.

- The Commission recommends supporting the increases in expenditures connected with the initiatives recommended here from part of the revenue from sales of emissions permits under the tradable permits system for greenhouse gas emissions recommended elsewhere in this report.

ERD³ INCENTIVES FOR INDUSTRY

The Commission recommends revising the energy-relevant provisions of the tax code to substantially increase private-sector incentives to invest in ERD³.

Section 41 of the Internal Revenue Code provides for a tax credit against federal income-tax liability for a portion of the amount by which a firm's qualifying research expenditures exceed the firm's historic level of expenses of this kind. The credit amounts to 20 percent of the qualifying increases, which must (1) be undertaken for the purpose of discovering information that is technological in nature; (2) be intended to be useful in a new or improved business component of the firm; and (3) consist of activities that constitute elements of a process of experimentation; a 20-percent credit is also available for increases in payments for "basic research" (which means research lacking a specific business objective) under contract with educational institutions and nonprofit research organizations.[9]

The effectiveness of the R&D tax credit in stimulating increases in private-sector energy R&D is limited by a number of important restrictions and exclusions in its coverage: it does not apply to expenditures outside the United States; overhead expenses and structures and equipment for the conduct of research are excluded; and in-house basic research is not credited at all. Its effectiveness is also compromised by its being only a temporary provision of the tax code: although it has been extended ten times since its inception in 1981, it has also been allowed to expire on a number of occasions, and its vulnerability to such lapses reduces the willingness of firms to count on it. In addition, complexities and constraints in its applicability to partnerships of firms with nonprofits reduce its usefulness for this increasingly important mode of energy R&D.

The Commission agrees with the Bush Administration's 2001 National Energy Policy report[10] that the R&D tax credit should be made permanent. It also believes that the credit should be increased from 20 percent to 30 percent for qualifying increases in general and to 40 percent for those relating to technologies aimed at increasing end-use efficiency or otherwise reducing greenhouse-gas emissions. Finally, the Commission recommends that the relevant tax-code provisions be further modified to allow credit for increases in R&D funded by U.S. firms overseas, and to eliminate the current barriers to rewarding R&D increases in industry-nonprofit partnerships.

INCREASED FEDERAL ERD&D

The Commission recommends doubling annual direct federal expenditures on ERD&D (corrected for inflation) over the period 2005–2010 — with increases emphasizing public-private partnerships, international cooperation, and energy-technologies offering high potential leverage against multiple challenges.

This recommendation is based on the Commission's conclusions about the magnitude of the energy challenges for which only improved technologies can provide cost-effective answers, about the inadequate pace of energy-technology innovation today in relation to those challenges, about the high-leverage opportunities for accelerating that pace (which a substantial literature — including but far from limited to reports the Commission sponsored — reveals in abundance), and about the limitations of what the private sector is likely to undertake on its own (even allowing for increased incentives from a tradable-permits program for greenhouse emissions and a strengthened R&D tax credit along the lines recommended above).

"The Commission recommends doubling annual direct federal expenditures on Energy RD&D"

No completely convincing analysis is possible that a doubling of public expenditures for ERD&D over this period is *exactly* the right figure — some will argue it is not enough, while others will say it's too much — but it is consonant with the recommendations of the other major studies cited here, as well as with the increases the Commission has found to be warranted in a number of particularly important areas of prospective energy-technology innovation that it examined in depth. Box 6-1 provides an illustrative budget to show roughly what a doubled ERD&D effort might entail, using the corresponding FY2004 appropriations and recommendations from the 1997 study by the President's Council of Advisors on Science and Technology (PCAST), which were initially intended to apply for FY2003, as reference points.

Within the expanded portfolio of federally funded ERD[3] activities, the Commission believes that high priority should go to technology options with high potential leverage against more than one of the major public-benefit issues that are so crucial in the energy-policy domain. The most promising options in this connection have all been discussed in the earlier sections of this report dealing with the particular challenges to which the options most directly relate, but they are mentioned again here because all require additional efforts at varying points along the ERD[3] chain if they are to reach their potential, and all share for varying reasons the characteristic that private-sector ERD[3] efforts alone are not likely to bring them to that potential at the pace that society's interests warrant. The principal clusters of such options are:

- ***clean and efficient automobile and truck technologies,*** including advanced diesels, conventional and plug-in hybrids, and fuel-cell vehicles (which can contribute simultaneously to reducing climate-change risks, reducing urban and regional air pollution, and improving energy security);[11]
- ***integrated-gasification combined-cycle coal technologies*** for polygeneration of electricity, steam, chemicals, and fluid fuels (addressing air pollution and fuel diversity as well as facilitating carbon capture to address climate change);[12]
- ***other technologies that achieve, facilitate, or complement carbon capture and sequestration,*** including the technologies for carbon capture in hydrogen production from natural gas, for sequestering captured carbon in geologic formations, and for using the produced hydrogen efficiently (climate change, air pollution);[13]
- ***technologies to efficiently produce bio-fuels*** for the transport sector (energy security, climate change);[14]
- ***advanced nuclear energy technologies*** to enable nuclear expansion by lowering cost and reducing risks from accidents, terrorist attacks, and proliferation (climate change, air pollution, energy security);[15]
- ***technologies for increasing the efficiency of energy end-use in buildings and industry*** (climate change, energy security, air pollution).

EARLY DEPLOYMENT — THE THIRD D IN ERD[3]

The Commission recommends creation of a serious and systematic "early deployment" component to complement the increased RD&D activity with effective, accountable, and performance-oriented approaches to accelerating the attainment of market competitiveness by the most promising technologies that successfully pass the demonstration phase.

Although current levels of effort in energy research, development, and demonstration certainly need to be increased, the biggest deficits may well be in efforts to bridge the gap between technology demonstration and full commercial competitiveness. Such efforts, in which the government's role should be concentrated on options promising substantial public benefit, may include government procurement programs, reverse auctions for subsidies for specified quantities of energy from advanced options, loan guarantees for "first movers" using new technologies at commercial scale, and tax incentives. Not all such interventions will necessarily be expensive for the government; loan guarantees for well chosen options may not be, for example, since for such options the probability of the guarantees being called upon will be small.

The proposition is sometimes advanced that the government has no business involving itself in the early-deployment stage of technology innovation at all, because this involves "picking winners" and the government lacks the skills to do so. But there are powerful counterarguments. First, if there is a public-benefit case for government engagement in research, development, and demonstration (which clearly there is), then there is also a case for government engagement at the early-deployment stage of high-public-benefit technologies whose introduction is being impeded by market barriers that the government is in a position to help overcome. Second, virtually everything the government does — as well as everything the private sector does — involves "picking winners" in one way or another. Doing this cannot be avoided, and neither can the risk of making mistakes. The key is rather to strive to continuously improve management discipline and the mechanisms for making good choices and for terminating investments in bad ones before the losses become too large. Competition takes care of this in the case of firms that persist too long in their mistakes or make too many of them; other mechanisms are available to limit the damage from bad choices in government.[16]

A large part of the solution in the case of ERD^3 is to ensure that essentially all activities promoted via government incentives or direct financial participation at the early-deployment stage of the ERD^3 process are carried out in partnership with the private sector, whose capacities "on the ground" generally cannot be matched by government. The Commission believes, in this connection, that government-imposed requirements for a fixed percentage of financial participation by the private firms engaged in early-deployment partnerships are not always desirable, insofar as high potential public benefits may justify proceeding in some cases even where the financial risks appear too large to attract large bets from the private sector.

Accumulating the recommendations for early-deployment initiatives and incentives offered in the various sections of this report suggests a funding increment in the range of $1.3 billion per year above the current expenditure level of about $0.6 billion per year in this category. The expanded initiatives include manufacturers' incentives for plant conversions to produce more efficient passenger vehicles and consumer incentives to purchase them; early-deployment incentives for clean-coal technologies, advanced nuclear reactors, and cellulosic-ethanol plants; and a significant expansion of the renewables production tax credit. Table 6-2 compares the FY2004 appropriations with the Commission's proposals.

EXPANDED INTERNATIONAL COOPERATION IN ERD^3

The Commission recommends expanding by at least three-fold, within the above-recommended increases in federal ERD^3 efforts, the government's activities promoting and participating in international cooperation in this domain.

International cooperation in ERD^3 is advantageous to the United States for several reasons. Cooperation with scientifically advanced partners in fundamental research on technologies far from commercial application offers obvious benefits through sharing costs and insights, with minimal risk of losing competitive advantage. Cooperation with less developed countries in development, demonstration, and early deployment helps them build the capacity to use advanced technologies that otherwise might remain confined to industrialized nations, at the same time as it helps U.S. labs and firms to develop and demonstrate variants of the technologies tailored to developing-country requirements and to market them successfully. Accelerating the pace at which advanced energy technologies are deployed in other countries is further in the U.S. interest because success in many of the most important energy challenges — for example those of nuclear-energy risks, globe-girdling air pollution, and climate disruption by greenhouse gases — requires that the correctives be available everywhere, not just in the United States or in the most advanced industrialized nations as a group.

The Commission concurs with the conclusion of the 1999 PCAST study that U.S. government investments in international cooperation on ERD^3 should at least be tripled from their late-1990s level — that is, from circa $250 million per year to $0.75–1 billion per year. The greatest emphasis in this expanded effort should go to cooperation with the countries that have the most rapidly expanding energy sectors and those that offer the greatest leverage in addressing the public-benefit issues that are correctly at the heart of government intervention in markets: China, India, Russia, Mexico, Brazil. But the increased cooperation should also include joint efforts with the most technologically and economically advanced among the rest of the world's countries — Japan, Canada, South Korea, the countries of Western Europe — on projects such as fusion where the difficulty and cost of the enterprise make sharing of expertise and financial burdens essential.

The substantive focuses of the expanded efforts should include the safety and terrorism- and proliferation-resistance characteristics of nuclear-energy technologies, affordable renewable-energy options, low-carbon fossil-fuel technologies and carbon sequestration, clean and efficient motor vehicles, and technologies to increase end-use efficiency in the industrial and buildings sectors. The mechanisms should range across the stages of energy-technology innovation, from building capacity for fundamental and applied-energy-technology research to helping finance the demonstration and early deployment of advanced energy technologies with high public benefits. As in the domestic initiatives recommended here, the initiatives the Commission envisions would provide for appropriate protection of intellectual property and make full use of the potential of public-private partnerships, above all in the development, demonstration, and early deployment phases of ERD^3. And, as in the domestic domain, expanded U.S. government investments in these activities will need to be accompanied by significant improvements in the organization and management of the government's efforts — to which the discussion now turns.

IMPROVED ORGANIZATION AND MANAGEMENT OF FEDERAL ERD^3 PROGRAM

The Commission recommends strengthening of the organization and management of the federal government's ERD^3 activities through continuation and expansion of the efforts already underway in the Department of Energy on improved communication, coordination, portfolio analysis, and peer review in DOE's ERD^3 programs and pursuing increased coherence and self-restraint in the Congressional "earmarking" process for ERD^3 appropriations.

Recommendations for strengthening the organization and management of the government's ERD3 efforts have emerged from every recent major study of federal activities in this domain of which the Commission is aware.[17] These recommendations have been strikingly consistent across studies.[18] They have called for more communication and coordination within DOE between fundamental and applied energy research and across the applied-energy-technology "stovepipes" (fossil, nuclear, renewables, end-use efficiency); improvement of evaluation through more peer review and better use of outside advisory panels; more systematic analysis and oversight of the ERD^3 portfolio as a whole; increased cultivation of partnerships linking firms, national laboratories, and universities; better coordination between DOE and other agencies with roles related to energy-technology innovation domestically and internationally (including especially the Departments of Commerce and Interior, the Environmental Protection Agency (EPA), and the U.S. Agency for International Development (USAID)); and finding ways to reduce the impacts of Congressional earmarking, micromanagement of programs, and dramatic year-to-year shifts in budget levels and directions. The Commission agrees with all of these thrusts.

Considerable effort has been devoted by DOE to implementing some of these recommendations — particularly in the last years of the Clinton administration following the release of the 1997 PCAST report, and in the first term of the Bush administration. Substantial progress has been made in, for example, creating more explicit goals and plans for the programs within DOE's Office of Fossil Energy and the Office of Energy Efficiency and Renewable Energy; in establishing criteria for investment, ongoing performance review, and disinvestment; and in upgrading mechanisms for internal and external peer review and advice.[19] But further progress is needed in high-level coordination of energy-technology-innovation programs across the Department; in establishing stronger mechanisms for review and evaluation; in fostering communication and coordination between DOE and other relevant government agencies;

Table 6-1

Illustrative Example of a Doubled Federal Budget

Simply as an illustration of the shape that a doubled budget for ERD&D might take, the Commission offers a set of numbers here that are largely based on analyses provided elsewhere in this report or in papers prepared for the Commission that nearly add up to a doubling of the total DOE ERD&D appropriation for FY2004. As indicated by the table, the Commission's proposals combine to an increase in annual spending of approximately $1.5 billion per year and $15 billion over ten years. All figures here are in millions of FY2004 dollars.

Category	Actual FY 2004*	Illustrative FY 2010
RD&D		
Energy end-use efficiency	*539*	*1150*
Transport	178	400
Hydrogen^	147	150
Buildings	60	300
Industrial	93	200
Distributed energy	61	100
Fossil fuels	*545*	*900*
IGCC, fuel cells, & other clean-coal technology	409	450
Carbon sequestration	40	300
Oil & gas recovery	69	100
Methane hydrates	9	50
Other	18	
Nuclear fission	*129*	*200*
Nuclear fusion	*163*	*250*
Renewables	*247*	*600*
Biomass	93	200
PV and solar thermal	83	300
Wind	41	50
Hydro, geothermal, & other	30	50
T&D, storage	*81*	*150*
RD&D Total	**1,704**	**3,250**

*Does not include funding for program management or international cooperation in RD&D
^This number includes hydrogen in connection with renewables and efficiency, but not with fossil fuels.

Data Sources: President's Council of Advisors on Science and Technology, 1999; United States Department of Energy, 2004 and in reducing the impacts of the current character of the Congressional budget process.

Recognizing that Congress alone is responsible for appropriations, the Commission would nonetheless be derelict if it failed to point out that the current practice of non-competitive earmarks bearing little relation to the ERD^3 goals and plans of the Department is harmful and raises questions about the effectiveness of public funds spent on energy-technology innovation. As much as half of the budgets of some of the energy RD&D programs of the Department are currently being expended on earmarks. The Commission recommends that Congressional leadership exert greater efforts to ensure that earmarks are consistent with the strategic objectives of the programs affected.

REVENUE NEUTRALITY AND SUSTAINABILITY FOR THE RECOMMENDED PROGRAMS

The Commission recommends supporting the increases in expenditures connected with the initiatives recommended here from the revenue from sales of emissions permits under the tradable-permits system for greenhouse gas emissions recommended elsewhere in this report.

Commission analysis indicates that sales of emission permits under the tradable-permits system it is proposing for greenhouse gas emissions would yield about $36 billion in the first ten years of the program's operation, which likewise corresponds to the increment in federal ERD^3 spending that this discussion has suggested is warranted.

Table 6-2

Tabulation of the Early Deployment Incentives Suggested by the Commission

This table accumulates the various early deployment initiatives and incentives recommended by the Commission in the various sections of this report. Actual appropriations for FY2004 are shown for comparison. As indicated by the table, the Commission's proposals combine to an annual increase in federal funding of approximately $1.4 billion or roughly $14 billion over ten years. All figures are in millions of FY2004 dollars.

	Actual FY 2004	Commission Proposal
Energy end-use efficiency	*389*	*650*
Weatherization & other buildings programs	309	350
Manufacturers' incentives for plant conversion to produce more efficient vehicles	0	150
Consumer incentives for purchase of more efficient vehicles	80	150
Fossil fuels	*0*	*400*
IGCC deployment incentives	0	400
Nuclear fission	*30*	*230*
Renewables	*200*	*750*
Renewables production tax credit	200	600
Cellulosic ethanol and other biofuels	0	150
Early Deployment Incentives Total	**619**	**2,030**

Data Sources: President's Council of Advisors on Science and Technology, 1999; United States Department of Energy, 2004

Table 6-3

Illustrative Example of a Tripled International Energy Cooperation Budget

This table suggests categories of increased funding for international cooperation in energy research, development, demonstration, and deployment. As indicated by the table, the Commission's proposal amounts to roughly a tripling of current expenditures for international cooperation, or an additional $500 million per year and $5 billion over ten years. All figures are in millions of FY 2004 dollars.

FY 2004 Budget Estimated at $250 million	Commission Proposal
Energy end-use efficiency	*150*
Fossil fuels and sequestration	*150*
Nuclear fission	*150*
Nuclear fusion	*150*
Renewables and Hydrogen	*150*
Early Deployment Incentives Total	**750**

Notes:

1. See President's Council of Advisors on Science and Technology (PCAST), Panel on Energy R&D, *Federal Energy Research and Development for the Challenges of the 21[st] Century* (Washington, DC: Executive Office of the President, 1997). Also see Jim Dooley and Paul Runci, "Energy and Carbon Management R&D Policy: Framing Considerations and Recommendation for the National Commission on Energy Policy" in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

2. See PCAST, *Federal Energy Research*; James J. Dooley, Shawn Peabody, Richard Newell, and Paul Runci, "U.S. Investment in Energy R&D," in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004); Dooley and Runci, "Energy and Carbon Management"; National Science Board (NSB), *Science and Engineering Indicators 2004* (Washington, DC: National Academy Press, 2004), App. Table 4-22, p. A4-41.

3. NSB, *Science and Engineering Indicators 2002* (Washington, DC: National Academy Press, 2002), Chapter 6.

4. See the 1997 White House review of U.S. energy R&D programs (PCAST, *Federal Energy Research*); World Energy Council (WEC), Energy RD&D Study Group, *Energy Technologies for the 21[st] Century* (London: World Energy Council, 2001); the 2001 US national energy strategy document produced by the "Cheney Commission": National Energy Policy Development Group (NEPDG), *National Energy Policy* (Washington, DC: Executive Office of the President, 2001). See also Martin I. Hoffert, Ken Caldeira, Gregory Benford, David R. Criswell, Christopher Green, Howard Herzog, Atul K. Jain, Haroon S. Kheshgi, Klaus S. Lackner, John S. Lewis, H. Douglas Lightfoot, Wallace Manheimer, John C. Mankins, Michael E. Mauel, L. John Perkins, Michael E. Schlesinger, Tyler Volk, and Tom M. L. Wigley, "Advanced Technology Paths to Global Climate Stability: Energy for a Greenhouse Planet," *Science* 298 (2003): 981-87, on the inadequacies of existing energy technologies in relation to the climate-change challenge. Also see the work on this topic prepared for NCEP: Dooley and Runci, "Energy and Carbon Management"; Ambuj Sagar and Kelly Sims Gallagher, Energy Technology Innovation Project, Belfer Center for Science and International Affairs, Kennedy School of Government, Harvard University, "Energy Technology Demonstration and Deployment," in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

5. For example, a recent National Research Council study that examined about 20% of DOE's investments in energy-efficiency RD&D for the period 1978-2000 found that the projects examined returned $30 billion in benefits to society for $1.7 billion invested. the same study looked at programs accounting for 70% of DOE's investments in fossil-energy RD&D in this period and found that these had costs equaling benefits for the whole period but had benefits of $7.5 billion versus costs of $4.5 billion in the last 15 years of the period -- when, evidently, the effort was more sensibly structured and better managed: National Research Council, Committee on the Science of Climate Change, *Climate Change Science: An Analysis of Some Key Questions* (Washington, DC: National Academy Press, 2001). See also Jeffrey Chow and Richard Newell, Resources for the Future, "A Retrospective Review of the Performance of Energy R&D," in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004); Richard Rosenzweig, Natsource, LLC, "The Economic Benefits of Technology in Stabilizing Concentrations of Carbon Dioxide in the Atmosphere: Challenges and Opportunities," in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004); and Sagar and Gallagher, "Energy Technology Demonstration."

6. Jae Edmonds, Tom Wilson, and Richard Rosenzweig, Global Energy Strategy Project of the Battelle Pacific Northwest National Laboratory, *Global Energy Technology Strategy Addressing Climate Change: Initial Findings from and International Public-Private Collaboration* (Washington, DC: Pacific Northwest National Laboratory, 2000); R.G. Richels, A.S. Manne, and T.L. Wigley, American Enterprise Institute/Brookings Institution Joint Center for Regulatory Studies, *Moving Beyond Concentrations: The Challenge of Limiting Temperature Change* (Washington, DC: Brookings, 2004); and Rosenzweig, "The Economic Benefits of Technology."

7. See Carolyn Fischer, Resources for the Future, "Balancing Mitigation and Technology Incentives in a Climate Policy Framework," in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

8. Secretary of Energy Advisory Board (SEAB), Task Force on Strategic Energy R&D, *Energy R&D: Shaping Our Nation's Future in a Competitive World* (Washington, DC: U.S. Government Printing Office, 1995); PCAST, *Federal Energy Research*.

9. Robert Nordhaus, "Restructuring and Financing Energy Research, Development, Demonstration, and Early Deployment," in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

10. NEPDG, *National Energy Policy.*

11. Joe Romm, The Center for Energy and Climate Solutions, "The Car and Fuel of the Future: A Technology and Policy Overview," in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

12. Robert H. Williams, Princeton Environmental Institute, Princeton University, "IGCC: Next Step on the Path to Gasification-Based-Energy From Coal," in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

13. Intergovernmental Panel on Climate Change, Working Group III, *Climate Change 2001: Mitigation* (Cambridge, UK: Cambridge University Press, 2001), 249-52.

14. Lee Lynd, Nathanael Green, and John Sheehan, Dartmouth College, Natural Resources Defense Council, and National Renewable Energy Laboritory, "The Role of Biomass in America's Energy Future," in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

15. John Deutch and Ernest Moniz, Co-Chairs, *The Future of Nuclear Power: An Interdisciplinary MIT Study* (Cambridge, MA: Massachusetts Institute of Technology, 2003).

16. See, e.g., PCAST, Panel on International Cooperation in Energy Research, Development, Demonstration, and Deployment, *Powerful Partnerships: The Federal Role in International Cooperation on Energy Innovation* (Washington, DC: Executive Office of the President, 1999); Sagar and Gallagher, "Energy Technology Demonstration."

17. These include SEAB, *Shaping Our Nation's Future;* PCAST, *Federal Energy Research;* PCAST, *Powerful Partnerships;* National Research Council, Committee on Energy Research at DOE, *Energy Research at DOE: Was it Worth It? Energy Efficiency and Fossil Energy Research 1978 to 2000* (Washington, DC: National Academy Press, 2001); and SEAB, Task Force on the Future of Science Programs at the Department of Energy, *Critical Choices: Science, Energy, and Security* (Washington, DC: United States Department of Energy, 2003).

18. Kelly Sims Gallagher, Robert Frosch, and John P. Holdren, Energy Technology Innovation Project, Belfer Center for Science and International Affairs, Kennedy School of Government, Harvard University, "Management of Energy-Technology-Innovation Activities at the Department of Energy" in *NCEP Technical Appendix* (Washington, DC: National Commission on Energy Policy, 2004).

19. See United States Department of Energy, Office of Energy Efficiency and Renewable Energy, *Strategic Plan: Clean, Abundant, Renewable and Affordable Energy,* DOE/GO-102002-1649 (Washington, DC: Energy Information Administration, 2002); and the favorable report of the National Academy of Public Administration on the management reforms in DOE's Office of Energy Efficiency and Renewable Energy: National Academy of Public Administration, *Office of Energy Efficiency and Renewable Energy: Reorganizing for Results* (Washington, DC: National Academy of Public Administration, September 2004).

CONCURRENCE - SHARON NELSON

The National Commission on Energy Policy has developed a balanced package of pragmatic recommendations that advance our nation's economic, environmental and security interests. While I support the package of recommendations, I wish to comment on two issues of particular significance to consumers.

The electricity sector provides an essential infrastructure for assuring the public safety, health and welfare. This report recognizes this practical reality and the significant need to re-establish some semblance of predictability for the electricity sector. It also encourages important efforts to address national security concerns, promotes coordinated regulation of all power plant emissions, encourages greater emphasis on energy efficiency, and supports much needed technology R & D. The report also recognizes that values other than market values still vitally affect the electricity industry and are affected by it. For these reasons, I support the Commission's electricity recommendations, despite the concerns described below.

I reside in a region of the country that has suffered from "market designs" we sought to avoid. In my view, markets are not designed. They may evolve, they may be influenced by public policy, but they are not the product of legislative or regulatory mandates. There are good reasons for the electricity industry to be the last of the network industries to experience "restructuring." As opposed to the transportation, banking, or telecommunications industries, the preconditions that characterized the other sectors' reformations (such as ease of access to capital markets, freedom of entry, well understood rules about interconnection) did not exist in the vertically integrated electricity industry. Indeed, one major difference here is the ownership structure of the industry. As opposed to the natural gas industry or the telecom industry, the electricity industry is characterized by a mix of public and private providers. The instantaneous nature of the product and the fact that electricity is not storable in any conventional sense distinguishes the physical reality of this market from the others.

Traditional institutional oversight for this complex industry is not the same as that "enjoyed" by parallel natural gas or telecom markets making legislative and regulatory initiatives even more complicated. Jurisdictional lines are anything but bright. The phrase "ensuring a level playing field" is a hackneyed one, but this common-sense goal is practically not achievable for the entire electricity industry in the nation's current electoral-political environment. The nation needs more thoughtful analysis of why the experiments in Pennsylvania, California, the United Kingdom, and Texas are succeeding or failing. The excellent study, "Toward a Consumer-Oriented Electricity System: Assuring Affordability, Reliability, Accountability and Balance After a Decade of Restructuring," conducted for the Commission by the Center for Public Interest Research, is a step in this direction. Once we draw some lessons from empirical studies, then maybe some more far-reaching and sensible policy reforms will advance.

I am concerned that the several of the Commission's recommendations for the electricity sector give too much deference to the Federal Energy Regulatory Commission which at this point does not manifest the institutional competence to warrant such trust. I am also concerned that some recommendations do not adequately recognize regional differences or honor traditional regulatory policy goals of ensuring cost containment, efficiency and customer class and intergenerational equity.

Despite these concerns, I support a significant majority of the Commission's electricity recommendations. The debate over the future direction of our nation's electricity system is fundamentally stymied. The hard work and significant agreements reached by our expert and diverse Commission at least identify and address the most pressing issues at stalemate in the current national policy debate. For this reason I concur.

Finally, I strongly endorse the view that significant increases in vehicle fuel economy are in the consumer interest. I believe that the Commission's CAFÉ reform recommendations (tradable credits and a safety valve) that are included to limit costs for the automobile industry are only justified if associated with an increase in fuel economy standards on the order of 10-20 miles per gallon.

CONCURRENCE – R. JAMES WOOLSEY

While I support the policy positions in the National Commission on Energy Policy's final report, I believe that the recommendation to "significantly strengthen" passenger vehicle fuel economy standards, while a step forward, is too vague. As discussed in Chapters 1 and 3, several studies published since 2000 have identified a host of fuel saving technologies that could dramatically improve passenger vehicle fuel economy levels to 34 or 44 mpg from today's combined car and light truck level of 24 mpg over the next ten to twenty years. The lower end of this range reflects the fuel economy potential of conventional technologies, while the higher end of the range would require significant penetration of hybrids and advanced diesels into the passenger vehicle market. Importantly, these improvements could be achieved without diminishing vehicle safety or consumer choice, and at technology costs that would pay for themselves in fuel savings over the full useful life of the vehicle. Even greater fuel economy improvements are possible – again without sacrificing safety or vehicle performance – through greater use of lightweight composite materials.

Recent history demonstrates that a 10 mpg increase in vehicle fuel economy over a decade is technically and practically feasible. Indeed, in response to Congressional direction, new passenger vehicle fuel economy rose to 26 mpg from 15 mpg between 1975 and 1987. Without government regulation, fuel economy in the United States has since stagnated while efficiency improvements have been used by car makers to increase vehicle weight by 24 percent and horsepower by 93 percent. The United States is home to one of the most gas guzzling vehicle fleets in the world, particularly compared to the European and Japanese passenger vehicle fleets which average 37 and 45 mpg today, respectively. Given this historic and international context, to issue a report without a numerical recommendation on passenger vehicle fuel economy, even a moderate 10 mpg increase over a decade, warrants a critique.

This is particularly the case because the costs associated with a 10 to 20 mpg increase in new passenger vehicle fuel economy are well justified given that our nation is at war with totalitarian and terrorist movements anchored in the oil-rich Middle East. The tragedy that befell the nation on September 11, 2001 was only one manifestation of this war. At a time of war, this nation must do everything in its power to weaken and destroy its enemies. Retooling auto manufacturing and supplier plants to produce fuel-efficient vehicles can be expected to run in the billions of dollars, but the benefits include cutting growth in U.S. oil consumption in half, robbing our enemies of financial support, and insulating the nation from the economic risks associated with oil price shocks. These latter can be caused at any time by terrorist attacks, coups, or simply policy decisions by governments in the region. The report's shortcoming lies not in its analysis or vision, but in its lack of a reasonable numerical fuel economy target that would reflect the wartime urgency, and the technological potential, of our time.

***Two original members of the National Commission of Energy Policy, Paul Joskow Ph.D. and Andrew Lundquist, withdrew from the Commission process prior to the completion of this Report. Dr. Joskow and Mr. Lundquist made significant contributions to this effort for which the Commission is grateful.

Technical Appendix

The findings in this Report are supported by numerous studies and analyses prepared by subcontractors to the Commission, Commissioners, or Commission Staff. These materials are collected in a Technical Appendix and are accessible electronically via "links" in each chapter of the Commission's Report and on the Commission's website, *www.energycommission.org*. The complete Technical Appendix is also available in hard copy and on CD-ROM.

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ENERGY SCENARIO SIMULATION TOOL

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TECHNICAL, RESEARCH, AND POLICY CONSULTANTS

The Commission has benefited from input from an array of organizations and institutions. In particular, we would like to thank the following organizations, who provided research, analysis, and technical support to the Commission during the course of its deliberations. Their work is compiled and available in the Technical Appendix to this Report. A full list of all organizations consulted is available on our website, *www.energycommission.org*.

NATIONAL LABORATORIES

Lawrence Berkley National Laboratory

Oak Ridge National Laboratory

Pacific Northwest National Laboratory

ACADEMIC INSTITUTIONS

Thayer School of Engineering, Dartmouth College

John F. Kennedy School of Government, Harvard University

Princeton Environmental Institute, Princeton University

Stanford Institute for Economic Policy Research, Stanford University

University of Michigan Transportation Research Institute, University of Michigan

Wheeling College

TECHNICAL, RESEARCH, AND POLICY ORGANIZATIONS

American Association of Blacks in Energy

American Council for an Energy-Efficient Economy

Americans for Equitable Climate Solutions

AMJ Energy Consulting

Analysis Group, Inc.

The Brookings Institution

Business Council for Sustainable Energy

Center for Energy and Climate Solutions

Center for Public Interest Research

Charles River Associates

Congressional Black Caucus Foundation

Earthtrack Inc.

Ecos Consulting

Energy and Environmental Analysis, Inc.

ICF Resources, Inc.

Jensen Associates

Komanoff Energy Associates

Meszler Engineering Services

Michael Walsh Associates

MJ Bradley and Associates, Inc.

Natsource Tullet Europe

On Location, Inc.

Pew Center on Global Climate Change

Redefining Progress

Regulatory Assistance Project

Resources for the Future

Synapse Energy Economics

Theodore Roosevelt Conservation Partnership

Van Ness Feldman

Glossary of Terms

Barrel: Standard measure for oil. One barrel equals 42 gallons.

British Thermal Unit (Btu): The quantity of heat needed to raise the temperature of one pound of water by 1 degree Fahrenheit at or near 39.2 degrees Fahrenheit; a measure of energy.

Dry ton: In this report, a measure of biomass; one dry ton equals 2,000 pounds of dried plant material.

Kilowatt (kW): One thousand watts. A kilowatt-hour (kWh) is the amount of energy expended by one kilowatt in one hour. Related terms include megawatt (MW – thousand kW) and megawatt-hour (MWh - thousand kWh), gigawatt (GW – million kW) and gigawatt-hour (GWh – million kWh), and terawatt (TW – billion kW) and terawatt-hour (TWh – billion kWh).

MBD: Million Barrels (of oil) per Day.

Metric ton: 1,000 kilograms or 2,205 pounds.

mmBtu: One million British Thermal Units. See British Thermal Unit.

$MTCO_2e$: Metric tons of carbon dioxide equivalent. A measure used to indicate the global warming potential for greenhouse gases in terms of the amount of pure carbon dioxide necessary to create the same effect. Since greenhouse gases vary widely in terms of climate change potential, converting to carbon dioxide equivalent allows for easier comparison. (Data Source: EIA, E*missions of Greenhouse Gases in the U.S 2002,* 2004.)

For one ton of:	$MTCO_2e$ Equals	For one ton of:	$MTCO_2e$ Equals
Methane	23	HFC-152a	120
Nitrous Oxide	296	HFC-227ea	3,500
HFC-23	12,000	Perfluoromethane	5,700
HFC-125	3,400	Perfluoroethane	11,900
HFC-134a	1,300	Sulfur Hexafluoride	22,200

Quad: One thousand trillion (10^{15}) British Thermal Units. Quads are frequently used when referring to very large quantities of energy, such as that consumed by an entire economy. See British Thermal Unit.

Short ton: 2,000 pounds.

Conversion Factors:

1 kilowatt hour (kWh) = 3,412 Btu

1 barrel of oil (bbl oil) = 42 gal = $5.800*10^6$ Btu

1 short ton = 0.9071 metric tons

1 metric ton = 1.102 short tons

1 million Btu (mmbtu) = 970.4 cubic feet of natural gas

1 quad = 10^{15} Btu = $2.930*10^{11}$ kWh = $9.704*10^{11}$ cubic feet of natural gas = $1.714*10^8$ barrels of oil

1 trillion cubic feet (TCF) of natural gas = 10^{12} cubic feet = $1.030*10^{15}$ Btu

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Figure 3-3: Market Share of Gasoline-Electric Hybrid Vehicles

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Figure 4-15: The Attributes of Corn Ethanol and Cellulosic Ethanol

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Figure 4-16: Broad Geographic Distribution of Renewable Waste Resources

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Table 4-2: Estimated Land Requirements for Producing Biofuels Sufficient to Fuel Half the Current U.S. Passenger Fleet.

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CHAPTER 5 – STRENGTHENING ENERGY INFRASTRUCTURE

Figure 5-1: Major National Energy Infrastructure Needs

- NCEP

Figure 5-2: The State of Electricity Restructuring

- Energy Information Administration, "Status of State Electric Industry Restructuring Activity as of February 2003," http://www.eia.doe.gov/cneaf/electricity/chg_str/restructure.pdf.

Figure 5-3: Transmission Capacity versus Peak Electricity Demand

o Eric Hirst, *US Transmission Capacity: Present Status and Future Prospects* (Washington, DC: Edison Electric Institute and United States Department of Energy, 2004), Adapted from Figs. 2, 5, and Table 2.

CHAPTER 6 – DEVELOPING ENERGY TECHNOLOGIES

Figure 6-1: Projected Investments in Energy-Supply Technology to 2050

o President's Council of Advisors on Science and Technology, Panel on International Cooperation in Energy Research, Development, Demonstration, and Deployment, *Powerful Partnerships: The Federal Role in International Cooperation on Energy Innovation* (Washington, DC: Executive Office of the President, 1999), http://www.ostp.gov/html/P2E.pdf.

Figure 6-2: Declining Public Support for ERD&D in the United States

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Figure 6-3: U.S. Private Sector ERD&D

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Table 6-1: Illustrative Example of a Doubled Federal Budget

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Table 6-2: Tabulation of the Deployment Incentives Suggested by the Commission

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