of schedule, demonstrated a new technique for establishing plasma current and reached one million amperes. Such work simultaneously advances basic research in plasma science and engineering, supports increasingly important industrial applications of plasmas from chip processing to pasteurization, and represents the kind of long term energy investment strategy that must be supported in the Federal energy R&D portfolio.

Renewable Energy

Renewable energy resources—wind, solar, geothermal, biomass, hydrogen and hydroelectric—are abundant. These alternatives are mainly used for power generation (biomass can be used for transportation fuel, and biomass, solar and geothermal for heating), and they produce virtually no emissions or solid wastes. Their primary challenges are the cost of producing power (except hydroelectric) compared with conventional sources, and in some cases, the need to modify infrastructures to deliver renewable power to markets.

The nation's diverse portfolio of renewable energy technologies offers increasingly affordable solutions for providing clean, reliable energy for the 21st Century and will be a key component of the nation's long-term energy future and economic role in global energy markets. Research and development efforts have continued to reduce the cost of renewable energy and focus areas include applications for distributed power and the development of advanced, domestically produced transportation fuels. In the relatively short period of Federal R&D on renewables, there has been significant progress. For example, the cost of producing photovoltaics has decreased 50 percent since 1980, making it cost-competitive in certain applications; and the real cost of wind power has decreased 85 percent over the same time period.

Renewable energy technologies have many other benefits. For instance, biomass energy crops planted on otherwise unproductive land (or the use of waste products from existing crops) offer exciting new revenue options for farmers. Likewise, many farmers and ranchers can lease small tracts of farm or grazing land to wind power developers in exchange for substantial annual payments—as much as $2000 to $3000 per year per wind turbine installed. Nationally, liquid fuels derived from biomass not only help reduce environmental emissions, but also decrease our consumption of gasoline. Biomass material can also replace oil as the source for important chemical precursors for plastics, pharmaceuticals, and other high value products.

Finally, in addition to their clear domestic benefits—less reliance on energy imports, virtually limitless resources, and clean power generation—renewables have benefits internationally. Because most of the world today still does not have adequate electric power service—or any electricity at all— the international market opportunities for advanced renewable energy and power delivery technologies are tremendous. These international opportunities mean potentially billions of dollars in export sales of U.S.- produced renewable energy and power delivery technologies, which translates into thousands of high-paying domestic jobs and a much-improved balance of trade, and reduced economic pressure on carbon based fuels.
(www.eren.doe.gov/power/)

→ Accomplishments and investments in a renewable energy future . . .

. . . to economically generate power from renewable energy sources to provide clean, abundant fuel for the future and reduce our reliance on imported and diminishing fossil fuel resources

Wind Energy Systems: In the 1990s, wind was the fastest growing source of electricity generation in the world. The Department's Wind Energy Program continues to support wind turbine manufacturers in their efforts to reduce costs. DOE is currently sponsoring a $50 million program to push the technology envelope further and develop the next generation of wind turbines, with 30 percent of these funds coming from private industry. Along with R&D investments, DOE also began funding the Wind Powering America Initiative in 1999, which is committed to increasing the use of wind energy in the United States from 2,500 megawatts to 10,000 megawatts within the decade. (www.eren.doe.gov/wind/)

- Photovoltaic (PV) Systems: The PV Program's goals are to reduce the cost of electricity generated by PV from 12-20 cents per kilowatthour today to less than six cents per kilowatthour by: making devices more efficient; making PV systems less expensive; and validating the technology through measurements, tests, and prototypes. Researchers in the National Center for Photovoltaics (NCPV) recently took a significant step in reducing cost through efficiency gains by setting a world record in efficiency for a thin-film solar cell. (www.eren.doe.gov/pv/)

- Geothermal Power: Currently in the United States, the installed capacity for geothermal energy is about 2,800 megawatts, providing enough electricity for over one million people. The cost of producing this power ranges from 5–8 cents per kilowatt hour. DOE sponsors research aimed at developing the science and technology to tap geothermal resources reducing the levelized cost of geo power to 3-5 cents per kilowatt hour by 2007. In addition, the Department announced the Geopowering the West Initiative in January, 2000, to increase the use of geothermal energy in the West, where geothermal resources are abundant.
(www.eren.doe.gov/geothermal/)

- Transpired Solar Collectors: Most industrial and commercial buildings require large quantities of ventilation air to maintain a healthful work environment. Transpired solar collectors, developed during the last decade, use 60 to 75 percent of the solar heat reaching a building to preheat incoming fresh air supplies. By raising the incoming air temperature, building heating systems use less energy to maintain comfortable indoor air temperatures. These reliable and low cost systems have a 30-year lifetime and typically pay back their initial purchase cost in 3 to 5 years through reduced energy bills. Over their lifetimes, the currently installed systems will displace 2.2 trillion btus of energy. (www.eren.doe.gov/solarbuildings/space.html)

- Million Solar Roofs: The goal of the Million Solar Roofs Initiative is to install one million solar energy systems on U.S. buildings by 2010. DOE, working through State and Community Partnerships, has obtained commitments for more than one million solar energy systems and nearly 100,000 systems have already been installed. (www eren.doe.gov/millionroofs/)

- "Fish-friendly" Turbines: About ten percent of the nation's electricity is generated by hydro power. The DOE Hydropower Program aims to develop advanced technology to allow the maximum use of hydropower resources, while minimizing adverse environmental impacts. Our focus is on developing "fish friendly" turbines to minimize fish mortality to two percent compared to the current 5-30 percent rates. Under a DOE-industry partnership, conceptual designs are now complete and we plan to complete full scale testing of prototype turbines in this decade to pave the way for market entry. (www.inel.gov/national/hydropower/)

. . . to cleanly power the nation's vehicles with renewable energy to improve the environment and increase our national energy security

- National Biomass Ethanol Program: DOE has been developing alternative fuels technologies in partnership with the industry for more than 20 years. Fuels and vehicles to use these fuels are at many different stages of development. In the case of ethanol, E85 (15 percent gasoline and 85 percent ethanol) vehicles have been available for purchase by the general public since 1982. DOE is currently sponsoring work to demonstrate the capability of an E85 vehicle to meet ultra-low-emission vehicle (ULEV) standards. The DOE biofuels production program is developing new technologies to lower the cost of ethanol by approximately 50 percent, while using renewable resources to minimize net emissions of carbon dioxide. (www.ott.doe.gov/biofuels/)

- Biomass Feedstock Production: Agriculturally-derived fuels have the potential to reduce the United States' dependence on imported petroleum and at the same time alleviate some environmental concerns. The Clinton/Gore Administration has set a goal of tripling U.S. use of biobased products and bioenergy by 2010, which would generate as much as $20 billion a year in new income for farmers and rural communities, while reducing greenhouse gas emissions by as much as 100 million tons a year—the equivalent of taking more than 70 million cars off the road. The U.S. Department of Energy's Bioenergy Feedstock Development Program (BFDP) has screened more than 125 tree and nonwoody species and selected a limited number of model species for development as energy crops. (www.bioenergy.ornl.gov/papers/ bioam2000/ppt/index.htm)

    - Ethanol Production: The approximately 1.5 billion gallons of ethanol produced each year is derived mostly from corn. The Department is concentrating its efforts on developing an alternative, low-cost feedstock–cellulosic biomass. Ethanol can be produced from plentiful, domestic, cellulosic biomass feedstocks such as bioenergy crops (herbaceous and woody plants), agricultural wastes (corn stover, bagasse, etc.), forestry residues, and municipal solid waste. DOE anticipates that within the next few years, the first commercial bio-mass ethanol plants will begin operation in the United States.

- Automotive Fuel Cells:. The goal of the DOE Fuel Cell Program is to develop highly efficient, low or zero emission automotive fuel cell propulsion systems. This government/industry alliance includes domestic automakers, component suppliers, fuel cell developers, national laboratories, universities, and the fuels industry. Pre-competitive fuel cell R&D managed by DOE is attempting to resolve fundamental problems and issues associated with fuel cells and ancillary components that apply to a number of different fuel cell propulsion systems. (www.ott.doe.gov/hev/fuelcells.html)

Hydrogen R&D: DOE's Hydrogen Program is a part of an integrated partnership with private industry, universities, and government laboratories to accelerate the introduction of cost-competitive hydrogen production methods and end-use technologies into the marketplace. The Program focuses on research and validation of various hydrogen production processes and appliances in order to provide clean, sustainable energy sources for buildings, vehicles and industrial uses. In addition to researching a variety of means for producing hydrogen with renewable energy, DOE is investing in R&D to create innovative technologies for purifying, storing, sensing, and using hydrogen. The long term transition to a hydrogen-based economy, in which renewable-produced hydrogen joins electricity as a major carrier of energy, would provide substantially greater flexibility in meeting energy needs throughout the economy. (www.eren.doe.gov/power/hydrogen.html)

The Administration's accomplishments will continue to enhance and improve the nation's energy security. Our investments will help meet tomorrow's energy challenges.

Energy Trends in Focus/Energy Challenges in Context

The unparalleled energy infrastructure that enables us to effortlessly flick on a light switch or turn an ignition key leaves most Americans unaware of the requirements to maintain and improve its performance, and is testament to the success of ongoing energy policies and technology investments.

Recent events however, with gasoline and heating oil prices and electric reliability and electricity prices, have once again brought energy issues to the forefront of the public dialogue. To a significant degree, the current volatility in energy prices and increasing concerns over power generation are symptoms of success—the very economic power and growth we have seen in the last decade has dramatically increased demand for energy. This increased demand is, in turn, straining our existing energy infrastructure and domestic energy resource base.

The energy trends through 2020 that are identified in the Energy Information Administration's Annual Energy Outlook/2000 help to focus our efforts on future energy challenges. These are long-term forecasts that are adjusted on annual basis. While forecasts of this nature are rarely accurate predictors of the future, they serve as useful tools in developing general directions for public policy and R&D investments. It should be noted that these forecasts generally represent "business as usual" and do not take into account substantial policy implementations or technological breakthroughs. Indeed, sound policy and sustained technology investments can significantly modify the scenarios so as to enhance our economy and environment relative to the reference case.

The EIA reference case suggest that by 2020:

On energy demand –

- Primary energy use in the U.S. is expected to grow from 97 quadrillion btus to 121 quadrillion (Figure 6—Primary Energy Use by Fuel.)
- The average American home is expected to be 2 percent larger and to rely more heavily on electricity-based technologies. Highway travel is expected to increase by 21 percent and air travel by 97 percent.

- Industrial energy use is expected to grow by 20 percent.
- Despite this growth in demand for energy services, maintaining the pace of energy efficiency gains will keep per capita energy intensity from rising.

On electricity –

- A thousand new power plants (with as many as 900 of these gas-fired) averaging 300 megawatts will likely be needed to meet growing demand for electricity.
- Retirements of nuclear power plants starting in 2010 could lead to higher fossil fuel use for power generation.

On energy technology –

- Municipal solid waste (MSW) and biomass will lead to growth in renewable fuel use for electricity (Figure 7—Nonhydroelectric Renewable Electricity Generation by Energy Source.)
- Advanced technologies could reduce residential energy use by 20 percent.
- Automobiles are expected to average 31.6 mpg through technology improvements.
- Advances in recovery technologies will increase gas production (gas prices are especially sensitive to technology.)
- Technology advances could increase offshore and Alaska oil and gas production.

On energy prices –

- Oil prices are expected to remain above 20 dollars per barrel (in real 1998 dollars.)
- Competition is expected to decrease electricity generation costs and provide new consumer services.
- Rising demand for natural gas will mean higher natural gas prices which will, in turn, encourage natural gas production.
- Processing costs for gasoline and jet fuel are expected to rise.
- Competitive markets will keep residential natural gas prices reasonable.
- Higher oil and gas prices will maintain coal-fired power generation and domestic coal demand will rise.
- Minemouth coal costs will continue to fall.

On energy production and infrastructure –

- Domestic oil production will decline until 2005 and remain flat after that.
- There will be high levels of gas reserve additions.
- Significant new gas finds are likely to continue increases in gas production.
- We will need significant new natural gas pipeline capacity to meet growing demand for natural gas, mostly for power generation.

- New U.S. refining capacity will likely come from existing refineries.
- Ethanol use as a gasoline additive will increase.

On the environment –

- High energy consumption will increase carbon emissions.
- Scrubber retrofits will be needed to meet sulfur caps.
- There will be a significant drop in NOx emissions. driven by legislation and regulation.
- Emissions caps will lead to the use of more Western low-sulfur coal.
- Carbon emissions from transportation will grow rapidly (Figure 8—Carbon Emissions by Fuel.)

The Nation's Emerging Energy Challenges

The trends identified in the Annual Energy Outlook 2000 reference case scenarios demonstrate the complexity of the linkages among many of the issues. which require a significant amount of strategic planning. investments in R&D. and policy and regulatory support. Current conditions in energy markets also enable us to draw many conclusions about future energy needs. Finally, the 1998 Comprehensive National Energy Strategy identified several preeminent energy challenges, which have been refined or updated to reflect new or additional market conditions and needs.

These challenges are not necessarily energy-source specific and more often than not identify extremely complex interrelationships between energy sources and their end uses, as well as the complicated cross-cutting nature of the actions needed to address them The Administration has taken a variety of actions to meet these challenges. and has proposed others to Congress that will require statutory changes or additional appropriations.

→ Challenge #1 Enhancing America's Energy Security

Mobility is key to our economic productivity and central to our quality of life. The U.S. transportation sector is 97 percent reliant on liquid fuels. There have been relatively low average oil prices over the last 15 years and abundant world supply. Past and very recent history. however. suggests that there are highly credible scenarios in which oil represents an energy security concern. EIA forecasts that by 2020:

- U.S. net petroleum imports. already over 50 percent of the 19 million barrels per day consumed. will increase to 64 percent of the projected 25 million barrels per day consumed. This is a continuing trend that has persisted since 1970. Domestic production declines will level out by 2005 but imports will still increase to meet increases in demand;
- World oil dependence will continue at nearly 40 percent of the energy consumed. Total petroleum imports by all countries will increase by 75 percent; and
- Increased oil demand will be met by OPEC nations and other oil-producing nations, some of which are in potentially unstable parts of the world.

There are also fuels-related environmental concerns. Vehicles currently account for a large portion of urban air pollution. including 77 percent of carbon monoxide, 49 percent of nitrogen oxides and 37 percent of volatile organic compounds. The transportation sector also produces over one-third of U.S. carbon dioxide emissions. In coming decades cleaner fuels could help address public health and environmental concerns.

Rapidly increasing worldwide demand for oil has dramatically reduced world excess oil productive capacity, leading to volatility in oil prices. This, together with high domestic demand and other factors, has led to tight and volatile U.S. product markets.

Oil, in contrast to other energy sources, is truly a global commodity, traded and sold in world markets. Reducing levels of oil imports is a goal of the Administration but absent extreme measures such as import quotas—which would have to be established by Congress and which would likely dramatically increase costs to U.S. businesses and consumers and adversely impact the economy—levels of oil imports will continue to be determined by supply and demand, and levels of capital investment will be determined by the cost of exploration and production.

In addition to the concerns about growth in oil demand and oil's impacts on the environment, the Administration's response to the important role of oil in our energy security recognizes the following:

- The cost of oil production in the U.S. is high relative to other producing nations;
- The price of oil is a world price. High or low prices worldwide will mean high or low prices domestically;
- Reducing volatility in world oil markets will most likely spur investment in oil exploration, production, refining, and distribution;
- Global production and refining capacity is very tight, contributing to market volatility;
- Increasing net imports are not only an indicator of flat or declining domestic production but also of increased domestic consumption; and
- Development and deployment of advanced demand-side technology and energy diversity is critical to long term success.

The Administration has taken or proposed significant actions to address the challenges presented by our ongoing and almost exclusive reliance on oil for our transportation needs and its implications for energy and national security.

Reduction in U.S. Oil Demand

As almost 67 percent of U.S. oil consumption is for transportation, vehicle efficiency is a ripe target for reducing the consumption side of the net oil import equation. Increasing the average fuel economy for cars and light duty vehicles by just three miles per gallon would save the United States almost one million barrels of oil per day. The importance of lowering oil demand without impacting the economy or quality of life is clear. Success depends on the development and deployment of advanced technology. The Administration will continue to invest in:

- Developing an 80 mile-per-gallon prototype sedan by 2004 through our Partnership for New Generation Vehicles Program;
- Improving light truck fuel efficiency by 35 percent while meeting newly-issued EPA tier 2 emissions standards by 2004;
- Developing technologies to increase fuel economy of the largest heavy trucks from 7 to 10 mpg (nearly 50 percent) by 2004;
- Increasing domestic ethanol production to 2.2 billion gallons per day by 2010;
- Tax credits for biofuels;
- Developing production prototype vehicles that will double the fuel-efficiency of tractor trailer trucks and triple the efficiency of heavy-duty pick-ups; and

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- Tax credits for hybrid vehicles.

Expensing of Geological and Geophysical, and Delay Rental Costs

To spur domestic oil and gas production and lower the costs of doing business—without imposing restrictions on imports that would raise costs to consumers—the President has proposed tax incentives for 100 percent expensing of geological and geophysical costs (G&G) and allowing the expensing of delay rental payments. G&G expensing will encourage exploration and production and delay rental expensing will lower the costs of doing business on public lands.

Continuation of the Oil and Gas Exploration and Production Program

DOE is continuing its Oil and Gas Exploration and Production Program to enhance the efficiency and environmental quality of domestic oil and gas production and utilization, helping ensure the availability of competitively-priced oil and natural gas supplies to support a strong U.S. economy. Even though remaining recoverable oil and gas in the U.S. is substantial, exploration and production is becoming increasingly expensive due to the maturity of this resource. Historically, technology advances have improved well success rates and cut oil and gas finding costs. However, continued technology advancement is necessary for cost effective recovery from geologically complex reservoirs and deeper water offshore fields compatible with environmental regulations. The program focus is on areas such as diagnostics and imaging, drilling, reservoir life extension, and environmental protection. (www.fe.doe.gov)

Offshore Technology Roadmap

The ultradeep waters of the Gulf of Mexico can significantly expand domestic natural gas supply. The National Petroleum Council in its December 1999 report on natural gas projected that deepwater Gulf of Mexico natural gas production would increase from 0.8 trillion cubic feet in 1998 to over 4.5 trillion cubic feet in 2010. Achieving this production, however, will present major technology challenges. Working with industry, the Department of Energy is developing a technology roadmap that will shape a research and development program to reduce ultradeep offshore drilling costs by 40 percent. (www.fe.doe.gov)

Promotion of International Investment in Developing World Oil Resources

The Department of Energy has organized three international energy summits involving Energy Ministers from the Western Hemisphere, Africa, and the Asian-Pacific Economic Cooperation (APEC) community to promote regional integration, to open markets and to plot a course for global energy development. In addition, Secretary Richardson visited OPEC and non-OPEC producing nations to encourage increased oil production by emphasizing up-to-date information about world supply, demand, and inventories. Since last year at this time, there are 4.0 million more barrels of oil per day on world markets. The Administration has invested a significant amount of diplomatic effort in developing oil resources in the Caspian Basin and the means to deliver this oil to Western markets. Just recently a significant find was made in the Caspian and potential reserves are thought to equal or surpass those of the North Sea. In 1998, the Department initiated an International Oil and Gas Industry Forum with the Chinese Government, which was based on a similar, highly successful initiative in Latin America. At meetings in Beijing and Houston, representatives of the two countries and senior executives of U.S. and Chinese Petroleum companies committed to working together to develop the policies, laws, regulations, and market operating systems needed to create an open market in oil and gas technology.

Reducing Volatility in World Oil Markets

To address volatility in world oil markets, the Administration has strengthened its ties with the world's oil producing nations, worked closely with oil consuming nations through organizations such as the International Energy Agency, and launched a campaign to improve the collection, dissemination, and understanding of world oil supply and demand data. Last January, the Department of Energy organized a forum of leading industry analysts and data experts to discuss how the quality, timeliness and availability of oil data might be affecting volatility in oil markets. This forum was followed by a recent international conference on the same subject, organized by DOE and attended by 23 consuming and producing nations. The International Energy Agency is expected to organize a follow-on conference later this year.

U.S. Petroleum Refining Industry: Meeting Energy and Environmental Needs

In June, 2000, the National Petroleum Council—an advisory body to the Secretary of Energy that includes representatives of the oil and gas industry, consumer and environmental groups, the financial community, and states—delivered a report to the Secretary on the U.S. petroleum refining industry which urged the government to continue to develop ways to mitigate the costs of environmental requirements on the U.S. refining industry. Consistent with these findings, DOE and the Environmental Protection Agency (EPA) are working together to develop regulations and technologies that meet our environmental needs and energy goals. For example, EPA promulgated final regulations to reduce the sulfur content of gasoline. DOE worked with EPA on these regulations in order to minimize the price impacts on producers and consumers while achieving clean air goals. Similarly, DOE is working with EPA on regulations that would reduce the sulfur content of diesel fuel to allow the use of advanced pollution control devices for diesel-powered vehicles that may optimize fuel efficiency and thus reduce oil demand. In addition, industry is working with DOE on the Ultra-Clean Fuels Program, designed to meet future fuels requirements in the context of the existing refining infrastructure. (www.npc.org)

Home Heating Oil Reserve

On July 10, 2000, President Clinton directed Secretary of Energy Bill Richardson to establish a home heating oil reserve in the Northeast to reduce the risks presented by extreme price spikes and possible shortages similar to those that occurred in winter of 1999-2000. DOE has completed the process of obtaining 2 million barrels of home heating oil to store at interim facilities in the Northeast through exchange of crude oil from the Strategic Petroleum Reserve. The Administration will continue to seek authorization from Congress for a permanent heating oil reserve in the Northeast and an appropriate trigger for using it. (www.fe.doe.gov)

→ Challenge #2: Increasing the Competitiveness and Reliability of U.S. Energy Systems

Over 40 percent of the nation's energy bill goes for electricity. With over $200 billion in annual sales, a reliable supply of electricity is vital to our economy and to the health and safety of all Americans. Electricity is increasingly the energy form of choice for myriad applications at home and at work. The network of power sources, transmission and distribution has served the nation exceptionally well but is confronting significant new challenges.

Rapidly increasing demand requires new generating plant and transmission capacity, with most of the new supply powered by natural gas. The digital New Economy is placing stringent demands for increased reliability and power quality on top of those requirements for the broad consumer base. Also, the linkage

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of the electricity grid with gas and telecommunications networks—the intergrid—presents new opportunities for customer service.

This growing relationship between natural gas and electric power generation suggests the need for greater coordination of policies, regulations and energy R&D investments. Realizing the new benefits and services that will result from this interrelationship will require new regulatory and government structures to encourage market competition and entrepreneurial opportunity. It will also require greater coordination of the entire electricity supply chain—from production, to transmission, to distribution. This increased need for policy and industry coordination is occurring at precisely the time states and the Federal government are restructuring the industry to stimulate competition.

Addressing these issues involves electricity industry restructuring "rules of the road," developing cleaner, more efficient fossil fuel power technologies, advancing renewable energy sources, enabling the benefits of distributed generation, and enhancing grid technologies to meet increased reliability requirements. The Clinton/Gore Administration is seeking to extend the role of markets and competition in the electricity sector and improve the reliability of our electricity grid.

Twenty-five states have now adopted electricity restructuring proposals that allow for competition at the retail level. Almost every other state has the matter under active consideration. The Administration believes that the full range of benefits from restructuring can only be realized within an appropriate Federal statutory framework. Electricity markets are becoming increasingly regional and multi-regional—actions in one state can and do affect consumers in others. States alone cannot ensure that regional power and transmission markets are efficient and competitive, nor can they provide for the continued reliability of the interstate bulk power grid.

The Administration has taken or proposed significant actions to address the challenges presented by our growing need for electricity, the environmental problems associated with this growth in demand, the need for greater reliability, the demand for significantly expanded natural gas supply, and the need to address these issues at the Federal level in order to provide for a smooth transition to competitive electricity markets.

- Comprehensive Electricity Restructuring Proposal

  In 1998 and 1999, the Clinton/Gore Administration presented the Congress with a comprehensive legislative blueprint of changes needed for updating the Federal statutory framework to support the advent of competition in electricity markets and to avoid some of the problems associated with the state-by-state, piecemeal restructuring we are witnessing today. This bill was a featured element of the Comprehensive National Energy Strategy the Administration sent to the Congress in 1998.

- Energy Infrastructure Reliability Initiative

  To ensure the reliability of the electricity and natural gas infrastructures, which will be increasingly linked in the future, the Administration has proposed a new Energy Infrastructure Reliability Initiative that would address three components:

  - Electric reliability by focusing on regional grid control, distributed resources and microgrids, information system analysis, possible offsetting of peak summertime electric load with distributed generation and natural gas cooling technologies for example, and high capacity transmission;
  - Natural gas infrastructure reliability to include storage, pipeline and distribution R&D; and
  - Critical infrastructure protection, secure energy infrastructures, vulnerability assessments, risk analysis, and the development of protection and mitigation technologies.

- Reliability Summits

Secretary Richardson hosted 11 regional electric reliability summits with Federal, state and local government officials, regulators, utilities and consumers during the spring and summer of 2000 to discuss ways to improve delivery of electricity to the American consumer, promote cooperative solutions to reliability problems, and improve the power grid of the 21st century.

- Office of Energy Emergencies

In spring, 2000, Secretary Richardson announced the creation of the Office of Energy Emergencies (OEE.) The Office will work within the Department and with Federal and state agencies and industry to anticipate, mitigate, and improve the coordination of the Federal response to a wide range of energy emergencies, such as summer electricity outages, or fall heating oil shortages. The OEE has had three emergency power outage exercises and plans a more comprehensive electricity/natural gas/ heating oil exercise this fall.

- Power Outage Study Team (POST)

The Power Outage Study Team was established in July, 1999 by Secretary Richardson in response to power outages across the nation. After visiting with utilities and other stakeholders in New York, Chicago, the Mid-Atlantic, South-Central States, and New England, the Team held three workshops to solicit industry and stakeholder comments, and published a final report in March, 2000, which contained recommendations to enhance electric reliability. (www.policy.energy.gov)

- Barriers to Distributed Generation

Government has a significant role to play in addressing barriers necessary to increase distributed generation. There are regulatory and institutional barriers that interfere with market development, e.g., the existing regulatory framework for energy generation, delivery, and use favors incumbent suppliers; environmental siting and permitting requirements are different from state-to-state. Output-based emissions standards and pre-certification of certain types of systems are being considered but further analysis is needed. Siting difficulties along with a lack of uniform interconnection standards across utility service territories often leads to costly delays in project schedules. Effectively addressing these technology, policy, and market barriers requires a comprehensive program strategy. (www.eren.doe.gov/power)

- National Petroleum Council Natural Gas Study/ Interagency Task Force on Natural Gas

Recognizing the growing demand for natural gas in the United States, particularly for power generation, the National Petroleum Council was asked to undertake a comprehensive study of the capability of industry to meet potentially significant increases in future natural gas demand. The resulting December 1999 study, "Natural Gas, Meeting The Challenges of The Nation's Growing Natural Gas Demand," listed seven major recommendations. Acting on these recommendations, the Administration has established an interagency working group to work with industry and other stakeholders to develop a path forward to meet the nation's natural gas supply, distribution, and safety needs. (www.npc.org)

→ Challenge #3: Mitigating the Environmental Impacts of Energy Production and Use

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Americans place a high value on environmental stewardship—to protect natural resources for future generations, to preserve the air and water quality that is essential to our health and quality of life. Efforts to improve the quality of our environment resulted in reductions in energy related pollution and environmental damage without substantial increases in energy prices. This achievement is due, in part, to the constructive role played by the Department of Energy in the development of environment-friendly technologies and the support of science-based regulatory policies that have enabled the energy industry to minimize costs and avoid supply disruptions.

Addressing the environmental impacts associated with increased demand and energy use will require ongoing technological innovation and policies that stimulate use of these technologies. In addition to further reducing the environmental impacts of energy use in the transportation and power sectors, we need to ensure that continued access of the energy industry to resource areas happens in a manner that protects our national heritage, and we need to ensure that regulation of the energy sector is based on sound science.

Internationally, responding to the threat of climate change is the greatest environmental challenge facing the energy sector. There is a strong scientific consensus that the greenhouse gas emissions have already raised average global temperatures and that a "business-as-usual" energy scenario will, within a century, lead to further warming, associated climate change, and possibly major societal dislocations.

A shared commitment between the Administration, the Congress, and the private sector would allow us to meet the greenhouse gas challenge while growing the economy, just as we have with other emissions, as shown in Figure 1. Because of the long time over which greenhouse gases reside in the atmosphere, prudence demands that we address now the more efficient use of fossil fuels and the aggressive development of renewable energy sources. It should be emphasized that such policies simultaneously advance our economic, security, and broad environmental goals. The record on SOx and NOx and energy use strongly suggests that reductions in carbon emissions could be achieved in an effective and economical manner.

Domestically, support for the development of technologies to reduce the environmental impacts of energy use remains a key element of the Administration's energy policy to:

- Produce cleaner fuels;
- Increase the efficient use of conventional energy sources, primarily fossil fuels; and
- Develop alternative sources of energy

In addition to the accomplishments and investments previously highlighted, the Administration has also taken more recent and specific actions to reduce the future impacts of energy use on the domestic and global environment.

Mitigating Global Climate Change through International Cooperation

The Administration will continue to work with other countries to elaborate rules and guidelines for the flexibility mechanisms identified in the Kyoto Protocol-emissions trading, the Clean Development Mechanism, and Joint Implementation. The full use of market-based emissions trading and related mechanisms is critical for substantially lowering or halting the growth in global greenhouse emissions without imposing significant costs on the United States. These mechanisms should lower costs and spur U.S. technology exports. The anticipated use of these mechanisms should also provide the economic incentive for developing countries to make meaningful commitments to greenhouse gas emissions reductions. In addition, carbon sinks achieved through forest and agricultural management practices can make a very significant contribution.

- Addressing Global Climate Change through Research and Development

To provide the technologies needed to reduce greenhouse gas emissions and to preserve U.S. competitiveness and economic growth, the Administration has proposed an aggressive $4.1 billion climate change package for fiscal year 2001. The package includes: the International Clean Energy Initiative; Clean Air Partnership Fund; Climate Change Technology Initiative; Biofuels and Bio Products Initiative; the Global Change Research Program; and other programs such as Carbon Sequestration. The program simultaneously achieves other key economic, security, and environmental goals.

- Expanding Alternative Energy Programs

In its 1997 review of the national energy R&D portfolio, the President's Committee of Advisors on Science and Technology (PCAST) recommended expanding a number of national energy R&D programs—renewable energy programs being among the highest priorities for increased funding. Renewable energy technologies provide multiple benefits, including air emission reductions and reduced dependence on imported oil. To respond to this recommendation, DOE is seeking a 32 percent funding increase (for FY 2001) for renewable energy programs. Included are programs on: alternative transportation fuels; solar buildings; photovoltaics; concentrating solar power; biomass; wind energy; geothermal; hydroelectric power systems; hydrogen; energy storage; high temperature superconductivity; programs to address the power needs of remote and Native American lands; power system reliability; distributed power; and electricity restructuring.

- Producing Cleaner Fuels

In addition to the President's Bioenergy and Biobased Products Initiative, DOE has also proposed a new initiative this year, the Ultra-Clean Fuels Initiative, to address the need for cleaner fuels within the context of the existing refining infrastructure. The initiative will mobilize industry and DOE's national laboratories to develop and demonstrate new technologies for making large volumes of clean fuels from our diverse fossil energy resource base. The initiative will also be integrated with our PNGV and truck programs to ensure that we have the clean fuels needed to power the next generation of more efficient vehicles.
(www.fe.doe.gov)

- International Clean Energy Initiative

In the next two decades, over half of global energy growth will be in the developing and transitional economies as those nations improve their standard of living. Developing country energy use will overtake that of industrial countries by 2020, accounting for three-fourths of the increase in global energy use over that time. This represents a challenge to oil supply, global environmental concern, and business opportunity. Between now and 2050, investments in energy technologies in developing nations will approach $15 to $25 trillion dollars, and ninety percent of the markets for coal, nuclear and renewable energy technologies are expected to be outside the United States in coming decades.

This represents a significant global challenge with economic, energy security and environmental ramifications. This initiative, following the recommendations of the President's Committee of Advisors on Science and Technology, will give U.S. companies access to innovative ideas and open doors to global markets; provide new technology for transportation and nuclear power generation to reduce risks associated with oil supply disruption and nuclear proliferation; and provide incentives for clean energy commercialization in the context of strengthened markets, vigorous economic development and expanded international trade.

☞ Creation of the National Energy Technology Laboratory

On December 10, 1999, Secretary Richardson, designated the National Energy Technology Laboratory (NETL) as the Department's 15th national laboratory. The primary mission of the new laboratory is improving the environmental performance of fossil fuels through technology advances. The laboratory's work will be dedicated to the goal of developing innovative, clean and efficient fossil energy technologies to meet the Nation's growing energy needs in environmentally sound ways. The new laboratory will have several key focus areas including carbon sequestration, combustion simulation, and ultra-clean petroleum fuels. In addition, the Secretary established a Strategic Center for Natural Gas Studies at NETL. This center will provide both a research and policy focus for natural gas from production and supply, to transportation and storage, to end use. (www.netl.gov)

→ Challenge #4: Providing Diverse Energy Technologies for the Future

Today's investments will meet tomorrow's challenges—Vision 21 technologies for virtually emission free coal utilization; carbon sequestration; Partnership for a New Generation of Vehicles and associated programs dealing with light and heavy trucks; alternative clean fuels, both fossil fuel based and biofuels; distributed hybrid energy systems, involving renewables, fuel cells and other modular technologies; smart buildings; and many more described in the Appendix.

Energy is a technology driven business. Over the long term, technology development and deployment uniquely provide the foundation for resolving our energy challenges. The Federal government has a significant public interest in ensuring that we have adequate R&D dollars to invest in the nation's energy future, especially when new technology can help address national policy concerns not reflected in the marketplace.

The private sector under-invests in R&D for breakthrough technologies for a variety of reasons. The industry is very fragmented in areas such as buildings or small scale oil/gas production. There is significant business risk associated with large scale investments in research and development. Also private investment in pre-competitive research is inhibited by the long time frames needed to achieve results and the inability to capture exclusive access to those results.

One consequence of restrictions in the various energy industries has been a corresponding decline in private sector investment in pre-competitive research and development. For example, the sectoral research organizations for electricity and natural gas—EPRI and GRI—have experienced 30-50 percent declines in research budgets. These declines are occurring precisely when we need new technologies to meet growing energy demand and further mitigate the impacts of energy production and use on the environment.

As noted, energy is a technology driven business—technology is, in turn, science-driven. The Department of Energy is the nation's principal funder of basic and applied research in the physical sciences and also builds and operates large cutting-edge facilities that are used by more than 15,000 of the nation's scientists from universities, laboratories, and industry. As one example, the Department supports wide ranging research in advanced materials, providing a scientific foundation for a broad spectrum of energy technology applications. Facilities such as the Advanced Photon Source at the Argonne Laboratory or the Spallation Neutron Source under construction at Oak Ridge Laboratory allow scientists to understand and develop such advanced materials. High temperature superconductors are examples of new materials that are beginning to affect the power sector and are likely to have profound impact in the next two decades.

The Department of Energy is also the lead Federal agency for energy research and development. Much of the Department's energy research and development work is carried out in partnership with the private sector, a formula that has, over the years, provided significant dividends across all areas of energy supply

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and use. Many examples of the impact of DOE-sponsored technology development have been discussed earlier in this report.

Nevertheless, the Department's R&D efforts need ongoing reevaluation in the context of evolving energy drivers and new scientific opportunity. Evaluation criteria, noted in the 1997 report of the President's Committee of Advisors on Science and Technology, include:

- Strategic criteria: The overall portfolio should address the principal energy-related economic, environmental, and security challenges facing the nation.
- Diversity criteria: The portfolio of R&D projects should have a balance across technologies, time scale for results, and degrees of technical risk.
- Public-private interface criteria: The portfolio should have potential societal payoffs that merit public investment and should be shaped to great extent in partnership with the private sector

In response to this need, the Department has developed a formal Energy Resources R&D Portfolio analysis process, engaging participants from the DOE national laboratories, universities, and the energy industry, to ensure that:

Energy Investments Reflect the Administration's Strategic Energy Goals

DOE's energy R&D portfolio, as shown in Figure 9—DOE Research and Development Portfolio, Energy Resources, is organized in three broad strategic areas, with their FY 2001 request:

- Reliable and Diverse Energy Supply ($170 million);
- Clean and Affordable Power ($542 million); and
- Efficient and Productive Energy Use ($437 million.)

A full description of DOE's energy portfolio can be found at www.osti.gov/portfolio.

In addition, the Department supports a basic science portfolio that supplies the foundation for much of the Department's applied research. The basic science programs are deeply engaged in developing crucial enabling knowledge and tools, such as large-scale scientific simulation, robotics and intelligent machines, advanced materials, nanoscience, plasma fusion science, and many others.

The Energy R&D Portfolio Addresses Emerging Energy Challenges

The Administration has, through PCAST and through the Secretary of Energy's Advisory Board, conducted several reviews of the adequacy and focus of our energy R&D investments. While the energy R&D portfolio lays out the programs according to strategic goals, the portfolio analysis evaluates the portfolio against the likelihood of significant progress against these goals. This process identified a number of gaps, opportunities, and program management needs in DOE's energy R&D portfolio, including:

- Energy infrastructure reliability;
- Carbon sequestration R&D;
- Bioenergy R&D;
- Methane hydrates R&D;
- Clean fuels R&D;
- Integration of fuel cells R&D efforts;

- Crosscutting management of distributed generation;
- Hydrogen R&D: and
- An international clean energy research, developmentr and deployment effort.

This portfolio analysis process can help guide the Administration and Congress to work together to direct R&D investments towards shared goals and emerging energy challenges. This activity is an important part of an integrated strategic national energy policy. It provides a dynamic element that keeps our energy investments aligned with marketplace realities and public needs.

DOE's Energy R&D Budget Request Reflects Energy Priorities and Investment Levels to Meet Energy Needs

This process has had tangible results in shaping the Administration's budget request, to address gaps and opportunities in the R&D portfolio earning strong support from the private sector. Some specific FY 2001 energy R&D budget requests that represent new thrusts in response to the portfolio analysis process include:

- The Energy Infrastructure Reliability Initiative

  In the transition from regulated to restructured electricity and natural gas markets, and in light of the increasing interdependence of the electricity, gas and telecommunication infrastructures, reliability and security of energy delivery systems is a clear priority. This initiative will advance technology areas such as power storage, real-time sensors and controls, distributed power architectures, integrated system simulation and management, and distributed intelligent systems.

- Enhanced Carbon Sequestration Program

  Carbon sequestration science and technology is a portfolio element with a long time horizon and potentially major implications for fossil energy utilization in a greenhouse gas constrained world. A significant expansion of this research program will include: better understanding of natural carbon sequestration processes in terrestrial and ocean systems; microbe sequencing for carbon sequestration or for methane/hydrogen production; and applied science and technology development for sequestration in geologic structures, oceans, and useful product forms.

- Combustion Science and Engineering

  Better understanding of the complex molecular processes and of the complicated and turbulent flows that take place in fossil fuel combustion will lead to much more efficient combustion devices and to concomitant economic and environmental benefits. The new generation of supercomputers will, for the first time, allow scientists to simulate these processes all the way from the molecular scale to the engineered device scale. Such work will be expanded very significantly, in concert with greatly enhanced experimental capabilities at Sandia National Laboratories, at the National Energy Technology Laboratory, and elsewhere. For example, the DOE's Combustion Research Facility, upgraded in 1999, performed novel experiments investigating the interplay of chemistry and turbulence that are leading to changes in current models of basic combustion processes.

Other initiatives described earlier which are a direct outcome of this process include the International Clean Energy Initiative, enhanced bioenergy R&D, and the Ultra-Clean Fuels Initiative.

It is essential that we pick up the pace of these R&D investments. This message was put forward forcefully and convincingly by the President's Committee of Advisors on Science and Technology in their 1997 report. As shown in Figure 10, the Administration has proposed significant increases for the energy business line and, particularly, for efficiency improvements and renewables development. The shortfall in R&D investments has been most pronounced in the conservation and renewables areas; together these areas account for 92 percent of the $1.5 billion cumulative shortfall. The cumulative effect of the lower appropriations level will be felt in the years ahead. Significant capital investments are required for energy supply, and the turnover time of energy investments is long—power plants take years to site, license and build; replacing the existing vehicle fleet takes over a decade; developing infrastructures to accommodate distributed power or alternative fuels or greatly expanded natural gas demand will take longer still. These decisions are made every day, locking in diminished economic performance, security, and environmental performance for over a decade if the most advanced technologies are not available in a timely way. Thus, the effects of delaying or forgoing sound energy R&D investments are compounded year by year.

Conclusion: Powering the New Economy

The economic policies of this Administration have helped ensure the Nation's successful transition from the 20th to the 21st century—clearly and cleanly moving us from the Industrial Age to the Information Age—giving the nation more jobs at higher wages, low unemployment, real increases in personal and corporate income, low inflation, more expendable income, and greater consumer choices.

At the same time, however, this economic success—and the energy requirements of the Information Age--has strained the nation's energy infrastructure, dramatically increasing demand for energy supply and energy reliability.

Consider the energy needs of the Silicon Valley for example. The 21st century's version of the steam engine—the computer—places additional and substantial requirements on the system for increased reliability and power quality as well. In many places such as the Silicon valley, backup or off-line power generation is supplanting grid power simply because businesses that rely on computers cannot afford even the occasional power losses associated with the current electricity grid.

This year's problems with heating oil and gasoline also highlight the stresses that economic success, and the attendant demand for energy, are placing on the nation's energy infrastructures. The Administration has invested a significant amount of time in encouraging OPEC and non-OPEC producing nations to increase oil production sufficient to meet increased demand. As noted earlier, due in part to this effort, world oil supplies are about 4.0 million barrels per day higher than this time last year—yet oil prices have continued to climb and we have not seen a significant decline in prices at the gasoline pump. World capacity is now only a few percentage points over world demand.

Not only is oil demand continuing to outpace supply, but U.S. and European refineries are running almost full out. Oil production capacity and refinery capacity are key issues we must confront in the very near future if we are to meet the increased near-term demand for the petroleum-based fuels that power our cars, trucks, and airplanes, and heat many of our homes, schools and businesses. We also need to re-double our investments in reducing the demand side of the oil equation and producing clean alternative fuels.

Finally, the recent natural gas pipeline rupture in New Mexico illustrates the significant issues associated with our future natural gas needs. The pipeline in New Mexico was over forty years old and showed evidence of corrosion. Also, this particular pipeline provides Southern California with a significant portion of the natural gas needed to generate electricity—natural gas and electricity supply are increasingly interrelated. Alternative supplies of natural gas for the region were temporarily met by using stored gas—we not only need more storage but ultimately, more natural gas supply and modern infrastructures.

What do these specific examples say about that nation's future energy challenges? We need:

- Federal electricity restructuring legislation if we are to create the investment certainty needed to expand the electric grid and increase its reliability. Congress needs to pass comprehensive electricity restructuring legislation.
- Investments in the technologies that will enable the inter-grid to operate at higher levels of reliability. The Administration has expanded its request for energy reliability R&D and Congress needs to fund our FY 2001 Energy Infrastructure Initiative at requested levels.
- To ensure the availability of clean, distributed power technologies and eliminate institutional, business and technological barriers to their use. The Federal government, state

governments, industry and consumer groups need to work together to reduce legal and institutional barriers to distributed generation. We need to continue to invest in clean distributed generation technologies and system architectures.

- Policies and investments that acknowledge and reflect the increasing interdependence of our electricity and natural gas infrastructures. The convergence of the electricity, natural gas, and telecommunications infrastructures has profound implications for energy reliability and presents significant opportunities for consumers and businesses. Government needs to support an overarching suite of technologies and policies that promote expanded, reliable, safe and secure energy infrastructures, and address the issues associated with converged energy/telecommunications markets.

- To ensure that we have adequate supplies of oil and natural gas to meet our near- to mid-term power and fuel needs. The Administration is supporting policies and R&D investments to increase energy supplies but we need to work with industry and Congress to provide additional incentives to meet growing demand for energy, focusing on areas of potential oil and natural gas development in the ultra deep Gulf of Mexico and in areas available to be produced in Alaska.

- To use energy more efficiently and to provide cleaner alternative sources of power and fuel if we are to meet our long-term national and energy security and environmental goals and needs. We need to continue and expand our efficiency and renewable research, and develop policies and regulations to help provide environmentally-friendly energy at affordable prices. We seek the cooperation and support of the Congress in addressing the very serious issues of global warming and climate change.

Many of the Administration's accomplishments, investments and responses to energy challenges address these needs but much work remains to be done, starting with a fuller understanding of the implications of stresses the increased energy demand of the 21st century is placing on the energy infrastructures of the 20th century. This understanding should extend to challenges faced specifically by the private sector in building the 21st century infrastructure. For example, developing such infrastructure, whether refining capacity or electricity transmission networks, is capital intensive and must compete with other investments that may have higher returns, such as some in the New Economy. Success will come through government/private sector dialog and partnership. Thus, while adhering to basic market principles, we should continually review our policies, programs, and incentives to sustain energy and environmental progress.

Finally, the United States has enormous stakes in helping to shape energy development at home and abroad. This is perhaps most obvious with respect to oil supply, the most widely traded world commodity and one that has been a core geopolitical issue throughout the twentieth century. But adequate affordable clean energy, particularly in the developing world, affects our interests in other ways too—satisfying economic aspirations and promoting stability, protecting the environment, providing markets for energy technologies, supporting market development for international trade. These considerations reinforce the importance of our energy policy integrated with economic, environmental, security and technology policies.

The economic policies of this Administration have helped ensure the nation's successful transition from the 20th to the 21st century—from the Industrial to the Information Age. We are proud of our energy accomplishments and look forward to working with industry, consumers, workers, environmentalists, the Congress, and state and local governments to meet the energy challenges of the new century.

PARTNERSHIP FOR A NEW GENERATION OF VEHICLES (PNGV)

The Challenge. The U.S. transportation sector is dependent on petroleum for nearly 97 percent of its energy, which translates into 12.3 million barrels per day (MBPD) of petroleum products to run our highway and passenger vehicles. Currently, over half of the petroleum used in the United States is imported. Annually, the cost of oil imports is one of the largest contributors to the U.S. balance of trade deficit—accounting for over 19 percent our merchandise trade deficit in 1998.

If we continue on with business as usual, by 2020, demand for energy to power our vehicles will increase by 45 percent— to 17.9 MBPD. The Department of Energy is working to reduce our dependency on petroleum, our reliance on imports, and our trade deficit by developing vehicles with substantially higher fuel economy.

Meeting the Challenge: Partnership for a New Generation of Vehicles. Since 1993, the Clinton/Gore Administration, through the joint DOE/Commerce/DOT/EPA Partnership for A New Generation Vehicles (PNGV) program, has been working to develop a prototype vehicle designed to triple the efficiency of passenger vehicles—an 80 mpg automobile that is clean, affordable, and has the performance features the American consumer expects.

The year 2000 marks a major milestone in the PNGV program—the unveiling by the big three auto makers of the PNGV proof-of-concept vehicles at auto shows in Detroit and Washington, D.C. All three vehicles—the Ford Prodigy, the General Motors Precept, and the DaimlerChrysler ESX3—featured advanced hybrid propulsion systems, high efficiency diesel engines, and extensive use of lightweight materials. Each vehicle is a significant technological achievement and the auto makers, who have spent over a billion dollars of their own funds on these models—applauded this historic partnership between the Federal government and the auto industry.

We have made progress but much work remains to be done. PNGV-related technologies include advanced propulsion systems such as fuel cells, energy storage, and lightweight materials, but we also need to further develop automotive integrated power modules, high power energy storage devices, pollution control devices, fuel cells, advanced clean fuels, and compression ignition direct injection engines to make these fuel-efficient cars a commercial reality.

In addition, PNGV technologies, which are targeted to the family-size car, are moving into larger and smaller vehicles designs. The automakers have announced that they will put hybrid SUVs in the marketplace beginning in 2003 and use these and other technologies to improve SUV fuel economy up to 25 percent.

Finally, to provide the training and expertise to support the PNGV program, DOE developed the Cooperative Automotive Research for Advanced Technology (CARAT) and the Graduate Automotive Technology Education (GATE) programs. CARAT's role is to develop advanced automotive technologies to overcome production barriers for ultra-high fuel efficiency vehicle. GATE is designed to train a new generation of automotive engineers in critical multi-disciplinary technologies.

The auto manufacturers met a major partnership milestone by introducing their concept vehicles in early 2000. GM Precept (80 mpg), Ford Prodigy (72 mpg), and DaimlerChrysler ESX3 (72 mpg.)

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VISION 21—NOT YOUR FATHER'S POWER PLANT

Tomorrow's power plants may scarcely resemble those of today. There may be no smokestack, for instance, because the futuristic power generators will emit no smoke. In fact, technological advances now being developed may make such plants virtually emission-free, instead turning pollutants into valuable commercial products such as chemicals and fertilizers. Advanced technology will permit carbon dioxide, the most important greenhouse gas, to be captured, and ultimately eliminated when viable sequestration approaches emerge in the next one-two decades.

Tomorrow's energy plants may also produce much more than just electricity. The Energy Department's Vision 21 concept, for example, envisions a new fleet of plants that would generate liquid fuels and chemicals, hydrogen, and industrial-grade heat in addition to electric power. This multi-product approach will squeeze every useable amount of energy out of a fuel source, achieving efficiencies that could approach 60 to 80 percent, well above the typical 33 to 35 percent efficiencies of today's conventional coal-fired power plants.

A Vision 21 plant would also have remarkable fuel flexibility. It could be fed by coal, or natural gas, or biomass, or municipal waste, or perhaps a combination of these fuels. Made up of modules that could be interchanged to meet different fuel and product needs, Vision 21 plants could be tailored for a variety of geographic regions and different energy markets.

In awarding a group of new Vision 21 projects, Secretary of Energy Bill Richardson said: "We are building the foundation for a new generation of energy facilities capable of efficiently using our most abundant traditional fuels while virtually eliminating environmental concerns. Vision 21 represents the future of clean energy."

The Vision 21 plant depicted here is extremely compact and efficient. With near-zero emissions, the plant will have no stack, and in some cases be sited near urban and industrial centers, thereby relieving the need for additional transmission lines.

DEEPWATER RECOVERY

The deepwater of the Gulf of Mexico (GOM) is characterized by many experts as the next Alaska "North Slope" and holds enormous potential to help meet the United States growing demand for natural gas and oil. This is in sharp contrast to the view just two decades ago that the Gulf of Mexico was a mature region with limited potential for further discovery and development.

These statistics tell the story of great potential—between 1985 and 1996, onshore domestic production of oil decreased by 30 percent but offshore production increased almost 8 percent. This turnaround, which has occurred primarily in the deepwater GOM, can be attributed, in large part, to government/industry investments in new technologies and to government incentives to develop the deepwater gulf. Oil and gas production in the deepwater GOM has grown dramatically in the last eight years. Gas production from deepwater increased ten-fold between 1992 and 1999, reaching 2.6 billion cubic feet per day. Oil production increased six-fold to 675 thousand barrels per day during the same period. Also, President Clinton signed the Deep Water Royalty Relief Act in 1995. Since then, deepwater GOM bids have gone from 10 percent of total leases to over 50 percent. The Administration is considering new incentives to encourage industry to move into even deeper waters.

Technology advances in reservoir detection and drilling have reduced the cost of finding offshore oil and gas from $15 per barrel of oil equivalent to $4 in the ten years from 1986 to 1996. However, offshore wells are still expensive to drill. For example, the total investment for establishing new production in the deepwater GOM, expressed on a per barrel basis, is several times higher than that for competing resources in most other parts of the world. Clearly we need to focus our efforts on technologies to change this equation and attract additional investment for more aggressive development of deepwater GOM resources.

The deepwater technology challenges are formidable— deeper wells encounter extreme temperatures and pressures and increased potential for intensively corrosive environments. The magnitude of these challenges may be doubled or tripled for ultra-deepwater wells. These conditions require high-strength materials and advanced drilling methods. To fully develop the potential in the deepwater GOM we will need innovative design, fabrication, installation, and automation and robotics techniques. We are now hard at work with oil and gas producers, service companies, National Labs, and Federal and non-governmental groups to develop a "roadmap" for addressing major technology needs, environmental and safety challenges, government/industry roles, and opportunities for collaboration and investment.

Deepwater drill ships such as Global Marine's Glomar Explorer help industry meet the challenge of recovering oil and gas from vast Federally-owned resources underlaying water depths from 7,000 to 10,000 feet.

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WIND IS POWERING UP

Wind was the 1990s fastest growing source of electric power generation. Indeed, the "wind is at our backs" in the expansion of world wind energy resources. In 1999, new worldwide wind-generating capacity grew by 3,600 megawatts, a 36 percent increase that brought worldwide wind-generating capacity to 13,400 megawatts. In the United States, this increase was even greater at 41 percent, bringing our 1999 total wind-generating capacity to 2,500 megawatts.

Working with private sector partners, DOE, through its Wind Energy Systems Program, is developing advanced wind turbine technologies capable of reducing the cost of wind energy generation to 2.5 cents per kilowatthour—making wind energy competitive with other power generation and putting us on track to meet our goal of 10,000 megawatts of installed wind-powered generating capacity in the U.S. by 2010. DOE also estimates that the Wind Energy Systems Program could displace as much as 10 million metric tons of carbon equivalent in 2010 if the program goals are met. Large wind projects can now achieve costs of around 4 to 5 cents per kilowatthour.

We need to look only as far as Lake Benton, Minnesota to see solid achievements from our investments in wind energy. The 107-megawatt wind power plant located near Lake Benton was the world's largest wind-generation facility at the time of its completion in 1998. Electricity generated by this facility will power 43,000 homes and displace greenhouse gas emissions equivalent to removing 50,000 new cars and light trucks from the road. The technical assistance, testing capabilities, and utility operating experience made possible by the Department's Wind Program were critical to the successful development of the wind turbines used in the Minnesota project.

Not only does wind energy have potential to add to the nation's power supplies and reduce harmful emissions, it has tremendous potential for serving remote rural areas that do not have access to the conventional power grid. DOE supported the design and installation of a 660 Kilowatt wind energy project for the Kotzebue Electric Association in Kotzebue, Alaska. Kotzebue's wind turbines are producing electricity for approximately 13 cents per kilowatthour, compared to the 20 cent cost of the diesel generation they replaced. The Kotzebue project is a model for other Alaskan and remote communities seeking to relieve their dependence on diesel power systems.

Finally, we are working to establish new sources of income for American farmers, Native Americans, and other rural landowners—and meet the growing demand for clean sources of electricity—through DOE's Wind Powering America Initiative. More than 500 megawatts of new wind generating capacity have been installed on farmlands in the Great Plains region of the United States, providing a substantial economic boost directly to farmers, landowners, and local communities while satisfying the growing demand for clean electricity. Wind farms create construction and service jobs in rural regions, as well substantial tax revenues for local municipalities.

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TOOLS OF THE ENERGY POLICY TRADE

The Administration relies on the best available data, combined with state-of-the-art economic, energy and environmental modeling and forecasting tools to develop its energy policies, measure their impacts, and assess the levels and types of Federal investment required to meet energy policy goals.

A wide range of analytical tools are needed to address the incredible variety of energy policy issues that face the nation—tools that make use of recent advances such as those in economics, operations research, and decision theory. These tools are increasingly dependent on modern computational techniques, making use of ever larger data sets and depicting complex inter-relationships. For example, the Policy Office at the Department of Energy maintains a complex model of the electricity system, allowing analysis of various policy alternatives for enhancing competition in the electricity sector. Oak Ridge National Laboratory maintains a sophisticated model of refinery operations that can be used to explore the supply and cost implications of new fuel specifications for gasoline and diesel fuel.

The Energy Information Administration (EIA) develops and maintains the National Energy Modeling System (NEMS)—an energy-economic modeling system of U.S. energy markets. NEMS projects the production, imports, conversion, consumption and prices of energy, subject to assumptions on macroeconomic and financial factors, world energy markets, resource availability and costs, behavioral and technological choice criteria, cost and performance of energy technologies and demographics.

Increasingly, the models used in the energy sector incorporate the situations faced by other countries, as markets become more global in nature. One tool used in analyzing the potential impacts of efforts to reduce emissions of greenhouse gases in developing and developed countries is the MARKAL energy model, which has modules for a number of countries, including fast growing countries such as China and developed countries such as the United States. Keeping these tools up-to-date and available for use on relatively short notice is a resource-intensive activity. However, because the foundation for good policy is good analysis, investments in these areas clearly have payoffs that exceed the overall costs.

Energy models are also used to analyze:

- The effect of appliance and equipment efficiency standards on manufacturing costs, product price, and environmental quality;
- The impact of financial incentives on the level and type of private investment in more energy efficient technologies;
- The degree to which policies to limit greenhouse gas emissions affect the demand, supply and price of energy, economic growth, and environmental quality; and
- The impact of more stringent fuel quality regulations on energy suppliers and consumers.

EIA data products on energy are frequently cited as the best in the world and have become industry standards. These include:

- The Annual Energy Outlook
- The International Energy Outlook
- Weekly Petroleum Report
- Short-Term Energy Outlook
- Natural Gas Weekly
- Summer and Winter Fuels Conferences

ON THE INTERNATIONAL FRONT: PROMOTING U.S. ENERGY BUSINESS, CLEAN ENERGY DEVELOPMENT, AND INFRASTRUCTURE INVESTMENTS

Over the next twenty years, China expects to add up to 170 million cars to its roads, almost all of which will be powered with petroleum-based fuels. Major population centers—India, Mexico, South Africa, Brazil, Chile, Argentina, Southeast Asia—need electricity and petroleum to develop their economies. At the same time, demand for energy and energy services in the industrialized world continues to grow—the United States is in the lead, with projected energy demand growth of over 20 percent by 2020.

Competition for energy resources and the capital to develop them will be intense. World energy demand is expected to double by 2030 and quadruple by the end of this century—much of this increased demand will be in the developing world. Total world energy consumption is projected to reach 560 quadrillion btus in 2015, an increase of 200 quadrillion btus over 1995. As energy demand and use grows, so do environmental problems. World carbon emissions are projected to increase by 3.5 billion metric tons by 2015, along with other harmful emissions and particulates.

At the same time, the global market for energy supply equipment is $300 billion annually. This will grow proportionately as world energy demand doubles in the next several decades. If we include the value of products whose marketability depends on energy performance—such as cars or appliances—the value of the global energy market reaches into the trillions of dollars. China serves as an example of this potential, recently announcing that it needs $14.5 billion to develop its natural gas resources over the next five years, and that "there will be no limits on the equity foreign partners can hold, and no restrictions on the forms of cooperation."

The Clinton/Gore Administration wants U.S. companies to get a substantial share of the world's energy business—we are aggressively promoting our business interests overseas, for both clean energy technologies, and energy production and infrastructure development. DOE activities in the international arena range from promoting distributed generation in countries that lack central power grid infrastructures . . . to encouraging power sector reform to increase foreign investment, energy production and energy efficiency . . . to opening the doors of foreign governments to U.S. company investments in upstream oil and gas exploration and production.

Promoting Clean Energy

In addition to launching the International Clean Energy Initiative, DOE has signed cooperative Clean Energy Statements with a number of countries to build support for market-based emissions trading mechanisms and new technology to reduce greenhouse gas emissions. We have also teamed up with U.S. businesses, and engaged energy ministers from the Western Hemisphere, Africa, and the Asia-Pacific Economic Cooperation (APEC) region, the International Energy Agency and the European Union to speed the export of U.S. clean energy technologies.

In October 1999, DOE signed a Joint Statement on Cooperation in Energy and Related Environmental Aspects with the Government of India. This set the stage for President Clinton's visit to India, which included the signing of an Energy and Environment agreement and a major U.S./South Asia Regional Initiative on clean energy development. In March 2000, a Joint Statement on Clean Energy and Climate Change was signed with the Government of the Philippines, facilitating international negotiations on climate change. DOE has also signed Clean Energy Statements with the Governments of Russia, Estonia, Latvia, Lithuania and the Kyrgyz

Republic. These statements emphasize the role of the energy sector in joint efforts to protect and enhance the environment, and advance the international negotiating process on climate change. In the Western Hemisphere, DOE has initiated clean energy programs with Bolivia, Costa Rica and Mexico. In Mexico, the focus is on clean and affordable fossil technology development and deployment. Bolivia recently agreed to develop a greenhouse gas emission target.

Promoting Investment in International Energy Production and Infrastructure

DOE cooperative programs helped advance passage of Russian Production Sharing Laws to encourage investment in the oil and gas sector. The first oil flowed from Sakhalin Island in 1999, a project developed jointly by Marathon Oil and Russian companies. In the Caspian region, bilateral policy dialogue with Turkey, Azerbaijan, Georgia, and Turkmenistan has fostered an investment climate to develop oil and gas resources and the pipelines needed to transport these products to Western markets. This was highlighted when President Clinton witnessed the signing of intergovernmental agreements among Turkey, Azerbaijan and Georgia for the development of a critical pipeline system from the Caspian region to western markets. The Department has also established a regional oil spill response system with the countries bordering the Black Sea, through a website and technical workshops in the region.

The Administration is also promoting energy efficiency and renewable energy in Russia through a host of measures including: regional energy efficiency laws, renovation of district heating systems; energy-savings codes and standards; advances in energy-efficient window technologies; and the construction of wind-diesel hybrid power stations at remote sites in the Northern Territories and a new geothermal power plant in Kamchatka

DOE has launched an $850,000 initiative in Ukraine to finance energy efficiency projects, to conduct energy audits of five industrial firms, and facilitate a $30 million World Bank loan to retrofit municipal buildings in Kiev. We actively participate in the U.S.-China Forum on Environment and Development, and together with the U.S. Export-Import Bank, have established a $100 million credit facility to finance energy efficient, clean energy systems. U.S. and Chinese government officials and petroleum industry leaders, working through the China Oil and Gas Industry Forum, have contributed to a major strategic decision by China to develop its natural gas resources, import liquefied natural gas, and permit foreign ownership of natural gas production and transportation infrastructure.

Good Policy/Good Business

The cooperative development of the world's energy resources and infrastructure is good public policy and good for business all around—we are helping spur economic development, creating new markets, encouraging stability, and promoting environmental responsibility.

A solar powered vaccine refrigeration unit developed for the World Health Organization (WHO.) This is part of an innoculation program conducted by WHO for the Bedouin tribes of the Sudan, East Africa.

ELECTRICITY RESTRUCTURING—THE NEED FOR FEDERAL ACTION

Would American consumers say "no" to a $20 billion reduction in their annual electricity bill, an entirely new range of services, new business opportunities, and a cleaner environment? The Clinton/Gore Administration doesn't think so. This list of benefits represents the promise of true competition in the nation's electric power industry—a promise we can deliver on through the enactment of comprehensive Federal electricity restructuring legislation.

Why do we need Federal restructuring? Already, twenty-five states have adopted state-specific restructuring programs and there are clear benefits—over the next two or three years, millions of additional consumers will have choices in electric power providers and, after a transition period, should realize the lower costs and better services that come with competition. According to regulators in Pennsylvania, for example, consumers have already saved $2.8 billion.

But these state-by-state patchwork efforts underscore the need for comprehensive Federal legislation. The absence of overarching Federal direction has created significant uncertainty in electricity markets—energy markets are becoming increasingly regionalized, but market requirements that change at each state border are discouraging the investments we need to modernize and expand the nation's power grid. This is showing up in regional electricity price volatility and needs to be addressed promptly.

Also, today's electricity infrastructure is being asked to operate in ways for which it was not designed, with ever growing demands for improved service and increased load. In addition, the digital New Economy is placing unprecedented reliability and power quality demands on the system. Power outages already cost the U.S. more than $50 billion annually, and in the growing competitive environment of state-by-state restructuring, owners and operators of transmission lines are increasingly focused on the bottom line—with far fewer incentives to comply with voluntary reliability standards or invest in system upgrades. Unfortunately, the consequences are now being seen in some regions of the country.

These uncertainties and the inability of the infrastructure to keep pace with demand, have translated into new, real, and growing problems. Generating capacity reserve margins have diminished. The construction of new major transmission facilities has virtually stopped. During this and recent summers, some regions of the country experienced major problems—as the heat rose, demand for electricity increased and the lights went out. In others, elected officials and utility executives had to make urgent public appeals for conservation to avoid the major blackouts that could result from stressed and inadequate facilities.

Without Federal action, state restructuring programs cannot reach their full potential—and in the end it will be electricity consumers that lose out. This is why the Clinton/Gore Administration has had comprehensive legislation before Congress since 1998, which would:

- Clarify key authorities for Federal and State agencies with respect to governance of the new electricity industry;
- Establish clear Federal policy support for retail and wholesale competition;
- Maximize consumer benefits through mechanisms and authorities to ensure true competition, including clear labeling for informed choices;
- Support for public benefits such as low income assistance, energy efficiency, renewable energy;
- Stimulate the use of advanced technologies and innovative services that reduce emissions and

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encourage efficiency and the use of green power;

- Provide incentives for distributed generation; and
- Strengthen system reliability while relying on traditions of industry self-regulation.

The electricity industry in the United States currently delivers over $200 billion worth of electric services every year, and has a book value of over $700 billion—we cannot neglect the engine that powers our economy. Electricity markets are crying out for the certainty needed to make essential investments in generation, transmission and distribution infrastructure.

The Federal government needs to send out the right signals—to establish the "rules of the road" and develop a comprehensive roadmap so that consumers, businesses and the environment will all benefit from the promise of electricity competition.

It is important that we act . . . we act wisely . . . and we act soon. The Clinton/Gore Administration stands ready—and has been over the last three sessions of Congress—to work with Congressional lawmakers to deliver on the promise of competition by passing comprehensive Federal electricity legislation.

THE SCIENCE OF CLIMATE CHANGE: WHY RESEARCH IS CRITICAL

Three years ago, the National Climatic Data Center reported that 1997 was the warmest year of the century. This record was quickly broken when 1998 drew to a close.

Data show that our climate is warming faster than at any other time in the 100 to 200 year history of widespread temperature measurement (including proxy data.) The top six warmest years of the century have all been in the 1990s. The current scientific consensus is that global average temperatures, in the "business-as-usual" scenario, will increase from two to six degrees Fahrenheit in the next hundred years, with a corresponding rise in sea level of six to 37 inches.

Half of the U.S. population and more than two-thirds of the global population currently live in coastal areas—future rises in sea level, altered storm patterns, and higher storm surges could have devastating effects. These changes will also have significant impacts on the environment, human health, the economy and society in general, affecting everything from energy use. . .to transportation. . .to water resource management. . .to international trade and development. . . to agriculture. . .to natural ecosystems.

A few years of warm weather and extreme weather events do not by themselves indicate global warming and climate change. However, the basic science of atmospheric greenhouse warming of the earth is indisputable. Indeed, it has been recognized for over a century that naturally occurring greenhouse gases in the atmosphere, such as water vapor and carbon dioxide, provide an essential blanket that sustains life on earth.

The challenge lies in the significant increase in greenhouse gas concentration, particularly carbon dioxide, since the beginning of the Industrial Age and especially in the last few decades. The Intergovernmental Panel on Climate Change (IPCC) has concluded that the balance of evidence suggest a discernible human influence on global climate. The energy sector is by far the dominant anthropogenic source of greenhouse gas emissions, and projected worldwide economic and energy demand growth point to further dramatic increases of greenhouse gas concentrations unless energy efficiency, production and use patterns are altered appropriately. Because of the long residence time of carbon in the atmosphere—about a century—the time to act is now.

Climate Research at DOE

With the stakes so high, it is imperative that our decisions reflect the best available scientific information, and that we act on this information to develop and deploy clean energy technologies. At DOE, our research is directed at understanding the basic chemical, physical, and biological processes of the Earth's atmosphere, land, and oceans, and how these processes may be affected by energy production and use, primarily the emission of carbon dioxide from fossil fuel combustion. Highlights of our research program include:

- Carbon cycle: We will continue a range of experiments that advance our basic understanding of the global carbon cycle and assess the potential consequences of increased atmospheric carbon dioxide on vegetative growth and ecological systems. This will be coordinated with numerous international research efforts. These scientific efforts provide the foundation for the Department's applied energy research programs for developing

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carbon sequestration technologies.

- Atmospheric Radiation Measurement Program: Through adjustments to this existing monitoring system, sites in climatically significant regions are being thoroughly instrumented to provide data critical to improving General Circulation Models so that these important computational tools can be used to provide reliable climate predictions under various scenarios of human activity.

- Computer Hardware, Advanced Mathematics and Model Physics Program (CHAMMP): This program is at the center of the Department's advanced climate prediction research. Advances in computing technology, computational science, experimental data, and theoretical developments contribute to state-of-the-science General Circulation Models, producing more accurate and reliable climate predictions.

- Climate Models: The development of a new generation of climate models that run on massively parallel high-performance scientific supercomputers is a major objective of the DOE Global Change and High Performance Computing and Communications programs. The increased computational power of parallel scientific super-computers will make it possible for future models to simulate climate processes at higher resolutions, thereby enabling decade and longer-term climate predictions to be more accurate and realistic. In particular, increased resolution will allow much better incorporation of important phenomena such as cloud formation and ocean vortices.

These programs contribute to the U.S. Global Change Research Program that was codified by the Congress in the Global Change Research Act of 1990. DOE continues to work closely with the USGCRP and its supporting agencies to develop and implement a comprehensive U.S. climate change research program. More information can be found at www.usgcrp.gov.

Shown here are the surface temperatures of the ocean as simulated with a 3 dimensional global ocean model developed at Los Alamos National Laboratory for Massively Parallel Connection Machine (CM-5) computer. Warm temperatures are shown in red and coolest in blue. Continents and islands are black. The computational grid employed represents the highest resolution used in any global ocean simulation performance to date, resulting in great detail visible in the eddies of various ocean currents. From the High resolution Global Ocean Circulation Model: "Parallel Ocean Program."

Appendix: Department of Energy Program Summaries

This Appendix contains additional information about Department of Energy programs, many of which are discussed in the text. While not a comprehensive review of DOE programs and R&D, these summaries provide a clear illustration of the range and depth of energy efficiency, oil and gas, coal, nuclear and cross-cutting programs. The summaries denote which DOE challenge they address, as well as describe the program activity and related accomplishments and benefits. Contact information is also provided for additional information. More complete information about DOE's energy resources R&D portfolio can be found at www.osti.gov/portfolio.

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Energy Efficiency

Vehicles

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Partnership for a New Generation of Vehicles (PNGV)

DOE Challenge: Enhancing Energy Security, Mitigating Environmental Impacts

Program Activity: PNGV is a government-industry, cost-shared program initiated in 1993 to reduce the cost and time of automotive development, improve fuel efficiency and emission performance of conventional vehicles, and develop mid-size vehicles that achieve up to 80 miles per gallon (mpg) while maintaining or improving safety, performance. emissions, durability, comfort, and affordability.

PNGV identified three major milestones for the 10-year program. Prior to 1997, the objective was to rapidly advance specific component technologies for vehicle application. In late 1997, the first major PNGV milestone was to select the most promising of these technologies for integration into concept vehicles. The second PNGV milestone was the display of concept vehicles in the year 2000 that demonstrate the technical feasibility of 80 mpg family sedans. The 2004 milestone is to have advanced vehicle production prototypes that contain enhancements of these technologies.

Accomplishments:

- The National Academy of Sciences recognized program schedule performance and commended the progress made by the partnership; and
- Met concept vehicle year 2000 milestone demonstrating the technical feasibility of 80 mpg family sedans. Ford. General Motors and DaimlerChrysler displayed their PNGV concept vehicles this year. Each concept showcased unique and innovative approaches to combining advanced technologies in an appealing. functional vehicle that could achieve between 72 and 80 miles per gallon (gasoline equivalent.)

Benefits:

- By meeting PNGV's goals and objectives. the nation will reduce its dependence on oil and achieve energy savings as well as reduce carbon emissions;
- By 2010, the entry of advanced automotive technologies into the market will displace 1.2 quads of primary oil. increasing to 2.5 quads by 2020;
- Resulting energy cost savings total $8 billion in 2010 and over $20 billion by 2020;
- Carbon reductions are estimated at 16.1 and 37.2 million metric tons in 2010 and 2020, respectively; and
- Displaced oil consumption would have a positive impact on the US balance of payments deficit.

For More Information, Contact: Ed Wall. Office of Advanced Automotive Technologies, (202-586-0410) or go to: www.ott.doe.gov/oaat/pngv.html

18104

DOE019-0071

Lightweight Vehicles

DOE Challenge: Enhancing Energy Security, Mitigating Environmental Impacts

Program Activity: The goal of the Lightweight Vehicles program is to reduce national petroleum dependency as well as local pollution and greenhouse gases emissions by developing lighter-weight autos, trucks and buses while maintaining or improving size, comfort, affordability/cost-effectiveness, safety and recyclability.

The DOE Lightweight Vehicles programs began in FY 1992 but have grown, especially for autos, since the advent of the Partnership for a New Generation of Vehicles (PNGV) in FY 1994. In FY 1996, efforts were formally split into two complementary programs, the larger on autos under the PNGV, the smaller on heavy-duty trucks. The majority of efforts to date have been on aluminum casting, aluminum sheet production and forming, and manufacturing of glass-fiber reinforced polymer-matrix composites (PMCs.) As those efforts have matured and have begun to be implemented by U.S. industry, the Lightweight Vehicle programs are focusing on development of carbon-fiber reinforced PMCs, magnesium casting, metal-matrix composites, titanium, crashworthiness and recycling/repair. All efforts are highly coordinated with, and cost-shared by, U.S. auto and truck manufacturers and their suppliers, notably the United States Automotive Materials Partnership. In addition, nine DOE National Laboratories participate.

Accomplishments:

- Demonstrated that a 40 percent reduction in the weight of the average mid-size family auto is technically feasible (though not yet economically competitive);
- Developed a cost-effective system for casting large, single-piece truck structures at rates required for high-volume production;
- Demonstrated that large, fiber-reinforced PMC components can be produced at typical auto production rates;
- Validated cost-effective technologies for producing dependable, high-quality, cast aluminum structural components at high production rates, and transferred the technology to Tier 1 auto suppliers; and
- Demonstrated technologies necessary to produce low-cost, continuously-cast, aluminum sheet and improved forming technology necessary to produce automotive components.

Benefits: Generally, lightweight materials technologies allow a 6 percent increase in fuel efficiency for every 10 percent decrease in vehicle weight, with corresponding decreases in tailpipe emissions. Light-weighting is viewed as the second most effective way of improving fuel efficiency, next to improvements in propulsion/drive train systems.

For More Information, Contact: Joseph A. Carpenter, Jr., Office of Advanced Automotive Technologies, (202-586-1022) and/or Sidney Diamond, Office of Fuels Development, (202-586-8032) or go to: www.ott.doe.gov/oaat/lw_materials.html

Advanced Combustion and Emission Control for Diesel Engines

DOE Challenge: Enhancing Energy Security. Mitigating Environmental Impacts

Program Activity: Addresses the future technology challenges faced by advanced diesel engines which the PNGV program identified as one of the most promising technologies for achieving the fuel economy goal of up to 80 miles per gallon. Today's diesel engines achieve impressive thermal efficiency; however, in order to meet future emissions standards, advancements in clean combustion, emission control technology, and fuels are necessary, including:

- Reducing and controlling unwanted nitrogen oxides (NOx) and particulate matter in the exhaust below current-technology diesel engine emissions; and
- Improving the durability and decreasing fuels sensitivity of emission control devices.

The Combustion and Emission Control program is a joint effort between industry and government. The program is focused on improving combustion processes and emission control technologies through basic and applied research in combustion modeling, materials research, and emission control system development.

Accomplishments:

- Demonstrated the potential of a new catalyst formulation to remove 95 percent of NOx emissions over a broad range of temperatures with ultra-low sulfur diesel fuel;
- Initiated programs with Cummins/Engelhard and Detroit Diesel/Johnson Matthey to develop and demonstrate emission control systems for passenger cars (PNGV) and light trucks that will enable compliance with future emissions standards;
- Received 1999 R&D 100 Award (R&D Magazine) for "Clean Diesel Technology"; and
- Tested DOE-sponsored microwave regenerative particulate trap technology successfully.

Benefits:

- Contribute to achieving 80 miles per gallon PNGV mid-size passenger vehicles, and significantly improved fuel economy for light trucks and sport utility vehicles, while meeting stringent Tier 2 tailpipe emission standards.

For More Information, Contact: Ken Howden and/or Kathi Epping, Office of Advanced Automotive Technologies, (202-586-3631) and/or (202-586-7425) or go to: www.ott.doe.gov/pdfs/Comb_ReportNew.pdf

Alternative Transportation Fuels

DOE Challenge: Enhancing Energy Security: Mitigating Environmental Impacts

Program Activity: To advance the Energy Policy Act of 1992 (EPACT) objective to increase the use of alternatives to petroleum in the transportation sector. EPACT seeks to achieve this goal via an increase in the use of alternative fuels and alternative fuel vehicles (AFVs) as well as through an expansion of the use of non-petroleum components (replacement fuels) in conventional petroleum-based fuels. EPACT section 502(b)(2) established goals of displacing 10 percent of motor fuel consumption in 2000 and 30 percent of motor fuel consumption in 2010 with alternative and replacement fuels.

Accomplishments:

- Implemented regulations governing the purchase of alternative fuels by State governments and fuel providers:
- Published an Interim Fina Rule governing the availability of alternative fuel vehicle credits through the use of biodiesel fuel.
- Supported Executive Orders resulting in over 40,000 alternative fuel vehicles operating in the Federal Government fleet. and
- Induced a total population of around 160,000 alternative fuel vehicles in the fleets of the Federal Government. State governments. and fuel providers.

Benefits:

- Displaced around 140 million gallons of petroleum fuels since 1992;
- Helped increase the number of AFV models available from 7 in 1993 to 29 in 2000; and
- Helped increase the number of alternative fuel refueling stations to 6000 in 2000.

For More Information, Contact. David Rodgers. Director. Office of Technology Utilization. EE-34. (202-586-9118) or go to: www.afdc.doe.gov

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DOE019-0074

Clean Cities

DOE Challenge: Enhancing Energy Security, Mitigating Environmental Impacts

Program Activity: Provides the technical assistance needed to expand the use of alternative fuel vehicles (AFVs) and their supporting infrastructure throughout the nation by building community networks. The Clean Cities program takes a unique, voluntary approach to AFV market development, working with coalitions of local stakeholders to help develop the AFV industry and integrate this development into larger planning processes.

The Clean Cities program thrives on strong local initiatives and a flexible approach to the challenge of building alternative fuels markets, providing participants with options to address problems unique to their cities, and fostering partnerships as the mechanism to overcome these problems. Current and potential members of the Clean Cities network also help each other by sharing local innovations, by addressing and relaying obstacles they encounter in pursuing alternative fuels programs, and by exchanging "do's" and "don'ts," based on experiences in these programs.

Accomplishments:

- Around 170,000 alternative fuel vehicles in service in Clean Cities;
- 80 participating communities: more than 3500 stakeholders;
- Over 4000 alternative fuel refueling stations in service in Clean Cities;
- 10 domestic AFV corridors under development;
- Six national conferences held, the most recent of which attracted almost 1000 attendees;
- Creation and maintenance of Alternative Fuels Data Center and Clean Cities websites, providing wide dissemination of alternative fuels and Clean Cities information; and
- More than $10 million in grants to States for innovative projects.

Benefits:

- Over 600 million gallons of petroleum fuel displaced since 1993;
- Over 130,000 metric tons of criteria emissions displaced since 1993; and
- Over 300,000 metric tons of carbon emissions displaced since 1993.

For More Information, Contact: Shelley Launey, Office of Technology Utilization, (202-586-1573) or go to: www.ccities.doe.gov

International Clean Cities

DOE Challenge: Mitigating Environmental Impacts, Enhancing Energy Security, Increasing Competitiveness and Reliability

Program Activity: Extending the Clean Cities model of public-private partnerships to enable developing countries to make use of U.S. Alternative Fuel Vehicles technology to mitigate pollution problems and build sustainable transportation. The international projects in the Clean Cities program facilitate international exchange and government/industry partnerships to promote alternative fuel technologies that address shared energy and environmental issues. Technical assistance and expert support:

- Build and maintain partnerships through international information exchange;
- Advance economic opportunities for U.S. and in-country industries; and
- Enhance and maintain the technological and analytical knowledge of the international community.

Accomplishments:

- Enrolled Santiago, Chile, Juarez, Mexico, and Toronto, Canada, into the Clean Cities International program;
- Conducted a reverse trade mission from Chile to the U.S. in February, 1999;
- Co-sponsored a Climate Change Initiative Workshop in San Salvador, El Salvador in March, 2000;
- Conducted a successful trade mission to Monterrey, Mexico in April, 2000; and
- Sponsored a transit workshop in Santiago, Chile in May, 2000.

Benefits:

- Chile has adopted tough new emissions regulations for transit buses and a financial incentive program for purchase of natural gas buses; and
- U.S. industry has developed partnerships in Chile, Mexico, and Canada to promote natural gas and other alternative fuel vehicle products.

For More Information, Contact: Marcy Rood, Office of Technology Utilization, (202-586-8161) or go to: www.hemis-ccities.doe.gov

Electric Vehicle Batteries

DOE Challenge: Enhancing Energy Security, Mitigating Environmental Impacts

Program Activity: Develop advanced energy storage and related systems technologies that simultaneously meet competitive requirements such as high power demand, fast rechargeability, long life, safety, low heat and low cost. Address barriers including high cost, inadequate performance and life, reliability, system safety, and disposal through high-energy battery research. Focuses on advanced energy storage technologies will enable full-range electric vehicles to travel at least 200 miles on a single battery charge. Working closely with U.S. automakers as part of the U.S. Advanced Battery Consortium (USABC), the Electric Vehicle Battery program is developing the next generation of nickel-metal hydride (NiMH), lithium-ion and lithium-polymer battery technologies.

Accomplishments:

- Completed nickel-metal hydride battery research activities with the delivery of production modules from SAFT America to DaimlerChrysler for use in the EPIC Electric Minivan and from GM Ovonic to General Motors for use in the EV-1 and S-10 electric vehicles;
- Demonstrated life of more than 500 cycles in laboratory tests of a lithium-polymer electrochemical cell cohort group representing an entire EV battery pack; and
- Developed a comprehensive series of tests to characterize the abuse tolerance of advanced batteries developed under the USABC and PNGV programs. These test procedures were published in July 1999 and have been recognized and adopted by the Society of Automotive Engineers (SAE) as the industry standard (J2464.)

Benefits:

- By 2010, 700,000 electric vehicles on the road replacing inefficient urban vehicles.

For More Information, Contact: Dr. Kenneth L. Heitner, Office of Advanced Automotive Technologies, (202-586-2341) or go to: www.ott.doe.gov/oaat/ev_batt.html

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Fuel Cell Development for Vehicles

DOE Challenge: Enhancing Energy Security, Mitigating Environmental Impacts, Providing Diverse Energy Technologies

Program Activity: A fuel cell is an electrochemical device that combines hydrogen and oxygen to produce electricity with zero emissions and high energy efficiency—either as a stationary means of producing electricity or a mobile propulsion system for vehicles. The DOE effort is designed to help industry develop effective, low-cost fuel cells, that move well beyond the costly fuel cells developed for the U.S. space program.

The U.S. Government owns and operates 30 fuel cell co-generation units, the world's largest fleet of fuel cells. Five cabinet-level Departments participate in fuel cell research and demonstration programs, investing more than $100 million per year. The U.S. Department of Energy spends about $50 million on research in molten carbonate and solid oxide fuel cells for stationary power and more than $30 million on transportation applications, primarily utilizing the Proton Exchange Membrane (PEM) technology.

Accomplishments:

- October, 1997. A government-industry team (Department of Energy, Ford Motor Company and International Fuel Cells) announced that for the first time, a PEM fuel cell system fueled by hydrogen, produced more than 50 kilowatts of electrical power without an air compressor;
- October, 1997. A breakthrough in "on-board" fuel processing demonstrated that ordinary gasoline and clean alternative fuels can be converted to power a fuel cell electric car; and
- January, 2000. PNGV effort produces 80-mpg concept cars by GM, Ford and DaimlerChrysler. One of the GM cars utilizes fuel cell/hybrid propulsion system and promises fuel efficiency of 108 miles per gallon (gasoline equivalent.)

Benefits:

- Fuel cells can provide major environmental, energy and economic benefits that advance critical national goals: clean air, increased national self-reliance for transportation fuels, and enhanced national security; and
- Continued aggressive development will help retain competitive advantage for U.S. fuel cell suppliers and automakers.

For More Information, Contact: Patrick Davis, Program Manager, EE-32, (202-586-8061)
or go to: www.ott.doe.gov/oaat/fuelcell_tech.html

18111

Energy Efficiency

Electricity Generation

18112

Gas Turbines

DOE Challenge Area: Mitigating Environmental Impacts; Increasing Competitiveness and Reliability

Program Activity: This program focuses on development and testing of advanced turbine systems to convert natural gas and other domestic fuels into electric power. These systems are ultra-efficient, near zero emissions, and affordable in today's power generation marketplace. The program includes research and development in critical research areas with U.S. DOE National Labs, 40 U.S. universities, and industry partners. The ATS program began in the year 1992 with the goals to achieve 60 percent net electrical efficient utility scale power plants, a 10 percent reduction in cost of electricity, and less than 10 ppm NOx emissions. The ATS program is a success with the General Electric 7H-ATS ready for demonstration at the Sithe Energy site near Scriba, NY and the Siemens-Westinghouse ATS currently being tested at Lakeland Municipal Utilities near Orlando, FL.

With environmental and energy security pressures continuing to grow in the U.S., the DOE is planning further development of next generation turbine systems for Vision 21 plants. By the year 2010, turbine based power systems developed will include turbine/fuel cell hybrids, flexible turbine systems, and revolutionary concepts such as the Ramgen and Clean Energy Systems concepts. By the year 2015, these systems will be enhanced and integrated into Vision 21 power plants.

Accomplishments:

- Development and testing of utility scale ATS which are 60 percent efficient, 10 percent lower in cost of electricity, and ultra-low emissions;
- 60 universities have contributed to the development of the ATS under the industry-university consortium; and
- DOE National Laboratories and industry have developed materials and combustion technology to achieve the cost and emissions goals of the ATS program.

Benefits: In the 2000 Annual Energy Outlook, the DOE EIA predicts that 300 gigawatts of new generating capacity will be required in the United States by 2020 to meet growing demand and to replace retiring units. Of the new capacity, 90 percent is projected to be combined-cycle or combustion turbine technology. Development of next generation turbine systems will provide the following savings to the U.S.:

- 4900 trillion btu of primary energy;
- $6,900 million fuel cost savings;
- 490 million metric tons of CO_2;
- 0.55 million metric tons of SOx; and
- 1.1 million metric tons of NOx.

In the near term, it is estimated that a reduction of up to 165 million tons of CO_2 per year could be achieved in the U.S. alone by displacing older, less efficient, intermediate coal, oil, and NG-fired steam plants with next generation technology.

In the long term, if turbine/fuel cell hybrid systems penetrate the U.S. market, these systems will produce less than 1 ppm NOx and virtually no SOx. They are at least 70 percent efficient, have a concentrated CO_2 stream, and no particulates even when utilized as electric generation modules for coal-fired power plants. With integration of the next generation technologies into Vision 21 plants, public benefits will be further increased due to significant long-term emissions reduction and fuel savings to the U.S. economy.

Currently U.S. turbine manufacturers annually export more than $3 billion worth of power generation systems. Maintaining the U.S. technological lead in gas turbines power generation equipment will provide for increased exports and enhance our industrial competitiveness. The U. S. Department of Commerce estimates that every $1 billion of exports equates directly to 20,000 jobs. More than 60,000 jobs can be accredited to U.S. turbine manufacturers through the export of power generation systems.

For More Information, Contact: Vic Der, Director, Power Systems, Office of Coal and Power Systems, (301-903-2700) or go to: www.fe.doe.gov/coal_power/ats/ats_sum.html

Fuel Cells for Utility Sector

DOE Challenge Area: Mitigating Environmental Impacts

Program Activity: In the near term, the Fuel Cell Program is committed to creating environmentally friendly technology for the expanding distributed generation market that has gained impetus from the deregulating electric industry. The molten carbonate and solid oxide fuel cell technology products should enter the near-term distributed generation market by 2003. In the long term, the Program is committed to realizing the full potential of ultra-high efficiency with zero emissions fuel cell technology and to wider, deeper market applications of the technology. The greatest opportunities in the fuel cell program are expected to be achieved through the Solid State Energy Conversion Alliance (SECA.) SECA comprises government agencies, commercial developers, universities, and national laboratories committed to the development of low cost, high-power density solid state fuel cells for a broad range of stationary and transportation applications. SECA technology will ultimately lead to megawatt-size configurations for commercial/light industrial packages and Vision 21 central power station applications.

Accomplishments:

- Commercialization of the phosphoric acid fuel cell and deployment of over 200 units worldwide has created the first generation of ultra-clean, highly reliable power plants that produce high quality electricity and thermal energy;
- The next generation molten carbonate and solid oxide fuel cell technology is being demonstrated and scaled-up to 1 megawatt; and
- The world's first fuel cell turbine hybrid is being tested.

Benefits:

- By 2010, molten carbonate (MCFC) and solid oxide fuel cell (SOFC) developers will produce 5,000-10,000 new jobs, $400 million/year in potential wages and $1 billion in tax revenue;
- The SOFC and MCFC developers will capture 10-15 percent of the 10 gigawatt per year European and U.S. distributed generation (DG) market;
- By 2010, the DG market is expected to be 20-40 percent of the total new and replacement market worldwide. The DG market could be potentially 40 gigawatts per year worldwide;
- In terms of CO_2 emissions, with an average efficiency of 50-60 percent (LHV), almost twice that of conventional power plants, CO_2 emissions would be reduced by almost 40 percent on all power plants using fuel cells. This would reduce the growth in new CO_2 emissions by 40 percent. In addition, NO_x and SO_x emissions would virtually be eliminated;
- Grid reliability will be enhanced through the ancillary services benefits of fuel cells (including power quality, premium power, voltage control, etc.); and
- Longer term, SECA will produce the first demonstrations of even lower-costs, Vision 21-enabling fuel cell technology concepts, such as solid-state fuels cells, networks, multi-staged designs, etc., to enhance wider and deeper penetration of the mature, competitive distributed generation market. These revolutionary fuel cells systems will target efficiencies of over 80 percent at costs below $400 per kilowatt, while reducing carbon dioxide emissions by over 56 percent. This breakthrough will allow widespread penetration into high volume stationary and transportation markets, ultimately leading to "Vision 21" central station power application of advanced fuel cell technology. The inherently high 60-70 percent conversion efficiencies of these solid state fuel cells will provide significantly reduced CO_2 emissions, in addition to negligible emissions of pollutants when operating using fossil fuels.

For More Information, Contact: Vic Der, Director, Power Systems, Office of Coal and Power Systems, (301-903-2700) or go to: www.fe.doe.gov/coal_power/fuel_cells/fc_sum.html

Combined Heat and Power

DOE Challenge: Enhancing Energy Security. Mitigating Environmental Impacts. Increasing Competitiveness and Reliability

Program Activity: This program is intended to assist industry and state agencies in developing and deploying clean, reliable, and affordable clean energy generation options for the 21st century. It focuses on identifying and removing regulatory and institutional barriers for the use of Combined Heat and Power (CHP) systems. DOE efforts provide leveraging mechanisms for accelerating the deployment of research, development and deployment investments in turbines, engines, fuel cells, HVAC, and humidity control equipment.

This is the second year of the CHP program. Activities have focused on launching a national information and education campaign on the energy, economic, and environmental benefits of CHP systems. The primary audience is state energy and environmental policy officials, particularly state public utility commissioners and staff and environmental siting and permitting officials. The Department has formed an alliance with the U.S. EPA to develop new policy actions and to clarify existing air quality regulations for CHP. EPA has joined with the Department in the CHP Challenge Initiative, which was announced in December, 1998 and aims at doubling the amount of CHP capacity in the U.S. by 2010. This means adding approximately 46 gigawatts of new CHP capacity in this timeframe.

To achieve the CHP Challenge Initiative goal, the U.S. Combined Heat and Power Association has started a vision and roadmap process to identify the most productive pathways for achieving the CHP Challenge goal. A series of conferences, workshops, and seminars have been held with CHP developers and state regulatory officials to identify better approaches for the siting, permitting, and interconnection of CHP systems. Financial assistance has been provided to state agencies in California, Washington, New York, Indiana, and Vermont to explore the CHP potential in those states and identify barriers to CHP implementation. Outreach workshops have been held in Maine, New York, and New Mexico. Regional workshops have been held in the Northeast, Midwest, and Pacific Northwest.

There is also a focused effort targeting increased use of CHP in commercial buildings. As part of this effort, the BCHP Initiative, a series of workshops have been held involving the natural gas industry, CHP developers, and building designers to determine R&D needs to tailor the integration of CHP systems for use in buildings for heating, cooling, power, and humidity control needs.

Accomplishments:

- Developed and disseminated information on CHP systems and regulatory and institutional barriers to CHP to hundreds of state officials, which has led to local efforts in New York, New Jersey, Illinois, Michigan, Wisconsin, Washington, New Mexico, and Maine to eliminate the unnecessary barriers to the installation of CHP systems;
- Held national and international conferences on CHP involving senior level policy officials and business executives to raise awareness of CHP benefits. This has led to the DOE-EPA partnership on CHP and a review of air quality regulations and their effects on CHP development. These conferences have also led to international initiatives with the UK, EC, and Canada on CHP development and deployment; and
- Launched the CHP vision and roadmap process led by the U.S. Combined Heat and Power Association involving hundreds of business executives representing equipment manufacturers, CHP developers, A&E firms, electric and gas utilities, energy services companies, and potential industrial and commercial CHP users.

Benefits: Doubling U.S. CHP capacity by 2010 will result in these net benefits:

- Net energy savings of 1276 trillion btus;
- Carbon reductions of 37 million metric tons;
- SO_2 reductions of 0.94 million tons;
- NO_x reductions of 0.42 million tons; and

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- Economic savings of $5.5 billion.

For More Information, Contact: Pat Hoffman, Team Lead, Distributed Energy Resources (202-586-2387) or go to: www.oit.doe.gov/chpchallenge

18117

DOE019-0084

Distributed Energy Resources

DOE Challenge: Enhancing Energy Security, Increasing Competitiveness and Reliability, Mitigating Environmental Impacts

Program Activity: In March 2000 a Distributed Energy Resources Task Force was established in the Office of Energy Efficiency and Renewable Energy (EERE), Office of Power Technologies. The Task Force consolidates the programs and staff from across EERE related to the development and deployment of distributed energy resources. The vision is for the U.S. to have the cleanest and most efficient and reliable energy system in the world through maximizing the use of affordable distributed energy resources. The focus is on technology development and the elimination of regulatory and institutional barriers to the use of distributed energy systems including interconnection to the utility grid and environmental siting and permitting.

The program directs and coordinates a diverse portfolio of research and development. Activities consist of investments in natural gas and renewable technologies including advanced turbines and microturbines, natural gas engines. fuels cells. and cooling. heating and power systems (CHP.) The program also conducts supporting research. development and deployment (RD&D) in enabling technologies such as advanced combustion systems. advanced materials. and sensors and controls. Additional efforts focus on energy generation and delivery systems and architectures for distributed energy resources to strengthen grid reliability in electricity transmission and distribution technologies. energy storage systems, grid interconnection technologies, power parks. mini grids. and district energy.

Outreach and implementation activities are also program priorities. These efforts are addressing infrastructure. institutional and regulatory needs in utility restructuring. environmental siting and permitting. uniform interconnection standards. tax provisions. state initiatives. and international recommendations of the Presidents Committee of Advisors on Advanced Science and Technology (PCAST.)

Accomplishments:

- Developed advanced turbine systems that achieve emissions (single digit NOx emissions), efficiency (40 percent LHV). and cost targets (competitive installation, O&M costs) for use in industry. commercial facilities. and district energy complexes for baseload power, backup power. and combined heat and power applications:
- Initiated RD&D for developing the next generation of microturbine and reciprocating engine systems for electric power and combined heat and power applications;
- Developed advanced engine driven heating. cooling. and humidity control equipment for use in commercial buildings that use natural gas. reduce electric power requirements, and are applicable to building cooling. heating. and power applications:
- Launched a transmission reliability R&D program aimed at understanding the technical requirements of competitive power markets and developing advanced systems for the interconnection of distributed power systems. real time systems control, and outage management:
- Developed advanced energy storage systems for use in utility applications for power quality and reliability; and
- Assisted state agencies in the development of utility restructuring concepts and plans to open electricity and natural gas markets to competitive market forces.

Benefits: Reduced air emissions. reduced fuel consumption. lower energy costs, greater power system reliability. better power quality. more customer choice. better customer energy services.

For More Information, Contact: Pat Hoffman. Team Lead. Distributed Energy Resources (202-586-6074) or go to: www.eren.doe.gov/der/

18118

Vision 21

DOE Challenge: Mitigating Environmental Impacts

Program Activity: The mission of Vision 21 is to effectively remove environmental concerns associated with the use of fossil fuels for producing electricity and transportation fuels (at competitive cost.) Vision 21 is a long-range (~15 year), industry-driven, research and development program aimed at creating technology that will allow future energy plants to achieve almost double the efficiency of today's power plants while virtually eliminating all harmful emissions. Technology innovation is emphasized. Designs for technology modules (plant subsystems and major components) will be developed along with the systems integration capabilities necessary to configure the modules into Vision 21 energy plants. Other products of the Vision 21 program will be improved computer design and simulation tools, including virtual demonstration, and spin-off technologies, e.g., air separation membranes for producing low-cost oxygen. The approach allows for the inclusion of carbon sequestration at a later time. In a report issued in May, 2000, the National Research Council recommends that over time, Vision 21 become the primary focus of the Office of Fossil Energy's program in coal and power systems. Also, the President's Committee of Advisors on Science and Technology (PCAST), in their November, 1997 report, endorse Vision 21. Vision 21, along with other Fossil Energy programs, plays a prominent role in the Department's Energy Resources R&D portfolio.

Accomplishments:

- Vision 21 solicitation issued September 30, 1999. The solicitation requests proposals in three areas: enabling and supporting technologies, systems integration, and advanced plant design and visualization software. There are four proposal submission periods; selections are made every three months. Minimum cost-sharing is 20 percent; and
- Selection of the first six projects was announced on March 7, 2000 (see DOE Techline.) These projects involve development of hybrid power systems (Fuel Cell Energy), oxygen separation membranes for fuel cell applications (Siemens Westinghouse and Praxair), hydrogen separation membranes (Eltron Research), a novel steam generator design for a high-efficiency power cycle (Clean Energy Systems), systems integration (National Fuel Cell Research Center), and model development for a virtual demonstration (Fluent.)

Benefits: A successful Vision 21 program will help ensure that our nation continues to have a plentiful supply of clean, low-cost energy essential to robust economic growth. When coupled with sequestration, Vision 21 technology will remove environmental concerns, including climate change, associated with the use of fossil-based energy. New advances for the manufacture of hydrogen will make gasification an important technology in the transition to a hydrogen economy.

For More Information, Contact: Vic Der, Director, Power Systems, Office of Coal and Power Systems, (301-903-2700) or go to: www.fe.doe.gov/coal_power/vision21/vision21_sum.html

Innovations to Existing Power Plants

DOE Challenge: Mitigating Environmental Impacts

Program Activity: The program is directed at existing power plants and has two major focuses: (1) develop advanced environmental control technology and (2) provide high-quality scientific data and analysis for use in policy and regulatory determinations. The program portfolio includes research and development activities aimed at either preventing the generation of pollutants during fossil fuel conversion or capturing them from effluents before they are released to the environment. Research is being conducted in the areas of control of fine particulate matter; mercury/air toxics, nitrogen and sulfur oxides, and utilization coal combustion byproduct. The program covers the entire "life cycle" of emissions and technology, from source speciation through advanced emissions control technology development and testing. The program has targeted a 50 percent reduction in overall environmental compliance costs through the development of advanced technologies and integrated systems. The achievement of this target is expected to provide over $6.5 billion per year savings by 2010.

Accomplishments: The Innovations for Existing Plants program has a strong history of assisting in the development of useful commercial products. Low-NOx burners (LNBs), advanced SO2 scrubbers, and other products have provided the United States with both billions of dollars of savings and a cleaner environment through lower-cost technology. For example, collaborative research with industry has lead to LNB technology capable of achieving 50 percent reductions in NOx emissions at an incremental cost of roughly 0.03 cents per kilowatt hour. In another example, advanced scrubbing technology developed under the program is lowering SO2 emissions at one Pennsylvania utility while saving the company over one-half million dollars in annual operational costs. The program has also provided unbiased, high-quality scientific and technical data to EPA and other federal agencies in response to regulatory actions regarding mercury, CCBs, and TRI.

Benefits: The aggregate cost of environmental compliance for coal-fired generators in the United States was $1.9 billion in 1997. It is projected that the cost of environmental compliance will increase by seven-fold to over $13 billion per year by 2010. This growth will be driven by calls for more stringent environmental regulations to address mercury, ambient fine particulates, regional haze, acid gases, acidification, eutrophication, air toxics, and their potential impacts on human health and on terrestrial and aquatic ecosystems. This Program will enable major reductions in this $13 billion annual compliance cost.

In addition, roughly 71 percent of the byproducts of coal combustion (CCBs) continue to be disposed of in landfills, at a cost of roughly $1 billion per year. New applications for CCBs will be developed to substantially reduce the volume of CCBs landfilled each year.

The program will meet these challenges through continued partnership with industry and other key stakeholders in the development of cost-effective technology and by providing quality scientific data and analyses associated with the environmental performance of coal-fired power plants.

For More Information, Contact: Doug Carter, Director, Planning and Environmental Analysis, Office of Coal and Power Systems, (202-586-9684) or go to:
www.fe.doe.gov/coal_power/environ/environ_sum.html

Power Plant Environmental Regulatory Analysis

DOE Challenge: Mitigating Environmental Impacts

Program Activity: DOE plays a significant role in the development of environmental regulation for the energy sector, particularly for fossil fuel-fired powerplants. Through one of the roles mandated DOE by Congress, to develop improved technologies to address environmental issues, DOE has amassed a large body of information on energy processes, energy conversion, the pollutants associated with such processes, and technologies to mitigate emissions. This knowledge base is provided to EPA, which has the final responsibility for regulations to protect the environment. This information has led to several positive outcomes, including the avoidance of unnecessary regulations, better approaches to address others, and development of altogether new technologies or technologies much less expensive than preceding technologies to reduce emissions.

Accomplishments:

- Development of information related to nitrogen oxides control technology to assist EPA in promulgating regulations for electric utilities. DOE participated in public meetings chaired by EPA, interagency regulatory review meetings chaired by OMB, and summarized information on the state of mitigation technology for the final EPA rule;
- Development of a database on toxic emissions from powerplants. The measured data demonstrated that emissions were much lower than previously estimated using less precise methods, and were used by EPA to avoid adoption of unnecessary regulations for several pollutants;
- Collection and analysis of data related to EPA's Toxic Release Inventory, and participation in interagency meetings influencing the final utility regulation by EPA: and
- Collection and analysis of data related to coal combustion wastes and participating in two cycles of interagency meetings leading to EPA decisions to regulate these wastes under State solid waste regulations, rather than more onerous Federal regulations.

Benefits: It is difficult to quantify the benefits of this activity because alternative outcomes are hypothetical. In just one of the rulemakings avoided, EPA cited costs up to one trillion dollars for the electric utility industry. In other rulemakings, development of advanced technologies enabled greater degrees of environmental protection than would otherwise have been possible.

For More Information, Contact: Doug Carter, Director, Planning and Environmental Analysis, Office of Coal and Power Systems, (202-586-9684)

Regulatory Oversight of Natural Gas Imports/Exports and Electricity Exports

DOE Challenge: Enhancing Energy Security

Program Activity: The Office of Fossil Energy (FE) is responsible for authorizing requests to import and export natural gas and electricity exports, as well as authorizing the construction of international electric transmission lines. Originally, the Federal Power Commission (FPC) exercised regulatory authority over cross-border natural gas and electricity trade; however, the Department of Energy Organization Act (1977) transferred this authority to the Secretary of Energy. This regulatory responsibility was given to the Secretary rather than to the Federal Energy Regulatory Commission (FERC), an independent regulatory body, because the DOE Act wanted all regulatory functions affecting international commerce to remain under the direct control of the President.

The principal objective of FE's regulatory oversight responsibilities is to maintain a program that promotes the freest possible international gas and electricity trade, with minimal government intervention. The regulatory program facilitates natural gas and electricity imports and exports which enhance the nation's energy security by minimizing our dependence on less secure supplies of oil; diversifying our energy sources; and reducing our vulnerability to the adverse impacts of supply disruptions. Further, the regulatory oversight promotes a level playing field that facilitates competition.

Accomplishments:

- Consistent with the Canada-United States Free Trade Agreement and the North American Free Trade Agreement, FE maintains a regulatory program that promotes market-sensitive natural gas and electricity trade, with minimal government interference;
- FE authorizes natural gas and electricity exports in a manner that encourages development of foreign markets for surplus natural gas and electricity supplies;
- FE determines the reliability and environmental impacts associated with installing international transmission lines and exporting electric energy;
- FE has extended the principles of non-discriminatory open access transmission service to international transmission lines; and
- FE monitors North American natural gas and electricity trade. It collects and publishes extensive data on cross-border natural gas trade in the Quarterly Report of Natural Gas Imports and Exports; the data are also used by the Energy Information Administration.

Benefits:

- DOE's light-handed regulatory policy regarding natural gas and electricity imports and exports has resulted in a more efficient, market-driven, and integrated North American energy market; and
- Natural gas imports have increasingly become a very important incremental source of supply to the growing gas demand in the United States. During 1999, natural gas imports from eight different countries (primarily Canada) supplied almost 16 percent of our country's total gas demand; this is compares with 4.2 percent in 1986.

For More Information, Contacts: Tony Como, Manager, Electricity Import Regulation, Office of Coal and Power Systems, (202-586-5935) or go to: www.fe.doe.gov/coal_power/elec_reg/elec_reg.htm

John Glynn, Manager. Natural Gas Import/Export Regulation. Office of Natural Gas and Petroleum Technology, (202-586-9454) or go to: www.fe.doe.gov/oil_gas/im_ex/gasimex.html

Energy Efficiency

Homes and Buildings

18124

Low Income Weatherization Assistance Program

DOE Challenge: Enhancing Energy Security, Mitigating Environmental Impacts

Program Activity: DOE's Weatherization Assistance Program has served as the nation's core program for delivering energy conservation services to low-income Americans since it was created by Congress in 1976. Low-income households spend about 14.9 percent of their income for energy needs, as opposed to the 3.5 percent of income spent on energy needs by other households. The Weatherization Program reduces this disproportionate burden. The program's resources are focused particularly on the elderly, persons with disabilities, and families with children.

Accomplishments:

- Through local agencies, the program has retrofitted over 4.7 million homes since 1976;
- Most local programs now use the National Energy Audit (NEAT), a computer program developed by ORNL for DOE which identifies the most cost-effective energy conservation measures specifically for each house, significantly boosting achieved energy savings;
- Improving program practices resulted in average savings of 33.5 percent of natural gas space heating consumption in 1996, 80 percent higher average savings than in 1989. Assuming that this same level of improvement was achieved in homes heated by other fuels, the annual energy savings for a home weatherized in 1996 is estimated to be 32.2 million btu. Over the 20-year average life of weatherization measures, this represents an energy cost savings of more than $3000 per house; and
- Over the average 20-year life of weatherization measures, these homes will save 108 trillion btu of energy, their occupants will pay $550 million less in utility bills, and 1.63 million metric tons of carbon emissions will be averted.

Benefits.

- Weatherization of low-income homes directly and immediately improves the health and safety of inhabitants by reducing carbon monoxide emissions and eliminating fire hazards, in addition to lightening the financial burdens of those most in need;
- The program's longer-term impacts include community revitalization; and
- The Weatherization Program also creates about 8000 jobs nationwide; 52 jobs grow directly from every million dollars invested in the program.

For More Information, Contact: Gail McKinley, Director, Office of Building Technology Assistance, (202-586-4074) or go to: www.eren.doe.gov/buildings/weatherization_assistance/

18125

Federal Energy Management Program

DOE Challenge: Enhancing Energy Security, Mitigating Environmental Impacts

Program Activity: The Federal Energy Management Program (FEMP) reduces the cost to government by advancing energy efficiency and water conservation, promoting the use of renewable energy, and managing utility costs of federal agencies. FEMP accomplishes its mission by leveraging both Federal and private resources to provide technical and financial assistance to other Federal agencies. The agencies make investments in projects that increase energy efficiency and renewable energy use, and reduce water consumption in their buildings, facilities and operations.

The President issued Executive Order 13123, "Greening the Government Through Efficient Energy Management," on June 3, 1999, providing new emphasis and commitment to improve the efficiency of Federal energy use. The Executive Order establishes new goals of improving efficiency in federal buildings by 35 percent by 2010 from the 1985 baseline, and reducing greenhouse gas emissions attributable to Federal buildings energy use by 30 percent from 1990 levels by 2010. FEMP helps agencies achieve their needs by providing alternative financing tools and guidance to use the tools, technical and design assistance for new construction and retrofit projects, training, technology transfer, procurement guidance, software tools, and reporting and evaluation of all agencies' programs.

Accomplishments:

- Between 1985 and 1999, the government achieved a 21.1 percent reduction in site based energy intensity (energy used per square foot of building floor space), meeting the 2000 goal one year early;
- Half of these savings is attributable to the FEMP program;
- FEMP trained over 13,000 Federal energy managers since 1992; and
- FEMP established 44 regional and technology energy savings performance contracts (ESPC.)

Benefits:

- FEMP helps agencies save energy and money;
- Agencies can potentially achieve an estimated $2 billion in cumulative investment in their facilities via FEMP Super ESPCs and utility energy service contracts over the 2002-2010 time frame (which averages to $240 million per year); and
- By the end of 2010, the Federal renewable energy use is estimated to increase by 7.5 percent relative to a 1990 baseline.

For More Information, Contact: Beth Shearer, Director, Federal Energy Management (202-586-5772) or go to: www.eren.doe.gov/femp

18126

Whole Buildings Approach

DOE Challenge: Mitigating Environmental Impacts

Program Activity: We have found that an effective way to optimize energy performance in buildings is to integrate efficiency components, accounting for all interactive effects, including non-energy effects. In addition to improved energy performance, the resulting improvements in indoor environmental quality, comfort, productivity (in workplaces and schools) and affordability will bolster support for improved building energy efficiency at all levels. However, the building industry encompasses literally thousands of different businesses and millions of individual decision makers. The resulting fragmentation separates developers, designers, builders, utilities, engineers, and occupants from one another as they pursue objectives which often are at cross-purposes. Fragmentation also results in lower-than-average profit margins for many firms, often making it difficult for these firms to invest in efficiency strategies that add to up-front construction costs.

The DOE Building America program is the flagship program of the whole building approach. The Building America program brings together architects, engineers, builders, equipment manufacturers, material suppliers, community planners, mortgage lenders, and contractor trades. These teams use a systems engineering approach to identify highly energy efficient building designs with little or no additional net up-front costs. Up-front cost savings can occur, for example, when improved insulation and duct systems allow the size of the heating and cooling systems to be reduced. Currently, there are five teams comprised of more than 50 different companies. Team members agree to evaluate their design, business, and construction practices to identify cost savings and re-invest cost savings in improved energy performance and product quality. Everyone benefits from the improved knowledge of which whole building strategies typically work best.

Concurrent DOE work on building performance design tools also contributes to the whole building approach, by helping builders take full consideration of energy efficiency options and their interactions in their building designs. The whole building approach is being extended to address efficiency improvement in existing homes (where the Weatherization Assistance Program already makes widespread use of similar building design tools), and new and existing commercial buildings. The lessons learned through these innovative research and engineering activities will be transferred to broader markets through state grants, community-based partnerships, and information and outreach efforts that catalyze rapid market adoption of the whole building approach.

Accomplishments:

- Building America partnerships have produced several hundred homes, and plans are in place to build several thousand more. Dissemination of results continues;
- Since its launching in 1998, Building America has led the energy efficiency efforts of the Presidential Initiative "Partnership for Advancing Technology in Housing"; and
- DOE-developed design tools are used by a wide spectrum of interests, from technology researchers, code developers, local officials, building designers, owners and developers.

Investments:

- Building America and related programs have averaged $7 million dollars in appropriated funding for technical assistance since 1996. No DOE funds are used for capital expenditures.

Benefits:

- The goal of the Building America program is to produce homes that: use 30 percent to 50 percent less energy; reduce construction time and waste by as much as 50 percent; improve builder productivity, provide new product opportunities to manufacturers and suppliers; and implement innovative energy- and material-saving technologies, all at little or no incremental cost to the builder or the consumer.

For More Information, Contact: John Talbott. Office of Buildings Systems, (202-586-9455) or go to: www.eren.doe.gov/buildings/building_america

18128

Appliance and Equipment Standards

DOE Challenge: Enhancing Energy Security, Increasing Competitiveness and Reliability, Mitigating Environmental Impacts

Program Activity: During its lifetime, the operating costs of an appliance may exceed its initial purchase price several times over. U.S. homeowners spend $1,329 per household each year to operate such home appliances as refrigerators, freezers, clothes washers, clothes dryers, water heaters, furnaces, air conditioners, and lights.

Recognizing the great potential for energy savings, many states began prescribing minimum energy efficiencies for appliances during the late 1970s and early 1980s. Anticipating differing state standards, manufacturers supported developing federal standards. These were enacted as the National Appliance Energy Conservation Act (NAECA) of 1987. There are now national efficiency standards for most home appliances and equipment. DOE periodically reviews and updates these efficiency standards for most household appliances. Although efficiency measures may add a small cost to products, the efficiency standards are set at levels where the extra costs are rapidly offset by energy savings.

Accomplishments:

- Final appliance standards have been issued for small gas furnaces and refrigerator products (1989), clothes washers, dishwashers and clothes dryers (1991), refrigerator products (1997), room air conditioners (1997), electric cooking products (1998), and for electric motors (1999) and plumbing products (1998) used in a range of applications;
- New standards are under development for fluorescent lamp ballasts, water heaters and residential central air conditioners and upgraded standards are under development for clothes washers and certain commercial heating, air conditioning and water heating equipment as contained in the American society of Heating, Refrigerating and Air-conditioning Engineers, Inc. (ASHRAE) and Illuminating Engineering Society of North American (IES) 90.1-1999; and
- Appliance energy costs have dropped significantly as a result. For example, the new standard for refrigerators which will become effective July 1, 2001 will reduce the energy consumption of the typical top-mount automatic defrost refrigerator-freezer to about 500 kilowatthours of electricity per year. (Similar models in use consume between 700-972 kilowatthours a year.)

Benefits:

- Since the enactment of the National Appliance Energy Conservation Act of 1987, the Department has issued eight appliance energy efficiency standards final rules. In 2000, these standards, including those set by law, are expected to save consumers $4.7 billion in reduced energy costs, or an average annual savings of $44 per U.S. household;
- Based on these forecasts, each federal dollar spent on the appliance standards program will result in consumer savings of about $1,000; and
- More efficient products are more competitive internationally and have environmental benefits from reduced atmospheric emissions.

For More Information, Contact: Ed Pollock, Office of Building Systems, (202-586-5778) or go to: www.eren.doe.gov/buildings/codes_standards/index.htm

Energy Efficiency

Industry

18131

DOE019-0098

Industries of the Future

DOE Challenges: Economic Security, Competitive Restructuring, Environmental Improvement

Program Activity: DOE partners with the most energy intense domestic industries to identify and pursue common technology needs through public-private sector partnerships. The industry visions process enables and encourages industries to work together to: create broad industry wide goals for the future that incorporate the DOE challenges and industry objectives; identify specific needs and their priorities through a system design modeling process called roadmapping and, to form cooperative alliances to help attain those goals cost effectively through diverse technology partnerships; take advantage of departmentally-developed crosscutting technical assistance.

Accomplishments:

Vision Title: Forest Products	Nov-94		initiative. selected for funding the first demonstration project. Have funded over 90 research and development projects. DOE has funded over 90 projects supporting the industry vision and roadmap. Partners include 20 universities, 11 national laboratories, 10 suppliers, 2 research institutes and about 30 forest product companies.
Steel	May-95	Aug-97	Twelve commercial successes including furnace sensors, models and controls, and new alloy (nickel aluminide) applications multiplying service life. Six process developments in the waste oxide recovery, recycling, steelmaking, furnace heating and coating. Two important steel technology showcases were held.
Aluminum	Mar-96	May-97	New energy efficient technologies developed include: A filtration system for primary aluminum, a novel grain refining system, a vertical floatation melter and scrap dryer, and vitrification technology to produce glass fiber from spent aluminum potliners. Three inert anode materials and cell designs have been developed and are being tested. Developed, tested and demonstrated improved wettable cathodes that could reduce energy intensity of primary production by 10+ percent.

Major Successes:

Roadmap Date:

Vision Date:

Mar-99 Launched gasification

18133

DOE019-0100

Vision Title: Sep-95

states. Commercialized a 3–sensor "air gauging system" for maintaining the dimensional accuracy of the advanced lost foam casting process.

Metal Casting

Commercialized a PC-based modeling program for die casting flow simulation to reduce development lead time and scrap from die try-outs. Developed a clean cast steel technology resulting in significant time and material savings, fewer defects and reduced weld repairs.

Jan-98

Commercialized oxy-fuel firing technology now in place in over 30 percent of all glass plants. Technology improved productivity, and reduces energy and environmental emissions. Helped to organize the Glass Manufacturing Industry Council (GMIC) representing over 72 percent of U.S. glass production Commercialized oxygen enriched air-staging which dramatically reduces NOx emissions.

Jan-96

Glass

Formed Computational Fluid Dynamics consortium whose tools are now used by chemical companies to shorten energy efficient production process technology development time. Commercialized Super critical CO2, Nylon Carpet Recycling process technology, Membrane technology to recover chemicals, and Silicone manufacturing waste recovery process. Developed a total cost assessment tool and sustainability metric methodologies to assess chemical plant impact on the environment.

Nov-98

Dec-96

Chemicals

Completed two mining roadmaps: crosscutting technologies and processing. Awarded 26 projects. Several technologies are nearing commercialization.

Feb-99

Sep-98

Mining

Major Successes:

Roadmap Date:

Vision Date: Mar-98

Broad partnership with industry involving 250 partners in 32

Vision Title:	Vision Date:	Roadmap Date:	Major Successes:
Agriculture	Apr-98	Feb-99	Established industry executive steering group to oversee implementation of vision and roadmap. Issued three solicitations since program inception with 16 project awards. In partnership with Cargill-Dow's joint venture, accelerated commercialization of technology for turning plant-derived matter into industrial chemicals at the first global-scale factory in Blair, Nebraska.
Petroleum	Feb-00	In process	A first round of procurements has been initiated to address key technology areas identified in the vision and roadmap. Vision signed in February, 2000.

Benefits:

- Enables industry cooperation and sharing of technology and resources;
- Encourages research, development and deployment (RD&D) that would not otherwise happen;
- The nation, its industries and consumers receive energy, environmental and cost savings years earlier;
- Through cooperative cost-shared RD&D programs industry and government pool resources and share risks; and
- Preserves and improves U.S. industry competitiveness.

For More Information, Contact: Douglas Kaempf, Program Manager, (202-586-5264) or go to: www.oit.doe.gov/industries.html

Oil and Gas

18136

Oil Supply Research and Development

DOE Challenge: Enhancing Energy Security

Program Activity: The Oil R&D Program focuses on the development of technology needed to sustain domestic oil production in an environmentally responsible manner. The program focuses on high-risk or underutilized technologies that private industry alone will not undertake.

Historical data demonstrate that technology advances are key to keeping energy prices low for consumers and maintaining the profitability and long-term survival of the domestic oil and gas industry.

Accomplishments:

- Oil Reservoir Class Program includes 32 projects with a total DOE investment of $118 million and industry co-funding of $150 million. In one project, reservoir characterization and process analysis of an idle lease in Midway-Sunset field, California found 4.5 million barrels of new recoverable reserves in new and previously abandoned reservoirs on the 40-acre property. The technology has already been transferred to other field areas;
- Petroleum Technology Transfer Council (PTTC), formed in 1994, to provide independent oil operators easy and timely access to new technology, includes 10 regional resource centers, workshops, websites, outreach activities, publications and software;
- Coiled Tubing Horizontal Drilling Systems models developed by the program increase coiled-tubing drilling efficiency and reliability. Coiled tubing drilling systems have a 50 percent smaller footprint and reduce drilling costs by almost 40 percent; and
- Four-Dimensional Seismic, which integrates multiple 3-D seismic surveys, has been commercially applied to 21 Gulf of Mexico fields after it was developed by the program in 1994.

Benefits

- Oil R&D Program projects are expected to add over 1 million barrels of oil per day in 2010.

For More Information, Contact: Edith Allison, Program Manager for Exploration, Office of Natural Gas and Petroleum Technology, (202-586-1023) or go to: www.fe.doe.gov/programs_oilgas.html

Natural Gas Supply Research and Development

DOE Challenge: Mitigating Environmental Impacts, Providing Diverse Energy Technologies

Program Activity: Natural Gas Research & Development Program focuses on the development of technology needed to supply the growing demand for natural gas. The program focuses on high-risk or underutilized technologies that private industry alone will not undertake.

Historical data demonstrate that technology advances are key to keeping energy prices low for consumers and maintaining the profitability and long-term survival of the domestic oil and gas industry.

Accomplishments:

- 3-D Seismic advances for fracture imaging and advanced drilling technologies developed by the Energy Department and the Gas Research Institute, led to record breaking horizontal well in the Greater Green River Basin in southwestern Wyoming. The additional drilling using this technology could generate almost $10 million in Federal and State royalties; and
- Horizontal Drilling research led to air motors now being used for most new wells drilled in eastern gas formations. Horizontal drilling techniques, that use air in place of mud to drive and cool the downhole bit motor and remove drilling debris, have vastly improved the efficiency of drilling in Appalachian reservoirs, where mud use causes formation swelling and fracture blockage.

Benefits: It is estimated that in 2010, almost 2 trillion cubic feet of gas per year will be produced as a result of projects funded within the Gas R&D Program.

For More Information, Contact: Edith Allison, Program Manager for Exploration, Office of Natural Gas and Petroleum Technology, (202-586-1023) or go to: www.fe.doe.gov/programs_oilgas.html

18138

Ultra-Clean Transportation Fuels

DOE Challenge: Enhancing Energy Security

Program Activity: The Ultra-Clean Transportation Fuels Program is a joint effort of the Office of Energy Efficiency and Renewable Energy and the Office of Fossil Energy. The goal of the Program is to promote, in partnership with all sectors of the refining and transportation industries, the development and deployment of advanced fuels, refinery processes and vehicle technologies. The advanced fuels technology will produce ultra-clean burning, high performance transportation fuels for the 21st century from a diversity of resources in addition to conventional petroleum. These will support the introduction of advanced, highly efficient fuel/engine combinations that meet EPA Tier II emission standards and possible future, more stringent standards. Promotion of resource diversity will result in other feedstocks in addition to petroleum (e.g. natural gas, petcoke, biomass, coal, etc.) being used to produce ultra-clean fuels, thereby reducing our dependence on imported petroleum. These ultra-clean liquid fuels will use the nation's existing transportation infrastructure.

Accomplishments:

- Determined diesel fuel formulation could reduce particulate emissions by up to 50 percent, and NOx emissions by up to 10 percent, without any changes to the engine;
- Demonstrated a light-duty diesel vehicle with prototype emission control devices that met the fleet average Tier 2 emissions for particulates and NOx for limited durability with ultra low sulfur diesel;
- Identified a group of 8 oxygenates that could reduce particulate emissions from diesel fuel and potentially increase its renewable content;
- Identified several new classes of ceramic membrane and seal materials that are necessary to reduce the capital cost of gas to liquids technology by 25-30 percent;
- Awarded several Early Entrance Coproduction Plant feasibility. These plants would co-produce ultra-clean transportation fuels, chemicals and electricity from a variety of feedstocks; and
- Received proposals for projects to be implemented under Ultra Clean Fuels Transportation Solicitation, 1st Round.

Benefits:

- Provides ultra clean fuels needed for advanced engines used to power automobiles (PNGV), light- and heavy-trucks while meeting Tier 2 emission standards.

For More Information, Contact: Lowell Miller, Director, Coal Fuels and Industrial Systems, Office of Coal and Power Systems, (301-903-9451), and Stephen Goguen, Team Leader, Office of Transportation Technologies, (202-586-8044) or go to. www.fe.doe.gov/techline/tl_ultrafuel1.html

Royalty Rates on Federal Lands

DOE Challenges: Enhancing Energy Security

Program Activity: DOE has worked with the Department of Interior, the Bureau of Land Management (BLM), and the Minerals Management Service (MMS) for the last 10 years to find cost-effective incentive royalty rates to promote development of petroleum resources on Federal lands.

Accomplishments:

BLM

- Worked closely with the BLM to develop royalty relief programs for stripper oil wells and heavy oil wells on onshore (BLM) Federal lands; and
- Provided expertise and modeling support for these initiatives. This work includes supporting the original development of these royalty relief programs in the last 7 years, and also the 5-year reviews of each program.

MMS

- Assessed and commented on royalty relief proposals by the Federal offshore (OCS) program. This includes the deepwater royalty relief program that was passed in 1995, and will expire in November, 2000.

Benefits:

- All of the current royalty relief programs were determined to be cost-effective for the government in terms of not losing (or adding) royalty revenues for the Federal Treasury;
- These programs have also benefitted the industry by supporting marginal operations or promoting new development in high-cost frontier areas; and
- The added supplies of oil and natural gas help supply the nation's demand for these products, and reduce imports

For More Information, Contact. John Pyrdol, Chief Economist, Upstream Natural Gas and Petroleum, Office of Natural Gas and Petroleum Technology (301-903-2773) or go to: www.fe.doe.gov/oil_gas/modeling/oilgas_modeling.html

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Market Access and Emergency Oil and Gas Loan Guarantee Programs

DOE Challenge: Enhancing Energy Security

Program Activity: The energy marketplace is undergoing profound changes. Small, independent oil and gas producers (the backbone of the domestic oil and gas industry) are finding it harder to obtain the capital needed to maintain and/or enhance production from marginal wells. Deregulation of the gas and electric industries is changing how these products are marketed and is creating numerous opportunities—and challenges—for small and disadvantaged businesses.

The Market Access Program works to provide opportunities for small, disadvantaged businesses, women and minority-owned businesses, small independent oil and gas producers, and oil field service companies, in this new energy marketplace. Begun in 1996, the Program works to remove or circumvent obstacles blocking small business access to oil and gas markets, identifies opportunities for small businesses in this market, and develops procedures to assist small businesses take advantage of these opportunities.

The Market Access Program is currently: working with the Emergency Oil and Gas Loan Guarantee Board to re-shape the Emergency Oil and Gas Loan Guarantee Program in a way that makes federal loan guarantees accessible to small, independent oil and gas producers and oil field service companies; developing workshops on opportunities for minority businesses in the natural gas industry; assisting small and disadvantaged businesses qualify for, purchase, and resell the royalty-in-kind natural gas being sold by the Minerals Management Service; and, identifying federal and state economic development funds for which small, independent oil and gas producers might qualify.

Accomplishments:

- Created the DOE Natural Market Access Program for Small and Disadvantaged Businesses. The Program, in turn, created a Roundtable that serves to coordinate DOE support to small and disadvantaged businesses competing in the natural gas marketplace;
- Took a credit instrument developed by a small business (the Funds Transfer Agent Agreement) and convinced the Gas Industry Standards Board (GISB) to incorporate this financial instrument in the GISB Base Contract for Short-Term Purchase or Sale of Natural Gas;
- Persuaded the Office of the Comptroller of the Currency to award Community Reinvestment Act (CRA) credit to banks that serve as a Funds Transfer Agent for small and disadvantaged businesses. Several banks are now using this instrument to provide financing to small and disadvantaged businesses marketing natural gas;
- Worked with the General Services Administration, Office of Public Utilities, to qualify small and disadvantaged businesses to market offshore royalty-in-kind natural gas to federal facilities;
- Signed an Memorandum of Understanding with the Small Business Administration under which SBA agreed to work with DOE to assist small, independent oil and gas producers qualify for SBA 7(a) loan guarantees;
- Assisted the Emergency Oil and Gas Loan Guarantee Board to develop Emergency Oil and Gas Loan Guarantee Program implementing regulations. Also, conducted a series of 10 workshops around the country designed to educate stakeholders in the domestic oil and gas industry about SBA and USDA loan guarantee programs and also the Emergency Oil and Gas Loan Guarantee Program; and
- With DOE encouragement, the National Association of Regulatory Utility Commissioners (NARUC) approved a Resolution, In Support of States Adopting Efforts to Increase Participation of Small and Disadvantaged Business and Women and Minority-Owned Business in the Natural Gas Industry. NARUC and DOE are collaborating on efforts to encourage state regulated utilities to diversify their supplier base.

Benefits:

- Preserve domestic oil and natural gas productive capacity;

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- Increase (or slow the decline of) domestically produced oil and natural gas;
- Promote natural gas utilization;
- Increase competition, and thereby reduce prices, for natural gas; and
- Support DOE Diversity Initiative.

For More Information, Contact: Peter Lagiovane, Analyst, Planning and Environmental Analysis, Office of Natural Gas and Oil Technology, (202-586-8116) or go to: www.fe.doe.gov/oil_gas/americaoil/loanprog_main.html

Public Lands Access

DOE Challenges: Enhancing Energy Security

Program Activity: DOE has worked with other agencies since 1994, to increase access to oil and gas resources on public lands for environmentally responsible and protective exploration and production. DOE funds research projects cooperatively with the Bureau of Land Management (BLM) and the Minerals Management Service (MMS) to understand the impacts of oil and gas activities on Federal lands and to improve environmental performance. Other parts of DOE's oil and gas research program improve access by developing technologies and practices that reduce footprint, reduce wastes, and improve environmental protection.

DOE also works with other agencies on regulatory and land management policy, making sure that the energy policy perspective is represented in their decisions, that regulations and processes are streamlined, and that credible data, sound science and technology advancements are incorporated in land use planning, NEPA decisions, and permit reviews.

Accomplishments:

- Worked closely with BLM on their Oil and Gas Performance Review to streamline and improve their leasing and permitting system;
- Contributed data and expertise to the Federal land access analysis section of the recent National Petroleum Council Natural Gas Study. Broadening that analysis in cooperation with BLM, the Forest Service, and USGS;
- Established an Interagency Work Group on Natural Gas within the White House National Economic Council to respond to the recommendations of the National Petroleum Council Natural Gas Study;
- Performed analysis of air quality modeling issues for assessing the impacts of oil and gas activities on Federal lands on air quality in the Rocky Mountain region;
- Submitted comments to BLM supporting environmentally responsible leasing of the NPR-A. Successful lease sale held in May, 1999. Three wells drilled during the 1999-2000 drilling season;
- Facilitated EPA's accelerated rulemaking for use of synthetic based, environmentally friendly muds for offshore drilling;
- Developed a Safety and Environmental Management Program template, cooperatively with MMS, for independent operators working in the OCS;
- Funding nine projects under the Public Lands Technology Partnership with BLM to improve access;
- Conducted modeling analysis for BLM of the impact of accelerated leasing on oil and gas production and reserve additions;
- Participating in the Federal Leadership Forum, an interagency group that is streamlining the NEPA process for oil and gas development on Federal lands in four western states; and
- Participating in the Wyoming Oil and Gas Assessment, a Federal-State effort to establish agreed-upon resource estimates and future oil and gas development scenarios for Wyoming, as a basis for resource management planning and environmental analysis.

Benefits:

- Promotes environmentally-sensitive development of oil and natural gas resources on Federal lands to meet the nation's needs for these products, reduce imports, and improve the environment; and
- The new development also generates additional royalty revenues for the Federal Treasury.

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For More Information, Contact: Bill Hochheiser, Manager, Oil and Gas Environmental Research, Office of Natural Gas and Petroleum Technology, (202-586-5614)

Alaska North Slope Oil Exports

DOE Challenges: Enhancing Energy Security

Program Activity: In 1995, Congress removed the ban on the exports of oil from the Alaska North Slope (ANS.) Recently, there have been proposals to reinstate the ban because of a concern about high gasoline prices in California.

DOE has assessed the situation, and concluded that allowing the export of ANS oil has benefitted the nation, and has not resulted in higher gasoline (or other product) prices to consumers.

Accomplishments:

- In 1995, DOE provided much of the analysis that supported the legislation to lift the export ban, forecasting benefits for domestic producers;
- In May 2000, DOE assessed the impacts of having the ban removed for the last 5 years; and
- Congressional staff have been advised that DOE has found the removal of the ban to be beneficial to producers, and has not resulted in higher prices for consumers. This conclusion is supported by GAO (in a 1999 study required by the 1995 law), and the Commerce Department.

Benefits:

- ANS producers, as well as California producers of oil with similar qualities, have benefitted from higher crude oil prices (about $1/bbl.) This will provide them an incentive for further exploration which could result in a more domestic oil and natural gas production to meet the nation's needs. This would also reduce imports;
- ANS producers have benefitted with more options to sell their crude oil;
- Alaska has benefitted with higher tax revenues associated with the higher ANS oil prices; and
- Consumers have benefitted because the prices they pay for petroleum products were not affected by lifting the ban.

For More Information, Contact: John Pyrdol, Chief Economist, Upstream Natural Gas and Petroleum, Office of Natural Gas and Petroleum Technology, (301-903-2773)

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Regulatory Streamlining in Oil and Natural Gas Supply

DOE Challenge: Enhancing Energy Security

Program Activity: The Department of Energy works cooperatively with States and other Federal agencies to streamline regulations and enhance the efficiency and effectiveness of government programs that affect U.S. oil and gas supply. These activities enable other agencies to make use of the Department's unique expertise in oil and gas supply issues and technology. DOE actively participates in advisory committees and interagency work groups to provide a national energy perspective and to promote cost-effective approaches for protecting the environment.

Accomplishments: Consistent with recommendations of the National Petroleum Council, an advisory body to the Secretary of Energy, on Future Issues – A View of U.S. Oil and Natural Gas in 2020 and Meeting the Challenges of the Nation's Growing Natural Gas Demand, DOE has worked with other agencies to address policy and regulatory issues related to oil and gas supply ranging from the regulation of consumer fuel choice to achieve national air quality objectives, Clean Water Act permitting, Federal land management, tax policy, royalty relief, conflicts on pipeline siting, safety and environmental management planning, and electronic permitting.

Highlights include:

- Work by DOE and other Executive Branch agencies on more than 14 priority Issues for Interagency Consideration identified by the National Petroleum Council in 1996;
- Efforts undertaken by DOE and other Executive Branch agencies to preserve the production capacity of the domestic oil and gas industry during the low oil price situation of 1998 and 1999 which included initiatives to lower the costs of oil and gas production;
- Grants from DOE that have enabled more than 14 States to adopt improved data management techniques to facilitate risk-based decisions for protecting ground water resources and more cost-effective implementation of oil and gas regulatory programs;
- The successful demonstration of an innovative on-line permitting system by the Railroad Commission of Texas, with support from DOE, that could save Texas oil and gas producers $3 million to $6 million per year;
- Efforts by DOE to increase awareness of the Environmental Benefits of Advanced Oil and Gas Exploration and Production Technology;
- Participation in the Federal Leadership Forum, an interagency group that is streamlining the NEPA process for oil and gas development on Federal lands in four western states; and
- Collaborative efforts undertaken by DOE and industry, in coordination with the Environmental Protection Agency, to ensure the availability of ultra-clean fuels.

Benefits: Potential outcomes of regulatory streamlining and improved government coordination include improved, more cost-effective regulatory and policy decisions, reduced delays, cost savings for industry and government, and related opportunities for more efficient recovery and utilization of our Nation's valuable oil and gas resources, increased Federal and State revenues, jobs and economic activity.

For More Information, Contact: Bill Hochheiser, Manager, Oil and Gas Environmental Research, Office of Natural Gas and Petroleum Technology, (202-586-5614) or go to: www.fe.doe.gov/oil_gas/modeling/oilgas_modeling.html

Natural Gas Infrastructure Reliability

DOE Challenge: Increasing Competitiveness and Reliability. Mitigating Environmental Impacts

Program Activity: Natural Gas Infrastructure Reliability program assists industry to ensure the integrity and efficiency of the Nation's natural gas infrastructure and storage system. The reliability of the natural gas distribution and transmission systems across the United States is essential to ensure the availability of clean, affordable energy for our homes. businesses and industries. The Natural Gas Infrastructure program includes the Gas Storage Technology program initiated in FY 1993, and a new program initiated for FY 2001—Enhancing Infrastructure Reliability. Efforts are being directed to enhance energy system reliability with the Nation's natural gas pipelines and gas storage facilities.

The goal of the natural gas infrastructure reliability program is to develop and promote, in partnership with the gas storage, transmission, and utility distribution segments of the gas industry, technologies to enhance and expand the gas system infrastructure to meet a 30 Tcf market by 2015.

The gas industry and its suppliers face significant regulatory, technology, and market challenges to reach the 30 Tcf market. Regulatory constraints in the expansion of transportation and distribution pipeline systems and storage facilities could impede industry progress, harm the economy, and weaken the environment. Technology constraints could lead to increased fugitive emission methane leaks from the aging gas transmission and distribution system. Market constraints could lead to higher gas prices for consumers and the power generation sector. Industry mergers and increased competition have reduced private sector incentives for long-term R&D. Many utility managers. in their efforts to reduce shareholder risk, have abandoned long-term resource planning and resisted making capital investments in pipeline operations and gas storage system development. Government funding of "public benefit" R&D has become essential and more critical to ensure the integrity of the gas delivery and storage infrastructures in maintaining system throughput and in meeting future gas demands as R&D funding by private firms and the Gas Research Institute (GRI) declines.

To achieve the DOE challenge, the Department and the National Energy Technology Laboratory (NETL). have started a process to develop a vision and roadmap to enhance infrastructure reliability. NETL held a series of meetings and workshops with business executives representing transmission and utility distribution companies, equipment manufacturers. energy service companies, gas storage operators, national laboratories, and Federal agencies and state government to identify the most productive areas of infrastructure research to ensure the integrity and efficiency of the natural gas delivery system.

Accomplishments:

- Launched natural gas infrastructure reliability program vision and roadmap process, led by NETL. which involved business executives representing transmission and utility distribution companies. equipment manufacturers. energy service companies, gas storage operators, national laboratories, and Federal agencies;
- Initiated advanced high-deliverability gas storage research in non-reservoir rock formations to serve peak power customers in the Northeast. Developed conceptual designs to demonstrate the feasibility and commercialization potential of Lined Rock Cavern Storage; and
- Initiated research on direct energy meters. capable of measuring gas volume flow, gas composition. and energy content.

Benefits.

- $200 million savings to consumers by 2010 from gas storage facilities using ultrasonic and direct energy meters;
- 255 Bcf/year of additional storage deliverability by 2010;
- Advanced storage well revitalization technologies will increase storage well deliverability

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(projected at 28 percent or 800 MMcf/day by 2010 for applicable sites) and lower utility storage costs;

- Salt cavern storage capacity will be increased (17 Bcf potential by 2010 with 10 percent reduction of minimum working gas pressure) without impact to environment and without increasing pipeline infrastructure;
- Supports use of technologies to detect and mitigate fugitive gas emissions to reduce greenhouse gas concentrations; and
- Supports distributed power systems and natural gas micro turbines and fuel cells.

For More Information, Contact: Christopher Freitas, Manager for Natural Gas Storage and Infrastructure, Office of Natural Gas and Petroleum Technology, (202-586-1657) or go to: www.fe.doe.gov/oil_gas/gasstorage/gas_storage.html

International Oil and Gas Forums

DOE Challenge: Enhancing Energy Security

Program Activity: The Forums, through structured discussions with foreign governments and companies, seek to promote the adoption of open-market principles and level playing field operations. These activities were developed through candid and open discussions between foreign government officials and petroleum companies and U.S. government and petroleum companies. The Forum format has proven successful in developing trust between parties in a low pressure environment that none the less has the benefit of government level assurances.

The program, begun in 1998, has as its focus developing trust between governments and petroleum companies in the development of policies, laws, regulations, and market operating systems that are open to all parties. The first Forum was conducted in 1998 in Beijing, China. Several U.S. government agencies and U.S. petroleum companies cooperated in the Forum which had participation of all the major Chinese government agencies related to petroleum production and all Chinese petroleum companies. A second Forum session was conducted in Houston, Texas in 1999.

Additional Forum sessions are planned for the future as well as ancillary meetings on specific topics such as natural gas regulation in the U.S. Other Forum structures with other governments are under consideration.

Accomplishments:

- Conducted Forums in China and the U.S. Expanded Forum activities to encompass Experts Working Groups of U.S. and Chinese government and industry participants.

Benefits:

- World-wide acceptance of open market principles protected by laws and regulations will facilitate the most efficient development of world petroleum resources, as well as provide opportunities for U.S. companies who are the leaders in petroleum technology development.

For More Information, Contact: Don Juckett, Director, Natural Gas and Petroleum Import and Export Activities, Office of Natural Gas and Petroleum Technology, (202-586-8830) or go to: www.fe.doe.gov/oil_gas/china_forum

International Oil Data Transparency

DOE Challenge: Enhancing Energy Security

Program Activity: Secretary Bill Richardson initiated a series of roundtable discussions regarding worldwide oil data to assess what could be done to provide better information regarding world crude oil supplies. The first roundtable was held on January 26, 2000. The U.S. Department of Energy and the University of Houston's Energy Institute co-hosted the event. The second roundtable was held in Madrid, Spain on July 14-15, 2000. The U.S. Department of Energy and the Government of Spain co-hosted the event.

The objectives were to promote a formal industry and government dialogue on what role, if any, data on international oil markets have played in recent oil price volatility, and whether improvements in data quality and collection will enhance market stability: and also to establish priority follow-up activities, including the need for additional discussion sessions.

Accomplishments:

- Drew audiences and panels from the best and most knowledgeable people in the oil data business, both domestically and internationally;
- Agreed that further discussions will be initiated and that they will have the support of the Secretary's office as well as other offices and organizations within DOE;
- An APEC initiative will begin action on production and consumption in the APEC economies beginning in October, 2000; and
- The International Energy Agency will host a continuation of the Madrid activity in the fourth quarter of 2000 to continue working on process related actions related to transparency in the producing and consuming nations.

Benefits:

- Assembling the best informed parties to discuss an issue that has great importance to large segments of the oil and gas industry is expected to bring about improvement in petroleum data gathering and analysis. This, in turn, will help stabilize the world oil marketplace and increase energy security for the U.S.

For More Information, Contact: Don Juckett, Director, Natural Gas and Petroleum Import and Export Activities, Office of Natural Gas and Petroleum Technology, (202-586-8830)

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International Oil Spill Workshops

DOE Challenge: Enhancing Energy Security

Program Activity: The workshops seek, through interaction with foreign governments and international organizations, using coordination and information sharing workshops, to improve the ability to respond to oil spills world wide. They will allow nations to better respond to oil spills within their borders and in international waters. Many American companies are preeminent in the field of oil spill containment and clean up and thus US industry should benefit from an increased international preparedness for oil spills.

The program, begun in 1999, has as its focus developing the ability of governments to respond to serious environmental threats brought about by oil spills. The first such workshop was conducted in 1999 for the Black Sea region. Many U.S. government and private organizations cooperated in the workshop, which had participation of all the Black Sea littoral states. A follow up workshop is planned for 2000.

Similar workshops are planned for the Caspian Sea, the Gulf of Guinea and Brazil.

Accomplishments:

- Conducted workshop on Black Sea, scheduled workshop for Cameroon, October 17-18, 2000.

Benefits:

- The existence of regional oil spill response organizations will lessen the chance of significant environmental degradation from oil spills. The ability to respond efficiently to oil spills will lessen the concern of environmental groups to development of world petroleum resources and thus provide for additional petroleum supplies available to the U.S. and others.

For More Information, Contact: Don Juckett, Director, Natural Gas and Petroleum Import and Export Activities, Office of Natural Gas and Petroleum Technology, (202-586-8830)

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International Production Sharing Agreement (PSA)

DOE Challenge: Enhancing Energy Security

Program Activity: Through interaction with executive and legislative branches of foreign governments, this activity seeks to improve the ability of the foreign government to offer PSAs and other appropriate contractual vehicles for oil and natural gas exploration and production. Such actions will allow those nations to better develop their petroleum resources, facilitate American company's participation in the host country's petroleum industry, and increase the availability of worldwide petroleum supplies.

The program, begun in 1998, has had its major focus in developing the legal system of Ukraine to permit the initiation of PSAs. 1999 saw the passage of the key legislation necessary for initiating PSAs in Ukraine, and in July, 2000, Ukraine legislature passed conforming legislative amendments to complete Ukraine's ability to offer competitive PSAs that conform to world standards. These actions allow US petroleum and other private companies to successfully participate in Ukraine's petroleum industry.

Similar, though less direct, activities will be carried out through the actions within the U.S./China Oil & Gas Industry Forum, through Asian-Pacific Economic Cooperation, and through cooperative activities with emerging economies where AID operates.

Accomplishments:

- Conducted several workshops in Ukraine;
- Provided assistance in Drafting PSA legislation;
- PSA legislation passed by Ukraine legislature;
- Provided assistance in Drafting conforming legislation; and
- Conforming legislation passed by Ukraine legislature.

Benefits:

- Several U.S. companies are participating in the initial activities relating to Ukraine's offering of PSAs for the development of domestic petroleum resources. This will increase the production of petroleum available to Ukraine and the worldwide oil market; and
- An expanded program will draw on the Ukrainian experiences to support better private investment access to emerging oil and natural gas economies.

For More Information, Contact: Don Juckett, Director, Natural Gas and Petroleum Import and Export Activities, Office of Natural Gas and Petroleum Technology, (202-586-8830)

Strategic Petroleum Reserve Fill—Royalty-In Kind

DOE Challenge: Enhancing Energy Security

Program Activity: On February 11, 1999, Secretary Richardson announced plans to resume fill of the Strategic Petroleum Reserve (SPR) using federal royalty oil from production in the Central Gulf of Mexico. The initiative was designed to replace approximately 28 million barrels of oil sold from the Reserve in FY 1996 and 1997 largely for deficit reduction purposes. The first contracts for the oil transfer were signed on March 31, 2000. Initially the oil was scheduled to arrive in batches continuously through November 2000. Some delivery schedules were renegotiated due to tight supplies and high oil prices, and deliveries initially scheduled from March through June were delayed. The delivery of oil is currently scheduled to continue until December 2001.

Accomplishments:

- DOE completed writing contracts for exchange and delivery of the oil to the SPR sites;
- The vast majority of the 28 million barrels have been delivered and are in SPR caverns, and all deliveries should be completed before the end of the year; and
- DOE gained over 600,000 extra barrels of oil as a result of the renegotiated schedules.

Benefits:

- Allows the U.S. to pursue long term energy security;
- Helps the United States to reassert international leadership among other energy consuming and stockpiling countries;
- Filling the SPR with royalty oil costs the Treasury revenues but does not require appropriations and allows the Government to retain a valuable asset; and
- Resuming fill of the Reserve increases the days of net import protection provided by the SPR and increases national energy security.

For More Information, Contact: John Shages, Director, Finance and Policy, Office of Petroleum Reserves, (202-586-1533) or go to: www.fe.doe.gov/spr/spr_rik.html

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Strategic Petroleum Reserve Life Extension

DOE Challenge: Enhancing Energy Security

Program Activity: On April 20, 2000, Secretary Richardson announced the completion of a 7-year, $328 million refurbishment of the Strategic Petroleum Reserve. The Life Extension Program was initiated in 1994 to upgrade or replace major systems by 2000, and ensure mission readiness through 2025. The program uses new technologies to increase reliability and reduce operating and maintenance costs.

Accomplishments:

- The Life Extension Program was completed ahead of schedule and nearly $42 million below its original cost estimate;
- Pumps have been upgraded, oil handling equipment streamlined and many of the control systems automated, making maintenance and inventory control more efficient and lower cost; and
- Close to half of the pumps, motors and valves have been eliminated from the physical infrastructure.

Benefits:

- Annual operating costs will be reduced by $12-$15 million per year over the next 25 years;
- The expected life of the four storage sites will be 25 years, essentially doubling the original design life and extending it to the year 2025;
- The critical systems reliability during a drawdown is greatly increased; and
- The number of employees has been reduced in compliance with the goals of the National Productivity Review.

For More Information, Contact: John Shages, Director, Finance and Policy, Office of Petroleum Reserves, (202-586-1533) or go to. www.fe.doe.gov/spr/spr.html

Home Heating Oil Reserve

DOE Challenge: Enhancing Energy Security

Program Activity: Last winter heating oil prices spiked to all time record highs. On March 18, 2000, the President proposed the creation of a 2 million barrel home heating oil reserve in the Northeast to supply additional heating oil to the market in the event of a future shortage. On July 10, 2000, the President directed the Secretary to use existing authority to establish an interim home heating oil reserve in the Northeast to help protect Americans from possible fuel shortages this winter. On July 19, 2000, the Defense Energy Support Center, acting as an agent for the Department of Energy, issued a solicitation requesting that companies submit offers to receive Strategic Petroleum Reserve crude oil in exchange for up to two million barrels of heating oil and storage capacity in the New England and New York/New Jersey areas. The Heating Oil Reserve will be in place by October 1, 2000.

Congress must enact legislation to provide specific authority for use of the Home Heating Oil Reserve. The House passed H.R. 2448 which extends the Energy Policy and Conservation Act and creates a heating oil reserve in the Northeast. The Senate amendments include set two conditions under which the President can release oil from the Home Heating Oil Reserve—a severe disruption in supply or an increase in the differential between crude oil and heating oil prices which is over 60 percent above the five year average.

Accomplishments:

- On July 10, 2000, Plan Amendment No. 6 was transmitted to Congress to establish a permanent Northeast heating oil reserve. The Plan Amendment becomes effective if Congress does not disapprove it in 60 days after submission;
- The FY 2001 Interior and Related Agencies Appropriations Bill included $4 million for the Home Heating Oil Reserve; and
- The Defense Energy Support Center awarded three contracts for two million barrels of storage—two contracts each for 500,000 barrels in New England (New Haven, Connecticut) and one contract for 1 million barrels in coastal New York Harbor (Woodbridge, New Jersey).

Benefits:

- A heating oil reserve would serve as an interim source of supplies to the region until other supplies can be transported either from other commercial sources or the Strategic Petroleum Reserve during a winter disruption preventing shortages and excessive prices;
- According to a 1998 DOE study, the expected benefits of a smaller 2 million barrels regional petroleum product reserve located in leased terminals in the Northeast would approximate or exceed its costs, provided that those costs could be reduced by trading Strategic Petroleum Reserve crude oil for distillate fill; and
- The distillate oil stored in the Northeast can be released in conjunction with Strategic Petroleum Reserve crude oil in the event of general oil disruption.

For More Information, Contact: John Shages, Director, Finance and Policy, Office of Petroleum Reserves, (202-586-1533) or go to: www.fe.doe.gov/programs_reserves.html

Coal

Coal-Related Activities

DOE Challenge: Mitigating Environmental Impacts

Program Activity: DOE/Office of Fossil Energy is the lead Federal agency for conducting research on coal use technologies, such as advanced coal-fired powerplants. This work includes policy and environmental regulatory analysis, as well as pure R&D.

Accomplishments:

- Coal use for generation of electricity in the U.S. has increased 17 percent over the past 10 years;
- 56 percent of U.S. electric power comes from coal;
- The price of electricity in the U.S. is among the lowest of any market economy, giving U.S. manufacturers a competitive edge in the global economy;
- A continuous stream of advanced technologies, developed through government/private sector partnerships, have enabled electric utilities to meet environmental standards which have become significantly more stringent over time;
- Advanced technologies are under development to provide near-zero emission coal-fired powerplants to meet future electricity needs; and
- Data and expertise have been provided to EPA to provide for more informed environmental regulations.

Benefits:

- Clean, low-cost power meeting more than one-half of U.S. needs;
- Pollution control technologies which have reduced environmental compliance costs by about one-half—with savings totaling several billion dollars per year; and
- Sound scientific technical data on which to base environmental regulations.

For More Information, Contact: Doug Carter, Director, Planning and Environmental Analysis, Office of Coal and Power Systems. (202-586-9684) or go to: www.fe.doe.gov/programs_coalpwr.html

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Clean Coal Technology Program

DOE Challenge: Mitigating Environmental Impacts

Program Activity: The Clean Coal Technology Program (CCT) began in 1985 as a joint effort between government and industry to demonstrate innovative coal-based technologies that addressed environmental and operational concerns in a competitive economic manner. A total of five competitive solicitations were conducted with the final project award occurring in 1996. Technologies demonstrated in the CCT Program include advanced electric power generation systems, environmental control devices, industrial applications, and coal processing for clean fuels. The program has a total of 38 projects and 26 have completed operational testing. Of the remaining 12 projects, five are in design, two are in construction, and five are in operation. Government participation is limited to 50 percent of the total project costs. However, industry has exceeded this requirement by funding over 65 percent of the total project costs for the 38 projects.

Accomplishments:

- Demonstrated a variety of NOx control technologies that provide a portfolio of cost-effective compliance options for the full range of boiler types;
- Demonstrated a variety of innovative flue gas desulfurization systems that have reduced capital and operating costs, can produce dry disposable wastes or valuable byproducts, and are capable of capturing multiple air pollutants;
- Provided valuable design and operational data for advanced combustion technologies including fluidized-bed combustion and integrated gasification combined cycle; and
- Reduced emissions and improved economic competitiveness of U.S. industry in energy-intensive applications through new combustion technologies, new fuel forms, and environmental equipment.

Benefits: The CCT Program has demonstrated the technology necessary to take advantage of the nation's coal resources while significantly reducing environmental impacts. Based on the performance demonstrated in the CCT Program, nearly one-half of the U.S. coal-fired generating capacity has installed low-NOx burners. Many of the flue gas desulfurization systems demonstrated in the CCT Program continue in operation today and hold significant promise for application in emerging markets. The advanced power generation projects are providing the basis for increased efficiency resulting in reduced greenhouse gases and very low pollutant emissions.

For More Information, Contact: Gene Kight, Financial and Procurement Director, Office of Coal and Power Systems, (301-903-2624) or go to: www.fe.doe.gov/coal_power/cct/cct_ipo/cct_ipo00.html

Sequestration

DOE Challenge: Mitigating Environmental Impacts

Program Activity: This Program focuses on development of technology to reduce net emissions by sequestering carbon, either through enhancing natural sinks (e.g., forestation) or by capturing the CO2 emitted from fossil-based energy systems and storing it in geologic formations of the deep ocean or converting it to benign (potentially reusable) form.

The primary goal of this research program is to be able to deploy sequestration technologies after 2015 which could offset all future growth in U.S. GHG emissions under a "business as usual" scenario, which amounts to hundreds of millions of tons of carbon per year by 2030, and increasing amounts thereafter. A secondary goal is to accomplish such reductions for less than $10 per ton of carbon—90+ percent below today's commercially available sequestration technologies. At $10 per ton, carbon reduction would be inexpensive enough that traditional market mechanisms, such as the vendors' desire to market "green power," could be sufficient to drive deployment of this technology.

Accomplishments: This long-term program is in its infancy, but several small-scale sequestration development projects are underway that were selected in the FY 1998 Novel Concepts solicitation, and feasibility studies have been initiated for projects selected under the Office of Fossil Energy's August and September 1999 solicitations.

Benefits: Sequestration is an essential tool, along with higher energy efficiencies and less carbon intensive energy sources, for long-term stabilization of atmospheric concentrations of GHGs at levels that protect the environment. Benefits include:

- Dramatically lower GHG emissions—potentially over 500 million ton per year carbon (2030);
- Substantially lower costs than other options with comparable reduction potentials; and
- Expanded policy options for managing climate change.

For More Information, Contact: Bob Kane, Manager, Climate Change Activities, Office of Coal and Power Systems, (202-586-4753) or go to: www.fe.doe.gov/coal_power/sequestration/index.html

Nuclear

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Advanced Light Water Reactor Program

DOE Challenge: Providing Diverse Energy Technologies for the Future

Program Activity: In the 1980s and 1990s the Department funded nuclear research that was cost shared with industry to develop the advanced light water reactors, a program established to ensure the viability of nuclear energy and to advance energy security and diversity in this century. This program was completed in 1997.

Accomplishments: Today, three vendors have brought their "evolutionary" designs to commercialization, with the first two boiling water reactors in operation today overseas. For example, the Kashiwazaki Kariwa Nuclear Power Station in Japan—the world's largest nuclear power station, supplying about 23 percent of Tokyo Electric's total capacity—is the site of the first operating General Electric Advanced Boiling Water Reactors. This past March, the U.S. Nuclear Regulatory Commission completed and issued the Standard Design Certification for the last of the advanced light water reactors funded under this program—the AP600, a Westinghouse passive-design, Pressurized Water Reactor. With this accomplishment, three designs are now available to be built and operated under a single license, significantly reducing the time needed to license a new plant in the U.S.

Benefits: Improved performance and safety of future nuclear power plants.

For More Information, Contact: Gail Marcus, Deputy Director of the Office of Nuclear Energy, Science and Technology, (202-586-2240) or go to: www.nuclear.gov

Nuclear Energy Research Initiative (NERI)

DOE Challenge: Providing Diverse Energy Technologies for the Future

Program Activity: Started in FY 1999 in response to the recommendations of the President's Committee of Advisors on Advanced Science and Technology, the NERI provides for innovative investigator-initiated, peer reviewed research and development at universities, laboratories, and industry to advance nuclear power technology, thus paving the way for expanded use of nuclear energy in the future and rebuilding U.S. leadership in nuclear technology. NERI research focuses on proliferation-resistant reactor and fuel technologies, high performance/efficient reactor technology, advanced nuclear fuels, new technologies for the minimization and management of nuclear waste, and fundamental nuclear science.

Accomplishments: In FY 1999, with $19 million, the initial NERI procurement resulted in the award of 46 one to three-year R&D projects involving research participants from 45 U.S. and 11 foreign universities, laboratories and industrial organizations. NERI is finding considerable success in helping place the U.S. once again in a key leadership role in the international exploration of nuclear technology, prompting interest, support, and collaborations from many other nations. Additionally, NERI has re-energized research in U.S. laboratories, universities and industry, and has begun to show the way towards solving some of the key obstacles to future expansion of nuclear energy.

In FY 2000, with $22.5 million, the Department will continue the research begun in 1999 and will award 8-10 new R&D projects, and complete 3 of the R&D projects awarded in FY 1999. While the NERI research was initially launched less than a year ago, progress has been made on all 46 projects. Some of the projects showing promise include using advanced ceramic materials in nuclear fuel, developing radiation-resistant alloys, automating future nuclear power plants, developing new proliferation-resistant nuclear fuels, exploring direct energy conversion technologies for nuclear power, and designing a low-cost proliferation-resistant reactor.

Benefits: NERI supports our nation's ability to apply nuclear technology to our energy, environmental, and economic goals. The objectives of NERI are to develop revolutionary advanced concepts and scientific breakthroughs in nuclear fission and reactor technology to address scientific and technical barriers to long-term use of nuclear energy; advance the state of nuclear technology to maintain a competitive position in overseas and future domestic markets; and promote and maintain the nuclear science and engineering infrastructure to meet future technical challenges.

For More Information, Contact: Shane Johnson, Acting Director, Office of Technology and International Cooperation, Office of Nuclear Energy, Science and Technology, (301-903-3860) or go to: nepo.ne.doe.gov

Generation IV Nuclear Power Systems

DOE Challenge: Providing Diverse Energy Technologies for the Future

Program Activity: The Gen IV program identifies and coordinates the R&D necessary to support development of next-generation reactors, specifically reactors that may be deployed in the next 20 years. The program began in FY 2000. In its initial stages, the program aims at working with other governments who may be embarked on similar R&D with an eye to eliminating duplicative research, establishing R&D collaborations and, to the extent possible, pooling research results. Countries include Argentina, Brazil, Canada, France, Japan, South Africa, South Korea, and the United Kingdom. Other countries have expressed interest in participating as well. FY 2000 accomplishments and benefits/beneficiaries are noted below. In FY 2001, the program expects to produce a Gen IV Technology Roadmap to define the path forward internationally.

Accomplishments:

- January 2000 meeting of the nine-country steering group:
  - Determined that the countries involved wanted to continue to pursue discussions of attributes and criteria associated with next generation reactor technologies; and
  - Recommended a subsequent meeting of senior technical experts to discuss opportunities for bilateral and multilateral research.
- April 2000 meeting of senior technical experts:
  - Identified nuclear R&D priorities of each participating country; and
  - Began identifying opportunities for collaborative research; and
- May 2000 International Generation IV Workshop identified characteristics and attributes of the next-generation reactors with respect to economics, safety, proliferation-resistance and waste, drawing on input from industry, universities and public interest groups. A report will be issued late spring 2000.

Benefits: The potential beneficiaries are countries that now or may in the future use nuclear power, as a successful Gen IV program will result in better-coordinated and more cost-effective R&D, in reactors that are safe, proliferation-resistant, less waste-producing and more economical than the current generation of plants. In addition, the Gen IV program puts a premium on developing reactors with the customer's concerns in mind, enhancing both their domestic and export value.

For More Information, Contact: Gail Marcus, Deputy Director of the Office of Nuclear Energy, Science and Technology, (202-586-2240) or go to: www.nuclear.gov

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Nuclear Energy Plant Optimization

DOE Challenge: Increasing the Competitiveness and Reliability of U.S. Energy Systems

Program Activity: This past year was in many ways a banner year for nuclear power in the U.S., with nuclear plants generating a record amount of electricity and performing at the highest average capacity factor, 85.5 percent, ever achieved.

Recognizing the important role that these plants will continue to serve over the next several decades in meeting demand for electricity in an environmentally sound manner, this fiscal year the Department launched the Nuclear Energy Plant Optimization Program (NEPO) as part of the President's Climate Change Technology Initiative in cost-shared cooperation with the Electric Power Research Institute, the research arm of the electric power industry. This program, recommended by PCAST and initially funded at $5 million, represents a Federal investment in intermediate-term, higher risk research that is needed to increase the pace of innovation for developing new technologies that enhance operation, reliability and safety of the nation's nuclear plants and addressing critical issues associated with aging and extended operation of these plants.

Accomplishments: Thus far, the Department and EPRI have established the Joint DOE-EPRI Strategic R&D Plan to Optimize U.S. Nuclear Power Plants. This plan is being used to prioritize the R&D that will be conducted. Additionally, the Department expects to complete the preparation of and sign a Cooperative Agreement with EPRI in May, 2000 that will provide for the solicitation and award of research contracts.

Benefits: Contrasting industry's $85 million annual investment—focused on a short term horizon that funds "just in time" solutions to problems for the existing plants—NEPO's investment leverages Federal dollars with industry's matching funds in order to expedite and conduct intermediate term research needed by all of the nuclear utility industry to address critical aging issues and issues associated with long-term safe, economic and reliable operation of the Nation's nuclear power plants.

For More Information, Contact: Shane Johnson, Acting Director, Office of Technology and International Cooperation, Office of Nuclear Energy, Science and Technology, (301-903-3860) or go to: nepo.ne.doe.gov

Nuclear Power Plant Relicensing

DOE Challenge: Increasing the Competitiveness and Reliability of U.S. Energy Systems

Program Activity: Three years ago, with electricity restructuring looming and concerns over regulatory relicensing uncertainty, the prediction was that some existing nuclear plants would be shut down prematurely and few if any nuclear plants would receive a renewed license for 20 years of additional operation. With the Department contributing as appropriate, the nuclear industry and the Nuclear Regulatory Commission took bold steps to resolve outstanding issues and to move the process forward. As a result, the NRC has now issued renewed licenses to two utilities for five reactors. Furthermore, three additional utilities have submitted license renewal applications and several other utilities have announced their intention to seek license extensions.

Accomplishments:

- March 23, 2000. The Nuclear Regulatory Commission approved the renewal of operating licenses for two reactors at the Calvert Cliffs plant. The Baltimore Gas and Electric Company, which owns and operates the Calvert Cliffs plant, was the first utility to seek NRC approval for a 20 year license renewal. During the 22 months that the NRC reviewed the Calvert Cliffs submittal, license renewal applications for another six of the nation's 103 reactors were filed with the agency, and utilities owning another 22 reactors informed the NRC of their plans to apply by the year 2003. (Original nuclear plant licenses are issued for a 40-year operating period); and
- May 23, 2000. The U.S. Nuclear Regulatory Commission (NRC) approved the renewal of operating licenses for Duke Power's three-unit Oconee nuclear power plant in western South Carolina. The approval made Oconee the second nuclear power plant in the country to have its operating licenses renewed.

Benefits: Nuclear power is the single greatest source of clean electricity in the U.S. and around the world. Continuing operation of our nation's safe and economic nuclear power plants can contribute significantly to achieving our goals for affordable and environmentally responsible power.

For More Information, Contact: Gail Marcus, Deputy Director of the Office of Nuclear Energy, Science and Technology, (202-586-2240) or go to: www.nuclear.gov

Renewable Energy

18166

DOE019-0133

Wind Energy Cost Reduction

DOE Challenge: Mitigating Environmental Impacts

Program Activity: Under the rapidly emerging U.S. restructured electricity generation environment, the competitive threshold for new supply technologies has been reduced dramatically in most regions of the country. The Wind Program has helped U.S. industry to significantly reduce the cost of wind energy, enabling wind to become a major new source for clean electricity. Today, wind technology can produce power for as low as 4 cents per kilowatthour, and the Program is working to achieve a goal of 2.5 cents per kilowatthour commercial technology by the end of the decade. This supports the Department's Comprehensive National Energy Strategy goal of achieving 25,000 megawatts of non-hydroelectric renewable generating capacity by 2010.

The Wind Program focuses on completing the research, testing and field verification needed by U.S. industry to fully develop advanced wind energy technologies, and on coordinating with partners and stakeholders to overcome barriers to wind energy use. Key activities include: Applied Research, which develops cutting edge tools and concepts for wind energy system design efforts, technologies to expand wind energy applications, and strategies to assure cost-effective wind plant operation; Turbine Research, which provides an opportunity for U.S. industry to apply the technology breakthroughs and design tools from Applied Research in developing advanced wind technology wind turbines; and Cooperative Research and Testing, which supports turbine certification and other activities for the domestic and international competitiveness of wind energy equipment and services offered by U.S. firms.

Accomplishments:

- R&D by the Department's Wind Program has helped lower the cost of wind generated electricity by 80 percent in the last 20 years. Wind electricity costs have dropped from over 30 cents per kilowatthour in 1980 to about 4 cents per kilowatthour in 2000;
- An example of the type of advancement accomplished by the DOE Wind Program are improved wind turbine airfoils, which have increased efficiency by up to 30 percent and have been adopted in most commercial U.S. wind turbines;
- Next generation wind turbines from U.S. companies are expected to reduce the cost of energy to about 2.5 cents per kilowatthour at 15 miles per hour average wind speed sites by 2003; and
- Wind Powering America was launched in 1999 to accelerate domestic use of wind.

Benefits:

- In 1999 about 5 billion kilowatthours of electricity was produced by wind turbines in the United States, enough to meet the needs of over 500,000 average U.S. households;
- In a recent 18 month period, over 900 megawatts of wind capacity was installed in the U.S., bringing the nationwide total to 2,500 megawatts in 2000. About $1 billion of private sector capital was invested in wind power plants in the U.S. over this period;
- 5,000 megawatts of domestic wind capacity is anticipated by 2005, and 10,000 by 2010; and
- By 2010 wind energy is expected to provide about 0.6 quads of primary energy and reduce carbon emissions by over 10 million metric tons of carbon equivalent.

For More Information, Contact: Peter Goldman, Director, Office of Geothermal and Wind Technologies, (202-586-1995) or go to: www.eren.doe.gov/wind

Photovoltaic Cost Reductions

DOE Challenge: Mitigating Environmental Impacts; Providing Diverse Energy Technologies

Program Activity: The technology revolution in the power generation sector has led to drastic decreases in the price of power from new sources of generation. For example, natural gas-fired combustion turbine technology produces electricity for about $0.03 per kilowatthour. Given the low domestic market prices of fossil fuels, market penetration of renewable energy technologies is occurring more quickly in remote locations domestically and overseas where the cost of electricity is generally much higher than in the U.S. Recent trends in the growth rate of global PV sales, especially in Japan and Germany, indicate that this rapidly accelerating market will more than double in the next two years.

The program conducts a balanced R&D effort in fundamental and applied research, materials and device development, advanced manufacturing R&D, module reliability, and system testing and evaluation. The strategy is to concentrate on areas of high-risk, high-payoff R&D, an area where private sector companies traditionally under invest, and where a national research program tapping the unique capabilities of our national laboratories can make a significant impact. As a result of efforts to date, the U.S. is the unquestioned world leader in the development of new advanced PV technologies such as thin films and high efficiency devices. The successful transition of these potentially low cost technologies to large-scale manufacturing is the foremost technical challenge for the Program and is critical to the ongoing viability of the domestic PV industry. The Photovoltaics Program, in partnership with the U.S. PV industry, universities and national laboratories, has established aggressive technical goals as measures of success in order to meet this challenge.

Accomplishments:

- In FY 2000, PV systems are delivering electricity for as low as $0.12 - $0.20 per kilowatthour—depending upon the specific technology—making clean, reliable PV systems competitive in many remote and on-grid sites here in the U.S. and around the globe. This compares with a cost of more than $1.00 per kilowatthour in the early 1980s; and
- R&D in crystalline silicon and thin film cells that have enabled a multi billion dollar industry.

Benefits:

- Reduces the dependency on fossil fuels;
- Provides increased reliability of energy service;
- Reduces the emission of greenhouse gases; and
- Establishes a $22.5 billion industry by 2020.

For More Information, Contact: Richard King, Office of Photovoltaics and Wind Technology, (202-586-1693) or go to: www.eren.doe.gov/pv

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Geothermal Energy Cost Reduction

DOE Challenge: Mitigating Environmental Impacts

Program Activity: The Geothermal Program has worked closely with U.S. industry to reduce the cost of geothermal energy, providing technology that has resulted in the installation of 2800 megawatts of domestic geothermal power. Today, geothermal technology can produce reliable power in the range of 5-8 cents per kilowatthour at average geothermal sites, and the Program is working to achieve a goal of 3-5 cents per kilowatthour by 2007. Geothermal energy will contribute as much as 6,000 megawatts to the Department's Comprehensive National Energy Strategy goal of achieving 25,000 megawatts of non-hydroelectric renewable generating capacity by 2010.

The Geothermal Program conducts the research, testing and field verification needed by U.S. industry to fully develop advanced geothermal energy technologies. This is accomplished in large part through cost-shared partnerships with industry. Key activities include: Geoscience and Support Research which investigates problems associated with finding and producing geothermal resources; Drilling Research directed at developing advanced drilling technology to reduce the cost of drilling geothermal wells; and Energy Systems Research and Testing which improves the efficiency of converting geothermal energy into electricity and tests new technology with the potential of reducing overall system costs.

Accomplishments:

- The Department's Geothermal Program has contributed to a 50 percent decline in the cost of geothermal electricity in the past 20 years. Costs at the best geothermal sites have dropped from an average of about 10 cents per kilowatthour in 1980 to about 5 cents per kilowatthour in 2000;
- An award-winning, advanced direct contact condenser resulted in a 17 percent increase in generation capacity at a geothermal power plant in 1999;
- Development of a high-speed, diagnostics-while-drilling system will reduce well costs by more than 20 percent, resulting in a reduction in geothermal development costs by as much as 10 percent by 2005; and
- In early 2000, the Department announced a new initiative, GeoPowering the West, to encourage the use of geothermal energy in 19 western states.

Benefits:

- Over 14 billion kilowatthours of electricity was generated by geothermal facilities in four states last year, meeting the needs of about 1.4 million homes;
- GeoPowering the West is expected to result in geothermal energy being used by 7 million homes or the equivalent of about 10,000 megawatts;
- Capital investment in geothermal facilities will total $50 billion over the next 20 years; and
- By 2020, geothermal energy will displace 20 million metric tons of carbon equivalent.

For More Information, Contact: Allan Jelacic, Office of Geothermal and Wind Technologies, (202-586-6054) or go to: www.eren.doe.gov/geothermal

Biobased Products and Bioenergy Initiative

DOE Challenge: Enhancing Energy Security. Mitigating Environmental Impacts.

Program Activity: As we move into the 21st century, a number of key issues challenge our nation's rural economy, energy security, and environment. Recent scientific advances in bioenergy and biobased products have created enormous potential to develop new economic opportunities for rural America, enhance U.S. energy security, help manage carbon emissions, and protect the environment. "The Bioenergy Vision: Achieving Integrated Development and Use of Our Nation's Biologically Derived Renewable Resources" developed by industry, challenges industry and government alike to develop a sustainable energy future founded on science, domestic resources, and the protection of the natural environment.

A 1999 Executive Order on Biobased Products and Bioenergy provides for coordinated Federal efforts to accelerate the development of 21st century biobased industries that use trees, crops, agricultural, forest, and aquatic resources to make an array of commercial products including fuels, electricity, chemicals, adhesives, lubricants, and building materials. Legislation in support of the principles established in the Executive Order has been introduced. The Agricultural Risk Protection Act of 2000 has received bipartisan support. The U.S. Department of Agriculture, EPA and others have joined DOE in focusing efforts toward integrated R&D that will support a strong industrial and agricultural participation.

The cornerstone of the initiative is a concept called "the biorefinery," similar to the refineries of the oil industry. These biorefineries will use biomass from today's farms and forests to create an array of products. Additional focus areas include outreach and analysis, combined with the integrated R&D to lead to cost-shared demonstrations. Future efforts will follow the new strategic plan that will be developed under the Executive Order and roadmaps identified under the Bioenergy/Bioproducts Initiative that utilizes biomass to advance both an integrated bioenergy industry, as well as its renewable bioproducts industry sector. It is anticipated that new partnerships will come together for the first time in an integrated fashion, leading to new business opportunities. Innovative approaches will be encouraged through a multi-agency, industry peer review project selection process.

Accomplishments: The initiative depends on the integration of the existing programs within DOE, including the EEREs Offices of Transportation Technologies, Power Technologies, and Industrial Technologies. These programs have been developing the core technologies needed to support the goals of the integrated Bioenergy/Bioproducts Initiative.

Benefits:

- The initiative goal is a tripling of U.S. use of biobased products and bioenergy by 2010;
- Reduced oil dependence; and
- Increased economic opportunities, especially in rural areas.

For More Information, Contact: Richard Moorer, Office of Transportation Technologies, (202-586-5350) or go to: www.eren.doe.gov/bioenergy_initiative

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Million Solar Roofs Initiative

DOE Challenge: Mitigating Environmental Impacts

Program Activity: Million Solar Roofs is an initiative to install solar energy systems on one million U.S. buildings by 2010. Announced by President Clinton on June 26, 1997 in his speech before the United Nations Session on Environment and Development, this effort includes two types of solar technology—photovoltaics that produce electricity from sunlight and solar thermal panels that produce heat for domestic hot water, space heating or heating swimming pools.

The U.S. Department of Energy is working with partners in the building industry, other Federal agencies, local and state governments, utilities, the solar energy industry, financial institutions and non-governmental organizations to remove market barriers to solar energy use and develop and strengthen local demand for solar energy products and applications. The Initiative works in a "bottom-up" fashion by attracting partners building by building, community by community, state by state and business by business. It also works in a "top-down" fashion by developing financing, leveraging resources, coordinating Federal agency support and sharing information. Any person or organization who installs the minimum size solar electric or solar thermal energy system on a residential, commercial, institutional or government building is able to register with the Million Solar Roofs Registry. President Clinton has committed the Federal government to install solar electric and solar thermal energy systems on 20,000 federal buildings by 2010. The U.S. Department of Energy's Federal Energy Management Program will assist Federal agencies to meet that commitment.

Accomplishments:

- The original Initiative Action Plan was developed with input from members of the solar energy community and was first introduced in April, 1998. Since then, it has been updated annually to set goals and prioritize actions. The 2000-2001 Action Plan will continue to build on that work;
- In April 2000, Secretary Richardson announced that the total number of preliminary pledges made by the Initiative's Partners has reached over one million solar energy systems. With the addition of seven new State and Local Partnerships this Spring, the total number of Partnerships has grown to 47 and the number of preliminary pledges to install solar energy systems has reached 1,000,440;
- As an example, the City of Chicago and ComEd will install $4 million worth of solar panels atop Chicago's nine major museums and Lincoln Park Zoo. Each installation will generate approximately 50,000 kilowatthours of electricity per year from the sun. In total, the solar panels will provide more than 600,000 kilowatthours per year, enough to power 60 average households;
- Photovoltaics were invented approximately 40 years ago at AT&T's Bell Laboratories and later developed as a means to power satellites and space vehicles. In the past two decades, research and development have improved the efficiency and reliability of photovoltaics and reduced the costs of photovoltaic electricity by a factor of 5; and
- The Federal sector has installed 1,745 solar energy systems as of April, 2000. They are well on their way to install 2,000 systems by the end of calendar year 2000.

Benefits:

- In 2010, with one million solar energy roofs in place, the Initiative could reduce carbon emissions in an amount equivalent to the annual emissions from 850,000 cars;
- By 2010, approximately 70,000 new jobs could be created as a result of the increased demand for photovoltaic, solar hot water and related solar energy systems;
- By increasing the domestic market for solar energy, increasing domestic production and reducing the unit cost for solar energy systems, the Initiative could enable U.S. companies to retain their competitive edge in the worldwide market; and
- By 2005, the photovoltaic market alone is expected to exceed $1.5 billion worldwide.

For More Information, Contact: Peter Dreyfuss. Energy Efficiency and Renewable Energy, (202-586-8779) or go to: www.eren.doe.gov/millionroofs/index.html

Environmentally-Friendly Hydropower Turbines

DOE Challenge: Mitigating Environmental Impacts

Program Activity: The Department's hydropower research and development program is focused on enhancing the environmental performance of hydroelectric generating systems. The Advanced Hydropower Turbine Systems Program was initiated in 1994 as a partnership with industry and other government agencies. Targeted improvements in environmental performance include greater survival of fish passing through turbines and improved water quality. Accomplishing these aims will support the Department's Comprehensive National Energy Strategy goal of maintaining the viability of existing hydropower sources.

Current activities involve turbine field testing and laboratory, field, and computational studies in a coordinated effort to improve fish survival in turbines. New "fish-friendly" turbine design concepts have been developed, along with a better understanding of biological criteria for turbine design, and improved sensor technology for measuring the physical conditions inside operating turbines.

Accomplishments:

- Conceptual designs for environmental upgrades of existing turbine designs were completed. Testing of one of these concepts, the minimum-gap runner, at Bonneville Dam resulted in 40 percent less fish injury than in the original design;
- An innovative conceptual turbine design was completed, and pilot-scale biological and engineering proof-of-concept testing activities have been initiated;
- Advanced "sensor fish" technology was developed and is now being used to measure the effects on fish passing through turbines; and
- Biological experiments to characterize and quantify shear and pressure stresses on fish in the turbine environment were completed.

Benefits:

- Turbine technology capable of reducing fish mortality to 2 percent or less will be commercially available by 2010, compared to current mortality levels ranging up to 30 percent or greater.

For More Information, Contact: Don Richardson, Office of Biopower and Hydropower Technologies, (202-586-4541) or go to: hydropower.id.doe.gov/

18173

Crosscutting

18174

Promoting International Cooperation for Clean Energy

DOE Challenge: Mitigating the Environmental Impacts of Energy Production and Use

Program Activity: The Department of Energy is pursuing international cooperation to address the challenge of affordable, efficient and clean energy on a global scale. Specifically, U.S. policies seek to develop competitive international energy markets, facilitate the adoption of clean, safe, and energy efficiency systems, and promote international science and technology cooperation in clean energy systems.

Accomplishments: The Department has obtained the agreement of several dozen countries in supporting clean energy technology, energy efficiency, and the Clean Development Mechanism. We have energy efficiency programs with numerous countries, including Brazil, China, India, Mexico, Russia, South Africa, Ukraine and Venezuela.

Through the U.S./China Forum on Environment and Development, led by Vice President Al Gore and Premier Zhu Rongji of China, DOE established, in cooperation with the U.S. Export-Import Bank and the State Bank of China, a $100 million Clean Energy Program, signed and implemented new protocols to promote clean fossil energy, renewables and energy efficiency, and launched a U.S.-China Oil and Gas Industry Forum to promote oil, natural gas and coal-bed methane development in China.

In October 1999, DOE signed a Joint Statement on Cooperation in Energy and Related Environmental Aspects with the Government of India. The Joint Statement has led to bilateral policy dialogue and a South Asia Regional Initiative on clean energy development and climate change. It set the stage for President Clinton's visit to India in March, 2000, at which time the Administration signed a Clean Energy and Environmental agreement. Also in March 2000, a Joint Statement on Clean Energy and Climate Change was signed with the Government of the Philippines, facilitating international negotiations on climate change.

The Department has initiated a program of clean energy cooperation with Mexico, Costa Rica and Bolivia. In Mexico, the focus is on clean fossil technology development and deployment, while maintaining the affordability of fossil fuels and fossil-based power generation.

DOE has signed bilateral Clean Energy Statements with the Governments of Russia, Estonia, Latvia, Lithuania and the Kyrgyz Republic. These statements emphasize the role of the energy sector in joint efforts to protect and enhance the environment, and advance the international negotiating process on climate change. The Administration has actively promoted energy efficiency and renewable energy in Russia through regional energy efficiency laws, renovation of district heating systems, improved efficiency in enterprise housing, energy-savings codes and standards, advances in energy-efficient window technologies, construction of wind-diesel hybrid power stations at remote sites in the Northern Territories, and a planned new geothermal power plant in Kamchatka. In Ukraine the Department has launched an $850,000 initiative for financing energy efficiency projects, sponsored energy audits for 5 industrial firms, and helped facilitate a $30 million World Bank loan to retrofit municipal buildings in Kiev. The Department has established a regional oil spill response system with the countries bordering the Black Sea. The effort includes a website for information exchange and technical workshops to build institutional capacity in the region.

Benefits:

- Accelerated deployment of clean energy technology in international markets;
- Reduced air and water pollution and a reduced rate of growth of greenhouse gas emissions worldwide; and
- More efficient use of fossil fuels.

For More Information, Contact: Matt Willis, (202-586-5800) or go to: www.osti.gov/international

18175

Promoting International Competition and Private Sector Investment

DOE Challenge: Enhancing America's Energy Security

Program Activity: The Department promotes the opening of global markets to U.S. trade and investment through encouraging competition, energy sector reform and regional market integration. In cooperation with U.S. business, the Department recently hosted three major international conferences involving Energy Ministers from the Western Hemisphere, Africa, and the Asia-Pacific Economic Cooperation (APEC) community. The Department is leading major energy initiatives in Africa, Asia, Latin America, and Europe.

Accomplishments: In the Asia-Pacific region, APEC energy ministers and leaders have endorsed the APEC natural gas initiative. This initiative seeks to accelerate investment in natural gas supplies, infrastructure and trading networks throughout the region, and has been developed in close collaboration with the business sector. The initiative aims to reduce investor risk through implementation of appropriate policies by the member governments of the APEC region. These policies include permitting private ownership of natural gas facilities, ensuring sanctity of contracts, establishing autonomous regulators, promoting non-discriminatory treatment of foreign and domestic companies, fostering competition among all sources of energy, and supporting the free flow of exports and imports of natural gas and natural gas-related products and services across borders.

With regard to China, the Department leads the Energy Policy Working Group of the US-China Forum on Environment and Development chaired by Vice-President Gore and Premier Zhu Rongji. The Department has set up an Oil and Gas Industry Forum, which encouraged China's decision to develop its natural gas resources, import liquefied natural gas, and permit foreign ownership of natural gas production and transportation infrastructure. DOE cooperative programs with Russia have resulted in passage of Production Sharing Laws to encourage investment in the oil and gas sector. In the Caspian region, bilateral policy dialogue with Turkmenistan, Turkey, Azerbaijan and Georgia has fostered an investment climate for private sector investment in oil and gas pipelines to transport oil and gas to markets outside of the region. In the Baltics and Eastern Europe, DOE has supported the efforts of U.S. companies to invest in the energy sector, and has encouraged host governments to adopt fair and transparent procurement practices, and to allow private investment. Through the International Energy Agency (IEA), the Organization for Economic Development and Cooperation (OECD), and the European Union (EU), the Department has accelerated the opening of the European gas and electricity sectors to competition and U.S. private investment.

Benefits:

- Enhanced energy security of nations through interdependence and competitive markets;
- Increased opening of international markets to U.S. trade and investment; and
- Accelerated deployment of clean energy technology in international markets.

For More Information, Contact: Matt Willis, International Affairs (202-586-5800) or go to: www.osti.gov/international

18176

Use of Energy Efficiency and Renewable Energy Technologies
in Clean Air Act State Implementation Plans

DOE Challenge: Mitigating Environmental Impacts, Enhancing Energy Security

Program Activity: Each year the nation spends over $100 billion to clean up pollution that is an unintended consequence of energy use. Much of this pollution could be avoided through wider application and use of clean energy technologies through comprehensive multi-pollutant prevention strategies. In recent years, the Administration has been aggressively pursuing these broader strategies to prevent pollution.

EPA's Clean Air Act programs are implemented by State governments through state environmental agencies. Particularly for the ambient air programs, each State develops a State Implementation Plan (SIP) which characterizes the nature of pollution challenges within the state and provides a plan of action by which the state can attain and maintain National Ambient Air Quality Standards. In order for a state to receive federal funds, EPA must find each SIP responsive to the requirements of statute, compliance with regulation and the needs of the environment. EPA produces guidance documents that provide states with an idea of what EPA will accept as applicable pollution reduction strategies.

DOE and EPA are currently working together to help provide for the widespread adoption of clean energy technologies by the States as a preferred means of reducing and preventing pollution.

Accomplishments:

- Development of Energy Efficiency & Renewable Energy Set-Aside in NOx Budget Trading Program;
- Assisted EPA with Monitoring & Verification strategies and requirements needed to implement this set-aside. In April, 2000, the EPA Office of Air and Radiation issued a Draft Guidance document entitled "Creating an Energy Efficiency and Renewable Energy Set-Aside in the NOx Budget Trading Program." This document is the second of three guidance documents that EPA is issuing to help states take advantage of the air quality benefits of voluntary energy efficiency and renewable energy actions; and
- Developed a strategy (with EPA and the Western Governors Association) for using renewable energy sources to help meet the regional haze rule.

Benefits:

- Simultaneous improvements to energy use, environmental quality and significant cost reductions.

For More Information, Contact: John Atcheson, Energy Efficiency and Renewable Energy, (202-586-2369) and/or David Bassett, Office of Planning, Budget and Outreach, (202-586-7943) and/or Greg Kats, Energy Efficiency and Renewable Energy, (202-586-1392)

Voluntary Partnerships with Industry

DOE Challenges: Enhancing Energy Security, Mitigating Environmental Impacts, and Increasing Competitiveness and Reliability

Program Activity: DOE actively seeks diverse partnerships to better develop, deploy and leverage the public investments in government and energy products and technologies. Our partnerships help develop the experience base, skill and knowledge pool, infrastructure, and user-familiarity that reduce the risk barriers associated with new technologies. They provide feedback to every stage of the continuous process of research, development, demonstration, production, deployment and market acceptance that is necessary for the accelerated evolution to a more balanced, efficient and productive energy economy.

Accomplishments:

- The DOE/industry's USABC developed the longer range battery used by PNGV partners, GM and DaimlerChrysler in their EV car, S-10 pickup and EPIC minivan. Customer response to these vehicles show satisfaction with their longer range and more consistent performance;
- Industry partnerships: OIT developed and commercialized over 100 technologies, saving more than 115 trillion btu. These advances reaped productivity improvements, reduced resource consumption, decreased emissions, and enhanced product quality;
- Wind Partnerships: DOE partnered with Enron Wind Corp., Zond Energy Systems, manufacturers and utilities to produce one of the world's largest wind generation facilities;
- Building America partnerships, with DOE and building industry members, cost-shares development and demonstration of new homes that are more than 50 percent more efficient, with no cost or performance penalty;
- Rebuild America partners established nearly 250 community partnerships to date that will reduce the energy costs of over 500 million square feet of building space;
- Energy Star commercial laundry partners, through a comprehensive program with EPA, retailers, the laboratories, and the appliance industry are, for example, cutting water consumption by 50 percent and water energy use by 44 percent, with membrane water filtration technology;
- Climate Challenge utility partnerships developed nine initiatives with over $50 million committed to accelerate commercialization of renewable energy technologies and energy-efficient electrotechnologies;
- Superconducting partnerships, utilizing superconducting cables in Georgia and Detroit, have set the world's benchmarks in transmission cables, transformers, motors, generators, and other electric power technologies. These are world firsts;
- Photovoltaic manufacturing partnerships have netted a 22 percent compound growth in the industry for the last 8 years, with 65 megawatts of U.S. manufactured PV sold in 1999 (200 megawatts total in 1999), and $2 billion in total sales in 1999 (2/3 foreign sales); and
- Federal partnerships with energy service companies have generated total private sector investment in Federal alternative financial projects of nearly $850 million.

Benefits:

- Pools large risks;
- Shares technology and resources;
- Accelerates research, development and deployment;
- Smooths market transformation; and
- The nations, its industries and consumers, receive energy, environmental, and cost savings years earlier and avoid significant opportunity costs.

For More Information, Contact: Mary Beth Zimmerman, Office of Planning, Budget and Outreach,

(202-586-7249)

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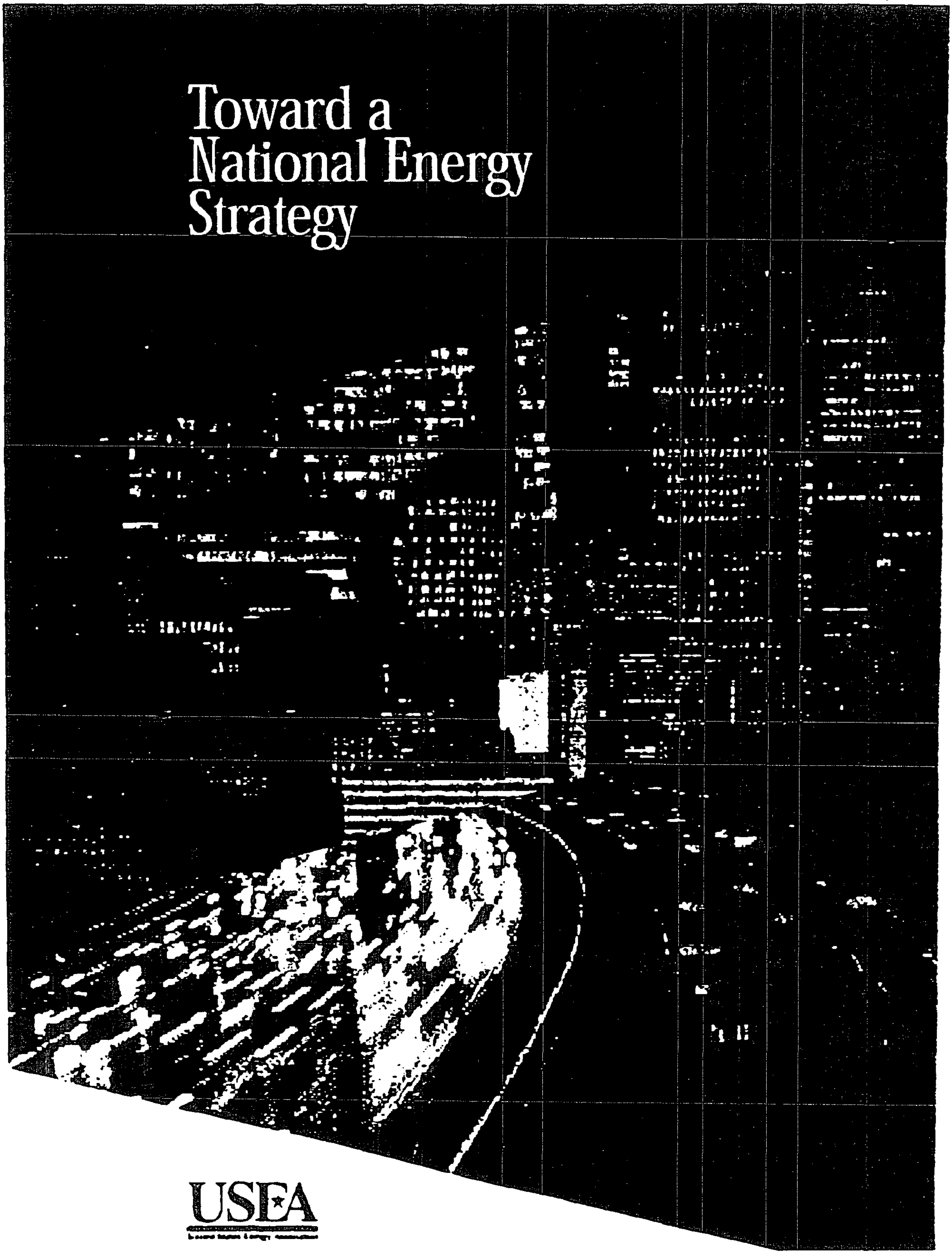
NATIONAL ENERGY STRATEGY
53 Pgs

Toward a National Energy Strategy



USEA

United States Energy Association

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ABOUT USEA AND THE NES STUDY

The United States Energy Association (USEA) is the U.S. Member Committee of the World Energy Council (WEC). USEA is an association of public and private energy-related organizations, corporations, and government agencies. USEA represents the broad interests of the U.S. energy sector by increasing the understanding of energy issues, both domestically and internationally.

In conjunction with the U.S. Agency for International Development and the U.S. Department of Energy, USEA sponsors our nation's Energy Partnership Program.

USEA sponsors policy reports and conferences dealing with global and domestic energy issues as well as sponsors trade and educational exchange visits with other countries.

The USEA Board of Directors agreed that the year 2000 was an appropriate time to take an in depth look at United States energy policy. Previously the USEA had published 11 Annual Assessments of U.S. Energy Policy. The Board approved the USEA National Energy Strategy project under the leadership of Richard Lawson, Chairman of its National Energy Policy Committee. The project was directed by Guy Caruso. Informed by the results of workshops on key energy issues, a working group representing all sectors of the industry has prepared the following report.

United States Energy Association

February 2001

Toward a National Energy Strategy

USEA

United States Energy Association

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ELEMENTS OF AN EFFECTIVE NATIONAL ENERGY STRATEGY

SETTING THE GOAL

Members of the United States Energy Association (USEA) believe that energy policy-makers, regulators, consumers and producers face critical policy and investment choices in the decades ahead. In many markets increased demand outstrips reliable supplies. Key industries are being deregulated Technology is advancing at an unprecedented rate. Environmental regulations have grown increasingly costly and complex. Consumers often express confusion at the array of energy choices now available. And energy companies confront both greater competition and unforgiving financial markets that can heavily penalize those companies that expand production to meet the increased energy demands of our growing population and economy.

The proper response to these uncertain times is the development and implementation of a sound National Energy Strategy (NES). USEA members propose that the objective of this strategy be the delivery to consumers—in a ready, reliable and environmentally responsible manner— of an increased supply of affordable energy resources and energy-related services from a broad range of energy providers

CORE PRINCIPLES

USEA members believe that this National Energy Strategy should be anchored in four core principles:

- Economic efficiency. Economic efficiency is maximized when competitive markets guide decisions affecting global energy supply and demand. Moreover, given the inherent uncertaint of energy markets and of efforts to project future trends, a diversity of fuels strategy has proven moreefficient than picking "winners and losers" when addressing long-term energy problems.
- Energy security. Energy security is best achieved through diverse supplies of all forms of domestic and international energy. Similarly, contingency plans are needed to mitigate energy supplydisruptions, and these U.S. plans can be enhanced through international cooperation.
- Energy technology. Research and development can spur improvements in energy technologies that produce long-term cost-effective solutions to many environmental concerns. Research to address environmental problems and to expand energy choices is an appropriate and essential role for government. Partnerships between public and private sectors (domestic and international) can also speed this process.
- Regulation and incentives. Government officials can use regulation and incentives to ensure public health, safety and consumers rights. Decisions to use these policy tools should be based on sound science and realistic needs. Such decisions also should be timely, consistent and coordinated so that the benefits of responsible environmental protection are kept in balance with the benefits of energy use.

A national goal and these core principles alone, of course, are insufficient to build an effective National Energy Strategy. The principles must be applied to key policy issues, and input should be sought from those most affected by policy decisions. It is critical that the new Administration focus not only on the near-term issues that are in today's headlines, but also on long-term issues. The concern over potential climate change, attributed in part to fossil fuel combustion, could be a major factor in shaping future energy choices. It is critical that policymakers and energy producers look to 2050 and beyond in shaping our research and regulatory agendas, and that we consider the long-term implications of policies we adopt today. Other long-term issues, such as depletion of traditional energy resources and the need for developing technologies to find and produce non-traditional energy resources must also be contemplated in current policies. This long-term planning, conducted in an open process with non-governmental organizations (NGOs) and private sector participation, is an appropriate federal role. The following are policy issues which USEA members regard as critical to the development of a sound National Energy Strategy.

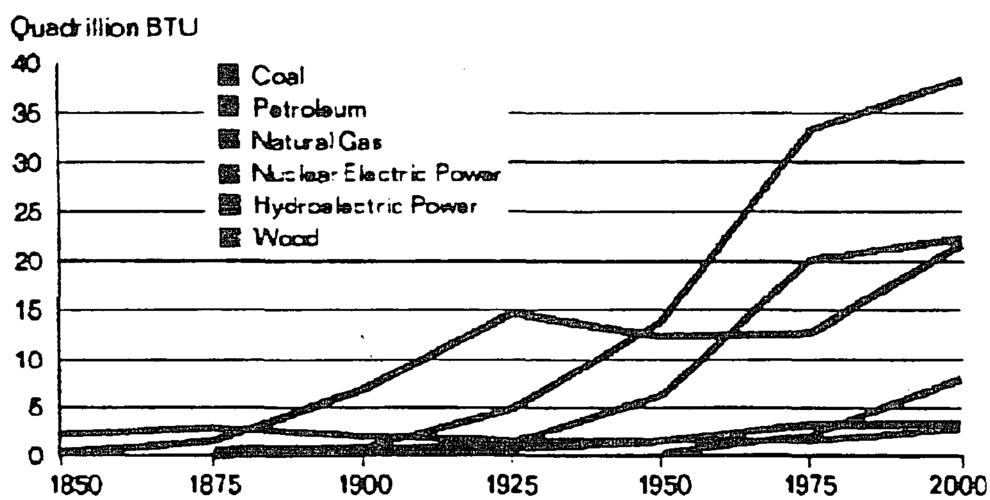
KEY ISSUES

Meeting U.S. Energy Requirements

The President and Congress can help energy producers and suppliers insure an adequate energy supply to support the nation's needs as we enter the 21st century. However, securing a reliable energy supply in the coming decades will require careful review of policy options and judicious action by policymakers and government officials at every level.

Careful deliberation is required because energy production and consumption is so inextricably tied both to economic growth and population growth. For example, the United States experienced a significant economic boom at the close of the 20th century, supported in part by a dramatic rise in consumption of affordable energy. However, this expansion of

Energy Consumption in the United States 1850 - 2000



Source: United States Department of Energy/ Energy Information Administration energy consumption occurred at a time when energy supplies, particularly in the electricity sector, barely expanded at all. Substantial reserve margins at the outset of the recent economic expansion made economic growth possible, but those margins have now been depleted. Electricity capacity and, more broadly, energy supply must be increased to support continued U.S. economic growth, even at a reduced annual rate.

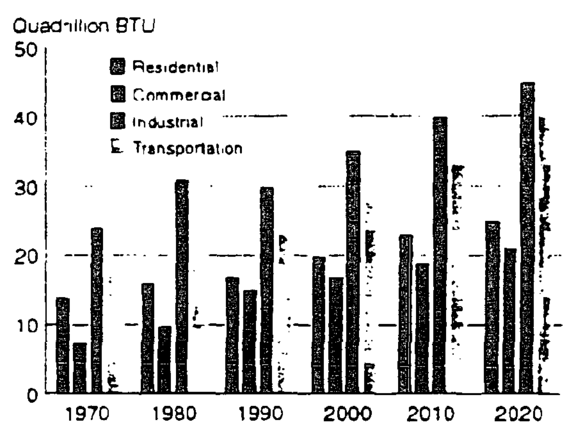
The Annual Energy Outlook 2001 Forecast

Energy policy must insure that supplies are adequate. The most recent Department of Energy/ Energy Information Administration Annual Energy Outlook 2001 (AEO) reveals that the demand for energy of all forms is likely to increase significantly over the next 20 years. By 2020, total energy consumption is forecasted to increase by 32 percent, petroleum by 33 percent, natural gas by 62 percent, coal by 22 percent, electricity by 45 percent and renewable energy by 26 percent. At the same time, energy efficiency is projected to improve by 1.6 percent per year. The forecasts in consumption are stunning. Not only has crude oil production fallen by 14 percent since its peak in 1970, natural gas production also has fallen by 14 percent since 1973 and has remained virtually flat for seven years. Moreover, refinery capacity has fallen by 11 percent since 1981 and one-half of refineries have been shutdown over the same period.

The AEO forecast implies that massive investments in infrastructure will be made to produce and deliver energy to American consumers. However, the record to date does not inspire confidence that the current regulatory structure will support these investments. For example, the AEO projects an increase in refinery capacity of 1.7 million barrels per day and an increase in refinery utilization from 93 to 95 percent. A new EPA interpretation of rules relating to the expansion of existing capacity raises considerable doubt that this capacity will be built. If the 1.7 million barrels per day requirement is to be met through new capacity additions, eight to ten new refineries would have to be built. A large-scale refinery has not been built in the U.S. in over 20 years. The forecast also calls for an increase in refined product imports of 3 million barrels per day. This raises the question: will there be sufficient foreign refinery capacity to meet our stringent fuel specifications—especially with increasing regulation?

Similarly, the forecast for oil and natural gas consumption implies the construction of major new petroleum products and natural gas pipelines. Other natural gas facilities and petroleum terminals and facilities will be needed to meet the increased demand. How are we going to do this given the daunting regulatory apparatus and the well entrenched "Not In My Back Yard" (NIMBY) culture? The answer is that we need to develop and implement an energy policy that focuses on adequacy of supply to meet the growing needs of consumers. The goal should be to provide reliable

U.S. Primary Energy Use



Source DOE/EIA

and affordable supplies of energy to consumers. If it is not produced here, petroleum can be imported but most natural gas must be produced in North America because of very limited LNG import infrastructure. The AEO forecasts an increase in net oil import dependence from 55 to 64 percent during the next 20 years. This raises numerous questions about diversity of supply, national security concerns and the potential for increased price volatility.

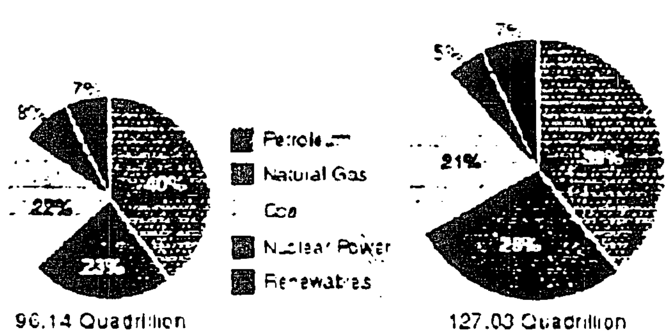
The current shortfall of reserve margins in electricity can be traced to a consistent pattern of demand growth exceeding expectations. Indeed, over the past decade almost all institutions engaged in predicting electricity demand growth have settled on the figure of an increase of about 1.5% annually. However, the actual growth rate has exceeded 2.0% annually. Recognizing this shortfall, the EIA's most recent forecast projects annual growth of 1.8% annually through the year 2020. By 2020, 393,000 MWs of new capacity will be required to meet demand growth and to offset capacity retirements. This is the equivalent of constructing approximately 40 new 500 megawatt power stations per year, over the next 20 years.

Closing this gap poses a major policy challenge. Moreover, policymakers face this challenge at a time when the national grid for electricity transmission is increasingly constrained and the ability to produce and deliver fuel to the generating facilities also is constrained. Furthermore, attracting investment and construction capital for infrastructure projects is growing increasingly difficult, as is permission to site new capacity, transmission and distribution facilities. In short, government intervention is required—in the form of an enlightened energy policy—in order to preserve economic growth, energy security and reasonable environmental protection.

Another major challenge is ensuring the reliability of the electricity transmission network, particularly at a time of increased market demand. Originally, transmission lines were used to deliver backup power and to economically exchange power among neighboring electric utilities. Today, market demand drives the use of the transmission system, and electricity is often "wheeled" great distances. Competition, in short, has turned local backup systems into a patchwork of interconnected electric super highways. This increased use has lead to concerns about congestion and reliability. Policymakers need to keep these new demands in mind and not create regulatory demands that compromise the transmission facilitates needed to carry power from where it is generated to where it is consumed.

Some have argued that America's energy problems can be resolved by increasing our reliance on solar, wind and energy efficiency measures. This report includes policy recommendations aimed at maintaining our diverse energy supplies. It also calls for more focused attention on energy research and development, and the continuation of efforts to develop solar, wind and efficiently applied technological initiatives that allow for market-based demand responses. However, the

Energy Demands to 2020



96.14 Quadrillion BTUs — 1999

127.03 Quadrillion BTUs — 2020

Source DOE/EIA

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principal focus of this report is on those energy resources and delivery systems that provide more than 98% of the nation's current energy supply. This is the appropriate focus for policymakers, too. Indeed, even if solar, wind, geothermal and efficiency measures quadrupled their contribution to the energy mix during the next 20 years, the dimensions of the energy supply issue described above remains essentially unchanged.

The evidence is everywhere that this nation faces a major energy supply challenge in the decades ahead. Failure to formulate effective policies to meet that challenge will likely compromise U.S. economic growth, energy security and social well-being.

Market-Based Energy Policies

The cornerstone of a sound National Energy Strategy is reliance on competitive markets to allocate energy supply and demand. This lesson is widely accepted and has proven, time and again, to be true. Of course markets are not perfect, particularly with respect to such externalities as energy security, public health and safety, and environmental protection.

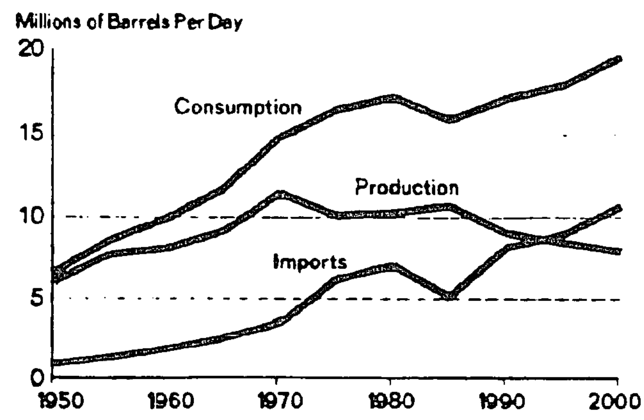
Here, government policy will continue to play an important role in the energy sector. However, government officials at all levels should not impose new regulations on the energy supply system—even in an attempt to address health, safety and environmental issues—unless those regulations are based on sound science and incorporate the most cost-effective options. Policymakers should also continue to substitute competition for regulation to achieve these same goals, whenever possible.

Security of Supply

The U.S. is the only major industrial nation that significantly limits access to its own energy resources. Because of these constraints, U.S. dependence on foreign energy supplies inevitably will increase over the next 20 years. Many of these constraints need to be reexamined. New technologies are regularly adopted for energy production, storage and delivery that address the very environmental or public safety concerns that originally led to constraints. These objections to energy development and production no longer may be relevant. As time and technologies change, so also should restrictive energy policies. Domestic energy resources, such as coal, petroleum, natural gas and uranium, must be made available for environmentally sound exploration and development.

Policymakers should also consider recent changes in the international arena. A disruption of U.S. energy supplies could cause signifi-

Petroleum Consumption, Production and Imports 1950- 1999



Source DOE/EIA

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cant damage to the U.S. economy. Terrorism, regional conflicts in energy exporting countries, industrial accidents and even acts of God require contingency plans and policies. A growing dependence on imported energy need not mean increased vulnerability to supply disruptions, provided effective emergency preparedness programs and policies are in place. Given the global nature of energy markets and the fact that the U.S. economy cannot be isolated from the risks of energy supply disruptions, contingency plans should include international cooperation as a key component.

Energy Efficiency

Investments in energy efficiency can reduce energy use and operating costs. The use of less energy can help protect the environment. When energy efficiency opportunities are identified, firms and individuals should take advantage of these opportunities. However, decisions that involve a trade-off between energy efficiency and energy production should be transparent. Such decisions also should not favor one option over the other, for the choice really involves a complementary relationship.

Indeed, when given appropriate competitive market signals, improved efficiency in energy production is as significant a priority as improved energy-efficiency among end users. In recent decades, improvements in technology and productivity have increased the efficiency of energy suppliers in all sectors. Policymakers should therefore allocate R&D energy efficiency funding on the basis of potential gain, regardless of whether that efficiency gain occurs during energy production or energy consumption.

Capital Investments

Enormous capital investments in all forms of energy—fossil fuels, nuclear energy and renewable energy—will be required to fuel the U.S. economy during the early decades of the 21st century. These investments will be needed in all phases of the energy sector, from production to generation to storage to transmission and distribution to improved end-use efficiency. A sound National Energy Strategy can help create the predictable operating and investment environment that all energy sectors require in order to thrive.

The regulatory process and tax policies are particularly important to attracting the requisite capital investment for growth in the energy sector, and the U.S. economy. Regulatory policies should be simple, durable and predictable, both at the national and local level. This is especially true of efforts to deregulate and restructure many U.S. energy markets. Such efforts are leading siting and transmission issues to become a matter of national policy. Federal policymakers should take these changes into account when reviewing energy laws and energy regulatory authorities. Tax policies should encourage investment for all forms of energy supply and infrastructure.

International Energy Trade and Development

Petroleum imports to the United States will likely increase for the next several decades, regardless of efforts to develop additional domestic energy resources. This reality, plus the continued globalization of the energy economy, will force U.S. policymakers to address international trade and development issues. Indeed, the future well-being of Americans and citizens of other countries will depend on the ability of U.S. leaders to promote open and fair trade practices in an effort to stimulate sustained economic growth in developing and transition economics.

Administration officials and Congressional members can take a number of steps to open energy markets. For example, they can:

- Include energy when negotiating Western Hemisphere free trade agreements.
- Work with the new government in Mexico to allow U.S. companies to participate in the oil, natural gas, coal and electric power sectors.
- Work with Canada as well as Mexico to develop a North American energy trade strategy.
- Incorporate as broad a definition of energy services as possible in the World Trade Organization's upcoming round of negotiations on "services."
- Drop unilateral trade and economic sanctions.
- Support the opening of markets currently closed to U.S. companies as a cornerstone of U.S. foreign policy.
- Utilize U.S. influence and credibility to discourage actions that damage the U.S economy by the Organization of Petroleum Exporting Countries.

The new Administration should refocus development priorities, giving top priority to programs that encourage domestic resource development and utilization. For example, policymakers could establish a more direct link between trade promotion and international development. After all, emerging democracies cannot develop into modern, civil, stable societies unless those nations provide their citizens affordable and reliable energy supplies. Additional U.S. assistance would help develop these much-needed energy supplies.

For example, hospitals cannot refrigerate vaccines, schools cannot provide adequate lighting and clean water systems cannot function without energy. Poverty stricken families in Africa may spend eight hours a day gathering fuel wood and animal waste to burn for light and heat. Providing basic supplies of energy can allow a mother these eight hours to teach children to read or to raise a crop for income. The cycle of poverty will never be broken without access to energy.

The World Energy Council indicates that as many as two billion people lack access to energy. The potential for social instability from poverty is a clear threat to U.S. security and our national interests. Increasing the supply of reliable and affordable supplies of energy to stimulate economic growth in developing and reforming nations must be a cornerstone of U.S. foreign policy.A new model of foreign assistance launched in 1990, energy partnerships, has proven to be more effective than traditional models in this area. The U.S. private sector, by donating their expertise, have fostered the development of economic climates conducive to trade and direct investment by U.S. corporations. These efforts have led to one dollar of matching expenditures by U.S. private sector organizations for every dollar of U.S. government assistance.

Another priority should be fostering international trade and investment, which is best done by creating appropriate legal, regulatory, tax, trade and financial frameworks that open markets and facilitate foreign investment. Energy related economic development assistance has created investment and trade opportunities in South America and Eastern Europe and are on the verge of paying off in Asia and Africa. These programs administered by the U.S. Agency for International Development (USAID) should be expanded.

Funding of programs to support international development, export and investment also should be strengthened in the U.S. Department of Energy, Trade & Development Agency, Export-Import Bank; Overseas Private Investment Corporation and the U.S. Department of

Commerce. Jobs for Americans and employment opportunities for citizens of client countries are enhanced when energy driven economic growth becomes possible in developing and transitional economies. Global trade and investment in creating the energy infrastructure critical for a modern, civil, democratic society pays dividends in terms of U.S. energy, economic and national security.

The need for global attention to developing countries energy requirements rivals the need after World War II for a Marshall Plan to rebuild Europe. In fact, an energy Marshall Plan for developing countries and transitional economies can re-establish U.S. global leadership in this area and mitigate our domestic energy problems and improve our economic and national security.

Energy Research, Development, and Deployment

Technological advances have allowed us to find, produce, transport and utilize energy in ways unimaginable only a few decades ago. Technology has contributed dramatically to an energy supply system that is efficient, safe, and environmentally secure. Future technological advances are expected to stimulate continued improvement in all of these areas as well as contribute to a diverse, robust, and economical energy future.

However, investments to maintain and improve the existing energy system have declined over the past few years, thus jeopardizing system reliability. The downward trend in investment is in part responsible for a rash of power system interruptions in the eastern and midwestern regions of the country in the summer of 1999, and the rolling blackouts in California in 2001.

Paralleling the reductions in investment in capital improvements is a sharp decline in both public sector and private sector energy R&D expenditures during the 1990s. Analysis currently underway within the World Energy Council indicates that this phenomenon is not limited to the United States, but is true of all OECD countries. Total research appears to be less than half of 1990 levels. Increases in research and development budgets are needed to create a new technology base on which to build modern infrastructures for the production and delivery of oil, natural gas, coal and electricity.

A key element of technology advance is the achievement of consensus on the issue of the role of the federal government in research, development, and deployment. Particularly in the case of technologies for critical energy infrastructures, where system failures can have consequences that reach far beyond state boundaries, a role for the federal government should be defined. In addition, where technical and business risks of new technologies are high, risk sharing through collaborative leadership initiatives involving the public and private sectors seems appropriate.

Priority should be given to research efforts that can contribute to production and utilization of domestic energy resources. The federal government should focus on basic and applied research that can increase energy supply while improving both energy efficiency and environmental protection. Research and development priorities should be reviewed to insure that those energy sources most likely to contribute to a diverse and robust fuel supply system over the next twenty years are adequately funded. Increased federal funding for research and development in all arenas—oil, gas, coal, nuclear, and renewable energy—should be considered.

Initiatives to improve energy delivery—including natural gas pipelines, electricity transmission systems, and energy storage facilities—also require increased funding. Near-term programs are needed to ensure reliability of supply while system upgrades are needed to handle the new patterns of traffic on electricity transmission systems and pipelines caused by wholesale and retail competition. Finally, new technologies must be developed to begin the process of transforming the entire electricity power system—from generation to end use – into the equivalent of continental-scale integrated circuit, able to respond rapidly to changes in system loading while retaining power stability. The result will be a digital infrastructure that links an upgraded transmission system to a new distribution system, capable of supplying all customers with affordable, abundant energy, and differentiated energy products and services.

U. S. public spending for R&D should be better coordinated with other OECD countries. Doing so will improve the efficiency of research efforts and minimize duplication of efforts. U.S. research programs should reflect the potential for applications outside the U.S., particularly in developing economies. As energy issues increasingly become global concerns, federal government investments in R&D will have higher paybacks if the new technologies are deployed globally as well as domestically.

Education and Public Awareness

Well-educated energy consumers enhance market efficiency, especially in an era of deregulation. Accordingly, policies that promote consumer awareness and education about key energy issues need to be an integral part of the proposed National Energy Strategy.

Workers in the energy sector can also benefit from education and training. This is particularly true at a time when labor markets are tight and enrollments in energy related disciplines are declining at most colleges and universities. The explosive growth during the 1990s of information technology companies—which compete directly with potential energy workers, especially for technically-trained people—has reduced the workforce pool for energy companies. Unless action is taken soon, the U.S. education system may be unable to produce a sufficient number of well-trained graduates to meet demand in the coming decades.

Balancing Energy Demand and Environmental Concerns

Energy and environmental issues have become inextricably linked to one another, and to national policy decisions. This linkage is both broad and deep, and involves concerns about air quality, toxic wastes and global climate change, to name a few policy issues. Balancing the economic efficiency and reliability of a competitive energy market with appropriate environmental policies is key to developing an effective National Energy Strategy. When balancing America's energy needs and our nation's broad economic and social goals, policymakers should be guided by sound scientific and economic analysis. They should also apply cost-benefit and risk analyses when reviewing environmental laws and regulations.

In short, environmental regulation should be formulated in a way that achieves reasonable environmental objectives while recognizing the on-going need to provide companies and consumers a reliable and affordable supply of energy so U.S. economic growth remains robust.

Global Climate Change - a Way Forward

Climate change is a long-term global issue that, in the last decade, moved from a scientific question into the international political arena. As recently as 1990 the United Nations-sponsored Intergovernmental Panel on Climate Change (IPCC) reported that a global warming trend may be underway, and that greenhouse gases emissions from human sources may increase the potential impact of global warming. The IPCC recommended that an international agreement be negotiated setting forth a pathway to limit man-made greenhouse gas emissions, especially energy-related carbon dioxide emissions. In 1992, 160 nations heeded this advise and signed the Rio Agreement on Climate Change, formerly known as the "United Nations Framework Convention on Climate Change" (FCCC).

The United States was among the nations to ratify this agreement, which has as its objective stabilizing the atmospheric concentration of greenhouse gases at a level that prevents dangerous anthropogenic interference with the climate system. In ratifying the FCCC, the United States, Europe, Japan and other industrialized countries agreed to take the lead in modifying longer-term trends in anthropogenic emissions, to make best efforts to reduce emissions to 1990 levels by 2000 and to provide technology and funds to developing countries to ensure that emission levels would remain as low as possible—without jeopardizing economic development.

In the months that followed, many U.S. companies, and even entire industry sectors, began to develop programs to increase operating efficiencies, put new technologies in place, and implement business practices aimed at lowering greenhouse gas emissions—while, at the same time, maintaining a growing U.S. economy. These voluntary programs, often in conjunction with government partners, have paid off. Recently, the Department of Energy released a report showing that U.S. greenhouse gas emissions are more than two hundred million tons per year lower than they would be had industry and business not taken these voluntary actions.

A sound long-term climate change policy that complements a sound long-term energy policy must be developed to ensure that the greenhouse gas emissions growth line continues to bend downward while the economic growth curve continues to move upward. Sound climate change policies can make this happen, particularly if these policies:

- Emphasize voluntary action;
- Are cost effective, flexible and focus on long-term solutions that recognize that our economy is built on the availability of reasonably priced energy of all forms;
- Address both cost-effective mitigation actions—such as avoiding emissions through enhanced energy or operating practices—and adaptation to changes that occur for whatever reason;
- Expand research programs that address science, economics and technology development;
- Remove barriers to the deployment of new technologies and encourage rapid deployment through incentives;
- Address the needs of developing nations, including their desire to build their domestic capabilities and grow their economies; and,
- Encourage local action and actions by governments as well as by industry.

Unfortunately, as we enter the 21st Century U.S. climate policy is not based on a long-term strategy. Over the last three years, the US Administration's strategy has been short term and directed at ratifying and implementing the 1997 Kyoto Protocol. This agreement, concluded in December 1997, would require the U.S. and other developed countries to meet mandatory emission reduction targets by 2008-2012. For the United States, the Kyoto Protocol would mean a reduction of greenhouse gas emissions to a level that is seven percent below 1990 levels with additional, but as yet unidentified reductions, after 2012. To meet the initial target the U.S. would have to cut its emissions by 30-35 percent below projected levels. Doing so would be very costly. Most analyses show that reaching this target in such a short time period would reduce the U.S. GDP by several percentage points.

To date, the Kyoto Protocol has not been submitted to the U.S. Senate. If it were, it likely would not be ratified, which is a requirement for the United States to be bound by that agreement. The United States in not alone in its concerns about the impact of the Kyoto Protocol. As of January 2001, no developed country has ratified the agreement. Most nations realize that the Protocol would require significant changes in energy, economic and trade policies and would seriously affect the lives of every citizen. Moreover, the European Union has strenuously resisted elements in the Protocol that theoretically could reduce the cost of compliance. These elements include a proposed emissions trading program, the Clean Development Mechanism (directed toward emissions abatement in developing countries) and land use and forestry programs. Such elements are key to offsetting costly short-term mandatory emission reduction targets. To date, nations are looking for reasonable and cost effective approaches to deal with the climate issue. Increasingly, it is appears likely that most nations will concentrate on new technology development, deployment and transfer to limit greenhouse gas emissions.

In the decade ahead, the federal government should seek to meet the commitment expressed in the FCCC by devoting sufficient scientific resources to determine the maximum atmospheric concentration of greenhouse gases that would "prevent dangerous anthropogenic interference with the climate system" (From Article 2 of the FCCC). Additionally, the U.S. should work with other nations, including developing countries, to establish an equitable long-range plan to prevent the exceeding of this unacceptable concentration. This plan should include all market-based measures that contribute to the ultimate goal, including making maximum use of cost-reducing implementation measures. Moreover, governments should work with industry to develop a broad suite of technology options from which energy users could select in order to meet climate change policy goals in 2050, 2075 and 2100.

POLICY RECOMMENDATIONS

Competitive markets, investment tax credits, deregulation, environmental impact statements and licensing permits are among the tools available to National Energy Strategy policymakers. The following are the policy recommendations and tools that members of the United States Energy Association believe would most effectively help a wide array of U.S. energy producers and energy-related service companies meet America's growing demand for ready, reliable, secure and affordable energy resources:

Enhancing Energy Supplies

- **The nation should encourage power supply expansion with policies that fully recognize that no single energy source can meet our growing energy needs.** This means that any federal incentive that encourages energy production should promote maintenance of a diverse energy portfolio made up of fossil fuels, nuclear and renewable energy sources. Sufficient availability of basic energy fuels as feedstock for non-energy applications should also be considered in the development of a diverse energy portfolio.
- **Policies that restrict access to energy sources should be modified to provide environmentally sound access to domestic resources in a way that supports the continuance of a diversified energy portfolio and reduces foreign dependence.** Such policies should not merely focus on one aspect of the energy supply system, but rather support and encourage all components of a sector's production and delivery of its energy supply (e.g., from oil exploration and production through the building of refining capacity). Congressional mandates under the Federal Land Policy Management Act and related acts should be adhered to. These acts require agencies to give balanced consideration to multiple competing uses of federal lands. Experience has shown that federal lands do not have to be restricted solely to environmental or aesthetic uses.
- **National policy should specifically focus on diversifying energy resources in the national portfolio.** The U.S. Strategic Petroleum Reserve should be maintained and utilized only for severe supply disruptions
- **Investment tax credit mechanisms and accelerated depreciation (or equivalent mechanisms) should be primary government tools to encourage reliable, affordable and environmentally effective energy supplies, end-use technologies and a sound energy infrastructure.** Private investment should be encouraged through flexible tax mechanisms that insure equitable opportunities for all energy sectors. In the interest of stimulating the use of the most market efficient technologies, tax incentives should encourage facility construction but not subsidize the delivery of products to consumers.
- **Tax incentives should be enacted to spur capital investment in the energy sector.** These tax incentives will help the U.S. energy industry ensure adequate and uninterrupted energy supplies and services to U.S. consumers and enhance U.S. national

security through the preservation of a viable domestic energy industry. For example, expensing of geological and geophysical (G&G) expenditures for oil and gas wells should be enacted. Tax incentives should also be utilized to encourage energy efficient capital stock.

Encouraging Energy Efficiency and Affordable Prices

- **Energy efficiency should be promoted through governmental policies that focus both on production and demand.** For example, the convergence of retail competition, wholesale competition, and improved technologies should greatly expand the type and magnitude of price-responsive demand in electricity markets. Efficiency products should be promoted through directed research and subsequent market availability. Artificial efforts to mandate market penetration of efficiency schemes should be avoided. Regulatory polices that allow and encourage retail customers to respond to market prices will improve economic efficiency, discipline market power, improve reliability, and reduce the need to build new generation and transmission facilities.

- **Policymakers should rely on a properly structured marketplace for energy decisions regarding pricing, technology deployment, energy efficiency, and selection of fuels and energy suppliers.** Market competition is a dynamic process that produces long-term benefits for the public. Governmental policies should seek to establish and preserve the conditions necessary for efficient competition to work. Government officials at all levels should only cautiously impose new regulations on the energy chain. Moreover, efforts to address health, safety, and environmental concerns should be based on sound science and cost-effective options. Specifically, regulations should not be imposed in the hope of reaching a goal that researchers cannot demonstrate as achievable at a reasonable cost.

- **Energy markets should be free and competitive, and utilities should be allowed to compete fairly in these markets.** Energy markets have been opened to competition, and increasingly consumers need to be free to buy their energy and energy-related services from whichever supplier they choose, including natural gas and electric utilities that wish to offer these services. Regulatory authorities should reject attempts to impose restrictions or competitive handicaps that limit the ability of distribution utilities to compete in newly emerging energy service markets, while ensuring against cross-subsidization between regulated and unregulated businesses. By doing so, regulators can preserve the social benefits of efficient competition in energy markets.

- **The low-income home energy assistance program (LIHEAP) should be extended and funding increased.** Currently LIHEAP funds are reaching only 15% of the households eligible for assistance. The low-income weatherization program should also be expanded.

Stimulating Global Energy Trade and International Development

- **U.S. leadership in energy services and technology should be promoted on a global basis.** Artificial constraints on exports and global market penetration should be severely limited. For example, unilateral trade sanctions damage U.S. companies, workers and consumers by excluding them from key markets in which foreign-based companies are free to invest.

- **Tax provisions which diminish the international competitiveness of U.S. multinational energy companies by exposing those firms to double taxation (i.e., the payment of tax on foreign source income to both the host country and the United States), and to restrictive anti-deferral rules, should be eliminated.** The complexity of the U.S. international tax rules obfuscates tax planning and often introduces substantial risks, hindering effective capital investment.

- **A cornerstone of U.S. foreign policy and development assistance should be to institute a "Marshall Plan" to increase the supply of reliable, affordable and market-based energy for developing countries and countries in economic transition in a manner that opens markets to U.S. goods and services, fosters cooperative partnerships between the U.S. and overseas energy firms, and enhances international economic and political security.** This plan would encourage the export of advanced U.S. technologies, policies and practices appropriate to developing countries for the efficient supply and use of energy.

- **Foster more open political, legal and institutional structures in developing and reforming countries so as to encourage energy trade and investment.** U.S. expertise and technology can be utilized to serve the global market through capacity-building, sectoral reform and financing.

Promoting Energy Technology Development and Long-Range R&D Initiatives

- **Investments in energy technology research and development should focus on energy sources and uses that realistically can be expected to have a significant impact on economic growth and environmental performance over the next 20 - 30 years.** This requirement implies the development of a balanced portfolio of energy sources and fuels (fossil, nuclear, renewables) to promote national security. Structural changes and technologies that increase the flexibility and value to the user of the energy system should also be encouraged. Finally, technologies must be developed to assure that we will be able to handle increased traffic levels and meet the needs of a digital economy.

Balancing Energy Use and Environmental Concerns

- **Government sponsored education programs should recognize the importance of energy infrastructure and energy sources to continued energy security and economic development.** Energy and environment programs should be deployed at all educational levels that recognize energy supply and energy efficiency as critical to the modern economy and national energy security. Maintenance of robust educational programs capable of producing engineers and technicians in sufficient numbers to meet the growing needs of the nation's energy infrastructure should be an important consideration in all government programs affecting educational institutions.

- **The development and deployment of energy infrastructure should favor all technologies that are capable of producing energy at emissions levels below existing national standards.** For example, if investment and production tax credits are used to encourage investment, the credits or other mechanisms should be available to all technologies that produce end-use energy below the emissions standards without the application of administrative credits. Moreover, national policies should promote—at current or better levels—the maintenance of non-emitting energy technologies in the nation's energy portfolio.

- **The safe and efficient movement of energy goods and services requires that increased attention be given to improving the United States transportation infrastructure.** For example, oil products and coal are heavily dependent on safe waterways and harbors and coal relies greatly on adequate railroad capacity. Most movement of energy goods and services require a well maintained road system.

Unifying the Energy Policy Process and Creating Regulatory Predictability

- **The President should establish an interagency task force on energy policy chaired by the Secretary of Energy.** The membership of the task force should include economic policy departments and agencies and the appropriate national security organizations.

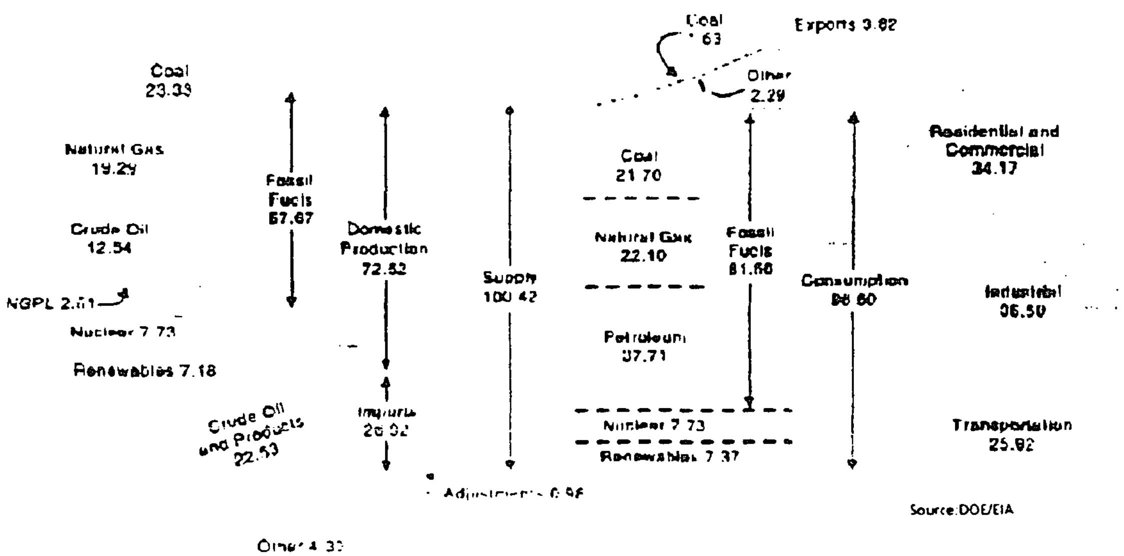
- **Energy Policy must be predictable.** In recognition of the capital-intensive and durable nature of energy infrastructure investments, energy policy requires the adoption of a long-term view. Private investors in energy projects must be able to plan such investment with the reasonable certainty that, once begun, a project can operate in a regulatory climate, which safely can be forecast for the duration of the construction period and operating life of that facility. Revised regulatory standards should not be imposed until acceptable technology to achieve the new standards is demonstrable. This requires the use of fresh approaches to coordination by relevant agencies, such as regulatory bodies and those federal agencies responsible for sponsoring energy R&D. The net effect may extend considerably the time required to alter regulatory standards, but this approach is consistent with practices affecting operating licenses, which, at least nominally, provide for use of a new facility for four or more decades.

- **Comprehensive electric industry restructuring should seek to encourage long-term improvements to the electric system.** Finding the right mix of market solutions and government oversight to ensure an economical and reliable electricity supply will be difficult—but is possible. For example, 17 electricity restructuring bills were introduced in the 106th Congress. While no consensus legislative package has yet developed, significant issues embodied in the proposed legislation include, among others, repealing PURPA and PUHCA, facilitating new state restructuring actions by resolving federal/state jurisdictional issues, resolving market power and transmission access problems, and grandfathering existing state restructuring plans to protect them from federal preemption. Tightly linked with the emergence of efficient competition in the electric industry is the need for comprehensive tax legislation that facilitates the construction of new transmission facilities and provides fair electric competition among publicly owned, cooperatively-owned and shareholder-owned electric companies.

Moreover, Congress and policymakers should develop polices that promote investment in new generation and transmission lines. Policies should also promote voluntary flexible approaches to the creation of regional transmission organizations and electricity markets. Finally, the North American Electric Reliability Council should evolve into a self-regulating organization, with FERC oversight, that enforces reliability rules on all transmission operators and users.

INDUSTRY SECTORS

U.S. Energy Flow Chart 1999
(Quadrillion BTU)



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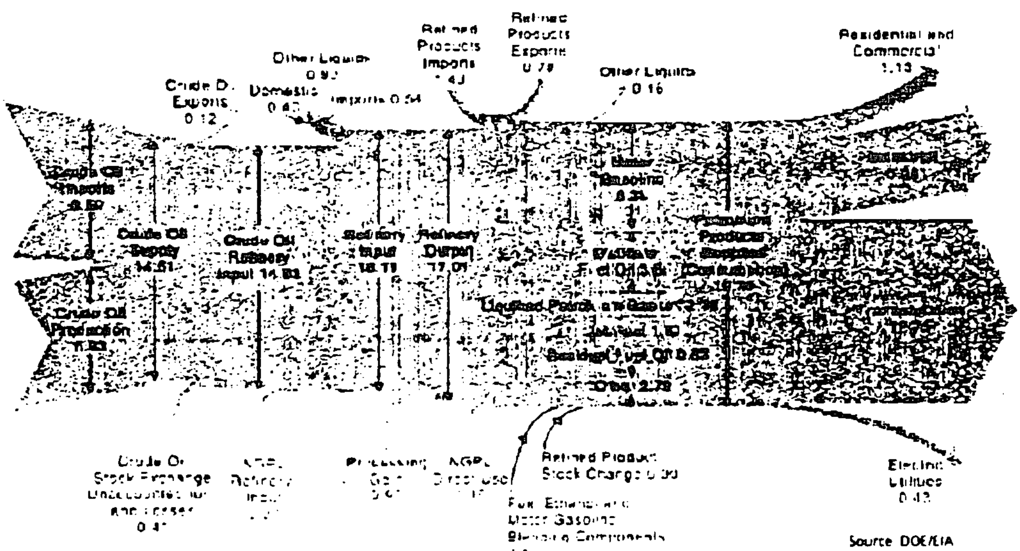
PETROLEUM

Petroleum Flow Chart 1999



Source DOE/EIA

OVERVIEW

While petroleum currently supplies 40 percent of America's primary energy needs, reliance on this fuel varies greatly by sector. For example, petroleum supplies 97 percent of transportation needs, 35 percent of industrial needs, 8 percent of commercial needs and 13 percent of residential needs. The most common—and important—petroleum products are gasoline, diesel fuel, kerosene, heating oil, residual fuel oil, liquefied petroleum gases, asphalt and petrochemical feedstocks.

Since 1970, production of crude oil has declined from 9.6 million barrels per day to 5.8 million barrels per day. At the same time, consumption has increased from 14.7 million barrels per day to about 20 million barrels per day, or some 300 billion gallons per year. During these same 30 years, oil imports have increased from 23 percent of U.S. petroleum demand to the current level of about 55 percent. The U.S Department of Energy's Energy Information Administration forecasts that petroleum demand will continue to grow during the next two decades.

The Energy Information Administration's (EIA) Annual Energy Outlook 2001 highlights several other important facts about the role of petroleum in our nation's future:

- Net petroleum imports are projected to increase to 64 percent of U.S. demand in 2020.
- The greatest growth in petroleum demand will occur in the transportation sector, where increased travel more than offsets fuel efficiency gains.

Clearly, petroleum will provide a major source of energy for years to come.

EMERGING CONSUMPTION PATTERNS

The Energy Information Administration projects an increase in demand for all petroleum products of 1.4 percent per year for the next twenty years, or slightly higher than the 1.3 percent per year that EIA projects for all energy sources during this same period. This projection for higher petroleum demand comes at a time when consumers have endured a heating oil price spike and a gasoline price spike, and at a time when petroleum refiners have faced significantly higher crude oil prices.

As demand has increased and supplies tightened, the Organization of Petroleum Exporting Countries (OPEC) has reasserted its grip on world oil supplies, keeping crude oil prices above $30 per barrel for almost one year. U.S. imports of crude oil and products have grown during this same period, as has utilization of refinery capacity. Indeed, the petroleum industry continues to strain as it seeks to meet the growing demand for home heating oil, gasoline, diesel fuel and petrochemicals. In recent months the U.S. economy has slowed somewhat, but overall economic growth remains a healthy 2.4 percent and demand for petroleum continues to grow despite higher product prices.

EIA's Supply-Demand Scenario

In Annual Energy Outlook 2001, EIA analysts set forth a scenario that they believe will close the gap between rising petroleum imports and product prices and America's need for affordable, reliable energy supplies. Here are the outlines of that scenario, which looks out to the year 2020:

- Crude oil production declines by 0.7 percent per year.
- Crude oil imports increase by 1.6 percent per year.
- Petroleum product imports increase by 4.6 percent per year.
- New light duty vehicle efficiency increases from 24.2 to 28.0 miles per gallon.
- Freight truck and aircraft efficiency increase by about 0.7 percent per year.
- Refinery capacity expands from 16.5 to 18.2 million barrels per day.
- Refinery utilization increases from 93 to 95 percent.

Policymakers concerned about our nation's economic and energy future must decide whether this scenario is realistic. While it is impossible to assess precisely the likelihood of any forecast, or even the many elements of the EIA forecast, it is possible to compare EIA's projections to historical experience. It is also possible to identify the policy assumptions used to create this forecast and, of equal importance, to present a series of ideas to help policymakers forge an effective National Energy Strategy for the decades ahead.

History vs. Projections

EIA analysts argue that domestic crude oil production will slow significantly during the next 20 years. However, when they quantify that argument, they propose a modest decline in petroleum production of a mere 0.7 percent per year. This figure does not represent historical trends, which show a decline in U.S. crude oil production during the 1990s of some 2.5 percent per year. This slower rate of decline in petroleum production translates into a lower than expected rate of growth in crude imports, at least in EIA's scenario.

More specifically, EIA forecasts that during the next two decades the United States will increase its crude oil imports at the modest rate of 1.6 percent annually. However, during the past decade, U.S. crude oil imports actually increased a substantial 3.9 percent per year. The EIA scenario for petroleum products also is at variance with the historical record. EIA projects that petroleum product imports will increase at the rate of 4.6 percent per year. During the past decade, petroleum product imports actually declined by 1.2 percent per year.

History is no guide, either, to EIA projections about increases in vehicle efficiency. The EIA scenario foresees a faster rate of vehicle efficiency in the next two decades than occurred during the past decade, but the projected rate is slower than the actual rate of improvement during the mid-1980s.

On the other hand, EIA projections hew fairly close to historical fact in the area of petroleum refinery capacity and utilization. During the past decade, U.S. refinery capacity has increased a total of approximately 850,000 barrels per day. This figure is comparable to EIA's forecast that within two decades, U.S. refinery capacity will have increased 1,700,000 barrels per day. The projected increase in refinery capacity utilization also appears to be close to the likely mark. While capacity utilization has increased from 86.6 percent to 93 percent during the past decade, EIA analysts forecast an increase of 2 percentage points by 2020.

POLICIES TO MEET AMERICA'S GROWING PETROLEUM DEMAND

While EIA's forecast is often at variance with the historical record, both history and EIA's most recent forecast indicate that petroleum demand will grow significantly in the decades ahead, even if all projected energy efficiency gains are realized. The only way to meet this increased demand for petroleum is to adopt national policies that support growth in petroleum supplies. The alternative is to limit demand by imposing sharply higher petroleum prices on U.S. homeowners, commuters, transportation companies and factories. However, these higher prices would slow U.S. economic growth.

Ensuring Adequate Supply

A National Energy Strategy can be developed that meets America's growing demand for petroleum without substantially raising prices. Studies have shown that vast amounts of proven crude oil reserves and undiscovered crude oil resources exist, both domestically and abroad. However, polices that support continued investments in finding and producing these resources are needed to bring these crude oil supplies to market.

Companies will make the decisions to invest in finding and producing the needed petroleum once policies are in place to support such long-term capital commitments. Unfortunately, the recent EIA forecast simply implies that significant investments will be made, domestically and abroad, without addressing the need to develop policies favorable to increased crude oil production.

The same is true of petroleum products. Stakeholders must come together to adopt policies that insure an adequate supply of gasoline, diesel fuel, home heating oil and petrochemicals. Concerns about environmental impact should take into consideration the unparalleled improvement in exploration and production technology. For example, the exploration footprint has been improved by 90 percent during the past decade, and similar, if less dramatic examples, exist in other areas of petroleum production.

Ensuring the Security of Petroleum Supplies

As noted, EIA analysts forecast a sharp increase in petroleum imports—the current rate of 55 percent to a rate of 64 percent in 2020. This increase in imports raises legitimate questions about security of America's petroleum supplies. What countries can supply this growing volume of crude oil and petroleum products to U.S. consumers? Are these countries reliable suppliers? Do new and more diverse sources of petroleum exist that are not included in the EIA forecast? What role will OPEC play with respect to future oil supplies and prices?

Clearly, OPEC members have constrained supply during 1999 and 2000 and maintained relatively high prices. Will this pattern continue? If new petroleum producing countries join the world energy markets, will these countries become members of OPEC or another cartel?

As these questions suggest, the United States has less control over the security of its petroleum supply as long as we are heavily dependent on petroleum imports. Policies that promote diversification of supply would reduce this uncertainty. So would policies that enhance domestic petroleum production.

Stimulating Needed Investments

Policies that encourage investments in crude oil exploration and production need to be included in the National Energy Strategy. So, too, should polices that encourage major investment in petroleum refining, distribution and marketing. For example, the EIA forecasts that an additional 1.7 million barrels of capacity will be needed to meet demand in 2020. Who will finance this increased capacity, and who will build it? Will companies expand existing refineries, or will they need to build new ones—as many as eight to 10 major refineries to meet EIA's petroleum demand projections?

And if refinery capacity utilization cannot increase to the 95 percent level that EIA forecasts, two additional new refineries will need to be constructed. However, no major refinery has been built in the United States during the past 25 years. What policies will Congress enact to support the construction of eight or more new refineries during the next 20 years? What policies will encourage major investment in the pipelines and terminals that will be needed to transport an additional 5 million barrels of oil per day to consumers?

The National Petroleum Council (NPC) published a study in June 2000 entitled "U.S. Petroleum Refining—Assuring the Adequacy and Affordability of Cleaner Fuels." The study assessed government policies and actions that would affect product supply and refinery viability. The study concludes that the refining and distribution industry will be significantly challenged to meet the increasing domestic light petroleum product demand with the substantial changes in fuel quality specifications recently promulgated and currently being considered. The NPC study contains specific recommendations and findings related to petroleum product supply and future refinery viability. The Secretary of Energy, in consultation with the governmental departments and federal agencies, shall report to the applicable committees in the houses of Congress on the findings and conclusions of the NPC study and on the adjustments to federal policy required to implement those findings and conclusions.

Encouraging International Energy Trade and Development

Because the United States faces increased dependence on petroleum imports during the coming decades, U.S. energy companies will need to be able to find and produce oil internationally. American companies are well positioned to do this. Most have gained a technological advantage that ensures a fairly high rate of discovery and production. However, policies to support these international initiatives, which often involve considerable financial risk, need to be place. Some existing tax laws and other public policies hamper international efforts to find and produce oil in promising areas. Such policies should be reviewed and, if needed, revised to strengthen U.S. leadership in new petroleum exploration and production.

Energy Technology R & D

The U.S. petroleum industry is one of the most technologically advanced in the world. In recent decades, American petroleum companies have dramatically reduced exploration and production costs while sharply reducing as well the footprint required for new oil exploration. Policies should be put in place that assign a value to these technological advancements that is equal to the value assigned to technological advances in other energy areas. Certainly, government officials should not select winners and losers. Rather, a range of energy technologies should be encouraged, and the market should be allowed to adopt the most successful technologies as each new technology proves its worth to consumers.

Environment

The U.S. petroleum industry has dramatically improved its environmental performance by investing more than $8 billion per year in environmental initiatives, or a total of more than $90 billion during the 1990s. The industry remains committed to ongoing environmental improvements, but any additional environmental rules or regulations need to reflect sound science and the likely impact of such policies on U.S. petroleum supplies and the U.S. economy.

Indeed, some existing regulatory polices require close scrutiny. Over the years, a patchwork quilt of conflicting and overlapping regulations has made expansion of the petroleum supply structure nearly impossible. Policies should be put in place that reflect growing demands on the U.S. petroleum supply infrastructure as well as the need to maintain environmental quality.

Transportation

The internal combustion engine—running on petroleum—will remain the dominant powertrain for personal vehicles for the foreseeable future. Even if promising advances in fuel cell and hybrid technologies produce a new breed of vehicle, years will pass before these new technologies significantly replace the current U.S. fleet of more than 200 million gasoline and diesel powered cars, buses and trucks.

For example, a recent study by the WEFA Group found that over 80 percent of the vehicles purchased today would still be on the road in 2008. In short, several decades are likely to pass before the current fleet is replaced by a new powertrain technology, or by significantly more efficient vehicles. Policymakers need to bear this hard fact in mind when developing transportation and environmental policies.

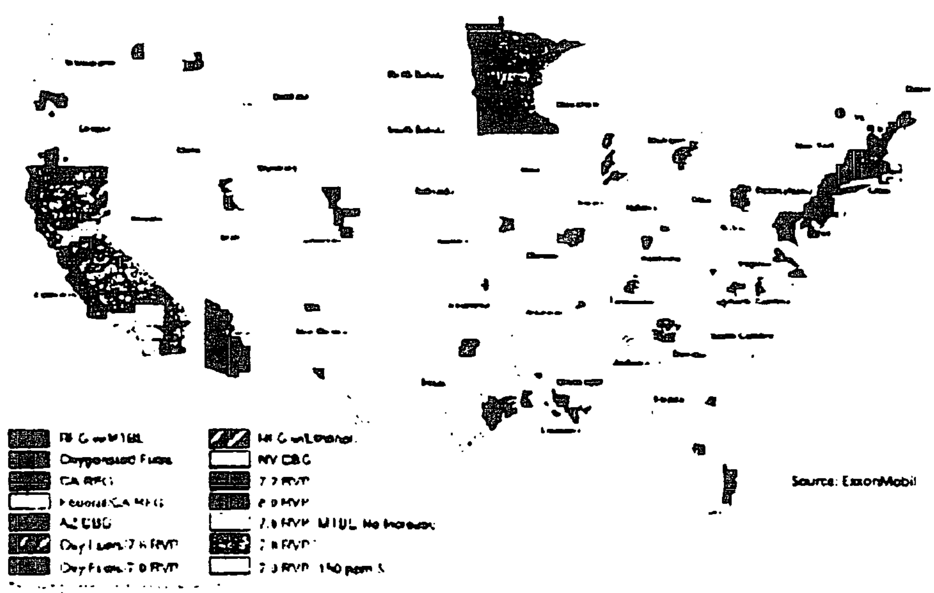
Moreover, most policymakers focus, understandably, on polices that affect cars, pickups and sport utility vehicles. However, other forms of transportation also merit consideration when formulating an effective National Energy Strategy. For example, trucks deliver over 70 percent of America's goods, measured by value. Rails, ships, pipelines and aircraft deliver the rest. All of these transportation modes rely on petroleum as their major source of fuel, not only to move freight but also to move passengers.

To be effective, future transportation policies must reflect the complex interrelationship between petroleum, people, the delivery of goods and services, the environment and economic vigor—and the inestimable capital investment Americans have made in the current transportation infrastructure.

The safe and efficient movement of goods through the United States' port system, including a significant share of energy products, requires that channels be dredged and maintained at safe depths on a consistent basis. Safe navigation also requires accurate and current navigational charts for U.S. waterways. To date, however, these programs have been and continue to be so severely underfunded that it will take the National Oceanic and Atmospheric Administration (NOAA) 20 years to eliminate the survey backlog. Hydrographic survey data, which is the basis for nautical charts, should be collected using the latest hydrographic survey equipment. Some hydrographic data still being used is over 40 years old. All available resources, both public and private, should be fully utilized, without limits placed on the sources of certifiable survey data. The Harbor Maintenance Trust Fund should be taken off budget and used exclusively for harbor services. This would guarantee that resources are available to meet the growing needs of maritime commerce.

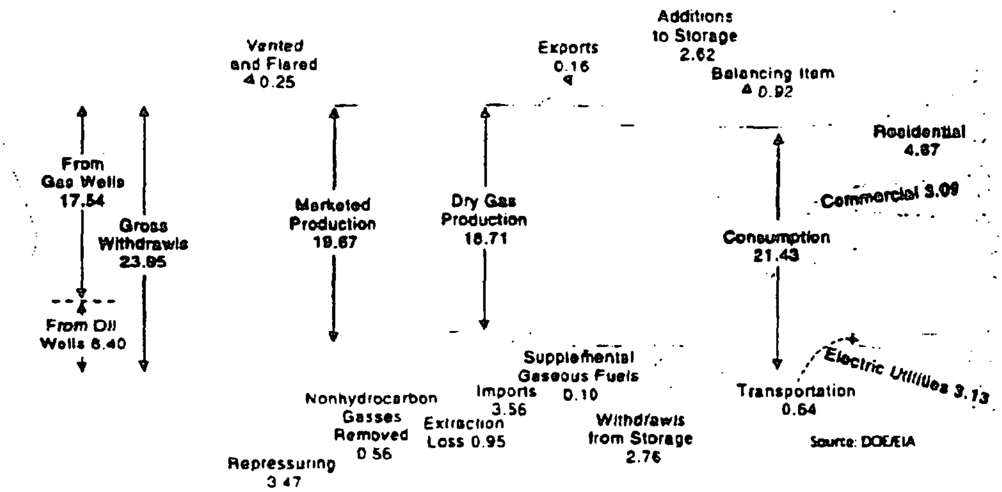
Finally, a national energy policy needs to recognize the international nature of oil transportation. Accordingly, the U.S. government should look to and support broad-based international solutions to marine regulatory issues. The International Maritime Organization (IMO) is the appropriate forum for discussions of such issues as vessel operations, ballast water management, marine air emissions, and vessel scrapping. The U.S. needs to remove barriers to the timely replacement of aging domestic tonnage and stimulate a robust domestic fleet.

U.S. Fuel requirements in 2000



NATURAL GAS

Natural Gas Flow Chart 1999
(Trillion Cubic Feet)



OVERVIEW

Natural gas—a fossil fuel composed almost entirely of methane—accounts for approximately one-quarter of the nation's primary energy consumption. Residential and commercial uses of natural gas include space heating, water heating, cooking, and clothes drying. Natural gas is used by industry both as feedstock in chemicals and in process applications. Moreover, power plants use natural gas to generate electricity, while private citizens use it for space cooling, as a vehicle fuel and in fireplaces.

Three segments of the natural gas industry deliver natural gas from the wellhead to the consumer. Production companies explore, drill and extract natural gas from the ground. Transmission companies operate the pipelines that link gas fields to major consumer areas. And local utilities, acting as distribution companies, deliver natural gas to individual customers.

The number of natural gas consumers has grown through the years, and now totals nearly 175 million Americans. Natural gas from 288,000 producing wells is forwarded by 125 natural gas pipeline companies through a 1.3 million-mile network of underground pipes to more than 1,200 gas distribution companies who provide customer service in all 50 states. Almost all of the gas consumed in the U. S. is produced in North America.

CONSUMPTION PATTERNS

U.S. consumption of natural gas has increased by roughly 13 percent over the last decade, and demand is expected to increase significantly in the future. This growth has occurred in

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all sectors of the economy. In the residential sector, for example, 70 percent of new single-family homes used natural gas their main source of heating fuel during 1998 and 1999. In the ten years since 1989, U.S. commercial use of natural gas has increased nearly 14 percent, and industrial consumption of natural gas has increased almost two quadrillion BTUs (quads). During this same period, natural gas use to generate electricity has risen approximately 12 percent.

This trend toward greater reliance on natural gas—which is expected to continue—can be attributed to a variety of factors, including favorable economic conditions, superior environmental qualities, and the high efficiency of gas systems. In addition, the natural gas resource base is far stronger than many people realized a decade ago. Moreover, opening natural gas markets to competition in recent years has contributed to efficiency improvements within the industry. The National Energy Strategy should encourage the continuation of these trends.

ENVIRONMENTAL BENEFITS

Natural gas offers numerous environmental advantages relative to many other energy sources. For example, natural gas emits negligible amounts of sulfur dioxide, particulate matter, ash, and sludge. Also, because it emits low levels of nitrous oxide and carbon dioxide, natural gas can help reduce acid rain, ozone, visibility problems, solid wastes and greenhouse gases. Of course no energy source is completely benign with respect to its environmental impacts, but natural gas is an extremely attractive option that can contribute significantly to a number of environmental objectives.

ENERGY EFFICIENCY BENEFITS

Only about ten percent of the natural gas produced is used or lost during production, processing, transmission, and distribution to the consumer. This gives natural gas a competitive advantage over many other energy sources. Equipment that utilizes gas is also far more efficient today than in the past. For example, gas-fired direct contact water heaters used in the textile industry achieve efficiency levels in excess of 99 percent, compared to a 33 percent efficiency level achieved using a prior technology. Similarly, new processes have enabled gas-fired infrared burners to triple their efficiency as well.

RESOURCE BASE

In the decades ahead, natural gas supplies likely will remain strong. Indeed, the North American resource base for this fuel should prove capable of sustaining current consumption levels well into the 21st century, and perhaps beyond. The National Energy Strategy should draw on this secure resource, secure because 87 percent of the natural gas consumed in America is produced in the United States, with the balance coming from Canada. Moreover, Mexico has a large natural gas resource base, and its high production capability makes this neighbor to the South a potential major natural gas supplier.

Although some have characterized the world's gas resource base as "finite," estimates of its size continue to grow. Indeed, as the tools and technologies used to estimate this resource base improve, most estimators have increased their numbers over time. For example, at year-end 1998, the Potential Gas Committee (PGC) estimated the United States' future supply of natural gas at 1,241 quads, or more than 60 years of supply at the current rate of domestic production and consumption. For the past 30 years, PGC members have produced their estimates every other year, drawing on the expertise of hundreds of petroleum geologists and engineers. Interestingly, despite the consumption of more than 149 quads since 1990, the Committee's 1998 estimate exceeds its 1990 estimate (1,207 quads) by 34 quads. This is a 15 percent larger estimate than the 1990 figure, even though significant production (and consumption) has occurred. Much of this increase can be attributed to technological advances, which permit producers to harvest portions of the resource base that previously were unattainable.

PRODUCTION CAPABILITY AND TECHNOLOGY

The National Energy Strategy should reflect the fact that the natural gas resource base has become increasingly diversified. For example, coalbed methane—which accounts for six percent of domestic gas production—was not acknowledged as an important source 10 or 15 years ago.

Tremendous technological advances in natural gas exploration and production also have occurred in the past decade, including three-dimensional seismology, horizontal drilling, and innumerable computer-related breakthroughs. Similar advances will be needed to satisfy potential demand levels. With such advances, domestic gas production can increase from today's 19-plus quads to more than 29 quads in 2020.

Canada will contribute a slightly greater share of total supply in the future by increasing its exports to the U. S. from its current three quad level. Abundant gas resources worldwide and in Alaska offer mid-term insurance, while methane hydrates and other more exotic sources of gas provide long-term potential.

POLICIES TO MEET AMERICA'S GROWING NATURAL GAS DEMAND

The Impact of Deregulation

Policymakers devising a National Energy Strategy will need to consider the dramatic impact that deregulation, or "unbundling," has had on the natural gas industry. Deregulation gives customers the opportunity to purchase natural gas from someone other than the local natural gas distribution company. This trend toward greater customer choice at first gathered strength slowly as local gas utilities increased customer service options, then accelerated dramatically following a 1985 Federal Energy Regulatory Commission (FERC) decision to promote open access to transportation on the interstate natural gas pipeline system for all gas buyers.

By 1999, customer choice volumes accounted for 61 percent of end-use natural gas purchases by customers. Under current and proposed tariffs and choice programs, 81 percent of the volumes could be purchased from a source other than the local gas utility. Almost all industrial and electric utility customers have this option, while almost 70 percent of commercial customers and almost half of residential customers have a choice as well.

Demand Forecast

Natural gas deregulation, the environmental benefits that natural gas can provide, improvements in end-use natural gas applications technologies, and the strong and secure resource base that this fossil fuel enjoys places it in a favorable position vis-à-vis policymakers and consumers in the coming decades. Indeed, both the Energy Information Administration's forecast and the American Gas Association's Fueling the Future study's accelerated demand projections estimate that, by 2020, natural gas consumption could reach 35 quads, compared to a demand for approximately 21 quads in 1999.

While the EIA forecast assumes most of the increased demand will be generated from the electric generation sector, Fueling the Future estimates that nearly half of this projected increase could come in the residential and commercial sectors, where more new customers are choosing natural gas and more existing customers are switching from other fuels to natural gas. The study also shows continued expansion in the amount of natural gas sold for relatively new applications such as residential gas fireplaces and commercial gas cooling systems. In addition, advances in distributed generation (e.g., reciprocating engines, micro-turbines, and fuel cells) are anticipated, and these advances could account for roughly 20 percent of all new electricity generating capacity in the coming decades.

Moreover, during the next 20 years industrial gas demand could grow approximately 2.5 quads under the accelerated projection, continuing the robust growth of the past 10 to 15 years. Although the cogeneration market shows signs of saturation, other forms of distributed generation are expected to prosper. Highly efficient heating, cooling and process equipment continues to evolve, enabling natural gas to remain the dominant source of energy for the nation's factories.

Natural gas-powered transit buses, trucks, vans and cars currently consume about one quad more natural gas under the accelerated projection. Although these vehicles account for less than one percent of the overall vehicular market in 2020, they can make significant contributions to air quality and operational economics, primarily in fleet applications in congested urban areas.

Although natural gas consumption used by central-station power plants to generate electricity more than doubles by 2020 under the accelerated case, this figure is lower than the EIA forecast. For example, natural gas would remain the dominant fuel for new generating capacity, even if some new coal-based capacity were to be added after 2010.

More significantly, less new generating capacity is expected to be required under the accelerated scenario than under other projections. That's because the accelerated scenario assumes that the lives of some existing nuclear and coal power plants will be extended and that strong growth will occur in the use of distributed generation. In the increasingly deregulated energy marketplace, consumers will determine the pace at which new energy technologies are brought on line. The forces of the deregulated natural gas marketplace need to be incorporated in a National Energy Strategy.

Investment Needs and the Policy Environment

The U.S. natural gas industry is both large and capital intensive. Existing natural gas industry assets total more than $250 billion, including a 1.3 million-mile transmission and distribution system valued at nearly $150 billion. Of the 1.3 million-mile total, nearly 1 million miles is devoted to distribution. The U.S. natural gas industry also counts more than 400 storage facilities among its holdings. These facilities are often located close to end-user markets, where the gas is injected during off-peak periods and withdrawn in periods of peak demand. The natural gas industry employs more than 150,000 people, and this figure does not include exploration and production employees.

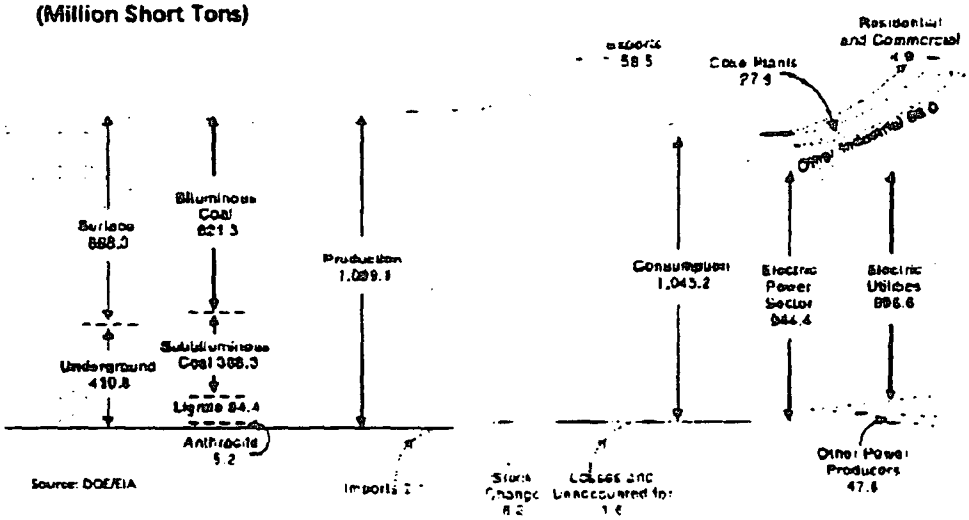
Legislators should develop supportive policies—and remove barriers—so that the natural gas industry can obtain the financing its needs to meet demand forecasts. For example, to meet the 2020 projection, current transmission and distribution line mileage must be increased some 30 percent. Doing so will cost more than $150 billion. Moreover, additions to the distribution system will cost nearly twice as much as additions to the pipeline system. Although these investment levels are certainly significant, they are not dramatically different from the levels experienced in the 1990s — a modest increase for distribution and a modest decrease for transmission.

The investment required for the necessary exploration and production activity assumed in the forecasts will certainly be greater than the requirement for transmission and distribution system expansion. More wells will need to be drilled, and more drilling rigs will be required. Although the number of oil and gas wells drilled per year may have to double—to approximately 50,000 new wells per year—this figure is well below the peak levels of the early 1980s, when from 70,000 to 90,000 new wells were drilled each year.

Finally, formulators of the National Energy Strategy should bear in mind that the natural gas industry's drilling fleet has aged, and that significant investments will be required for upgrades. Capital investments of $40 billion per year ($1998) may be necessary, and acquiring this level of capital may prove difficult in an economy that still places a premium on "high-tech" investment opportunities. However, raising these funds is not an insurmountable task. Compared with the investment levels of the mid-1980s, future investment requirements appear less extreme. Moreover, drilling activity slowed significantly in the 1990s, so the expanded drilling activity needed to meet the accelerated projection demand looks quite dramatic—until one compares it to a longer historical standard.

COAL

Coal Flow Chart 1999
(Million Short Tons)



Source: DOE/EIA

OVERVIEW

Coal accounts for approximately one-third of the United States' primary energy production. the single largest share of any domestically produced fuel. Estimated recoverable reserves in the United States total 275 billion short tons. or a 250-year supply at today's production rates. according to a 1997 Energy Information Administration update. Reserves are located throughout the nation. and current productive capacity is sufficient to meet the expected continued increase in demand.

Currently. coal accounts for approximately 23 percent of U.S. energy consumption. While coal is primarily used to generate electricity. it is also essential to the production of steel and cement. Other industries. including paper and chemical manufacturers and the food processing industry. use coal to create steam and electricity. Finally. coal is used to generate heat in some small commercial establishments. but this use is diminishing rapidly.

Coal is an affordable and reliable domestic energy source and therefore contributes significantly to the security of the nation's overall energy supply. The coal that is not consumed here is exported to other major industrial or emerging economies. thus contributing positively to the U.S. balance of trade and the global economy.

PRODUCTION AND CONSUMPTION PATTERNS

The U.S. coal industry grew at a slow but steady pace during the 1990s. Production increased an average of 1 percent per year and is expected to reach 1.1 billion short tons when figures for the year 2000 are finalized.

Coal is Produced in 26 States

An effective National Energy Strategy will take into account the fact that coal is produced in 26 states, which the industry typically groups in three geographically distinct regions:

- The Appalachian states, ranging from Pennsylvania to Alabama, which produce approximately 40 percent of the nation's coal, the entire nation's metallurgical coal, and most of our export coal. Underground operations are dominant in this broad region.
- The Interior states, which include Illinois, Indiana and Western Kentucky. Here, steam coal is produced by medium sized surface mines.
- The Western states, and particularly Wyoming—the largest coal producing state in the country—which use large surface mines to produce steam coal.

During the past decade, coal production has shifted from the eastern to the western United States. For example, in 1999 more than half the 1.1 billion tons of production originated in western states. Moreover, as demand has increased for lower sulfur coal, larger users of coal also have shifted from east to west.

Economic Benefits

The U.S. coal mining industry generates some $160 billion in economic activity, including $19 billion in revenue for federal and state governments and $105 billion in income to coal and its supporting industries. The coal industry directly employs 80,000 workers, and the nearly one million industry-related jobs produce $37 billion in annual wages throughout all 50 states.

Productivity, Reserves and Demand

During the past decade, productivity in the coal industry has nearly doubled. This trend is expected to continue as new technologies and more productive mining methods are brought on line. These same new technologies make mining safer than ever. Moreover, new technologies and advances in mining techniques have increased coal resources and output while protecting the environment. Whether meeting air or water quality standards, protecting wetlands or reclaiming surface mined land to better than original conditions, coal producers meet and exceed all current legal standards. The industry is committed to continuing this high level of performance.

POLICIES THAT THREATEN MINING CAPACITY

Current production capacity and coal reserves are sufficient to meet any increase in domestic demand. However, at least two current policies discourage investment that would expand coal mining capacity in the United States. Indeed, several policies could eliminate some current mining capacity. Such policies should be reviewed during the formation of a National Energy Strategy.

For example, the Environmental Protection Agency (EPA) interprets Clean Water Act regulations regarding valley fills in a way that threatens even near term coal production from several operating mines in some Appalachian states. Eliminating production from these

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mines would strain productive capacity in other coal producing areas and would significantly disrupt the coal transportation system.

Similarly, land access policies affect both current and future coal production capacities. For example, the decision to use the Antiquities Act to declare certain federal lands "National Monuments" effectively removes a large portion of the western reserve base from production. Actions by the Bureau of Land Management and the U.S. Forest Service, which place reserves on federal lands managed by those agencies off-limits to development, also potentially limit mining capacity. Over time, such actions could deplete the U.S. coal reserve base.

LOOKING TO THE FUTURE

Coal Consumption Data

Almost all the 1.1 billion tons of coal produced in the United State is used domestically. In 2000, utilities and independent power producers will use 973 million tons of coal to generate almost 2 trillion-kilowatt hours of electricity for use in homes and businesses throughout the United States. Coal use for electricity is an even 200 million tons, or 25 percent more than coal used by the utility sector in 1990. Coal is a popular fuel for the utility industry because, on a cents-per-million Btu basis, coal remains the lowest cost fuel available for the generation of electricity. This gives coal-fired utilities an advantage in an increasingly deregulated and competitive, market. Moreover, advances in combustion technology have increased fuel efficiency while lowering the emission of all legally identified pollutants.

Coal use is not exclusive to the electric utility industry, however. Steel mills are expected to consume some 28 million tons of special grade metallurgical coal to make coke in 2000. Major industrial users of energy and retail users, such as homes, hospitals, schools and small commercial establishments, are expected to use approximately 70 million tons of coal this year. Finally, in 2000, U.S. coal producers will export 58 million tons of coal to steel mills and electric utilities in Canada, Europe, South America and, to a lesser extent to the Far East and Japan. Given the domestic abundance of coal, import figures are insignificant and are expected to remain so in the coming decades.

Demand Forecasts

All forecasts of future energy demand show that coal will continue to play a vital role in the United States energy picture. Most forecasts estimate that production will increase from today's level of 1.1 billion tons to from 1.2 to 1.4 billion tons by 2020.

In the future, coal is expected to continue to be used to generate electricity, with as much as 1.1 to 1.25 billion tons consumed annually for this purpose by 2020. The deregulation—and increased competitiveness—of the electricity generating industry places a premium on coal, which is both inexpensive and abundant relative to other domestic fuel sources available to this sector of the economy.

Coal use in other markets is expected to remain at current levels for the foreseeable future. For example, coking coal use by U.S. steel mills is expected to remain in the 25 – 28 million ton range in the years ahead. This is a floor below which steel cannot go in the near term, but, because technological advances will likely continue in the steel making process, coal consumption is not likely to grow soon. Industrial coal use also is expected to remain fairly steady at 70 -75 million tons annually over the next 20 years. Export levels will depend on overseas demand, which in turn depends upon each nation's rate of economic growth and environmental policies, particularly those policies directed toward carbon reduction. The competitiveness of coal relative to other fuels likely will play only a secondary role in these export markets.

U.S. POLICY ENVIRONMENT

Whether the anticipated demand for coal is realized in the United States will largely depend on whether policymakers change existing policies that restrict both coal's availability and its use in the electricity sector.

Electric Utility Policy

As discussed in other sections of this report, demand for electricity is expected to continue to increase at a rapid rate during the next two decades. This increased electricity demand should translate into greater coal demand. However, because the electric utility industry is moving from a regulated to an unregulated market environment, both risk and uncertainty have been introduced vis-à-vis coal demand.

On the one hand, competition should dictate that the lowest cost producer of electricity—companies who use coal—should have an advantage in the open market. However, competition can also move generators of electricity toward the lowest risk option when considering new capacity additions, or even maintenance of, or modifications to, existing capacity. These considerations may dampen demand for coal.

Indeed, signs of this trend already are evident. Even though utility executives are thinking about new generating capacity and modifications of the existing fleet, electricity producers are not making investments to increase the use of coal, even though coal is the lowest cost alternative. One concern is that construction or modifications made to accommodate increased coal use will be rendered obsolete by regulation or litigation. Electric generators are facing an unprecedented wave of new environmental requirements, some of which are being imposed retroactively and thus produce protracted court action. For example, although great strides have been made in reducing emissions of SO2 and NOX, and the requirements laid out in the Clean Air Act Amendments of 1990 are being met, the Environmental Protection Agency has proposed even lower caps on emissions than those legally established by the amended Clean Air Act. The possibility of controls on mercury emissions adds yet another uncertainty.

In short, conflicting forces are at work here. The competitive market trend is toward lower cost generation—which argues for greater use of coal—while recent regulatory decisions are pressuring utilities to rapidly lower certain emissions levels—which increases the cost of using coal.

The Kyoto Protocol

The Kyoto Protocol, or the possibility of some other legally binding international agreement to reduce carbon emissions, adds to the uncertainty of the current U.S. regulatory situation. For example, a recent analysis by the Electric Power Research Institute (EPRI) shows that, if all proposed regulations and the Kyoto Protocol were to take effect, the amount of coal-generate electricity would decline to less than 300 million tons by 2020. Clearly, this is an extreme scenario, but a number of environmental issues now under consideration could sharply limit future U.S. coal use, if these issues are not resolved in a reasonable manner.

OPPORTUNITIES IN TECHNOLOGY

The Role of Technology in Energy Policy

A sound technology policy is key to balancing the growing demand for energy and the trend toward increasingly stringent environmental regulations. Effective technology policies will allow coal to reach its full potential, meet required environmental standards, and ensure that the United States utilizes its most abundant and reliable energy resource.

The nation also needs an energy policy which industry and consumers alike can depend upon for long term consistency—in other words, an energy policy that does not change rules in mid-stream, or retroactively, or based solely on political considerations.

During the past two decades, the use of new technologies and improved operating practices have improved the "environmental efficiency" per ton of coal consumed to increase by almost 70 percent. This trend will continue even as new SO_2 and NO_x controls come on line because advanced retrofit and repowering technologies enhance environmental performance and efficiency of existing coal-based generation plants.

The use of advanced coal technologies that are now, or will soon be, ready for deployment would effectively eliminate emissions that are considered a health risk, as well as substantially improve efficiency. The nation's energy policy must include a technology strategy that incorporates a comprehensive clean coal technology program to assist new and existing coal-fired units to remain competitive and meet environmental requirements. This technology strategy must encourage on-going research. It also must provide financial incentives sufficient to encourage application of advanced technologies at existing units, as well as encourage a program to demonstrate new technology.

Beyond control of traditional emissions, the coal industry also recognizes that carbon sequestration will be vitally important if it is found that reduction of CO_2 emissions is necessary. A National Energy Strategy will not be complete unless it includes policies that stimulate the research, development and deployment of technologies to sequester carbon.

Deploying Technologies Internationally

In many countries throughout the world, energy use during the next two decades is expected to increase even more rapidly than in the United States. For example, the International Energy Outlook 2001, published by the U.S. Energy Information Administration, growth in energy consumption in the developing world, excluding Africa but including China, India and the countries in South America, is projected to exceed 3.5% per year through 2020. Conversely, United States and other industrialized countries will see an increase of approximately 1.0 percent or less per year on average. This rapid ramp up in energy use among developing countries will occur regardless of policies in the United States and other developed nations. That's because additional energy will be needed to support economic growth, and larger populations and a rising standard of living in these nations. The World Energy Council cites that up to 2 billion people lack access to commercial energy supplies in 2001 and that unserved population could reach 3 to 4 billion by 2050.

As in the United States, worldwide energy demands will increasingly be met by a reliance on electricity. Accordingly, technologies developed in the United States will need to be deployed overseas in order to meet the expected demand for twice the current level of energy and three times the current use of electricity. With proper technology policies, it is possible to meet these demands while attending to environmental concerns.

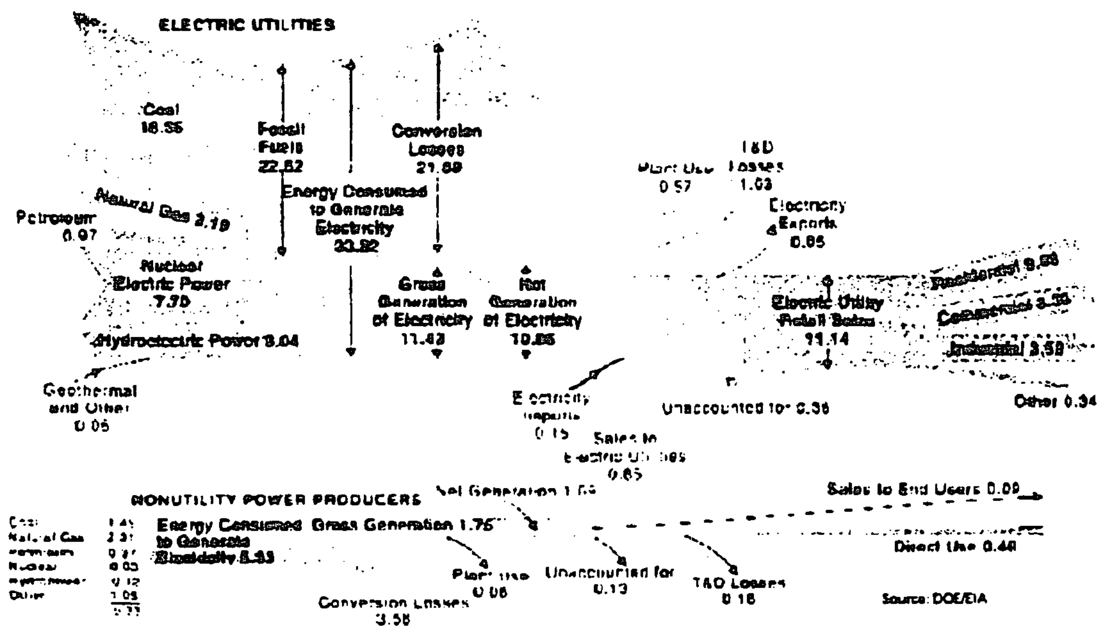
SUMMARY

An effective National Energy Strategy will keep all energy options available in order to meet growing energy demands. Coal can continue to play a vital role in global energy markets. For example, by 2020, some 3.6 billion tons of coal will be consumed in the regions comprising the "developing countries," double current consumption in those countries. Moreover, more than 44 percent of the electricity used in these countries will be generated by coal, both because it is an indigenous resource in many of these countries and because its cost is often low relative to other energy sources.

Clearly, future coal use will not be limited to the developing world. Coal is now, and will continue to be, a major energy resource in all regions of the world. Coal use in the industrialized world will remain at approximately 1.6 billion tons, increasing in the U.S., Canada, Australia and Japan and decreasing only in Western Europe and in the countries of the former Soviet Union. For the foreseeable future, coal will remain an important contributor to the global energy mix.

ELECTRICITY

Electricity Flow Chart 1999
(Quadrillion BTU)



OVERVIEW

Until quite recently, the electric industry has been characterized as a natural monopoly, subject to extensive rate regulation of its generation capacity, transmission lines and local distribution systems. Today, a dramatic restructuring of this industry has forced sweeping changes on the institutions, institutional relationships, and the role of regulators. Some vertically integrated utilities have unbundled their generation, transmission, and distribution functions, and in many cases, sold their generation resources. Increasingly, generation is owned and managed by independent companies or unregulated utility affiliates, not by regulated companies, and output is sold at market-based rates. Moreover, the Federal Energy Regulatory Commission (FERC) and some industry participants now seek to establish new regional transmission organizations (RTOs). Policymakers may also remove federal barriers in order to promote effective wholesale competition and facilitate state restructuring activities and retail competition.

Retail markets were most immediately affected by the Congressional passage of the Energy Policy Act of 1992 (EPAct). This bill modified federal laws in such a way as to facilitate wholesale electricity competition. Today, all fifty states and the District of Columbia have considered some reform of their retail electric service system. Moreover, almost all of

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the so-called "high-cost" states (i.e., where average rates are above the national average) have adopted retail competition systems that involve non-discriminatory access to the local distribution system and customer choice of energy supplier. Currently, more than 60 percent of the U.S. population lives in the 24 states and the District of Columbia that have decided to transition to open access for retail energy suppliers and customers. State officials continue to address difficult transition questions, including how to handle stranded costs, consumer education and protection, public benefits programs, and residual obligations of incumbent utilities following liberalization.

The recent problems in California's electricity markets, however, are having national implications that impact all stakeholders in the electric industry. Extreme price volatility and shortages in the California market have been brought about, in part, by inadequate market design and public policies that are incompatible with an efficient market environment. As a result, the pace of deregulation and the transition to retail competition in the other states may be affected. In the emerging market environment, it is important that public policies facilitate new investments in generation and transmission.

PATTERNS OF CONSUMPTION

Although many consumers can now choose their retail electricity supplier, most have chosen to remain with their incumbent supplier, the utility distribution company. One reason they have chosen not to switch is that state-mandated rate reductions for standard offer services undercut the entry rate of new retailers. Standard offer service typically obliges the incumbent utility to provide fully bundled electric service at fixed or indexed rates for several years (e.g., during the transition period), usually following the introduction of retail competition. In some states, standard offer rates have been set so low as to discourage customers from switching to new entrant retailers, who must recover costs associated with setting up shop in local markets as well as the cost of purchasing energy in wholesale markets. Other states have established generation credits (so-called "shopping credits") for customers who no longer take power from the incumbent. In some cases, the credit exceeds the costs of generation that the incumbent avoids when a customer switches to a new supplier. While programs with high credits appear to be more successful in getting customers to switch suppliers, they do so by offering credits that bear no relationship to wholesale power costs or retail marketing costs.

In electricity markets with effective competition, consumers may have a greater number of options, both in terms of their supplier and the type of fuel used to generate electricity. Indeed, some states now require that all registered sellers generate a portion of their electricity using renewable supplies, such as solar, geothermal, and wind resources. However, because the cost of these resources is higher than conventional (fossil) fuels, a renewable portfolio standard raises the overall costs of power purchases. This forces higher costs on all electricity consumers.

Several polls suggest that consumers are willing to pay more for electricity generated by renewable energy resources. Some factual evidence supports these polls. A number of California customers selected a "green" power supplier when they switched suppliers. Customers in open states should be allowed to choose whether to purchase power from higher cost, renewable suppliers. An important but often overlooked low-cost, renewable resource is hydropower. Although new dam sites are not being proposed, existing resources could supply more electricity if steps were taken to streamline the burdensome re-licensing process and if additional resources were channeled toward increased research and development of more efficient technologies.

Some consumers can also supply their own electricity, using internal combustion and reciprocating engines, solar panels, and emerging technologies such as fuel cells and microturbines. This approach allows customers to generate electricity at its point of use, reducing, and in some cases eliminating, the need to use a traditional transmission and distribution network.

FUTURE DEMAND

Although the U.S. Energy Information Administration recently forecast that distributed generation will provide less than one percent of the nation's electricity requirements by 2020, a number of states are looking closely at interconnection standards for distributed generation, the design of appropriate rates for standby and backup services, and the recovery of interconnection costs (or any costs of additional facilities) required to accommodate a distributed generation unit. Regulatory policy should be competitively neutral with respect to distributed generation. Indeed, market-based price signals are the best approach to developing economically efficient investment in distributed generation systems.

POLICY ENVIRONMENT

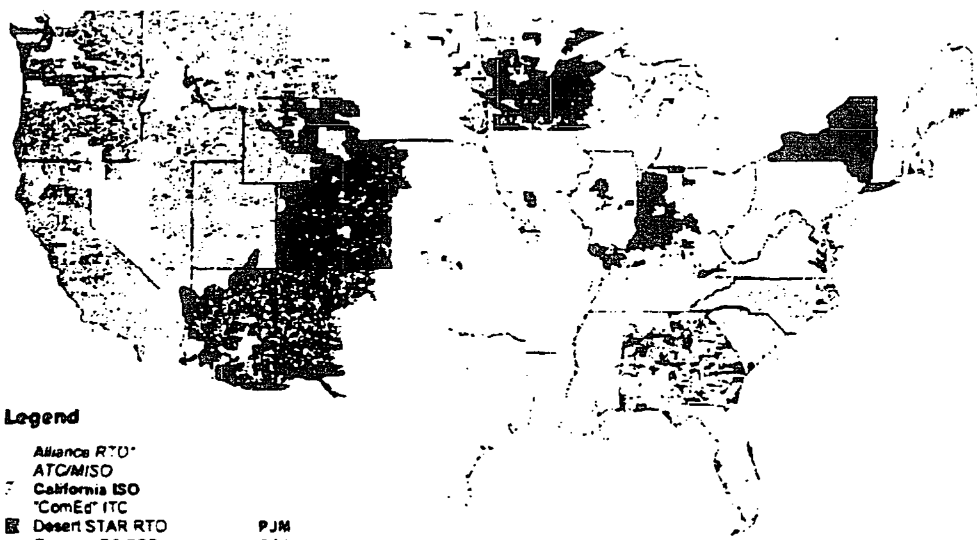
Seventeen electricity restructuring bills were introduced while the 106th Congress was in session. To date, no legislative package has gained consensus support, but significant issues embodied in many of these proposed bills are under serious consideration. For example, several bills propose the repeal of PURPA and PUHCA. Others would encourage state restructuring actions by resolving federal/state jurisdictional issues. Still others encourage the formation of regional transmission organizations (RTOs), including for profit transmission companies, propose resolving market power and transmission access problems, and/or the grandfathering of existing state restructuring plans to protect state plans from preemptive federal action.

Consensus has formed among publicly-owned and shareholder-owned companies in support of comprehensive tax legislation to facilitate fair electric competition. For shareholder-owned utilities, taxes that discourage the upgrades of distribution facilities would be eliminated. Moreover, the consensus agreement would defer taxes on the sale of transmission facilities, as well as eliminate taxes on the spin-off of such facilities. Both actions would stimulate the formation of independent RTOs. For public power utilities, the consensus agreement would modify private use provisions of the tax code, thereby encouraging these providers to open access to their transmission lines and also encourage them to participate in RTOs. Indeed, support is growing for broad tax legislation that would eliminate impediments to electric cooperatives interested in joining RTOs and opening their systems to competition.

There is recognition that critical bulk power system reliability issues need to be addressed. With the lead of the North American Electric Reliability Council (NERC), a broad consensus is being forged on reliability legislative language. Proposed legislation would extend FERC's authority for reliability (but not for economic regulation) to all segments of the U.S. electricity industry. This authority would ensure that all participants in electricity markets – independent power producers, distribution utilities, transmission utilities, system

Regional Transmission Organizations

Utility Participation as of January 2001



operators, power marketers, and customers –play by the same reliability rules and share equitably in the costs of reliability. At present, FERC has jurisdiction over only shareholder-owned utilities, which encompasses about two-thirds of the transmission facilities in the country. The proposed legislation would grant FERC the authority to approve and oversee one national electricity reliability organization. This organization, expected to evolve from NERC, will be responsible for developing, implementing, and enforcing mandatory reliability standards nationwide, with FERC oversight. Currently, compliance with NERC standards is voluntary, subject only to peer pressure. This new reliability organization will also have the authority to delegate certain responsibilities to regional entities, with approval from FERC.

The Role of the Federal Energy Regulatory Commission

In its role as overseer of wholesale markets and transmission, the Federal Energy Regulatory Commission has implemented the EPAct provision that modified federal laws in order to facilitate wholesale competition. Specifically, the Commission pushed wholesale competition forward in 1996 when it issued Order Number 888 and Order Number 889. In these landmark rules, FERC required the industry to provide comparable, non-discriminatory open access to the transmission grid and to unbundle generation, transmission, and ancillary service functions. The Commission also provided for recovery of wholesale stranded costs and established standards of conduct and methods to exchange wholesale market information on same-time electronic databases, known as OASIS. Recently, both FERC Orders were upheld in the Court of Appeals of the District of Columbia Circuit Court.

Moreover, in December 1999, FERC approved another landmark order promoting the development of regional transmission organizations (RTOs). Order Number 2000 calls for voluntary participation in RTOs. FERC stated its objective that all transmission-owning entities, including non-jurisdictional utilities, join RTOs. Order Number 2000 requires that RTOs be independent of market participants, serve a region of sufficient size and arrangement to maintain reliability, support efficient and non-discriminatory power markets, serve as the security coordinator for its prescribed region, and have exclusive authority over the maintenance of short-term reliability of its part of the grid, including the authority to redispatch generation resources.

Regional Transmission Organizations

FERC expects regional transmission organization to be operational by December 15, 2001. However, the establishment of RTOs is an arduous, time-consuming process that requires a satisfactory resolution of many contentious, critical issues among many interests. Several of the existing independent system operators (ISOs, one type of RTO) were developed from existing tight power pools; other RTOs will not have this advantage and will be more difficult and take longer to construct.

As of January 2001, 12 regional transmission organizations were in their formative stage. By the December 15, 2001 deadline, these entities are expected to manage the bulk power grid for over 85 percent of the nation's electricity consumers, based on current participation figures. Five independent system operators are already operational, and currently serve 33 percent of the nation's electricity consumers. An additional three such entities are approved, but are not yet operational.

Policy Challenges in the Transmission Sector

Over the years, U.S. electric utility companies, regulators and shareholders have built the most reliable electric system in the world. This record of achievement must not be tarnished during the transition to competitive power markets. The transition from an electricity industry that consisted primarily of regulated, vertically integrated utilities to one that emphasizes competitive markets for generation raises many concerns about reliability. Even though there is little evidence that overall reliability levels have changed in recent years, dramatic changes in the structure, operation, and regulation of the U.S. electricity industry require analogous modifications in reliability practices and institutions.

The current transmission system is comparable to the national highway system, a mix of two-lane state roads, multiple lane freeways, access roads, beltways and interchanges. Originally built to move limited amounts of power over relatively short distances, the electricity interconnections that were enhanced to bolster reliability created new opportunities to reach more distant customers, some in quite distinct markets. In today's increasingly competitive electricity marketplace, a greater number of suppliers are faced with bottlenecks and congestion because they often hit a two-lane road after having been on an eight-lane interstate highway, limiting the benefit of increased marketplace transactions. If more transactions are to be accommodated, more transmission facilities will have to be built or other means will need to be found to enhance the transfer capacity of the existing system. Otherwise, the expectation of lower costs for consumers may not be realized.

Most analysts agree that expansion of the transmission grids has not kept pace with growth in electricity demand. For example, annual investments in new transmission have declined by about $100 million a year during the past two decades. Moreover, between 1989 and 1998, the miles of transmission lines per MW of sum mer demand declined by 16 percent, and some projections show a further decline in transmission capacity of some 13 percent by 2008.[1]

The current focus on regional transmission operations may provide incentives to build needed transmission facilities. FERC has stated its receptivity to different forms of RTO structures including non-profit independent system operators and stand-alone transmission businesses (often referred to as TRANSCOs). Advocates of ISOs argue that transmission owners can, with relative ease, turn over control of their transmission assets to an ISO and that a non-profit ISO would more likely operate the system for the ultimate benefit of consumers. In contrast, TRANSCO advocates believe that the for-profit motive underlying their approach will result in improved performance and encourage the efficient expansion of transmission grids. For its part, FERC will consider new, innovative rate mechanisms such as performance-based rate making to meet the requirements of Order Number 2000, so long as commensurate benefits to consumers can be demonstrated.

KEY MARKET ISSUES

Challenges to Expanded Generation

The issue of expanded electricity generation—as well as the issue of transmission—will challenge policymakers in the years ahead. Certainly, electricity generation has not kept pace with consumer demand. Recent events of extreme price volatility and price spikes in light of record demand has made the need to preserve reliability a paramount concern. Generation reserve margins have been declining for at least the past two decades, at a rate of almost one percent per year. Currently, reserve margins are tight in some regions of the country, suggesting that additional generation is needed soon. While few utilities are planning to build much generation as part of their regulated rate base, unregulated utility affiliates and independent power producers have announced plans for more than 100,000 MWs of new capacity, more than enough to meet expected needs for the next several years. About 90 percent of new generators will be fired with natural gas. How much of this capacity will actually get built, and when, is not known, given the recent rise in natural gas prices. The key question is whether competitive market forces, when co-mingled with policies which restrict infrastructure expansion, will be sufficient to provide enough generating and transmission capacity to provide reliable power supplies for the U.S. economy.

Marketplace Dynamics

Existing independent system operators have experienced many difficulties in establishing and operating real-time markets for energy and reliability services. The California market in particular has been hampered by extreme price volatility and shortages. The problems in California point to need to design market rules and public policies, which jointly work to effect efficient market outcomes.

For example, existing markets are largely one-sided, with competition among generators but no competition between the supply and demand sides of the equation. Although volatile electricity prices contain important information for electricity consumers and suppliers that

[1] See "Electric Reliability: Potential Problems and Possible Solutions," Eric Hirst, May 2000

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can help maintain reliability, most consumers today continue to face time-invariant prices. Customers, especially large, sophisticated industrial customers, should have the opportunity to face time-varying (hourly) electricity prices and to participate in reliability markets (e.g., by offering to sell load reductions as contingency reserves). By allowing customers to voluntarily choose among multiple pricing products with varying degrees of price risk, the magnitude of the price spikes and overall system power costs can be substantially reduced. Even if only a small fraction of retail load chooses to face real-time prices, price spikes would be less frequent and dramatic, and the need for additional generating capacity would be reduced.

Because of the physics inherent in electric system operations, generation can be operated in a manner that can reduce potential transmission imports from other regions, block or interrupt sales by competitors, restrict generation output and raise prices, or inhibit construction of new, competing generation. Many industry stakeholders believe that the key to transitioning to competitive regional markets for wholesale power will require finely tuned market rules to eliminate the potential for gaming and to prevent the abuse of market power. They advocate market monitoring of the wholesale market and regulatory oversight to prevent market manipulation and consumer abuse, with potential abuses of market power investigated, mitigated and remedied.

BALANCING ELECTRICITY USE AND ENVIRONMENTAL CONCERNS

The U.S. electricity industry faces critical energy and environmental challenges in the coming decades. Electricity producers will be called upon to provide cost-effective and reliable power to fuel U.S. economic growth and an improved quality of life. Environmental regulators will face pressures to develop more efficient policies to meet well-established challenges—including targets for air and water quality—as well as new policies to meet emerging challenges such a climate change.

Environmental and energy policies sometimes conflict with one another. For example, efforts to improve urban air quality are not always consistent with efforts to lower electricity rates, or even to provide greater competition among suppliers. Although some conflicts represent inherent public policy tradeoffs, other conflicts can be avoided or reduced through more effective and efficient policy approaches. For example, potential air quality and climate change policies strongly encourage the development of natural gas, while policies restricting energy exploration and facilities siting would make production and use of natural gas more difficult. Policymakers engaged in developing a National Energy Strategy can reduce these conflicts by developing environmental policies that minimize the cost of achieving specific environmental objectives and by limiting inappropriate interference with market-driven fuel choices.

NUCLEAR POWER

OVERVIEW

The U.S. nuclear energy industry supplies about 20 percent of our nation's electricity. Behind this seemingly simple statement lies an extraordinary story. While nuclear powered electricity capacity has remained fairly constant, the amount of nuclear energy generation—which does not release air pollutants and is our largest source of emission free electricity—has increased significantly as U.S. demand for electricity has risen. The reasons behind nuclear power's success are many.

During the past decade, the efficiency, safety and reliability of operating nuclear plants have grown steadily and dramatically. The average capacity factor of the U.S. nuclear power fleet has increased over 16 percent since 1990 to 86.8 percent. This is the result of improved maintenance conducted in shorter and shorter refueling outages and longer intervals between refuelings. The result has been the effective equivalent of adding over 23 new 1,000 MW nuclear plants on line.

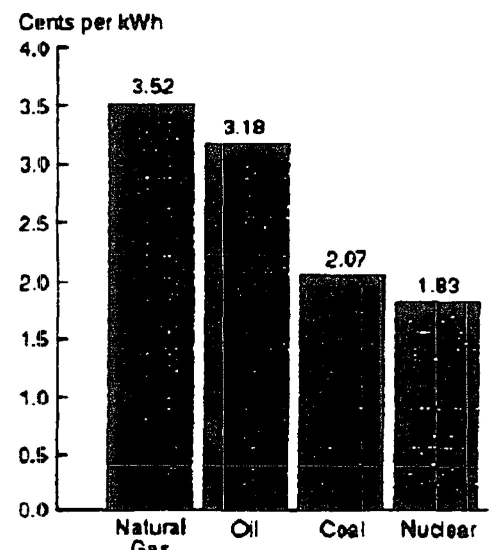
REGULATORY ENVIRONMENT

Under the careful oversight of the U.S. Nuclear Regulatory Commission (NRC), the regulatory environment for nuclear powered utilities has improved in the areas of operating safety and efficiency. Four decades of commercial nuclear operations have yielded a growing understanding of factors that influence operating safety. This experience has resulted in the revision of regulations and practices, making nuclear powered plants even safer than before.

Deregulation of the electric power industry also has sharpened the focus on safe, efficient operating practices. Industry restructuring has produced fewer nuclear power plant operating companies, but these companies include highly focused management teams able to provide consistent and reliable solutions improving efficiency and safety. Consolidation has also created new efficiencies in the administrative management of the nation's nuclear power plants.

These same trend lines have reduced overall operating costs. Today, the nuclear

Energy Production Costs in 1999



Source: Utility Data Institute

energy industry has achieved very competitive production costs, measured in cents per kilowatt-hour. At the same time, industry restructuring has recast fixed costs such that total electricity costs are highly competitive. Nuclear units across the industry can run at total costs of 2 to 2.5 cents per kilowatt-hour. Of this, the cost of nuclear fuel, including a charge for the ultimate disposition of the used fuel that all operators pay, is about one-half cent per kilowatt-hour.

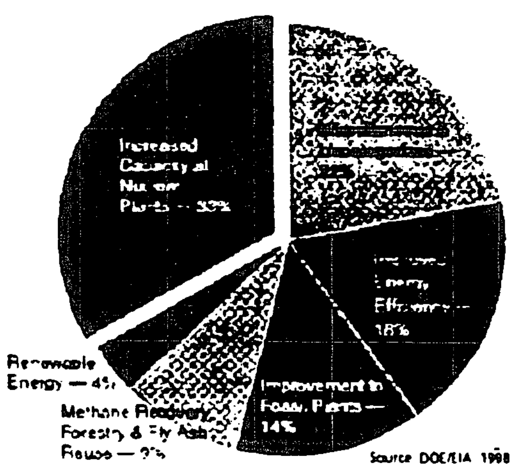
LICENSE RENEWALS

In March 2000, the NRC renewed the licenses for the two-unit Calvert Cliffs nuclear plant for an additional 20 years of operation beyond the 40 years originally licensed. Two months later the three-unit Oconee nuclear station received a 20-year renewal. These renewals recognize that conscientious operations and maintenance have sustained and improved the value of these plants. It is expected that almost all nuclear power plants will apply for and obtain a renewal license that adds 20 years to these facilities. License renewals further increase the competitiveness of nuclear powered electric utilities.

ENVIRONMENTAL ADVANTAGES OF NUCLEAR POWER

From an environmental point of view, nuclear energy offers several important advantages. Since the combustion process is not needed to produce nuclear energy, there is no adverse impact on air quality. This is an important environmental consideration. In 1999 the United States generated a record 728 billion kilowatt-hours using nuclear power. That production avoided the emission of 1.92 million short tons of NOx, 3.97 million short tons of SO2 and 167.8 million metric tons of carbon, compared to the current mix of fossil energy resources. From a policy perspective, it is ironic that environmental credits are extended to energy producers that adversely impact air quality, but not to electricity generators, such as nuclear and hydro, that entirely avoid air quality impacts. Nuclear energy is the most significant source of CO2 reduction through its increased production over the last decade in the voluntary program to mitigate carbon emissions.

Voluntary Carbon Emission Reductions



Indeed, if nuclear energy were not part of the nation's generating mix, most current clean air act standards—particularly those areas with large concentrated populations and heavy industrialization—would not be met. In areas of high density power use, the environmental benefits of nuclear energy can be leveraged to provide heating, cooling and transportation in the form of electrified rail and mass transportation. It is most efficient when operated at full power, 24 hours per day to supply base-line power needs. Nuclear energy is wisely used in a diverse combination with other fuels that use technologies well adapted to cycling or peaking loads. The presence of nuclear power plants in these areas of high electricity demand is a significant factor, which allows the siting of other emitting forms of generation while maintaining overall emissions within federally mandated levels.

URANIUM FUEL SUPPLY AND DISPOSAL

Uranium, the heaviest of all naturally occurring elements, powers nuclear plants. Nuclear reactors release energy by splitting uranium atoms. Since no combustion takes place during the generation of electricity from reactor fuel, air quality and the atmosphere are not affected. Once the nuclear reaction takes place, energy is transferred to turbines that generate electricity in a closed process. All waste products are retained in the solid fuel pellets and isolated from the environment.

Uranium is abundantly available in the earth's crust, both in North America and elsewhere, and the capability to extract ore and convert it to reactor fuel is available domestically. The primary, and almost sole, use of uranium is the production of energy. Robust supplies of reactor fuel can be made available from domestic sources without threat of international interference. Reactors can also consume the uranium and the man-made element, plutonium, which were produced as stockpiles for national defense purposes. Commercial reactors are being used to reduce the threat of nuclear proliferation using these inventories as fuel for the generation of electricity.

In recent years, the U.S. government has pursued policies aimed at consuming excess inventories of weapons grade uranium that had accumulated in the former Soviet Union. Such policies reduce the threat of nuclear warfare and spur international economic activity, but they also depress demand for U.S. mining, conversion and enrichment services. Indeed, U.S. businesses may become unprofitable and exit the market. The long-term impact of this possible threat to U.S. energy security should be examined closely by policymakers when they formulate a National Energy Strategy.

Some believe that the Achilles' heel of nuclear energy is the disposal of used nuclear fuel. However, this objection to its use is not based on facts. In the roughly 40 years of commercial nuclear operation in the United States, there has been no impact on the environment from used nuclear fuel. It remains at the power plants where it was used, fully accounted for, with no measurable impact on the environment. By act of Congress, a decision has been made to take central accountability for used nuclear fuel. Exercise of this option by the federal government when it is ready, will also result in negligible impact to the environment, according to federal studies. In the meanwhile, except in a few jurisdictions that have set artificial deadlines for the federal government to accept custody of the fuel, no major barrier exists to maintaining past practice of storing fuel where it was used, even though this does not represent the best public policy.

Moreover, once used fuel is deposited in a central repository, that site will become a strategic fuel reserve. Used nuclear fuel contains a high residual energy content, which can be recovered through reprocessing. Currently, U.S. policies do not allow the reprocessing of nuclear fuel, even though it is permitted elsewhere in the world. Reprocessing is not economical at the present time. If circumstances change, all fuel in the central repository could be reprocessed. In addition, future reactors can be designed to produce more fuel than they consume. This would make nuclear power a renewable energy resource.

COMPETITIVE COSTS

The abundance of uranium and the relatively low cost of converting it to reactor fuel mean that nuclear fuel costs are likely to remain stable for the next several decades. Moreover, the continued reliance on nuclear energy as part of the nation's diversified electricity portfolio should minimize price volatility in electrical markets. A stable price environment for energy means, in turn, that the overall U.S. economy should grow more efficiently.

Production of energy from nuclear fuel results in relatively high-energy yields per stable unit of fuel consumed. For example, one cubic inch of uranium 235 contains the energy equivalent of over 650 thousand gallons of oil, 3,300 tons of coal or 7 billion cubic feet of natural gas. Although there are environmental impacts from the extraction of uranium and speculative environmental impacts from the disposition of used nuclear fuel, they are relatively minimal because of the very small quantities of fuel required.

EFFECTIVE R&D AND INVESTMENT POLICIES COULD ENHANCE THE USE OF NUCLEAR POWER

Increased research and development could lead to discoveries that would improve operating efficiencies of current reactors, improve the design of future reactors and develop nuclear fuel sources that do not produce weapons material as a by-product. For example, small, transportable reactors have been designed for military use, but little work has been done to make these prototypes commercially viable. Such reactors could be put to a number of good uses, including water purification. An aggressive research program could ensure the availability and wise use of this emission free, abundant and compact source of energy.

Like other critical infrastructure systems, including railroads and highways, energy suffers from a lack of adequate capital investment. Nuclear energy is no exception. Currently, investors are not attracted to the modest return on most nuclear power plants, compared with the potential return on investments in information technology or other high technology industries. In the case of energy infrastructure, the issue is compounded by the perceived risk of investing in an industry sector that is undergoing deregulation and restructuring.

Eventually, of course, energy prices will rise to such a level that profits and return on investment in the energy industry will appear commensurate with other investment opportunities. The better approach, however, would be the creation of incentives for needed infrastructure investments in the near term. In the decades ahead, policymakers will need to devise policies that encourage investment while not interfering with free markets and the growth of competition within and among energy sectors. If such policy measures are not formulated and implemented soon, the likelihood increases that policymakers will have to respond to public outcries against high-energy costs by developing ill-conceived policies that do interfere with the market.

THE ROLE OF EDUCATION

The United States also needs to invest in an educated workforce that is capable of supporting the energy infrastructure that experts have forecast. This is not an easy task, both because the demand for skilled engineers and technicians is growing rapidly and because fewer and fewer students are pursuing courses of study that would prepare them for work in energy related industries. Indeed, enrollment is declining among institutions that offer such educational programs and degrees. Unless action is taken soon, the educational system may be unable to support the demand for energy that appears inevitable during the next decade.

Education also is needed to change the public's perception of nuclear energy. Understandably, that view is largely negative. The first demonstration of nuclear energy that commanded world attention was a bomb that yielded devastating results. The generation of electricity from nuclear fuel is physically very different from the technology required for destructive use, but the perceived connection between the two has been skillfully exploited by some to alarm the public and the political system for decades. An effective National Energy Strategy would address this adverse image by engaging every educational level, and by stressing the environmental and security benefits that the safe use of nuclear energy affords our nation.

SUMMARY

Nuclear energy has been a growing component of the energy mix in the United States for more than 40 years. No member of the public has been harmed by nuclear energy during this period. Moreover, public polls have shown for years that a substantial majority of the American public believes that nuclear energy is safe and beneficial. However, in follow-on questions, that same substantial majority incorrectly believes that, individually, they are in the minority in their support and confidence in nuclear power.

A National Energy Strategy needs to be developed that brings nuclear energy back into favor. After all, nuclear energy provides substantial environmental benefits while producing baseload levels of electricity. Because combustion is not required to release energy, no air pollutants are emitted into the environment. Moreover, because small amounts of fuel create large amounts of electricity, the extraction and disposal of nuclear fuels can be readily controlled and managed. Nevertheless, many environmental groups oppose nuclear energy, for reasons which are not clear to industry experts and scientists.

In time, some external pressures — global environmental concerns, high population densities, alternate uses for land and raw materials, or price volatility—and a heightened political grasp of the benefits of nuclear energy use will create an environment favorable to its increased use. Until that time, however, the nuclear industry will have to remain focused on activities that dispel public misconceptions about this energy resource.

Global pressures already are at work that will have an impact on the future of this industry. As energy demand increases, few developing nations will have the ability to manage this technologically complex energy resource. Developed nations such as the United States will need to adopt policies that ensure its safe use by other nations. Certainly the United States, which has led the world in the development of nuclear energy and is now reaping the environmental and economic benefits of this fuel, should provide for its continued global use in a responsible manner. The world remains hungry for energy and the countless economic, social and personal benefits from an adequate, reliable and affordable supply of energy.

ENERGY EFFICIENCY AND RENEWABLE ENERGY

OVERVIEW

In the portfolio of energy options for the 21st century, energy efficiency and renewable energy are two that have demonstrated their potential to significantly contribute to U.S. energy needs in a cost effective and environmentally friendly manner.

Diverse forms of energy efficiency are widely diffused throughout the U.S. economy. End-use efficiency improvements occur from the market penetration of process controls, thermal barrier technologies, and other design improvements in industrial, residential, commercial, and transportation equipment.

Supply-side improvements include advanced combustion/gasification technologies, combined heat and power stations, district heating and cooling, and more efficient power transmission and distribution technologies. Although micro-turbines and fuel cells have not yet had substantial market penetration due to high initial cost, they hold promise for future improvements in supply-side efficiency.

At the macroeconomic level, there has also been a shift in the share of Gross Domestic Product (GDP) from more to less energy intensive activities. Part of this shift is the result of the rapidly falling cost of information and information technologies.

Renewable energy options are also diverse. These resources may be converted into electricity, heat, or mechanical power. Renewably based electric generating plants may be connected to a central grid or freestanding. The resources from which renewable energy is extracted include:

- **Solar radiation** - Sunlight can be used to produce thermal energy for space and hot water heating, or electricity generated from either photovoltaic panels or high temperature solar collectors that produce steam to drive turbines. Diffuse radiation is available through the country, while direct radiation for concentrating collectors is strongest in the Southwest.
- **Running water** – The largest source of renewably generated electricity, hydropower, is harnessed by creating reservoirs or by installing run-of-river turbines. Future expansion of hydropower capacity is limited by resource constraints.
- **Wind** – Commercial wind-farms are sprouting up throughout the country with individual turbines as large as one megawatt. The largest wind resources are found in the midwest.
- **Biomass** – Woody and herbaceous materials can be burned directly for electricity or heat, gasified, or liquefied. In some cases, forest or agricultural residues are used; dedicated biomass feedstocks are grown for energy production.
- **Geothermal heat** – High temperature geothermal energy for large-scale power production is located primarily in the western U.S. However, low temperature heat from the earth is also used in "ground-source" heat pumps as a source of residential and commercial space conditioning.

Renewable Electricity Generating Capacity, 1999

Technology	Capacity in Operation (in MW)
Biomass	10,570
Geothermal	2,697
Hydro (includes pumped storage)	94,789
Photovoltaics	15
Solar Thermal	354
Wind	2,602

Source: "REPIS: The Renewable Electric Plant Information System" 1999 Edition, NREL.

As of 1999, renewable electric generating capacity was about 111,000 Mw, mostly from large hydropower facilities.

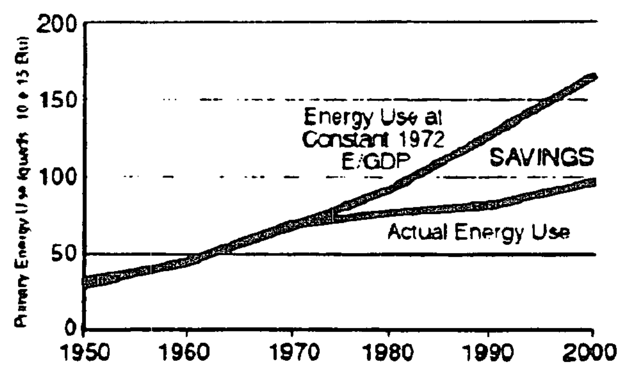
A key advantage offered by energy efficiency and renewable energy options is low environmental impacts, especially with respect to air emissions. Clearly, energy efficiency improvements and renewable energy will be essential to meet our energy needs.

TRENDS

Energy efficiency improvements have had a major impact in meeting national energy needs since the 1970s, relative to new supply. Energy intensity improvements are a combination of end-use efficiency improvements, supply-side improvements, and structural shifts in the economy toward less energy intensive sectors. If U.S. energy intensity (Quadrillion Btu per GDP) stayed constant since 1972, consumption would be about 70 Quads (74 percent) higher in 1999 than it actually was.

One of the drivers for improved energy intensity has been the implementation of appliance efficiency standards. The standards for different appliances came (or will come) into effect over the period 1988-2005. As more efficient models of appliances and equipment penetrate the market, they shift the overall efficiency of the nation's capital stock. Air conditioner manufacturers recently called for further improvements in efficiency.

U.S. Trends Shows Reduction in National Energy Intensity



Source: DOE/EIA

One recent exception to positive trends in end use efficiency is in the transportation sector, where average fuel economy of motor vehicles has been flat or deteriorating due to the increased sales of light duty trucks and 4-wheel drive vehicles and increased miles driven per vehicle.

Structural shifts in the economy have been away from manufacturing and toward the commercial and service sectors. Not only have knowledge-based sectors gained a larger share of our national GDP, the declining cost of information and communication services has allowed all sectors to substitute information for activities that use energy. Although office and network equipment constitute only a small fraction of U.S. electricity use, the digital economy requires a high level of power reliability, a characteristic that creates new opportunities both for energy efficiency in managing system load and for renewables in providing back-up power.

Renewable electric generation is projected to increase in absolute terms (from 389 billion kWh in 1999 to 448 billion kWh in 2020). At the same time, it is projected to decline in its share of the overall generation mix from 10.5 percent in 1999 to 8.5 percent in 2020, under business as usual assumptions (US Energy Information Administration, Annual Energy Outlook 2001, Market Trends).

COSTS AND COMPETITIVENESS

The cost of energy from renewable sources (notably photovoltaics and wind) has declined substantially over the past twenty years. These declines, however, have not necessarily made renewable energy competitive since the cost of competing energy sources has in some cases also declined.

Electricity industry restructuring has had a major impact on utility investment in energy efficiency and renewable power generation. Electric utilities have been a major source of investment in both end use efficiency (called demand-side management) and renewable electricity. Since the early 1990s, however, utility investment has diminished as competition or the threat thereof grew and regulatory mandates waned. At the same time, restructuring has been accompanied by falling reserve margins and concerns over system reliability, trends that may offer new opportunities for distributed supply and demand side resources.

Finally, certain global trends have implications for energy efficiency and renewables. In particular, developing countries are projected to make enormous investments in energy-producing and consuming capital stock during the coming decades. This long-lasting infrastructure will commit these countries to levels and types of energy use for decades to come thereby creating an excellent opportunity to improve developing country energy efficiency by utilizing new end-use energy technology.

POLICY ENVIRONMENT

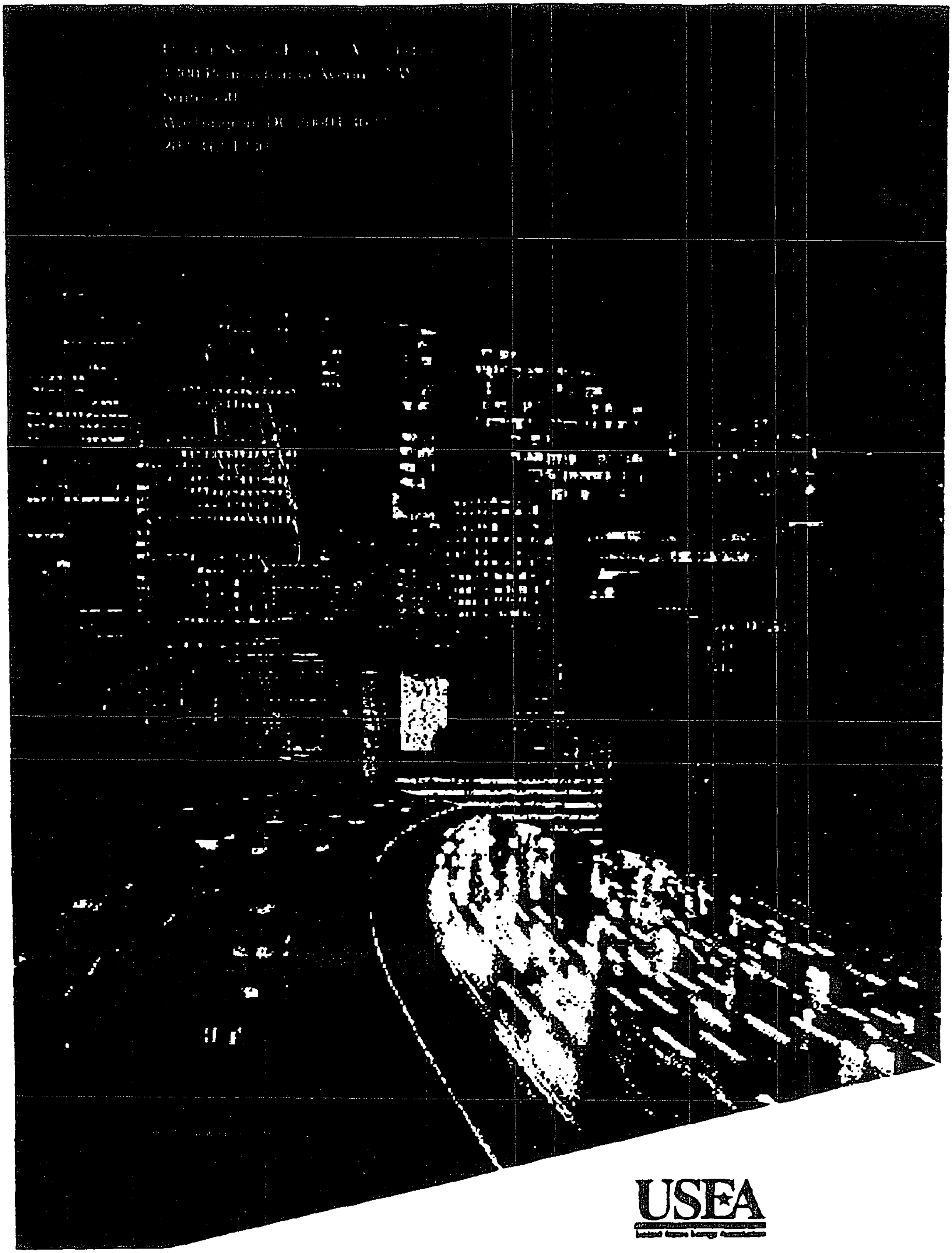
Electricity Restructuring

The decision by policymakers to unbundle heavily regulated electric utilities while simultaneously introducing wholesale and retail competition into the U.S. electricity industry has thinned reserve margins, increased investment risks in new power generation, and increased price volatility. Under these circumstances, energy efficient practices and technologies (especially ones that can be targeted to specific times and locations) have added value. For example, some small-unit renewable energy technologies can now compete with conventional energy suppliers in geographic areas where the cost of conventional energy is high. Moreover, some power retailers have offered their customers the option of paying a bit more for power generated from renewable sources through green pricing and marketing initiatives. Policymakers should strive to ensure that compensation to distributed generation (DG) and combined heat and power (CHP) owners for sales back into the grid include payment of their fair share of the distribution systems they use, while eliminating unreasonable or unnecessary barriers to DG/CHP deployment. By preventing cost-shifting (e.g., from DG/CHP customers to other utility customers) policymakers can ensure that customers are encouraged to deploy DG/CHP where they are efficient.

Policymakers should take these trends into consideration when developing a National Energy Strategy. While energy efficiency practices do not generate additional electricity reserves, good energy management practices do extend the resources that are available. Policymakers can encourage such practices by ensuring that consumers face accurate time and location-specific price signals and have access to accurate information about the environmental implications of their energy use. Where necessary, policymakers should also implement initiatives that assist low-income consumers in paying higher prices and that overcome market barriers inhibiting all consumers from responding to energy price signals.

International Cooperation and Technical Assistance

U.S. security analysts are increasingly aware of global competition for fossil fuels and potential threats to the global environmental. The United States can diminish both risks by encouraging developing countries to use the most energy-efficient and clean technologies available. One way to do so would be through educational programs aimed at encouraging developing countries to utilize advanced U.S. energy technologies, energy management practices and market-based policies. The United States is also uniquely positioned to help emerging nations build energy capacity, institutional capacity and finance energy-related activities and services. Doing so could prove to be a cost-effective investment, both for the United States and emerging economies.



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CEF Chapter 1
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Chapter 1

INTEGRATED ANALYSIS AND CONCLUSIONS[1]

This report presents results of a study of the potential for efficient and clean energy technologies to address a number of energy-related challenges facing the United States. These challenges include global climate change, air pollution, oil supply vulnerability, energy price volatility, and inefficiencies in energy production and end-use systems. Some of these concerns are visible today and are clear public priorities; others are emerging as issues or are possible outcomes of an uncertain future. How the nation responds to them will affect the prosperity and well-being of future generations.

The stimulus for this study derives from the recognition that any national effort to address these challenges must consider ways of increasing the productivity of the nation's energy system, while decreasing its carbon and pollution content. Conducted by researchers from five U.S. Department of Energy national laboratories[2], this study makes a strong case for the value of energy technology research, development, demonstration, and deployment as an effective public response. The study identifies specific public policies and government efforts that could foster solutions with positive economic impact.

1.1 STUDY OBJECTIVES

The principal goal of this study is to produce well-documented scenarios that assess how public policies and programs can foster efficient and clean energy technologies to meet the nation's energy-related challenges. The energy-related challenges addressed in this study include:

- the threat of global warming and the possibility that human activities are contributing significantly to long-term climate change with potentially large economic and social costs;
- the possibility of increased acid rain, urban ozone, and other air pollution problems resulting from the continued growth in coal and petroleum use forecast for the next two decades;
- the vulnerability of U.S. oil supply and price volatility associated with the continued concentration of oil supplies in politically unstable parts of the world; and
- the existence of inefficiencies in energy production and end-use systems[3].

While cognizant of all of the above challenges, *Scenarios for a Clean Energy Future* (aka. the CEF study) concentrates primarily upon the challenge of global climate change – this is the principal focus of the supporting policies. In this context, the term "clean energy technologies" refers to technologies that result in fewer carbon emissions per energy service delivered (e.g., lighting, heating, refrigeration, mobility, and industrial processes). Using the framework of the 11-Lab study (DOE National Laboratory Directors, 1998), these technologies include:

[1] Authors: Marilyn A. Brown, Oak Ridge National Laboratory (ORNL), Mark D. Levine, Lawrence Berkeley National Laboratory (LBNL), and Walter Short, National Renewable Energy Laboratory (NREL). Jonathan Koomey and Cooper Richey (LBNL) and Marilyn Brown and Stan Hadley (ORNL) produced the integrating cost calculations reported in this chapter.

[2] The five national laboratories are: Argonne National Laboratory (ANL), Lawrence Berkeley National Laboratory (LBNL), National Renewable Energy Laboratory (NREL), Oak Ridge National Laboratory (ORNL), and Pacific Northwest National Laboratory (PNNL). This study has benefited greatly from reviews by representatives of the business, government, university, and nonprofit segments of the scientific community who provided important advice and feedback. Their assistance does not imply endorsement. The final responsibility for the content of this report lies solely with the authors.

[3] These challenges, and their relationship to DOE's energy R&D portfolio and its Comprehensive National Energy Strategy are described in DOE (1998 and 1999).

- measures that reduce the energy intensity of the economy (e.g., more efficient lighting, cars, and industrial processes),
- measures that reduce the carbon intensity of the energy used (e.g., renewable energy resources, nuclear power, natural gas, and more efficient fossil-fueled electricity plants), and
- measures that integrate carbon sequestration into the energy production and delivery system (e.g., integrated gasification combined cycle plants with carbon separation and storage).

Other energy-related challenges (i.e., air pollution, oil supply vulnerability, and inefficiencies in energy production and end use) are addressed both as co-benefits of climate change mitigation and as the target of policies specifically designed to tackle them.

Overview of the Report

Chapter 2 provides introductory and background material, including an overview of recent energy and CO_2 emission trends, an explanation of the energy efficiency paradox, an explanation for the government role, and an overview of several past energy policy and program successes. Chapter 3 describes the analysis methodology employed in this study.

Chapters 4 through 7 address each of the major energy sectors: buildings (Chapter 4), industry (Chapter 5), transportation (Chapter 6), and electricity (Chapter 7). The following topics are covered in each of these chapters:

- the sector's current energy technology and fuel characteristics;
- the business-as-usual forecast for the years 2010 and 2020, including the amounts and types of forecast energy requirements and production;
- barriers to accelerated use of clean energy systems;
- public policies and programs that could address these barriers;
- the methodology employed to analyze these policies;
- the analysis results, including a description of key technologies, policies, end-uses, and energy resources; and
- remaining analysis needs.

Chapter 8 looks beyond 2020 at the longer-term, global context. This broader scope ensures that our near- to mid-term scenarios are responsive to anticipated, long-term energy needs, technology developments, and market opportunities, while also reflecting the increase in uncertainty that characterizes 50-year planning.

Additional details on the study can be found in the appendices. Appendix A itemizes the alterations made to the Energy Information Administration's National Energy Modeling System (NEMS) to create the CEF-NEMS. Appendix B provides details on the policy implementation pathways, including timing and magnitudes, how the policy was modeled, an explanation of key assumptions, and citations to key references justifying the assumptions, modeling approach, and inputs. Appendix C presents key technology assumptions used in the modeling, and Appendix D presents detailed results. Appendix E describes several ancillary analyses. These appendices are available at: http://www.ornl.gov/ORNL/Energy_Eff/CEF.htm

This study builds upon the results of a previous report. *Scenarios of U.S. Carbon Reductions* – also known as the "Five-Lab study" (Interlaboratory Working Group, 1997). This earlier report quantified one potential path for energy-efficient and low-carbon technologies to reduce carbon emissions in the United States to their 1990 levels by the year 2010. Key sectors of the economy were examined independently: buildings, transportation, industry, and electric generators. Specifically, the report identified one set of technologies with the potential to restrain the growth in U.S. energy consumption and carbon emissions so that levels in 2010 could be close to those in 1997 (for energy) and 1990 (for carbon). The report concluded that if feasible ways could be found to implement this technology set, the resulting reduction in energy costs would be roughly equal to or exceed the direct costs of implementing the technologies[4].

Unlike the Five-Lab study, the current study identifies specific policies and programs needed to motivate consumers and businesses to purchase the technologies that make up its scenario. Specifically, it examines the potential impacts of different packages of public policies and programs in an effort to identify feasible, low-cost policy pathways to a cleaner energy future. As such, the CEF study responds to a recommendation by the President's Committee of Advisers on Science and Technology (PCAST), Panel on Energy Research and Development (1997), that the nation identify and adopt a commercialization strategy to complement its national energy R&D portfolio.

The Five-Lab study also did not conduct an integrating analysis and was therefore unable to assess the full range of effects of its technology scenarios on the U.S. economy[5]. The need for an integrating analysis was recognized by the authors and was addressed in a subsequent peer-reviewed report sponsored by the U.S. Environmental Protection Agency (Koomey, et al., 1998). An integrating analytical framework is also used in the CEF study. In particular, a variant of the Energy Information Administration's (EIA's) National Energy Modeling System (NEMS) -- called the Clean Energy Future-NEMS (CEF-NEMS) – provides integrated results across individual sectors[6]. The integration step allows the effects of changes in energy use in each sector to be taken into account in the energy use patterns of the other sectors. For example, if electric generators should shift significantly to natural gas while at the same time energy consumption in buildings and industry grows, natural gas prices would rise, and some switching to other fuels would result. Through the integration process, such interactions are assessed.

Although this study builds on the Five-Lab study, it stands on its own. Its purpose, scope, and methodology are different, and as a result its findings, while complementary, are distinct. In addition to the differences noted above, the CEF scenarios extend beyond the Five-Lab study's horizon – by looking quantitatively to 2020 and qualitatively to 2050 – and they address an array of multiple challenges, not just global climate change. By documenting the benefits that efficient and clean energy technologies can deliver in the short term and by characterizing the potential of emerging technologies, the CEF report informs a broad range of readers about policy-driven, technology-based approaches to reducing greenhouse gas emissions and addressing other energy-related challenges.

1.2 STUDY METHODOLOGY

The methodology developed for this study is driven largely by the objective of assessing national policies to address the multiple energy and environmental challenges facing the United States. This objective requires that the methodology be scenario-based, integrated across sectors, and flexible (yet consistent) in

[4] Direct costs include the increased technology cost plus an approximate estimate of the costs of program and policy implementation.

[5] This limitation and the lack of specific policies and programs were noted in a General Accounting Office review of the Five-Lab study (GAO, 1998, pp. 5–6).

[6] Koomey, et al. (1998) was based on many of the technology assumptions of the Five-Lab study. It used the NEMS integration module but changed the characterization of consumer behavior, the technology characteristics, and many assumptions of the end-use models. It found that the results were not significantly altered by the integration step.

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handling a variety of policy options, market sectors, and technologies. The methodology developed here meets these requirements by employing a combination of tools and analytical approaches.

1.2.1 CEF Scenarios

A scenario-based approach is used to allow examination of a range of public policies that address energy-related challenges. Scenarios are stories of how the future might unfold; they are not predictions. They are useful for organizing scientific insight, gauging emerging trends, and considering alternative possibilities. A range of assessment methods, analytic tools, and expert judgement is used to analyze the impacts of individual policies. The CEF-NEMS model is then employed to integrate the impacts of each scenario's set of policies. Macroeconomic impacts and feedback are assessed through an analysis of previous modeling results.

The study employs three scenarios – Business-as-Usual (BAU), Moderate, and Advanced. The BAU forecast assumes a continuation of current energy policies and a steady pace of technological progress. In contrast, the Moderate and Advanced scenarios are defined by policies that are consistent with increasing levels of public commitment and political resolve to solving the nation's energy-related challenges. Some of the public policies and programs that define the scenarios are cross-cutting; others are designed individually for each sector (buildings, industry, transportation, and electric generators) and assessed for impacts out to 2020. Numerous policies are examined, including fiscal incentives, voluntary programs, regulations, and research and development.

The CEF scenarios are quantitatively assessed as a package in terms of both benefits and costs projected out to 2020. The benefits include lower greenhouse gas emissions, reduced local air pollution, reduced oil imports, and energy savings from more efficient energy production and use. The costs include the necessary private-sector investment in efficiency and low-carbon technologies, the cost of implementing federal programs designed to encourage such technologies, and the indirect costs of shifts in energy supply that will lead to changes in employment and economic activity.

The CEF scenarios address U.S. energy and environmental issues for the next 20 years. They are not long-term, global, integrated assessments. This 20-year domestic focus is not meant to minimize the importance of longer-term global energy issues such as:

- air pollution problems in many countries around the world,
- access to electricity for the third of the world's population that is currently unserved, and
- long-term fossil fuel resource limitations and distribution.

To place the CEF scenarios within this expanded context, an array of additional technology options are qualitatively described. With successful research, these options could provide additional pathways to address global energy-related challenges through 2050. These include carbon sequestration, novel nuclear reactor designs, advanced gas and chemical separation technologies, fuel cell/turbine hybrids, and a host of efficient and renewable energy technologies. However, the scope of our quantitative analysis is limited to near-term domestic issues to illuminate specific technology and policy opportunities for the U.S. today and in the near-term.

1.2.2 Treatment of Uncertainties

The use of scenarios in this study addresses one key uncertainty – the public response to the nation's energy-related challenges. However, additional uncertainties are associated with any study that estimates future impacts of technology and policy. Principal among these is the assumed cost and performance of technologies that are under development. Uncertainties also arise from imprecision in modeling consumer behavior and policy impacts on that behavior. Consumer preferences for new technologies are unreliable and subject to change. And certainly, the connection between public policy and such consumer preferences is even more tenuous.

Based on the scenario definitions and modeling approach used in this study, the CEF scenarios do not portray sudden shifts in policies, technologies, or market preferences. Rather, the scenarios are more incremental and continuous, based on an accumulation of policies impacting numerous technologies, sectors, and markets. To the extent we have failed to anticipate revolutionary technology- and market-driven developments, the CEF characterization of policy impacts over the next 20 years may be off target. However, given the time required for breakthrough technologies to penetrate the market – partly due to the longevity of equipment and infrastructure already in place – it is unlikely that yet-to-be-discovered technologies could have a major impact on the U.S. energy system during the 20-year modeling period.

All scenario-building exercises run the risk of unanticipated breakthroughs. History has experienced numerous transformations that were unanticipated by qualified planners. For instance, energy analysts in the 1970s failed to predict America's massive shift to sports utility vehicles in the 1990s – a shift that interrupted the post-oil embargo's decade of steady gains in automobile efficiency. Similarly, electricity analysts in the 1970s failed to foresee the extraordinary consequences of the gas turbine technologies developed for the defense industry, which became the "technology of choice" in the 1990s – a shift that transformed the electricity industry.

We may also have failed to fully reflect transformational trends that are already under way. The scenarios do not, for instance, take into account the exploding growth of e-commerce and the Internet economy, which could fundamentally reshape the nation's demand for energy services. On the one hand, Romm (1999, p. 9) argues that e-commerce could lead to significant reductions in the demand for energy services: "The Internet has the ability to turn retail buildings into Web sites and to turn warehouses into better supply chain software, to dematerialize paper and CDs into electrons, and to turn trucks into fiber optic cables." Others argue that the explosion of Internet usage and e-commerce could increase demand for energy services.

Despite such potential omissions, the CEF study undertakes a diverse array of sensitivity cases to examine a number of key "what if's." These range from analysis of:

- energy prices: e.g., what if natural gas or petroleum prices rise substantially over the next two decades?
- technology breakthroughs: e.g., what if international markets could significantly drive down the price of new nuclear plants in the U.S.?
- technology failures: e.g., what if research is unable to produce a clean diesel engine for automobiles?
- policy preferences: e.g., what if the only acceptable new policy is a domestic carbon trading system?

These sensitivity cases allow the reader to examine numerous possible future scenarios and to determine the degree to which the "core" ones (i.e., the Moderate and Advanced scenarios) are robust over a multitude of circumstances. The overall conclusion of these sensitivities is that the existence of a wide array of policy and technology options provides many low-cost pathways to a cleaner energy future.

In the end, we take advantage of the data available, use our best judgment tempered by external expert review, and employ scenarios and sensitivity analysis to bound the uncertainties. For example, in addition to our three scenarios, we include high-level sensitivities in which we consider only demand-side policies or only supply-side policies (i.e., policies that impact electricity supplies). We also have examined the sensitivity to a limited number of specific major policies such as the renewable portfolio standard and tougher corporate average fleet efficiency standards.

In spite of our scenarios, sensitivities, caveats, and protests to the contrary, it is tempting to use point estimates provided by the individual scenarios as "the estimate." In hindsight, we might have devoted more of our limited resources to developing a range of estimates for each scenario. For now, the reader is cautioned to consider the values shown as simply representative of a range of possible outcomes.

One remaining question is whether this range of possible outcomes might be large enough to reverse some of the principal findings of the study. In the end, each reader must weigh the data, methods, results, and sensitivities to answer this question. However, the size of the net "direct" benefits of the Advanced scenario, the robustness of the findings with respect to the sensitivities conducted, and the market's inherent ability to innovate beyond that which can be anticipated by any study all lend credence, in our opinions, to the conclusions drawn. While the authors of this report have a range of views about the results, they believe that with sufficient commitment, the United States could achieve a substantial portion of the future portrayed by the Advanced Scenario.

1.3 POLICY IMPLEMENTATION PATHWAYS

This study does not make policy recommendations. Rather, the purpose of the study is to better understand the costs and benefits of alternative sets of policies to accelerate clean energy technology solutions. Some of these policies are not the policies of the current Administration. In addition, the policies do not address the complete range of policy options. For example, the scenarios do not include international emissions trading which could be important to meeting possible carbon emission targets.

As noted, the analysis focuses on three scenarios: BAU, Moderate, and Advanced. The BAU forecast describes a future in which policies and the implementation of energy efficiency and low-carbon technology are not greatly different from today. It is based on the Reference case developed by the Energy Information Administration (EIA) and published in the *Annual Energy Outlook 1999* (EIA, 1998a). To follow a path that leads to the Moderate and Advanced Scenarios, new or strengthened policies and programs will be needed.

Tables 1.1 through 1.4 illustrate the types of policies and programs that define the Moderate and Advanced scenarios for buildings, industry, transportation, and electricity supply, respectively. The lists simply summarize each policy; a complete description of the policies can be found in each of the sector chapters that follow.

Many of the policies were selected on the basis of their potential to reduce carbon emissions. Others were designed specifically for air quality (e.g., reducing SO_2 emissions in the electric sector), oil security (e.g., alternative fuels R&D), and economic efficiency (e.g., restructuring of the electric sector). Regardless of the driving force behind them, almost all reduce carbon emissions and improve air quality. Policies are generally stronger in the Advanced than the Moderate Scenarios, with larger expenditures on public-private R&D partnerships, stricter standards, higher tax incentives, and greater government investment in programs that promote efficient and clean technologies. Two key differences for all of the sectors is the addition of a domestic carbon trading system to the Advanced scenario and increased R&D resources in both the Moderate and Advanced scenarios.

- **Domestic carbon trading system.** Emissions trading programs work by allocating allowances that permit the release of limited quantities of emissions during a specified period (e.g., annually). They allow sources to comply with the cap by reducing emissions or purchasing permits from other sources that can reduce emissions at lower cost. A firm's response will depend on its costs of control compared with the market price of carbon permits.

We assume that the domestic carbon trading program is announced in 2002 and is implemented in 2005[7]. Each year, beginning in 2005, permits are sold in a competitive auction run by the federal government. The carbon emissions limit is set so that the permit price equilibrates at $50/tC (in 1997$) throughout the study period[8]. (A $25/tC case is also analyzed.) The federal government collects the carbon permit revenues and transfers them back to the public. The idea of the carbon permit rebate is to leave people's "incomes" intact while changing the relative price of carbon-based fuels.

- **Increased R&D resources.** The Moderate scenario assumes a 50% increase in federal government appropriations for cost-shared research, development, and demonstration (RD&D) in efficient and clean-energy technologies. The increase is based on an assumed baseline of $1.4 billion in current federal energy R&D. This baseline, and the assumed increase includes research on energy-efficient end-use technologies as well as power generation technologies using renewable resources, natural gas, coal, and nuclear energy[9]. Since these resources are spent in public/private RD&D partnerships, they are matched by private-sector funds. The increase is assumed to be implemented gradually between 2000 and 2005, and to continue through 2020.

  The Advanced scenario assumes that the federal government doubles its appropriations for cost-shared RD&D, resulting in an increase of $2.8 billion per year (half as federal appropriations and half as private-sector cost share). Both scenarios assume a careful targeting of funds to critical research areas and a gradual, 5-year ramp-up of funds to allow for careful planning, assembly of research teams, and expansion of existing teams and facilities.

A set of guidelines was developed for selecting policies for each sector and scenario. These are described in Chapter 3. More than 50 policies are modeled; therefore, it is not possible to estimate the impacts of each policy in isolation. As a result, we focus on scenarios that involve collections of policies, tailored to meet the needs of each sector.

For buildings, the policies and programs include additional appliance efficiency standards; expansion of voluntary programs such as Energy Star, Building America, and Rebuild America; increased efforts on building codes; and expanded R&D. They also include tax credits consistent with the Clinton Administration's 1999 Climate Change Technology Initiative (CCTI); continuation of market transformation programs such as Rebuild America and Energy Star labeling; and related public benefits programs financed by electricity line charges.

[7] To model the effect of announcing a carbon trading system in 2002, we assume that the market operates as though there were a gradually increasing increment to the cost of carbon-based fuels. The increase is based on the addition of $12/tC beginning in 2002, rising to $25/tC in 2003, $37/tC in 2004, and $50/tC in 2005. This modeling approach is equivalent to assuming that a domestic carbon trading program is implemented in 2002 with a carbon emissions limit that is increasingly constraining over the four-year period, causing carbon permit values to rise to $50/tC in 2005.

[8] $50 per tonne of carbon corresponds to 12.5 cents per gallon of gasoline or 0.5 cents per kWh for electricity produced from natural gas at 53% efficiency (or 1.3 cents per kWh for coal at 34% efficiency). $25/tC corresponds to half these incremental costs.

[9] The estimate of current federal energy R&D is based on a 1997 report by the President's Committee of Advisors on Science and Technology (PCAST, 1997), entitled "Federal Energy Research and Development for the Challenges of the Twenty-First Century." This PCAST report recommended that the United States double its federal energy R&D expenditures by the year 2003. EPRI (1999) recommends a 150% increase (i.e., more than doubling) of U.S. electricity-related R&D in order to resolve the energy–carbon conflict and achieve other energy-related goals.

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Table 1.1 Illustrative Buildings Sector Policies, By Scenario

Moderate Scenario	Advanced Scenario
➢ Expand voluntary labeling and deployment programs such as Energy Star, Building America, and Rebuild America to increase the penetration of efficient technologies in the market	➢ Enhanced programs, more end-uses covered, and more penetration
➢ Implement new efficiency standards for equipment, beyond those already planned	➢ More end-uses covered by standards; another round of standards for some products
➢ Increase enforcement and adoption of current building codes (Model Energy Code and ASHRAE 90.1R)	➢ More stringent residential building code in 2009 that is gradually adopted by states
➢ Implement tax credits as proposed by the Clinton Administration in the Climate Change Technology Initiative (CCTI) (e.g., $1,000 tax credit for new homes that are at least 30% more energy efficient than the International Energy Conservation Code, through 2004)	➢ Same credits but with longer time periods before phase-out; size of tax credit increased for heat pump water heaters as well
➢ Expand cost-shared, federal R&D expenditures by 50%	➢ Double cost-shared, federal R&D expenditures, leading to greater cost reductions, more advanced technologies, more penetration associated with R&D
➢ "Public benefits" (lines) charges for states implementing electricity restructuring (full national restructuring in 2008)	➢ Higher line charges
➢ Government procurement assumed to increase in scope over current efforts: increase Federal Energy Management Program (FEMP) efficiency goals by executive order; adopt renewable power purchase requirement for federal facilities[a]	➢ More rapid implementation of FEMP efficiency goals and faster expansion of Energy Star purchasing to state and local governments as well as large corporations; more stringent renewable power purchase requirement for federal facilities.
	➢ Domestic carbon trading system with assumed permit price of $50 per metric ton of carbon, announced in 2002 and implemented in 2005

[a] Unlike other policies enumerated here, we do not explicitly model government procurement policy in this analysis. However, we recognize it here as an important and strategic enabling policy that is essential for the voluntary programs to achieve their estimated penetration levels.

For industry, the pathways include voluntary agreements with industry groups to achieve defined energy efficiency and emissions goals, combined with a variety of government programs that strongly support such agreements. These programs, detailed in Table 1.2, include expansion of existing information programs, financial incentives, greater cost-shared R&D investments, and strengthening of energy efficiency standards on motors systems. Measures are taken to encourage the diffusion and improve the implementation of combined heat and power (CHP) in the industrial sector.

Table 1.2 Illustrative Industrial Sector Policies, by Scenario

Moderate Scenario	Advanced Scenario
➢ Build upon existing voluntary sector agreements with associations and companies to achieve an energy efficiency improvement of 0.5% per year over the BAU scenario	➢ Build upon existing voluntary sector agreements with associations and companies to achieve an energy efficiency improvement of 1.0% per year over the BAU scenario
➢ Voluntary programs: increase motor, compressed air, steam, and combined heat and power (CHP) challenge programs: expand floorspace covered by Energy Star Building program by 50%	➢ Voluntary programs: extend challenge programs to smaller companies and other activities; increase floorspace covered by Energy Star Building program by 100%; expand number of pollution prevention program partners grows to 1,600 by 2020 (from 700 in 1997)
➢ Information and technical assistance: expand audit programs (Industrial Assessment Centers–IACs) and labeling programs	➢ Information and technical assistance: expand audit programs (IAC) and labeling programs
➢ Regulation: Mandate upgrades of all motors to EPACT standards by 2020	➢ Regulation: Mandate upgrade of all motors to Consortium for Energy Efficiency standards by 2020
➢ Investment enabling: expand Clean Air Partnership and line charges to 30 states, provide tax rebates of 50% of the salary of 5,000 energy managers by 2020	➢ Investment enabling: Extend Clean Air Partnership and expand line charges to 50 states, provide tax rebates of 50% of the salary of 10,000 energy managers by 2020
➢ CHP Policies: CCTI tax credits, expedited siting and permitting, interconnection standard in 2002	➢ CHP Policies: Extend tax credits beyond 2003, increase state grants through Clean Air Partnership Fund, further reduce expense associated with interconnection
➢ Expand cost-shared federal R&D expenditures by 50%: increase industries-of-the-future effort and cross-cutting industrial efficiency R&D programs	➢ Double cost-shared federal R&D expenditures: include new industries-of-the-future effort and further expand cross-cutting industrial efficiency R&D programs
	➢ Domestic carbon trading system with assumed permit price of $50 per metric ton of carbon, announced in 2002 and implemented in 2005.

For transportation, the scenarios result from a combination of financial incentives for efficient automobiles ("golden carrots"), strengthened R&D, several government programs, and voluntary energy efficiency targets for light-duty vehicles. The pay-at-the-pump automobile insurance program involves paying for a portion of automobile insurance by means of an added fee to gasoline, thereby "variabilizing" the cost of insurance to reflect miles traveled. Thus, the increase in the price of gasoline is somewhat offset by lower insurance premiums (depending on how much one travels).

Table 1.3 Illustrative Transportation Sector Policies, by Scenario*

Moderate Scenario	Advanced Scenario
➢ Expand cost-shared, federal R&D expenditures by 50% (e.g., achieving 7.4 mpg for heavy trucks in 2020)	➢ Double cost-shared, federal R&D expenditures (e.g., achieving 7.9 mpg for heavy trucks in 2020)
➢ Implement vehicle purchase tax credits as proposed in the CCTI (e.g., $2,000 credit for vehicle that is two-thirds more fuel efficient than a comparable vehicle, for purchases in 2003 through 2006)	➢ Tax credits are extended
➢ Accelerate air traffic management improvements to reduce the time spent waiting "on line" on the ground and circling airports	➢ Same
➢ Program to promote investment in cellulosic ethanol production	➢ Same
➢ Invigorated government fleet program promoting alternative fuels and efficiency	➢ Same, with more rigorous requirements
	➢ Voluntary agreements to improve fuel economy for light-duty vehicles (40 mpg autos, 30 mpg light trucks in 2010; 50 mpg autos, 35 mpg light trucks in 2020)[a]
	➢ "Pay-at-the-pump" automobile insurance (paid for by adding 34¢ per gallon of gasoline in 2010 and 51¢ per gallon in 2020)
	➢ Intelligent traffic systems controls, including intelligent roadway signing, staggered freeway entry and electronic toll collection
	➢ Domestic carbon trading system with assumed permit price of $50 per metric ton of carbon, announced in 2002 and implemented in 2005

*A side analysis examines the potential reduction in vehicle miles of travel from policies that affect the evolution of land use patterns and investments in highway infrastructure.
[a] These voluntary agreements, because they are met in the Advanced scenario, would have the same effect as a CAFE standard of the same level.

For electricity, the policies include extending the production tax credit of 1.5¢/kWh over more years and extending it to additional renewable technologies, setting stricter standards, enhancing RD&D, and facilitating the deployment of wind energy. The scenarios also include net metering capped at 1% in the Moderate scenario and 5% in the Advanced scenario. This policy allows on-site generation that exceeds site loads to be sold back to the grid at retail electricity prices. Net metering creates incentives for distributed generation that can have environmental and reliability benefits through higher efficiencies and reduced transmission and distribution requirements.

Table 1.4 Illustrative Electricity Sector Policies, by Scenario

Moderate Scenario	Advanced Scenario
➢ Wind deployment facilitation (e.g., facilitate siting on Federal land, design operator protocols to accommodate wind intermittency)	➢ Same
➢ 1.5¢/kWh production tax credit (PTC) for the first 10 years of operation for wind and biomass power installed through 2004	➢ Same, for all non-hydro renewable electricity options
➢ 1¢/kWh credit for biomass cofiring during the years 2000-2004	➢ 1¢/kWh credit for biomass cofiring during the years 2000-2014
	➢ Renewable portfolio standard – represented by 1.5¢/kWh PTC in 2005-2008 to signify cap in Clinton Administration proposal
➢ Enhanced R&D – represented by the electric technology cost and performance of the AEO99 high renewables and high fossil cases	➢ Limited additional technology advances beyond those of the Moderate scenario; includes carbon sequestration option
➢ Up to 1% net metering	➢ Up to 5% net metering
➢ Full national restructuring of the electricity industry in 2008 resulting in marginal cost pricing, lower reserve margins, etc.	➢ Same
	➢ SO_2 ceiling reduced in steps by 50% between 2010 and 2020 to represent tighter particulate matter standards
	➢ Domestic carbon trading system with assumed permit price of $50 per metric ton of carbon, announced in 2002 and implemented in 2005

The policy set examined here is not exhaustive. Some potentially complementary policies are not included because of modeling difficulties (e.g., in the case of policies that target the improved performance of roofs, wall, windows, and foundations in existing buildings). In other cases, policies included in the CEF study are less stringent than the policies modeled in other studies (e.g., Geller, Bernow, and Dougherty, 1999; Tellus Institute, 1998). Examples include the higher levels of efficiency for appliances and the larger annual reductions in energy intensity for industrial plants specified by Geller, et al. (1999). Policies aimed at reducing vehicle miles of travel (vmt) were not included, because the BAU forecast already includes a vmt growth rate that our reviews indicated are unrealistically low (Appendix E-2). Finally, numerous policies examined in other studies are omitted, because they were considered to exceed the levels of action or cost that were used as guidelines to define the Moderate and Advanced scenarios. Examples of policies **not** included are:

- **Buildings:** mandate the demand-side management programs run by electric utility companies in the 1980s and first half of the 1990s, which were responsible for a substantial fraction of the energy efficiency improvements already realized in the buildings sector.

- **Industry:** establish tax incentives for new capital investments in energy equipment to accelerate the rate at which technological innovation diffuses into industries, thereby more quickly retiring outmoded and inefficient production equipment and facilities.
- **Transportation:** enact greenhouse gas standards for motor fuels that would be specified as a limit on the average greenhouse gas emissions factor of all motor fuels.
- **Electricity:** require all coal-fired power plants to meet the same emissions standards as new plants under the Clean Air Act, thereby removing the "grandfathering" clause that has allowed higher polluting, older coal-fired plants to continue to operate unabated.

Clearly, inclusion of such policies would result in accelerated progress toward meeting the nation's energy and environmental goals. Thus, if the nation requires acceleration, these other studies could be consulted to identify stronger actions.

1.4 POLICY SCENARIO RESULTS

This section begins with a discussion of the BAU forecast, since it provides the baseline for assessing the impacts of alternative policy scenarios.

1.4.1 The Business-as-Usual Forecast

The BAU scenario was developed from EIA's AEO99 Reference case (EIA, 1998a). Like the EIA Reference case, it is based on federal, state, and local laws and regulations in effect on July 1, 1998, and does not reflect the potential impacts of pending or proposed legislation. However, the BAU forecast does incorporate the impacts of scheduled administrative actions, such as the issuance of scheduled standards which the EIA estimates do not. In addition, BAU is based on the assumption that federal funding of energy R&D continues at current levels. This ongoing investment, in combination with other private- and public-sector actions, is presumed to result in a steady pace of technological progress. For instance,

- New residential building shell efficiencies are assumed to improve by approximately 25% by 2020 relative to the 1993 average, due to advanced insulation methods and windows.
- In industry, total energy intensities are forecast to decrease by 1.1% annually, of which a reduction of 0.3% annually is through efficiency improvements.
- Switching to low rolling resistance tires is assumed to reduce fuel consumption by 1 trillion Btu (or 125,000 gallons of gasoline) in 2010, and purchases of alternative-fuel vehicles by state governments are assumed to increase to 75% of state fleet purchases in 2001 (EIA, 1998a, pp. 220-223).

The BAU scenario forecasts that U.S. energy consumption will increase 1.2% annually from 94 quads in 1997 to 110 quads in 2010 (Table 1.5). During the subsequent decade, the annual growth rate will drop to 0.8%, bringing total U.S. consumption to 119 quads in 2020. While there is necessarily great uncertainty associated with any specific forecast, all indications are that, without change, the United States is on a path toward increasing energy consumption well into the foreseeable future.

Table 1.5 Primary Energy and Carbon Emissions, by Sector: Reference Case vs. Business-as-Usual Forecasts

	Primary Energy (quadrillion Btu)				Carbon Emissions (MtC)			
	2010		2020		2010		2020	
	AEO99 Reference Case	BAU Scenario	AEO99 Reference Case	BAU Scenario	AEO99 Reference Case	BAU Scenario	AEO99 Reference Case	BAU Scenario
Residential	21.1	21.2	22.9	23.1	333	330	375	363
Commercial	17.2	17.3	18.1	18.3	282	280	308	300
Industrial	39.4	38.7	42.1	41.1	549	534	595	563
Transportation	33.1	33.1	36.9	36.8	626	626	697	696
Total	110.8	110.2	119.9	119.4	1790	1769	1975	1922
Electric Generators[a]	39.2	39.2	42.1	41.9	655	645	746	718

Notes: BAU = Business-As-Usual scenario. Source for AEO99 Reference case forecast: Table A2, EIA, 1998a.
[a]The primary energy consumed by electric generators, and their carbon emissions, are distributed across consumption sectors and therefore are fully included in the row labeled "Total."

The CEF study's BAU scenario varies only slightly from the EIA Reference case. The differences reflect three changes. First, the BAU forecast assumes lower nuclear power relicensing costs than the EIA Reference case (these lower costs are believed to be more realistic). Second, the BAU forecast modified base year values as well as retirement rates in three industries – cement, iron and steel, and pulp and paper – based on detailed studies of these industries. Finally, it uses higher retirement rates for all industrial sectors and lower lifetimes of equipment to reflect actual lifetimes of installed equipment, based on detailed assessments of the same three industries. The input variations that distinguish these two cases are documented in Appendix A.

BAU forecasts that U.S. carbon emissions from fossil fuel consumption will increase 1.4% annually from 1,480 MtC in 1997 to 1,769 MtC in 2010 (Table 1.5). During the subsequent decade, the annual growth rate is forecast to be 0.6%, increasing emissions to 1,922 MtC in 2020. The carbon emissions forecasts of the BAU scenario and the EIA Reference case vary somewhat more than their energy forecasts. This is because in addition to assuming slower growth in energy consumption, BAU extends the operation of some nuclear plant capacity assumed to be shut down in the AEO99 Reference case, resulting in a slower rate of growth in the CO_2 emitted per kWh. Carbon emissions in the BAU scenario are almost 1% less in 2010 and are 3% less in 2020 than in the EIA Reference case.

The latest information on energy consumption and greenhouse gas emissions in the U.S. (EIA, 1999a, Tables A2 and A19, EIA, 1999b) indicates that in 1998, the nation's energy consumption grew by only 0.5%, and carbon emissions grew by only 0.4%, relative to 1997 levels. During the same year, the economy exhibited continuous growth, with approximately a 4% increase in Gross Domestic Product (GDP). Unlike buildings and transportation, the industrial sector's emissions actually dropped in 1998. This decline was likely affected by a warmer than normal winter season and structural shifts in U.S. manufacturing away from energy-intensive industries and toward information-intensive businesses. If this slowdown in energy demand and carbon emission growth rates reflects long-term structural shifts, then both the BAU and AEO00 forecasts for carbon and energy may be too high.

Notwithstanding these 1998 estimates, both BAU and the Reference case anticipate that each sector (buildings, industry, transportation, and electric generators) will increase its carbon emissions over the next 20 years. Emissions from the transportation sector are expected to grow most quickly and emissions from industry, least quickly. Without strong policy intervention and/or significant energy price increases, it appears unlikely that carbon emissions in the United States will stabilize or decline.

Results of the two policy scenarios are described in the following sections, in terms of energy savings, carbon reductions, key policies and technologies, and costs and benefits. In each case, the policy scenarios are compared with the BAU forecast to assess the magnitude and nature of their impacts.

1.4.2 Energy Savings of the Policy Scenarios

Table 1.6 and Fig. 1.1 present the energy use trajectories produced by the Moderate and Advanced policy scenarios and the BAU forecast. The presentation of values with three or more significant figures in this table and throughout the report is not intended to imply high precision, but rather is designed to facilitate comparison among the scenarios and to allow the reader to better track the results. An uncertainty range for each value would be preferred to our single-point estimates, but the analysis required to prepare such ranges was not possible given our resources and the CEF-NEMS methodology described earlier.

In the Moderate scenario, energy consumption grows at an annual rate of 1.0% between 1997 and 2010. Instead of reaching 110 quads in 2010, energy use increases to 107 quads. Overall, the Moderate scenario for 2010 shows an increase of 13% above the 94 quads consumed in 1997 (26% above the 84 quads used in 1990). During the second decade, energy consumption grows at an annual rate of 0.3%. Instead of reaching 120 quads in 2020, it increases to 110. The two quads saved in this scenario in the residential sector in 2020 is enough to meet the current annual home energy needs of 11 million households. The 2.7 quads of energy saved in the transportation sector in 2020 is equivalent to the energy needed to fuel 44 million of today's cars for a year.

Despite these energy savings, the Moderate scenario for 2020 shows an increase of 17% above the 94 quads consumed in 1997 (31% above the 84 quads used in 1990). Transportation energy use grows considerably faster than energy use in the other sectors.

In the Advanced scenario, with its more aggressive policies, energy consumption grows at an annual rate of only 0.4% between 1997 and 2010, approximately half the growth rate of the Moderate scenario. In the second decade, the accelerated penetration of efficient technologies in each end-use sector reverses the growth trend. Energy use between 2010 and 2020 decreases at a rate of 0.3% annually. The Advanced scenario projects an overall increase in energy use to 100 quads in 2010, just 6% higher than in 1997. Energy use in 2020 decreases to 97 quads, just 3% above 1997 levels and 15% above the 84 quads consumed in 1990. This energy savings of 23 quads in 2020 is enough to meet the current energy needs of all the citizens, businesses, and industries located in the top three energy consuming states (Texas, California, and Ohio) or the combined current energy needs of the 30 lowest consuming states.

An off-line analysis of combined heat and power in industry suggests that policies tackling barriers to this technology could increase energy savings by an additional 5 to 10%. Specifically, energy consumption is estimated to decrease by a further 0.3 quads in the Moderate scenario in 2010 and by an additional 0.5 quads in 2020. In the Advanced case, the potential additional reduction from CHP policies is estimated to be considerably larger: 1.1 quads in 2010 and 2.4 quads in 2020.

Table 1.6 Primary Energy by Sector (quadrillion Btu)*

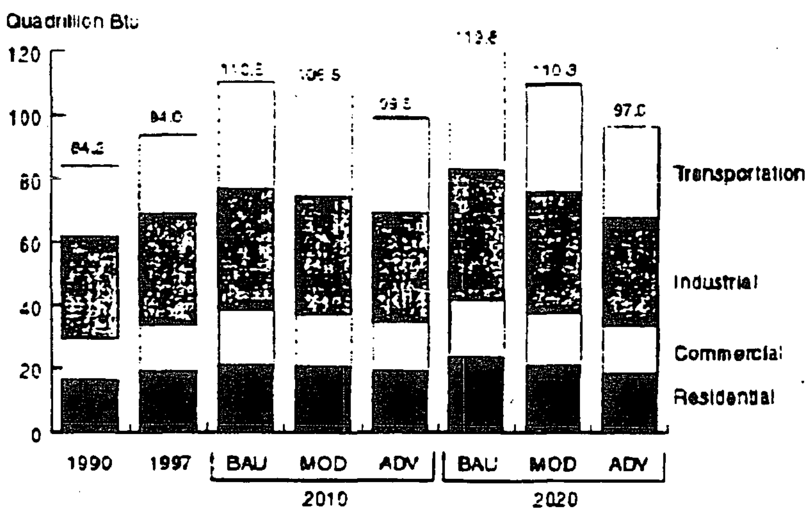
			2010			2020		
	1990	1997	BAU	Mod.	Adv.	BAU	Mod.	Adv.
Residential	16.3	19.0	21.2	20.4 (-4%)	19.3 (-9%)	23.2	21.1 (-9%)	18.3 (-20%)
Commercial	13.1	15.2	17.3	16.7 (-3%)	15.9 (-9%)	18.5	17.0 (-9%)	15.4 (-18%)
Industrial	32.2	34.8	38.8	37.2 (-4%)	34.7 (-11%)	41.2	38.0 (-8%)	34.3 (-17%)
Transportation	22.6	25.0	33.1	32.2 (-3%)	29.8 (-10%)	36.8	34.1 (-7%)	28.9 (-21%)
Total	84.2	94.0	110.3	106.5 (-4%)	99.5 (-10%)	119.8	110.3 (-8%)	97.0 (-19%)
Electric Generators[a]	30.1	34.2	39.3	37.5 (-5%)	34.6 (-12%)	42.9	38.4 (-10%)	32.6 (-24%)

Notes: BAU = Business-As-Usual; Mod. = Moderate; Adv. = Advanced. Numbers in parentheses represent the percentage change compared with BAU. Source for 1990 electric generators data: Energy Information Administration (1990), Table A2, p. 44. Source for other 1990 data and 1997 data: Energy Information Administration (1998a), Table B2, p. 141.

*A number of key technologies were not modeled within the CEF-NEMS framework and are therefore not reflected in these numbers, including combined heat and power (CHP), solar domestic hot water heaters, and fossil fueled on-site generation in buildings. An off-line analysis suggests that policies tackling barriers to CHP in industry could reduce energy consumption by an additional 0.3 quads in the Moderate scenario in 2010 and by an additional 0.5 quads in 2020. The energy saved by new CHP systems in the Advanced case are estimated to be considerably larger: 1.1 quads in 2010 and 2.4 quads in 2020.

[a]The primary energy consumed by electric generators is distributed across consumption sectors and therefore is fully included in the row labeled "Total."

Fig. 1.1 Primary Energy by Sector (quadrillion Btu)



Note: BAU = Business-As-Usual; MOD = Moderate Scenario; ADV = Advanced Scenario. See Table 1.6 for the values associated with this graph.

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Table 1.7 and Fig. 1.2 show the energy consumption by fuel type for the BAU, Moderate, and Advanced scenarios. This table includes several notable observations.

Table 1.7 Energy Consumption by Source (quadrillion Btu)*

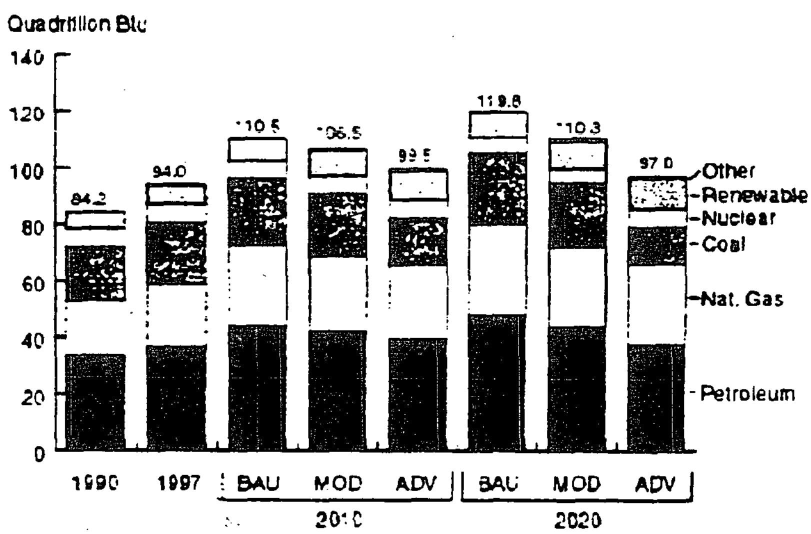
			2010			2020		
	1990	1997	BAU	Mod.	Adv.	BAU	Mod.	Adv.
Petroleum	33.6	36.5	44.1	42.5 (-4%)	39.7 (-10%)	47.9	43.7 (-9%)	37.8 (-21%)
Natural Gas	19.3	22.6	28.3	26.1 (-8%)	26.2 (-7%)	32.1	28.1 (-12%)	28.2 (-12%)
Coal	19.1	21.1	23.7	22.6 (-5%)	16.3 (-31%)	25.0	23.0 (-8%)	12.7 (-49%)
Nuclear Power	6.2	6.7	6.2	6.2 (0%)	6.7 (8%)	5.6	4.9 (-13%)	6.4 (14%)
Renewable Energy	6.2	6.8	7.8	8.6 (10%)	10.2 (31%)	8.9	9.9 (11%)	11.3 (27%)
Other[a]	0.3	0.3	0.4	0.5 (25%)	0.4 (0%)	0.4	0.6 (50%)	0.6 (50%)
Total	84.1	94.0	110.5	106.5 (-4%)	99.5 (-10%)	119.8	110.3 (-8%)	97.0 (-19%)

Note: BAU = Business-As-Usual; Mod. = Moderate; Adv.= Advanced. Numbers in parentheses represent the percentage change compared with BAU.

*The off-line analysis of CHP policies suggests that increased CHP in industry would result in the following adjustments to the above Moderate and Advanced scenario results, both in 2010 and 2020. It would increase natural gas consumption, decrease petroleum-based industrial boiler fuels, decrease coal in both the electricity and industrial sectors, and slow the growth of wind and biopower, especially in the Advanced Scenario in 2020.

[a]Other sources include methanol and liquid hydrogen.

Fig. 1.2 Energy Consumption by Source (quadrillion Btu)



Note: BAU = Business-As-Usual; MOD = Moderate; ADV = Advanced. See Table 1.7 for the values associated with this graph and for explanatory footnotes

First, fossil fuel consumption is reduced in both the Moderate and Advanced scenarios, compared with the BAU scenario, while a higher proportion of nuclear power is retained and renewable energy grows more rapidly. However, the magnitude and composition of these trends differ across the two policy scenarios. For example, coal consumption is impacted much less in the Moderate than in the Advanced scenario. In the Moderate scenario, coal consumption increases from 1997 levels in both 2010 and 2020. Relative to BAU, coal consumption declines by about the same magnitude as natural gas and petroleum in both 2010 and 2020 – on the order of 5 to 8% from 1997 levels. However, in the Advanced scenario with a $50/tonne carbon permit price, coal use declines to 77% of 1997 consumption in 2010 and 60% of 1997 consumption in 2020.

Even with the significant decline in coal consumption in the Advanced scenario, the growth in demand for natural gas is lower than in the BAU scenario. This is because the increased energy savings from efficiency investments, increased use of renewable energy, and maintained use of nuclear power in the Advanced scenario are greater in magnitude than the decline in coal use.

The use of renewable energy sources increases above BAU by 10% in the Moderate scenario and by 31% and 27% in the Advanced scenario for 2010 and 2020, respectively. In 2020, non-hydro renewables double from 2.3 quads in the BAU scenario to 4.6 quads in the Advanced scenario. Such contributions, consistent with cost projections for renewables in this time period, are especially notable for their longer term role. This analysis suggests that the 20-year CEF scenario horizon could see the beginning of a significant growth in renewables.

Another implication of the fuel use results is that growth in petroleum consumption slows in both the Moderate and Advanced scenarios (by 9% to 21% in 2020 compared with BAU). Nuclear power retirements continue in all cases, but at much lower rates in the Advanced scenario than in BAU (6.4 quads of nuclear power consumed in 2020, compared with 5.6 quads in BAU).

The off-line analysis of CHP policies suggests that increased CHP in industry would result in the following adjustments to the scenario results, both in 2010 and 2020. It would increase natural gas consumption, decrease petroleum-based industrial boiler fuels, decrease coal in both the electricity and industrial sectors, and slow the growth of wind and biopower, especially in the Advanced Scenario in 2020.

1.4.3 Carbon Emissions Reductions of the Policy Scenarios

Table 1.8 and Fig. 1.3 display the carbon emissions by sector for the three scenarios.

In the Moderate scenario, carbon reductions generally follow – but are somewhat greater than – the reductions in energy use for buildings, industry, and transportation. Between 1997 and 2010, carbon emissions grow at an annual rate of 1.0%. Instead of reaching 1,769 MtC in 2010 (BAU), they increase to 1,684 MtC. During the second decade, carbon emissions grow at an annual rate of only 0.3%, to 1,743 MtC instead of 1,922 MtC in 2020. Annual carbon emissions in 2010 are 85 MtC lower in the Moderate scenario than in BAU, and in 2020 they are 179 MtC lower. However, in both timeframes, carbon emissions are considerably higher than in 1990 or 1997.

In contrast, the Advanced scenario – with its more aggressive demand- and supply-side policies, and with a domestic carbon trading system – shows markedly greater percentage reductions in carbon emissions than in energy use. Between 1997 and 2010, carbon emissions do not grow at all; and during the second decade they decrease at an annual rate of 1.0%. Instead of growing to 1,922 MtC per year by 2020, carbon emissions are brought close to 1990 levels in 2020 (i.e., 1,357 MtC). Carbon emissions in 2010 are 302 MtC lower in the Advanced scenario than in BAU (a 17% reduction), and in 2020 they are 565 MtC lower than in the BAU scenario (a 29% reduction).

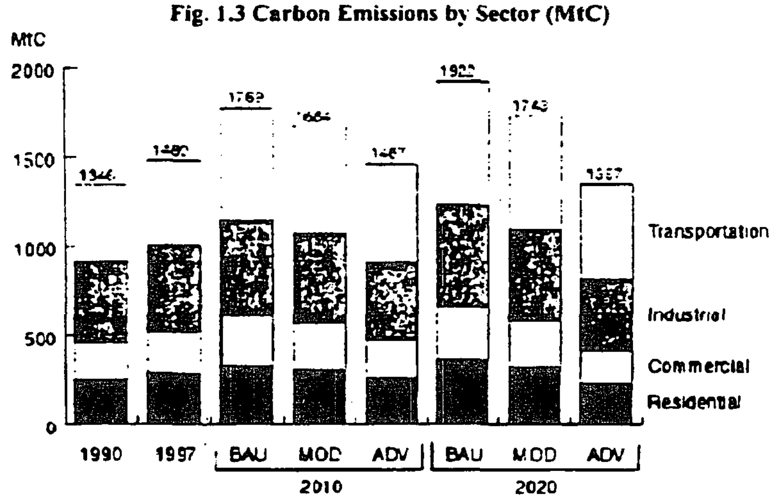
The most significant carbon emissions reductions in the end-use sectors occur in buildings and industry. These reductions result from two changes: increased energy efficiency and reduced carbon in the fuels used to generate electricity. An off-line analysis of combined heat and power in industry suggests that policies tackling barriers to this technology could reduce carbon dioxide emissions by an additional 5 to 8%. In the Moderate scenario they would reduce emissions by an additional 5 MtC in 2010 and 10 MtC in 2020; in the Advanced scenario they would reduce emissions by an additional 26 MtC in 2010 and 40 MtC in 2020.

Table 1.8 Carbon Emissions from Fossil Energy Consumption, by Sector (MtC)*

			2010			2020		
	1990	1997	BAU	Mod.	Adv.	BAU	Mod.	Adv.
Residential	253	287	330	311 (-6%)	260 (-21%)	363	323 (-11%)	230 (-37%)
Commercial	207	237	280	263 (-6%)	218 (-22%)	300	271 (-10%)	195 (-35%)
Industrial	454	483	534	505 (-5%)	429 (-20%)	563	511 (-9%)	399 (-29%)
Transportation	432	473	626	606 (-3%)	560 (-11%)	696	638 (-8%)	533 (-23%)
Total	1346	1480	1769	1684 (-5%)	1467 (-17%)	1922	1743 (-9%)	1357 (-29%)
Electric Generators[a]	477	532	645	597 (-7%)	460 (-29%)	709	623 (-12%)	382 (-46%)

Note: BAU = Business-As-Usual; Mod. = Moderate, Adv. = Advanced. Numbers in parentheses represent the percentage change compared with BAU. Source for 1990 and 1997 data: Energy Information Administration (1998b), Table 7, p. 21.
*An off-line analysis of CHP in industry suggests that policies tackling barriers to this technology could decrease carbon emissions by an additional 6 to 9%.
[a]The carbon emissions from electric generators are distributed across consumption sectors and therefore are fully included in the row labeled "Total."

Fig. 1.3 Carbon Emissions by Sector (MtC)



Note: BAU = Business-As-Usual; MOD = Moderate; ADV= Advanced. See Table 1.8 for the values associated with this graph.

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The carbon intensity of the U.S. energy system is forecast to remain unchanged in the BAU scenario. Measured in terms of million metric tons of carbon emissions per quadrillion Btu of energy, the economy continues to produce 16.0 MtC per quad of energy consumed (Table 1.9). The electricity sector is forecast to undergo a slight trend toward decarbonization, reducing its carbon emissions by 7% from 172 gC/kWh in 1997 to 160 gC/kWh in 2020.

Table 1.9 Changes in Carbon Intensity and Allocation of Carbon Reductions*

	2010			2020		
	BAU	Mod.	Adv.	BAU	Mod.	Adv.
Carbon Intensity:						
Primary Energy: MtC/quad (Note: 1990=16.0, 1997=15.7)	16.0	15.8 (-1%)	14.7 (-8%)	16.0	15.8 (-1%)	14.0 (-13%)
Electricity Only: gC/kWh[a] (Note: 1990=167; 1997=172)	164	159 (-3%)	131 (-20%)	160	161 (1%)	109 (-32%)
Percent Reduction in Primary Energy Relative to BAU (A)		3.5	9.9		7.9	19.0
Percent Reduction in Carbon Emissions Relative to BAU (B)		4.8	17.1		9.5	29.4
Carbon Reductions due to End-Use Energy Reductions (in MtC)[b]		62	175		152	366
Carbon Reductions due to Lower Carbon Intensity (in MtC)		23	127		27	199
Total Carbon Reductions (in MtC)		85	302		179	565

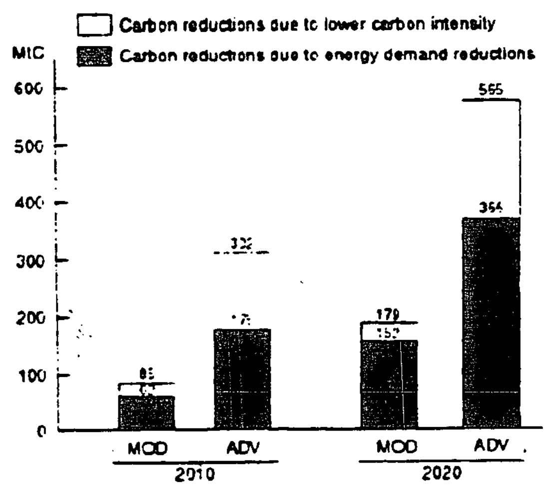
Note: BAU = Business-As-Usual; Mod = Moderate; Adv. = Advanced. Numbers in parentheses represent the percentage change compared with BAU.

*A number of key technologies were not modeled within the CEF-NEMS framework and are therefore not reflected in these numbers. These omitted technologies include: combined heat and power (CHP), solar domestic hot water heaters, and fossil fueled on-site generation in buildings. An off-line analysis of CHP in industry suggests that policies tackling barriers to this technology would decrease carbon emissions in both scenarios. In the Moderate scenario they would reduce emissions by an additional 5 MtC in 2010 and 10 MtC in 2020, and in the Advanced scenario by an additional 26 MtC in 2010 and 40 MtCin 2020.

[a]Excludes electricity cogeneration.

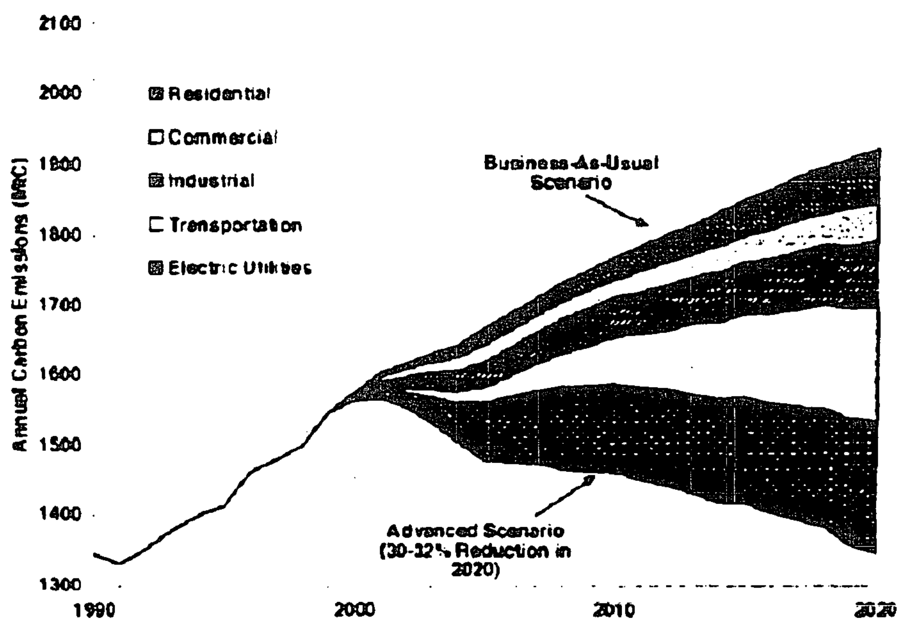
[b]Calculated as (A)/(B) times total carbon reductions.

Fig. 1.4 Allocation of Carbon Reductions



The carbon intensity of the U.S. energy system also changes very little (only 1%) as a result of the Moderate scenario's policies, decreasing by only 1% throughout the two decades. The electricity sector tracks the BAU scenario with a 7% decrease from 1997 intensities to 161 gC/kWh in 2020. As a result, most carbon reductions from the Moderate scenario, in both 2010 and 2020, are due to reductions in energy demand in the end-use sectors. Estimates of these demand-driven reductions are provided in Table 1.9 and Fig. 1.4. The carbon reductions due to demand-driven reductions were estimated by (1) dividing the percent reduction in energy by the percent reduction in carbon, and then (2) multiplying that fraction by the total carbon reductions.

Fig. 1.5 Carbon Emission Reductions by Sector, in the Advanced Scenario



The carbon intensity of the U.S. energy system is reduced significantly by Advanced scenario policies, decreasing by 8% in the first decade and 13% in 2020 relative to essentially unchanged. The electricity sector undergoes even greater decarbonization in the Advanced scenario. It drops 20% in 2010 (from 164 gC/kWh in BAU to 131 gC/kWh in the Advanced scenario), and 32% in 2020 (from 160 gC/kWh in BAU to 109 gC/kWh in the Advanced scenario). As a result, more than one-third of the carbon reductions from the Advanced scenario, in both 2010 and 2020, are due to the lower carbon intensity of the energy system (labeled "electric generators" in Fig. 1.5).

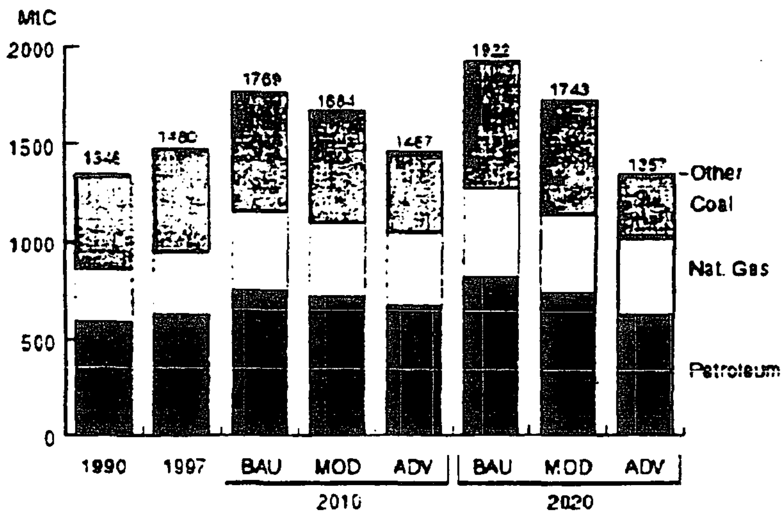
Much of the difference in carbon emissions between the two scenarios is caused by the policies in the Advanced scenario, including carbon trading, that increase the use of low-carbon fuels for electricity generation. These policies result in greater switching from coal to natural gas, increased use of renewable electricity, and extended nuclear power plant operation in the Advanced scenario, relative to the Moderate scenario (Table 1.10 and Fig. 1.6).

Table 1.10 Carbon Emissions from Fossil Energy Consumption, by Source (MtC)

			2010			2020		
	1990	1997	BAU	Mod.	Adv.	BAU	Mod.	Adv.
Petroleum	591	628	755	727	673	818	742	627
				(-4%)	(-11%)		(-9%)	(-23%)
Natural Gas	273	319	404	373	375	460	402	398
				(-8%)	(-7%)		(-13%)	(-14%)
Coal	482	533	608	581	418	642	593	328
				(-4%)	(-32%)		(-8%)	(-50%)
Other[a]	0	0	1	3	2	2	5	3
				(200%)	(100%)		(150%)	(50%)
Total	1346	1480	1769	1684	1467	1922	1743	1357
				(-5%)	(-17%)		(-9%)	(-30%)

Note: BAU = Business-As-Usual: Mod = Moderate: Adv.= Advanced. Numbers in parentheses represent the percentage change compared with BAU. Source for 1990 and 1997 data: Energy Information Administration (1998b). Table 6, p. 21.
[a]Other sources include methanol and liquid hydrogen.

Fig. 1.6 Carbon Emissions by Source (MtC)



Note: BAU = Business-As-Usual; MOD = Moderate; ADV= Advanced. See Table 1.10 for the values associated with this graph.

1.4.4 Key Policies and Technologies

The success of different types of policies and programs varies by end-use sector, reflecting sector-specific market and organizational barriers and imperfections that inhibit the full implementation of cost-effective technologies. Two policies, however, are important to all of the sectors in the Advanced scenario: the domestic carbon trading system and the doubling of federal RD&D appropriations. The importance of the carbon trading system is documented in the sensitivity analysis described in Section 1.5. The importance of expanded R&D is illustrated in Table 1.11.

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Table 1.11 Illustrative R&D Advances in the Advanced Scenario

Buildings	Industry
Heat Pump Water Heaters (HPWHs): R&D reduces the cost of HPWHs by 50% in 2005, relative to the BAU	**Iron and Steel Technologies:** Development of near net shape casting technologies saves up to 4 MBtu/ton steel and reduces production costs between $20 and $40/ton Smelt reduction starts to replace blast furnaces at the end of the scenario period, reducing energy use by 20-30% in ironmaking as well as emissions from coke ovens and ore agglomeration
Small Metal Halide (Mini-HID) Lamps: R&D produces a 20-Watt mini-HID with an electronic ballast that has the same brightness as a 100-Watt incandescent lamp and an incremental cost of $7.50, available in 2005	**Pulp and Paper Technologies:** R&D produces an efficient black liquor gasifier integrated with a combined cycle making a kraft pulp mill a net electricity exporter; this results in primary energy savings of up to 5 MBtu/ton air-dried pulp New drying processes (e.g., condebelt and impulse drying) in the paper machine is successfully developed and commercialized resulting in energy savings of up to 1.4 MBtu/ton paper
Transportation	**Electric Generators**
Direct Injection Diesel Engines: R&D enables direct injection diesel engines to meet EPA's proposed Tier 2 NO_x standards in 2004	**Natural Gas Combined Cycle:** R&D reduces capital costs from the BAU forecast of $405/kW to $348/kW for the 5th of a kind plant; carbon sequestration adds $4/MWh
Hydrogen Fuel Cell Vehicles: R&D drives down the cost of a hydrogen fuel cell system from $4,400 more than a comparable gasoline vehicle in 2005 to an increment of only $1,540 in 2020	**Wind:** R&D reduces capital costs from $778/kW throughout the period in the BAU down to $611/kW in 2016; fixed O&M costs decline from $25.9/kW-yr throughout the period in the BAU down to $16.4/kW-yr in 2020

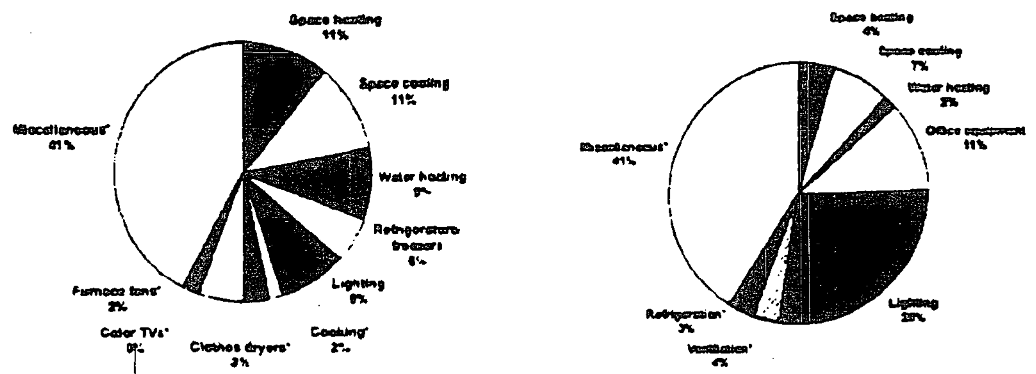
Buildings. The largest energy and carbon savings in residential buildings occur in the category "all other" uses (including cooking, clothes dryers, clothes washers, dishwashers, color TVs, and personal computers – see Fig. 1.7). A large fraction of these savings comes from movement toward a "one-watt" standby loss goal by 2010, based on the switch-mode power supplies that are now widely used in the best new equipment. Next in rank order are space cooling, space heating, water heating, and lighting.

In commercial buildings, lighting and "all other" end-uses dominate the energy and carbon savings. "All other" in the commercial sector includes a collection of small end-uses that are explicitly represented in CEF-NEMS, including ventilation, cooking, and refrigeration, as well as other unidentified uses.

Minimum equipment efficiency standards and voluntary programs are the two most important contributors to energy savings: building codes, tax credits, other incentive programs, and R&D generally play a supporting role. In residential heating and cooling end-uses, building codes take on a larger role.

For electronics end-uses, where rapid technological innovation and the proven success of voluntary efforts hold sway, the voluntary programs capture most of the savings.

Fig. 1.7 Carbon Emission Reductions in the Advanced Scenario in 2020, by Buildings End Use
(Reductions are Relative to the Business-as-Usual Forecast)



Residential Buildings
Constituents of the "All other" category shown in Tables 4.8 and 4.9 are marked with asterisks above. "Miscellaneous uses" include clothes washers, dishwashers, other home electronics, ceiling fans, pool pumps, and other unidentified end-uses.

Commercial Buildings
Constituents of the "All other" category shown in Tables 4.8 and 4.9 are marked with asterisks above. "Miscellaneous uses" include transformers, traffic lights, exit signs, cooking, district services, automated teller machines, telecommunications equipment, medical equipment, and other unidentified end-uses.

Note: Carbon savings from electrical end-uses include both demand-side efficiency and supply-side effects.

Industry. Energy is saved in all industrial subsectors under both the Moderate and Advanced scenarios. Continuing intra- and inter-sectoral shifts, as well as ongoing efforts to reduce environmental impacts and improve energy efficiency, contribute to the savings within the industrial sector. Decarbonization of the power sector contributes to savings, especially in electricity-intensive industrial subsectors (Fig. 1.8).

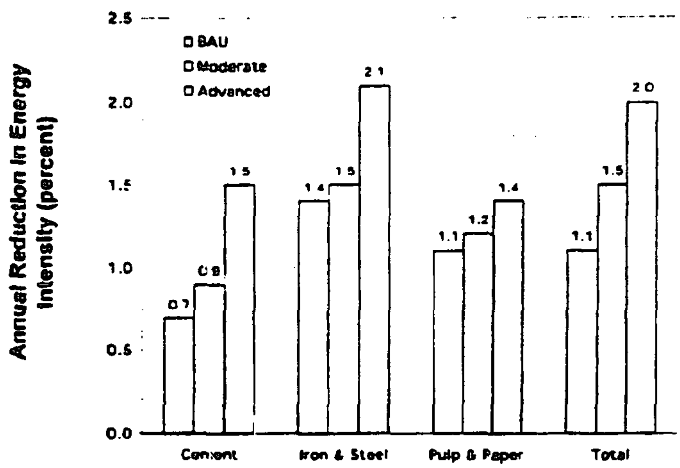
Voluntary agreements between government and industry are the key policy mechanism for achieving these savings. The following policies and programs support the voluntary agreements:

- information programs,
- technology demonstrations,
- energy efficiency audit programs,
- financial incentives, and
- funding for R&D.

The energy-efficiency improvements across scenarios are attributed to increased awareness among plant and company management of opportunities to cut energy costs, as well as strengthened programs to assist in implementing technologies and measures to reduce carbon emissions.

A number of cross-cutting technologies – such as combined heat and power, waste recycling, process control and management, steam distribution system upgrades, improved energy recovery, motor and drive system improvements, and preventive maintenance – contribute significantly to the savings in the policy scenarios. Much of the efficiency improvement results from replacing old process equipment with state-of-the-art equipment instead of new equipment of average efficiency as components and plants are retired. Energy savings in the steel, cement, and aluminum industry are also influenced by the increased use of waste materials. Large improvements in the generation, distribution, and use of steam contribute to savings in the food, paper, and chemical industries.

Fig. 1.8 Annual Reductions in Energy Intensity in the Industrial Sector



Based on off-line expert analysis, the CEF policy scenarios accelerate the development and implementation of these practices and technologies. This will increase energy efficiency beyond that assumed in the BAU scenario. In the steel industry, new technologies such as scrap preheating for electric arc furnaces are more efficient than the technologies used in existing plants, and new casting technologies reduce material and energy losses further. New advanced smelting reduction technologies lead to significant savings after 2010 in the Advanced scenario. In the pulp and paper industry, improved paper machines as well as reduced bleaching and increased wastepaper recycling impact energy use, and black liquor gasification substantially changes the energy profile of pulping in the long term. In cement making, the key technologies and measures are the introduction of blended cements and the gradual retirement of old wet-process clinker plants, which are replaced by modern pre-heater pre-calciner kilns. While some of these technologies are currently available or being developed, there is still a large potential for further development or deployment.

Transportation. The rate at which carbon emissions from transport can be reduced is limited by the lack of opportunities for retrofitting technologies, together with constraints on the quantities of low-carbon fuels, such as cellulosic ethanol, that can be supplied over the next 10 to 20 years. As a result, the impacts of policies and technologies in 2010 are far less than their impacts in 2020. Indeed, the maximum impacts of advanced technologies are yet to be realized even in 2020.

In the Moderate scenario, a combination of several conventional technologies and the turbo-charged direct injection (TDI) diesel have the greatest impact on passenger car and light-truck fuel economy. Even with incentives of up to $4,000 per vehicle, advanced alternative technologies appear to be unable to overcome the market barriers of higher initial cost (especially at low production volumes) and, in the case of alternative-fuel vehicles, limited fuel availability. Encouraged by continuing, though decreasing, tax subsidies, cellulosic ethanol is a key technology for reducing carbon emissions, because it can be readily

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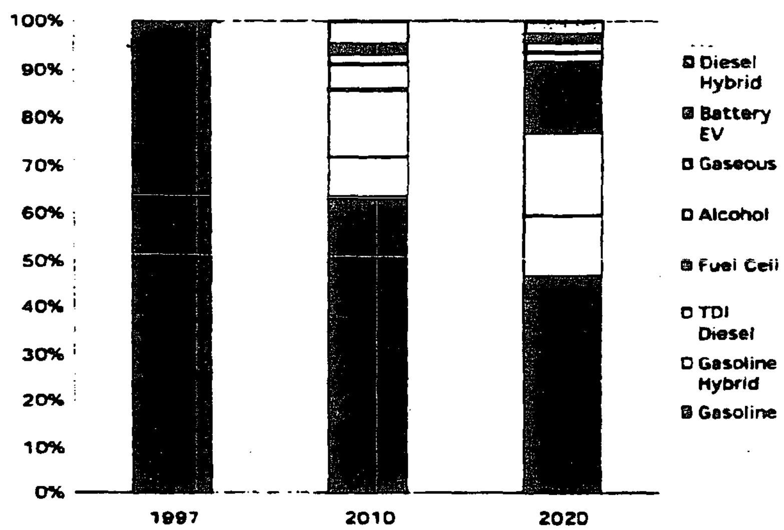
integrated into existing fuel systems via blending with gasoline. Similarly, modest gains are achieved in non-highway modes of transport.

The key distinguishing features of the Advanced scenario are:

- the greater degree of technological success, attributed to a doubling of R&D investment;
- a voluntary commitment to improved efficiency by vehicle manufacturers that accelerates the introduction of technology and, for cars and light trucks, de-emphasizes vehicle weight and horsepower; and
- significant fuel price signals for highway vehicles in the form of pay-at-the-pump insurance fees and a modest carbon permit price.

The combined effect of these measures is an array of impressive new technologies in large numbers (Fig. 1.9). TDI diesels play a major role in the light-duty vehicle market, with sales exceeding 1 million after 2005 and standing at 2.6 million per year in 2020. In the same year, 2.2 million fuel cell vehicles are sold, representing 10% of the new light-duty vehicle market. Hydrogen fuel cell vehicles, which according to our assumptions are cheaper and more energy efficient, are the most successful, accounting for 1.0 million of the 2.2 million total sales in 2020. In 2020, 3.9 million hydrogen fuel cell vehicles are on the road consuming 0.1 quads of hydrogen annually. Advanced technologies also improve fuel economy significantly in non-highway transport.

Fig. 1.9 Advanced Scenario New Light-Duty Vehicle Sales



Energy efficiency is also improved by restraining the large forecasted growth in vehicle horsepower (hp). In 1998, the average hp of new passenger cars sold in the United States was 155. In the BAU case, passenger car hp increases to 251 by 2020. Light truck horsepower increases even more, from 189 in 1998 to 293 in 2020. The Advanced scenario foresees much more modest increases, to 174 hp for cars and 199 hp for light trucks. However, vehicle weight decreases in the Advanced scenario by about 12 percent for passenger cars, so that vehicle acceleration performance would still be about 25 percent faster than today's cars.

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Electric Generators. The demand reductions due to policies described in the end-use sectors greatly limit the growth in electric generation, especially in the Advanced scenario. Within the electric sector, the key policy driving the changes is the domestic carbon trading system in the Advanced scenario. The resulting carbon permit price:

- makes the building of new coal plants cost-ineffective and increases the retirement of coal and other fossil steam plants between 1997 and 2020 – from 66 GW in the BAU scenario to 187 GW in the Advanced scenario.
- impacts the variable cost of production, causing the remaining carbon-intensive technologies to lower their capacity, and
- encourages extension of the life of existing nuclear plants and development of non-hydro renewables, especially wind and biomass.

Restructuring also plays a significant role. By removing incentives for regulated utilities to retain capital investments that are no longer cost-effective, deregulation encourages the retirement of inefficient plants when new plants represent a more cost-effective option. A somewhat contrary impact is that restructuring promotes real-time pricing and customer shifts in peak load requirements. This lowers the need for additional capacity as existing plants operate more fully, which in turn reduces the need to build new, cleaner plants that displace older plants. In the Advanced scenario, while generation drops 2% between 2010 and 2020, generation capacity declines by 4%.

A third major policy driving the changes in the electric sector is the production tax credit (PTC) for non-hydro renewable energy, especially wind. The Renewable Portfolio Standard (RPS) also creates strong incentives for renewable energy development. By creating growth in wind energy through 2004 or 2008, it encourages the development of a strong capacity base that leads to further growth, but at a slower pace after the PTC and RPS expire. In the Advanced scenario, wind generation grows from 7.1 TWh in 2000 to 129 TWh in 2008, as a result of the PTC and RPS incentives, with help from the carbon permit penalty on other technologies and advances in technology. This 18-fold increase would require an unprecedented growth in production capacity of suppliers of wind generation equipment. In the Moderate scenario, with its shorter schedule for the PTC and no RPS or carbon permit price, wind quadruples by the time the PTC expires (2005). Other renewables are helped as well, but to a lesser extent. Biomass cofiring tax credits increase the use of biomass up to 50% in the Moderate scenario before the PTC expires, and biomass replaces up to 1.2% of coal consumption in 2004. Even higher amounts of cofiring occur in the Advanced scenario as other policies influence its use.

Improvements in technologies through R&D expand opportunities for carbon reductions. They provide effective alternatives to reducing demand or requiring higher prices for the permits. Without technology improvements, low- and non-carbon supplies are more expensive and less likely to displace current inefficient and carbon-intensive sources. Technology advances alone are generally insufficient to impact the overall carbon intensity of the production, but they are powerful in conjunction with the carbon permit price. In the BAU scenario, the carbon intensity by 2020 is 160 gC/kWh. The Moderate scenario, with only modest improvements in fossil technology efficiencies and lower demand growth, actually has 2.3% higher carbon intensity; lower demand means fewer opportunities to build low-carbon systems. Also, with no carbon permit price, there is little incentive to reduce carbon emissions. The Advanced scenario has higher fossil efficiencies but lower demand still. When the Advanced scenario was modeled without a \$50/tC permit price, carbon intensity declined by 3% from BAU. With the carbon permit price, the intensity dropped 32% to 109 g/kWh.

Advances in non-hydro renewable technologies help increase the penetration of new technologies into the market and help make them a viable long-term supply. Production of non-hydro renewable energy in the

Moderate scenario is 28% higher than in the BAU by 2020. But that figure represents only an increase from 3.7 to 5.4% of total production, so non-hydro renewable technology advances alone have a relatively small impact on carbon emission reductions. In the Advanced scenario, with other policies in place as well, non-hydro renewables double their production compared with BAU and represent almost 10% of production. Once again, the synergies of multiple policies contribute more than any one set of policies alone.

Cross-Cutting Technologies. Several technologies apply to multiple sectors. These include combined heat and power systems, bioenergy, and fuel cells. The use of CEF-NEMS as an integrating model, which considers all sectors simultaneously, simplifies the evaluation of these technologies. Special considerations in their treatment are discussed in Chapter 3. The following box shows where the reader can find information on these technologies.

Where Did the Cross-Cutting Technologies Go?

Several technologies apply to multiple sectors and are therefore discussed in more than one of the chapters in this report. The following "wiring diagram" shows where the reader can find information on three of these cross-cutting technologies.

Cross-Cutting Technology:	Where to Find Them:
Bioenergy	→ Biomass Gasification (Industry--Chapter 5) → Biofuels (Transportation--Chapter 6) → Biopower (Power--Chapter 7)
Combined Heat & Power	→ District Energy Systems (Buildings--Chapter 4) → Biomass Gasification (Industry--Chapter 5) → Electricity Production (Electricity--Chapter 7)
Fuel Cells	→ Stationary Applications in Buildings (Buildings--Chapter 4) → Transportation (Transportation--Chapter 6) → Ternary Cycle in Natural Gas Combined Cycle & Integrated Gasification Combined Cycle (Electricity--Chapter 7)

1.4.5 Costs and Benefits of the Policy Scenarios

In this section, we report our estimates of the first-order economic impacts of the CEF scenarios. Specifically, five "direct" cost and benefit components are examined:

- policy implementation and administration costs incurred by the public sector;
- R&D costs incurred by both the public and private sectors;
- incremental technology investment costs;

- changes in the energy bill, including the cost of carbon permits; and
- return of the carbon permit revenues to the public.

In the CEF scenarios, these costs and benefits arise over time as follows.

As policies are enacted, the government begins to incur direct costs for their implementation and administration. Energy prices then change as the market reacts to these policies, including higher fossil fuel prices in response to the purchase of carbon permits and lower energy costs due to reduced demand. Consumers react to the policies directly and to the changing energy prices by modifying their demand for energy services and investing in more energy-efficient and low-carbon technologies. The nation's energy bill reflects the changing energy prices and demands. The investments made in more efficient end-use technologies, on the other hand, are not reflected in this bill and must be accounted for separately. With the annual auction of carbon permits, the government accrues revenues. These revenues are then distributed back to the public.

Economic Climate Change Consensus

"Economic studies have found that there are many potential policies to reduce greenhouse gas emissions for which the *total benefits outweigh the total costs*. For the United States in particular, sound economic analysis shows that there are policy options that would slow climate change without harming American living standards, and these measures may in fact *improve U.S. productivity in the longer run.*"

— From a statement signed by ~2500 economists led by Nobel laureates Kenneth Arrow and Robert Solow, at a January 1997 meeting of the American Economics Association. *Italics added for emphasis.*

Summary of Direct Costs and Benefits. In both the Moderate and Advanced scenarios and in both timeframes (2010 and 2020), the estimated annual energy bill savings exceed the sum of the annualized policy implementation costs and the incremental technology investments. This finding is consistent with many economic-engineering studies (Section 1.6) and with the views of many economists (see box). The gap is wider in 2020 than in 2010, reflecting the greater energy reductions as more cost-effective, clean energy technologies are developed and deployed. These net benefits do not reflect the macroeconomic impacts of the scenarios.

Two externality benefits are quantified but are not monetized: improved air quality and energy security. Amenity costs that may result from the CEF scenarios are also not monetized. One of these, however, is discussed: the lower horsepower of light-duty vehicles purchased by consumers in the CEF scenarios relative to the BAU forecast. Long-run macroeconomic costs are discussed primarily in terms of estimates reported in other published studies. In addition, we describe some industries and regions likely to experience significant economic impacts, at least in the short run, if the nation transitions to the type of clean energy future characterized in the two policy scenarios.

Policy Implementation and Administrative Costs. Policy implementation costs include the costs of administering the public policies and programs that are modeled in each scenario, various fiscal incentives, and the incremental R&D costs. For the purposes of this project, ***administrative costs*** include the following costs to the public agencies implementing the policies and programs:

- program planning, design, analysis, and evaluation;
- activities designed to reach customers, bring them into the program, and deliver services such as marketing, audits, application processing, and bid reviews;

- inspections and quality control:
- staff recruitment, placement, compensation, development, training, and transportation;
- data collection, reporting, record-keeping, and accounting; and
- overhead costs such as office space and equipment, vehicles, and legal fees.

Preliminary cost increments were developed by estimating the administrative costs and energy savings associated with 12 policies and programs that have operated over the past decade or two. (Details on these 12 cases are provided in Appendix E-1.) Administrative costs associated with these 12 policies range from S0.052 to S2.49 per MBtu saved. The average value was rounded to S0.6 per MBtu, the increment used in the CEF study. It is added to the annualized incremental technology costs required to generate one MBtu of primary energy savings. This value is consistent with the findings of Berry (1991), who reviewed the cost of implementing demand-side management programs in the 1980s.

Based on these assumptions, the policy administration costs of the Moderate scenario are estimated to range from S3 to S7 billion per year in 2010 and 2020, respectively (Table 1.12). For the Advanced scenario, they range from S9 to S13 billion per year in 2010 and 2020.

Table 1.12 Annualized Policy Implementation and Administration Costs of the Advanced Scenarios in 2010 and 2020 (in Billions 1997S per Year)

	Moderate Scenario		Advanced Scenario	
	2010	2020	2010	2020
Residential	0.5	1.5	1.0	2.7
Commercial	0.5	1.1	0.8	1.6
Industrial	1.0	2.2	2.3	3.9
Transportation	0.5	1.6	1.9	4.6
Electric Generators	0.4	0	2.8	0
Total	2.9	6.4	8.8	12.9

In addition to these administrative costs, other policy implementation costs must be considered.

- The fiscal incentives include the production tax credit for renewable energy in the power sector. In 2010, these amount to S0.4 billion in the Moderate scenario and S0.6 billion in the Advanced. These values are part of the "electric generators" row in Table 1.12. These costs do not occur in 2020, because all costs to the government end before 2020. (Note: Fiscal incentives for energy efficiency measures such as the credit for efficient new homes and vehicles are taken into account as incremental technology investment costs. These are shown in Table 1.14.)

- When actually implemented, the cost of an RPS would be captured within the energy bills of consumers. However, in our CEF-NEMS modeling of the RPS, we employed a 1.5¢/kWh tax credit as a surrogate for the RPS with its 1.5¢/kWh allowance cap. Thus in CEF-NEMS, the cost of the RPS is not captured by the utility bill but must be accounted for separately. The annual cost between 2010 and 2015, when the RPS terminates, is S2.2 billion. This value is part of the "electric generators" row for the Advanced scenario in Table 1.12.

RD&D Costs. The Advanced scenario assumes that the federal government doubles its appropriations for cost-shared RD&D in efficient and clean-energy technologies; the Moderate scenario assumes a 50% increase (Table 1.13). Since these resources are spent in public/private RD&D partnerships, they are matched by private-sector funds. Altogether, the Advanced scenario assumes an increase of $2.8 billion per year by approximately 2005 (half as federal appropriations and half as private-sector cost share). This increment continues through 2020. The Moderate scenario assumes an additional $1.4 billion per year over the same period. Both scenarios assume a careful targeting of funds to critical research areas and a gradual, 5-year ramp-up of funds to allow for careful planning, assembly of research teams, and expansion of existing teams and facilities.

Table 1.13 Research, Development, and Demonstration Costs in 2010 and 2020 (in Billions 1997$ per Year)

	Moderate Scenario		Advanced Scenario	
	2010	2020	2010	2020
RD&D Costs	1.4	1.4	2.8	2.8

Incremental Technology Investment Costs. Incremental technology costs refer to the additional investment in technology required by consumers and businesses to purchase more efficient equipment and energy services. Since we compute costs and benefits on an annual basis, we emphasize the annualized incremental technology costs for each year. The annualized cost for a particular year is the annualized cost of the total investment made to that time. We approximate the annualized cost by calculating an investment cost per unit of energy conserved and multiplying this cost of conserved energy (in $/kWh or $/MBtu) by the energy savings in that year.

For example, policies promoting more efficient residential refrigerators are projected to save 6 billion kWh in 2020 in the Advanced case. The cost of conserved energy for those savings is $0.034/kWh (every kWh saved costs 3.4¢). In addition, the program implementation cost for capturing those savings is $0.006/kWh. The annualized technology cost associated with these savings would be 6 billion kWh times $0.034/kWh, or about $0.2 billion per year. Including program costs, total annualized cost for capturing these savings would be 6 billion kWh times ($0.034 – $0.006), or $0.24 billion per year.

Between 2010 and 2020, the annual incremental technology investment costs – totaled across all technologies and sectors – increase from $11 billion to $30 billion in the Moderate scenario, and from $31 billion to $66 billion in the Advanced scenario (Table 1.14). The transportation sector accounts for approximately half of these costs in both years.

Table 1.14 Annualized Incremental Technology Investment Costs in 2010 and 2020 (in Billions 1997$ per Year)

	Moderate Scenario		Advanced Scenario	
	2010	2020	2010	2020
Residential	1.9	5.8	3.8	9.1
Commercial	2.0	4.6	2.7	5.8
Industrial	3.1	6.7	6.9	11.8
Transportation	4.3	13.4	16.2	39.1
Electric Generators*	0	0	0	0
Total	11.4	30.5	29.6	65.9

*These investment costs are reflected in the price of electricity and hence in the bill savings calculation

It is also useful to estimate the incremental capital outlays required each year to purchase the energy efficiency and clean energy technologies that are promoted by the CEF scenarios. These costs reflect the actual incremental expenditures needed for each scenario in each year. They can be calculated from the year-by-year annualized costs of these investments shown in summary in Table 1.14. The annualized cost calculations involve spreading the cost of capital across the operating lifetimes of new investments, while calculating the capital outlays requires removing that annualization and determining the change in actual capital investments from one year to the next. The actual capital outlays allow us to examine how the nation's investment capital would be affected by the CEF policies.

We are only able to estimate the incremental capital outlays for demand-side technologies and electricity supply-side technologies from the outputs of the CEF-NEMS model. It is not possible to estimate these same requirements for all parts of the supply-side investments that would come about in our policy scenarios. By limiting our estimates to the demand-side, we are likely overestimating the total net investment costs. Because the demand for electricity and fuels is reduced relative to the BAU forecast in both the Moderate and Advanced scenarios, investment capital required to build and operate new generation capacity, mines, and refineries will be avoided. The extent of these capital savings, however, cannot be estimated accurately. As a result, our estimates of incremental technology investments are based solely on the need to invest in improved demand-side technologies in the buildings, industry, and transportation sectors, with the recognition that these estimates are probably upper bounds to the net capital investments required in any given year.

The incremental capital outlays vary year-to-year in both the Moderate and Advanced scenarios. In the Moderate scenario they increase from several billion in 2000 to $17 billion in 2015, after which they decline gradually. In the Advanced scenario, incremental technology investments increase more rapidly from $4 billion in 2000 to $30 billion in 2005; after that they decrease to $17 billion in 2020. These energy-efficiency capital outlays are small relative to gross private domestic investments made in the United States on an annual basis, which totaled $1.7 trillion in 1999 (Bureau of Economic Analysis, 2000). By comparison, the AEO99 reference case projects Real Investment at annual rates of $2,011 billion in 2010 and $2,508 billion in 2020 (in 1997$).[10] Thus, the CEF capital outlays are no more than 2% of total capital investments in any year between 2000 and 2020.

Changes in the Energy Bill. The total change in energy bill is a function of changes in energy prices, as well as changes in amounts and types of energy used. Generally, both factors are at work and are described below. The energy bill is calculated as the sum over all fuels (including electricity) in all end-use sectors of the fuel price times the amount of fuel used minus the pay-at-the-pump fee[11]. Average energy prices to all users are shown, by type of energy and by scenario, in Table 1.15 and Fig. 1.10. Prices for fuels are shown in 1997$ per million Btu. Energy prices are given in more common units (e.g., gallons of gasoline and thousand cubic feet of natural gas) in Table 1.16. The Advanced scenario prices include the $50/tonne carbon permit charge that energy producers are assumed to add to energy prices as a result of the domestic carbon trading system. Scenarios can project energy price increases (as when carbon permit costs are added or in the case of more costly, but cleaner energy options) or decreases (as in the case of reduced energy use resulting from energy-efficient technologies).

The BAU scenario assumes that electricity prices will be 12% lower by 2010 than in 1997 and will decline another 8% by 2020 due to electricity restructuring in parts of the U.S. [Note: Following the lead of EIA's Reference case, the BAU assumes that five regions of the United States transition to competitive pricing with full consumer access and fully competitive prices beginning in 2008 (EIA, 1998a, p. 62).] The Moderate scenario results in even lower electricity prices in both 2010 and 2020, due largely to full national electricity restructuring and the decreased demand resulting from improved end-use energy

[10] The 1992 dollars of the AEO99 reference case are converted to 1997 dollars using the 1997 chain-type price index for Fixed Gross Private Domestic Investment (AEO99, Table 20; Council of Economic Advisers 1999, Table B-7).

[11] An additional $44 billion is paid for motor gasoline in 2010 due to the pay-at-the-pump increment for automobile insurance, and an additional $56 billion is paid in 2020. These costs are actually transfer payments (they offset other payments for insurance elsewhere in the economy) and are therefore not treated as an addition to the nation's energy bill.

Table 1.15 Average Energy Prices to All Users

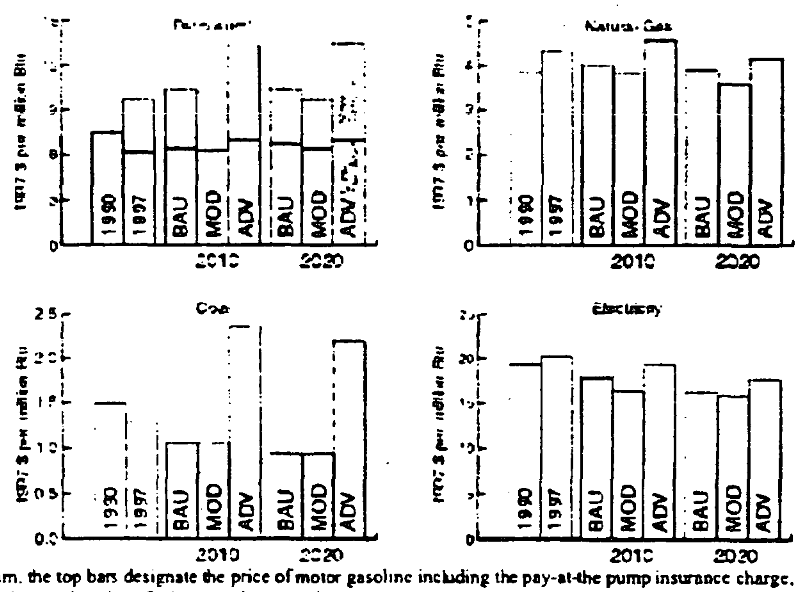
Average Energy Prices (1997$ per Million Btu)	1990[a]	1997	2010 BAU	2010 Mod.	2010 Adv.[b]	2020 BAU	2020 Mod.	2020 Adv.[b]
Motor Gasoline	9.96	9.70	10.40	10.16 (-2%)	13.41 (29%)	10.41	9.74 (-6%)	13.54 (30%)
Other Petroleum	6.72	6.17	6.38	6.27 (-2%)	7.09 (11%)	6.65	6.36 (-4%)	7.01 (5%)
Natural Gas	4.20	4.32	4.02	3.80 (-5%)	4.55 (13%)	3.90	3.56 (-9%)	4.14 (6%)
Coal	1.63	1.28	1.07	1.06 (-1%)	2.35 (120%)	0.94	0.93 (-1%)	2.22 (136%)
Electricity	21.08	20.26	17.85	16.44 (-8%)	19.32 (8%)	16.15	15.51 (-4%)	17.92 (11%)
Energy Bill (billion 1997$)	516	552	651	595 (-9%)	634 (-3%)	694	594 (-14%)	572 (-18%)

Note: BAU = Business-As-Usual; Mod = Moderate; Adv = Advanced. Numbers in parentheses represent the percentage change compared with BAU.

[a] Source: EIA (1998d), Tables 3.3 and 3.4, inflated to 1997$ using consumer price indexes for energy from Table B-58, Council of Economic Advisers (2000).

[b] The Advanced scenario prices include the $50 tonne carbon permit cost that energy producers are assumed to add to energy prices as a result of the domestic carbon trading system. Motor gasoline prices also include the pay-at-the-pump insurance charge of $2.72 per MBtu in 2010 and $4.08 per MBtu in 2020. The pay-at-the-pump insurance charge is not included in the energy bill shown in the last row of this table.

Fig. 1.10 Average Energy Prices to All Users
(1997 $ per Million Btu)



*For petroleum, the top bars designate the price of motor gasoline including the pay-at-the pump insurance charge, while the lower bars designate the price of other petroleum products

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Table 1.16 Average Energy Prices in Common Units

		2010			2020		
Average Energy Prices (1997 $ per Million Btu)	1997	BAU	Mod.	Adv.[a]	BAU	Mod.	Adv.[a]
Motor Gasoline (1997 $ per gallon)	1.21	1.30	1.27 (-2%)	1.68 (29%)	1.30	1.22 (-6%)	1.69 (30%)
Natural Gas (1997 $ per Mcf)	4.44	4.13	3.90 (-6%)	4.67 (13%)	4.01	3.66 (-9%)	4.25 (6%)
Coal (1997 $ per ton)	27.26	22.79	22.57 (-1%)	50.04 (120%)	20.02	19.80 (-1%)	47.27 (136%)
Electricity (1997 cents per kWh)	6.91	6.09	5.61 (-8%)	6.59 (8%)	5.51	5.29 (-4%)	6.11 (11%)

Note: Mcf = thousand cubic feet; BAU = Business-As-Usual; Mod. = Moderate; Adv. = Advanced. Numbers in parentheses represent the percentage change compared with BAU.
[a]The Advanced scenario prices include the $50/tonne carbon permit cost that energy producers are assumed to add to energy prices as a result of the domestic carbon trading system. The gasoline prices also include the pay-at-the-pump insurance charge of 34¢ per gallon in 2010 and 51¢ per gallon in 2020.

efficiency. The Advanced scenario. on the other hand, produces electricity prices that are 9% higher than BAU in the two timeframes. This increase is due largely to the inclusion of the $50/tC carbon permit price[12]. It also is affected by the greater use of renewable resources in power production.

The end-use price trajectories for natural gas are similar to those for electricity. In the BAU scenario, end-use prices are forecast to decline by 7% between 1997 and 2010 and by another 3% over the subsequent decade. The Moderate scenario results in even lower natural gas end-use prices in both 2010 and 2020, due largely to decreased demand resulting from energy-efficiency improvements. The Advanced scenario, on the other hand, results in 13% higher gas prices in 2010 (relative to BAU), but the relative increase drops to 6% by 2020. As with electricity prices, the increased natural gas prices in the Advanced scenario are due primarily to the domestic carbon trading system. Improved energy-efficiency reduces demand for natural gas in industry and buildings, which prevents price escalation as the result of rising natural gas demand in the power sector.

The same price trends occur for coal, but the effects of the Advanced scenario are more pronounced. Coal prices are forecast to decrease in the BAU scenario, and they decrease 1% further in the Moderate scenario because of decreased demand for electricity and steam coal. In the Advanced scenario, coal prices increase 120% in 2010 and 136% in 2020 relative to BAU.

Trends in prices for motor gasoline and other petroleum products are considered separately, because the pay-at-the-pump insurance charge applies only to gasoline. In the BAU scenario, gasoline and other petroleum product prices are forecast to grow only modestly over the next two decades. In the Moderate scenario, petroleum prices – especially gasoline prices – grow even more slowly because of dampened growth in demand. By 2020, gasoline prices have returned to 1997 levels. In the Advanced scenario, with its carbon permits and pay-at-the-pump fees, motor gasoline prices are 30% higher than the BAU

[12] The carbon allowance in the Advanced scenario adds 0.66¢ per kWh to the price of electricity in 2010. In 2020, it adds only 0.55¢ per kWh because of the lower carbon content of electricity in that year.

forecast, both in 2010 and 2020. Prices for other petroleum products in the Advanced scenario are 11% higher than the BAU forecast in 2010 and 5% higher than the BAU in 2020.

The magnitude of change in motor gasoline prices is perhaps best understood in terms of 1997$ per gallon of gasoline. In the Advanced scenario, a gallon of gasoline costs $1.68 in 2010 and $1.69 in 2020, compared to $1.30 in the BAU forecast for both time periods and lower prices in the Moderate scenario. In the Advanced scenario, 12¢ of the increase is a result of the carbon permit cost. The pay-at-the-pump increment is 34¢ in 2010 and 51¢ in 2020. The price of gasoline does not rise in full by the sum of these increments because the reduction in demand exerts downward pressure on prices.

While gasoline prices are higher in the Advanced scenario than in the BAU forecast, the cost of fuel per mile of travel is essentially unchanged. In 1997, gasoline prices averaged $1.21 per gallon and the average light-duty vehicle got 20.5 miles to the gallon – resulting in a fuel cost of 5.90¢ per mile. In the Advanced scenario in 2020, paying $1.69 per gallon of gasoline (including the pay-at-the-pump increment) results in a fuel cost of 5.98¢ per mile traveled. Thus, consumers pay essentially the same per mile of travel in the Advanced scenario in 2020 as they do today, while also paying for a portion of their insurance premiums through the cost of their fuel.

The combination of evolving prices and demand for energy results in energy bill trajectories that vary widely across the scenarios (Table 1.17). Under BAU conditions, the U.S. energy bill is forecast to increase 26%, from $552 billion in 1997 to $694 billion in 2020 (in 1997$). In both the Moderate and Advanced scenarios, the nation benefits from lower energy bills relative to the BAU increases. The energy bill is reduced in each of these scenarios, because the policies cause prompt efficiency increases and decreased energy use in the end-use sectors. In the Moderate scenario, U.S. energy cost savings are $55 billion in 2010 and increase to $100 billion in 2020.

In the Advanced scenario, efficiency increases in the end-use sectors are large enough to reduce the nation's energy bill even with increased energy prices. The energy bill savings in 2010 are $16 billion, which is much smaller than in the Moderate scenario because of the energy price increases and the time required to turn over the existing stock of equipment. The savings rise to nearly $122 billion in 2020 as a result of improvements in the performance of energy-efficient technologies and their greater penetration in buildings, industry, and transportation. The transportation sector accounts for a large portion of the energy bill savings in both 2010 and 2020.

Table 1.17 Net Energy Bill Savings in 2010 and 2020
(in Billions 1997$ per Year)

	Moderate Scenario		Advanced Scenario[a]	
	2010	2020	2010	2020
Residential	12.6	19.3	2.8	20.1
Commercial	14.1	17.7	0.7	8.2
Industrial	13.5	19.3	-5.4	8.0
Transportation	15.0	44.0	18.3	85.6
Total	55.3	100.3	16.4	121.9

[a]The energy prices used to calculate the energy bill savings in the Advanced scenario include the cost of the carbon permit charges. They do not include the pay-at-the-pump fees for motor gasoline.

Return of Carbon Permit Revenues to the Public. The Advanced scenario assumes that each year beginning in 2005, carbon emissions permits are auctioned at a permit price of $50/tC. The government collects the carbon permit revenues and returns them to the public, offsetting revenues paid by the public in increased energy costs caused by the carbon permit. The idea of the carbon permit rebate is to leave people's "incomes" intact while changing the relative price of carbon.

As a result, the domestic carbon trading system imposes minimal first-order changes in the total income of "the public." Distribution of income will change, with some winners and losers, but aggregate income will change very little. This is a fairly gross system, but more refined rebate and allocation options are emerging (Bovenberg and Goulder, 2000; Center for Clean Air Policy, 1999; Weyant and Hill, 1999; Fischer, Kerr, and Toman, 1998a, b). The value of the transfer payments is shown in Table 1.18.

As with a tax, the carbon permit payments to the government reduce both consumer and producer surplus. Consumers pay a higher price and demand less fossil-fuel-derived energy, while producers see a lower demand, and, after subtracting the carbon payment to the government, a lower marginal price of supply. These price and quantity changes are reflected in the nation's energy bill. A small portion ($1.8B to $2.5B per year) of lost consumer and producer surplus is not captured in the energy bill calculation of the Advanced scenario. It is part of the macroeconomic costs that are discussed later in this section.

Table 1.18 Net Transfers to the Public of the Carbon Permit Revenues in 2010 and 2020 (in Billions 1997$ per Year)

	Moderate Scenario		Advanced Scenario	
	2010	2020	2010	2020
Total	0[a]	0[a]	72.9	67.4

[a]The domestic carbon trading system operates only in the Advanced scenario

The method used to transfer carbon permit revenues back to the public will not affect the direct costs and benefits of the Advanced scenario, but it could affect the magnitude and nature of second-order impacts. Two fiscal policy approaches were analyzed in the Energy Information Administration's assessment of the Kyoto Protocol (EIA, 1998c):

- Returning collected revenues to consumers through personal income tax rebates, and
- Lowering the social security tax rate as it applies to both employers and employees.

Both of these fiscal policies would ameliorate the short-term impacts of higher energy prices on the economy by bolstering disposable income.

Net Direct Savings. Table 1.19 shows the "net direct savings" of the two policy scenarios. The total savings are the difference between the direct benefits shown in Tables 1.17 and 1.18 (i.e., net energy bill savings and carbon permit revenue transfers to the public) and the direct costs shown in Tables 1.12 through 1.14 (i.e., annualized program implementation and administration costs, RD&D costs, and annualized incremental technology investment costs). The direct costs for both scenarios rise over time at a nearly linear pace. The energy bill savings of the Moderate scenario also rise at an essentially linear rate, as does the sum of the net energy bill savings (which includes the cost of carbon permits) and the carbon permit revenue transfers in the Advanced scenario. The net energy bill savings are negative in 2005, but by 2010 and in subsequent years, consumers experience positive net energy bill savings.

In 2010, net energy bill savings and carbon permit transfer payments exceed direct costs by $39 billion in the Moderate scenario and by $48 billion in the Advanced scenario. By 2020, the gap has widened to an estimated $62 billion of direct savings in the Moderate scenario and $108 billion in the Advanced case.

Figures 1.11 and 1.12 compare the annual gross energy savings with the two measures of incremental technology investment costs: the annualized costs and the annual capital outlays. These figures show that the investments spurred by the CEF policies quickly pay back in terms of reduced energy costs. This is true in both the Moderate and Advanced scenario.

Table 1.19 Net Direct Savings of the Clean Energy Future Scenarios in 2010 and 2020 (in Billions 1997$ per Year)*

	Moderate Scenario		Advanced Scenario	
	2010	**2020**	**2010**	**2020**
Policy Implementation and Investment Costs:				
• Annualized policy implementation and administration costs	-3.2	-6.7	-9.1	-13.0
• RD&D costs	-1.4	-1.4	-2.8	-2.8
• Annualized incremental technology investments	-11.4	-30.5	-29.6	-65.9
Total Investment Costs	**-16.0**	**-38.6**	**-41.5**	**-81.7**
Net Energy Bill Savings:				
• Gross energy bill savings	55.3	100.3	89.2[a]	189.3[a]
• Carbon permit costs	0	0	-72.9	-67.4
Net Energy Bill Savings	**55.3**	**100.3**	**16.4**	**121.9**
Carbon Permit Revenue Transfers to the Public	**0**	**0**	**72.9**	**67.4**
Total	**39.3**	**61.7**	**47.7**	**107.6**

*These net direct savings do not account for the macroeconomic impacts of the scenarios. For example, the savings in the Advanced scenario are decreased by a small loss in consumer and producer surplus due to the domestic carbon trading system. These are estimated to be $2.5 billion in 2010 and $1.8 billion in 2020. Other macroeconomic costs are discussed later in this chapter and in Appendix E-4.

[a]The gross energy bill savings do not include pay-at-the-pump fees for automotive gasoline. These fees, which are part of the Advanced scenario policy portfolio, are treated as transfer payments and are therefore omitted from this table.

Externality Costs and Benefits. A variety of externality costs and benefits would also accompany the CEF scenarios. The environmental externality benefits, for example, could be substantial. They include the possibility of reduced damages from global climate change and avoided costs of adapting to changing climates, such as stronger physical infrastructures, more effective emergency preparedness programs, and increased investments in air conditioning.

More certain environmental externality benefits include cleaner air and water, which can produce significant public health benefits (Romm and Ervin, 1996). The "clean air story" is described in the following box. The CEF policy scenarios also result in energy security externality effects. Oil security, for instance would be enhanced. (This is one of the aspects of the "oil story.")

A variety of ancillary or collateral costs and benefits would accompany the CEF policy scenarios. On the cost side are:

- amenity losses (e.g., from cars with lower horsepower) and

- opportunity losses (e.g., from investing in energy efficiency retrofits to manufacturing plants when more profitable investments such as creating a new product line may be available).

These costs are not captured in the analysis of direct costs and benefits, but could be considerable. On the benefits side are:

- the productivity and product quality gains that have accompanied many investments in industrial efficiency improvements (Romm, 1994; Romm, 1999) and
- the growth in export markets for energy technologies.

Fig. 1.11 Annual Gross Energy Bill Savings and Incremental Technology Investments of the Moderate Scenario: 2000 through 2020

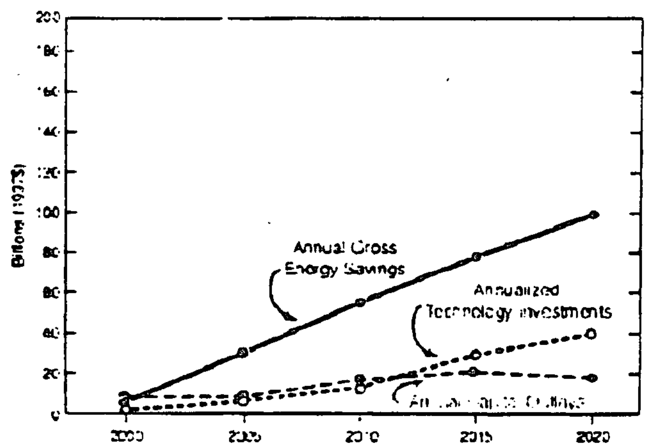
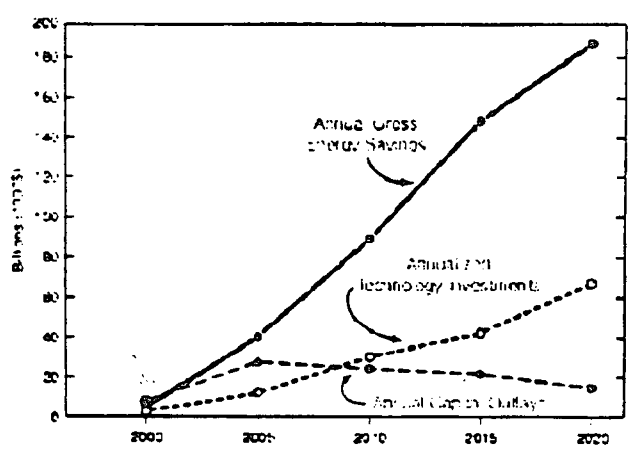


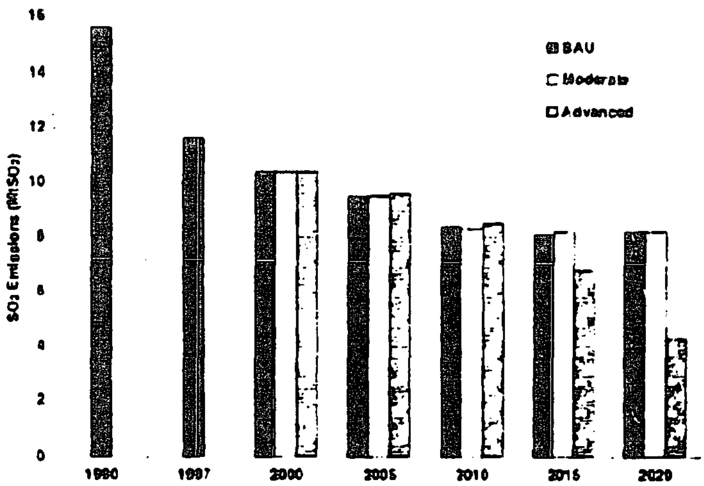
Fig. 1.12 Annual Gross Energy Bill Savings and Incremental Technology Investments of the Advanced Scenario: 2000 through 2020



The Clean Air Story

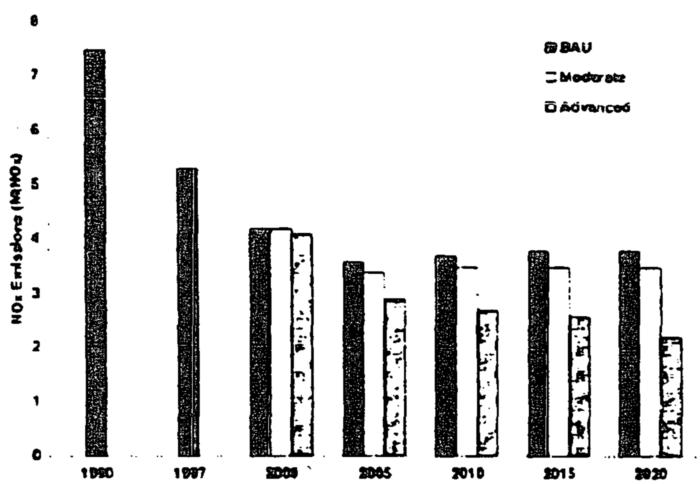
In both the Moderate and Advanced scenarios, emissions of local air pollutants are substantially reduced. These reductions are an added benefit of the cuts in fossil fuel combustion that occur largely as a result of policies directed at increasing energy efficiency and reducing carbon emissions.

SO_2 Emission Reductions in the Electric Sector



In the Moderate scenario, SO_2 emissions from the electric sector in 2010 remain at the limits set by the Clean Air Act Amendments of 1990. However, the allowance price needed for SO_2 to keep emissions at that level drops to \$96/ton in 2020 (a 16% decrease relative to the BAU forecasted allowance price of \$114/ton). With lower demand and improved new technologies, it is easier to meet the limits. NO_x and mercury emissions also decline in the Moderate scenario.

NO_x Emission Reductions in the Electric Sector



In the Advanced scenario, a policy is modeled that calls for SO_2 emissions to be reduced in steps between 2010 and 2020, so that by 2020 they have declined to half the Phase II limits set by the Clean Air Act Amendments of 1990. This policy is designed to represent tighter particulate matter standards. As a result, the cost of sulfur allowances in the Advanced scenario in 2020 rises to \$161/ton in 2020. Simultaneously, NO_x emissions by 2020 fall to less than half of the current NO_x emissions from the electric sector, and mercury emissions decline significantly.

While the monetary value associated with clean air is difficult to estimate, the benefits of the Clean Energy Future scenarios are clearly positive in terms of improved human and ecological health.

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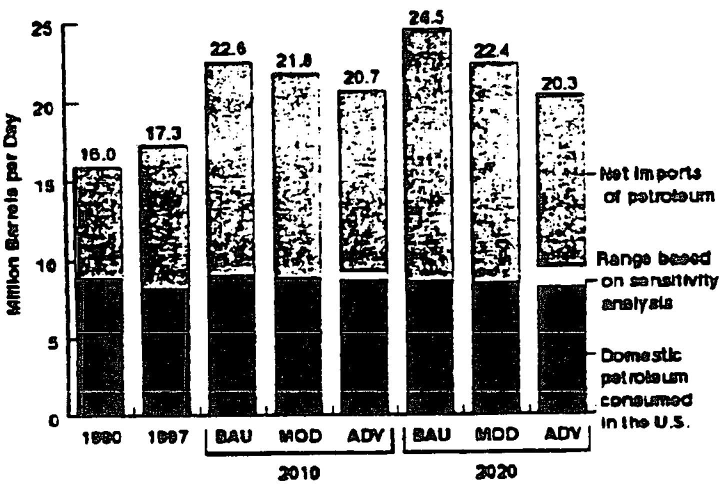
The Oil Story

What is the possible fate of oil in twenty-first century America? The Advanced scenario shows that it is possible for the United States to significantly decrease its use of oil in the coming decades, while growing the economy. It illustrates a future in which oil is a smaller percentage of the fuels used to run the economy, which translates into a more secure energy future.

In 1997 the U.S. consumed approximately 17 million barrels per day (mmbd) of crude oil and petroleum products.[13] Consumption of these fuels is forecast to rise to approximately 23 mmbd by 2020. The aggressive policies in the Advanced scenario bring petroleum consumption in 2020 down to 1997 levels, resulting in a savings of approximately 5 mmbd in 2020, when compared to the BAU forecast[14]. Over the same two decades, the population is expected to grow by 20%. Thus, the oil-to-GDP ratio in the Advanced scenario is much lower in the Advanced scenario in 2020 than the ratio today.

The Advanced scenario also brings about a reduction in the nation's expected reliance on imported oil. This translates into a significant improvement in the nation's balance of payments.

U.S. Consumption of Domestic and Imported Crude Oil and Petroleum Products



The reduced oil consumption is brought about by the improved performance and deployment of energy-efficient technologies in cars, trucks, and home heating equipment, motivated by an array of policy changes. Technology such as the turbo-charged diesel injection engine, cellulosic ethanol, hydrogen fuel cell vehicles, and lightweight materials will enable the transportation sector, the main consumer of oil, to use petroleum more efficiently and to increase its reliance on alternative fuels.

While gasoline prices are higher in the Advanced scenario than in the BAU forecast, the cost of fuel per mile of travel is essentially unchanged because of fuel efficiency gains. In 1997, gasoline prices averaged $1.21 per gallon and the average light-duty vehicle got 20.5 miles to the gallon – resulting in a fuel cost of 5.90¢ per mile. In the Advanced scenario, gasoline prices increase to $1.69 in 2020, and fuel efficiency of the existing fleet of light-duty vehicles increases to 28.3 mpg. This results in a fuel cost of 5.98¢ per mile. Thus, consumers pay essentially the same per mile of travel in the Advanced scenario in 2020 as they do today, while also paying for a portion of their insurance premiums through the cost of their fuel.

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[13] One million barrels per day of petroleum use is equivalent to an annual energy consumption of 2.1 quadrillion Btu.

[14] The numbers given here assume the same world oil prices in both scenarios. As a result, they overestimate the reduction of oil imports and underestimate the economic benefits resulting from lower oil prices. A sensitivity analysis testing alternative assumptions about OPEC behavior and world oil prices is described Chaper 6 (Section 6.5.5.)

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Neither of these benefits is included in the analysis of direct costs and benefits, yet they could be considerable. Results reported in Elliott et al. (1997) and Laitner (1999) indicate that the total benefits –including both energy and non-energy savings – that accrue from so-called "energy-saving" projects can be much greater than the energy savings alone. In fact, based on numerous case studies, the authors conclude that the average total benefits received from "energy-saving" projects in industry are typically two to four times the value of the energy savings alone.

Macroeconomic Effects. The CEF study does not model the macroeconomic impacts of its two policy scenarios because of the difficulty of estimating transition and long-term macroeconomic effects on costs and investments that average less than 1% of national GDP over the study period. Instead, we commissioned the preparation of a short discussion paper, which appears in Appendix E-4. The purpose of this appendix is to review the issue of second-order or macroeconomic effects that might occur as a result of the energy price changes that could result from the permit trading option included in the Advanced scenario. The conclusions of this paper are summarized here.

A key premise of the CEF study is that large-scale market and organizational failures, in addition to potentially substantial transaction costs, prevent consumers and firms from obtaining energy services at the least cost. The essential conclusion of the study's scenarios is that this problem can, to a considerable extent, be overcome through policies that correct these market failures and reduce the transaction cost barriers to the diffusion of energy-efficient technologies. This conclusion is supported by numerous past energy policy and program successes, as described in Chapter 2.

The authors conclude, based on information presented in Chapter 2, that the economy is not currently operating in an optimal fashion with respect to the provision of energy services (i.e., it is not operating on its aggregate production-possibilities frontier). As a consequence, Pareto improvements are available through policy interventions. Thus, whatever shifts or adjustments in markets occur as a result of such policies, *the aggregate result is a gain in economic efficiency*. In the case of the domestic carbon trading policy, however, the question arises of the possibility of substitution between GDP and carbon reductions. That possibility motivated the analysis of the $50/tonne carbon permit price in Appendix E-4.

Appendix E-4 assesses the macroeconomic costs of a $50/tonne carbon permit price by examining the Energy Modeling Forum's recent compilation of results from simulations using seven of the leading energy/economic models (Weyant and Hill, 1999). These seven models provide alternative estimates of what it might cost to achieve carbon emissions at 1990 levels from energy use and generation. The scenarios varied according to how much (and among which countries) international trading was allowed to occur. Four trading scenarios were run: (1) no trading of international emissions rights; (2) full Annex I (or Annex B)[15] trading of emissions rights; (3) the "double bubble," which considers separate European Union and "rest of Annex I" trading blocs; and (4) full global trading of emissions rights.

To estimate the GDP loss associated with a $50/tonne carbon permit price, the authors of Appendix E-4 calculated a "GDP response curve" for each model indicating the expected response of GDP to various carbon permit prices. Each curve was determined by a quadratic extrapolation using the Annex I trading and global trading scenarios as reported by the Energy Modeling Forum (EMF-16), in Weyant and Hill (1999). (These are the scenarios with carbon permit prices that bracket or are close to the $50/tonne level.) For each model, the origin and the two estimates of implicit carbon permit price and GDP loss determine a unique quadratic response curve.

[15] The Annex I (of the 1992 Framework Convention on Climate Change) countries include the U.S., OECD-Europe, Japan, CANZ (Canada/Australia/New Zealand), and the EEFSU (East Europe and Former Soviet Union) countries. The Annex B (of the Kyoto Protocol) list varies slightly from the Annex I list (Weyant and Hill, 1999).

The estimated 2010 GDP losses (in 1997$) associated with $50/tonne carbon permit price range from $4 billion for the MERGE3 model to $66 billion for the CETA model. These are the same order of magnitude as the $48 billion in net direct benefits estimated for the Advanced scenario in 2010.

Appendix E-4 also explores the transitional macroeconomic adjustment costs of the carbon permit price caused by the economy's reacting to higher energy prices in the CEF scenarios. This is accomplished by examining two EIA analyses that use the DRI model to examine the effects of introducing carbon permit prices into the U.S. economy (EIA, 1998c and 1999c). When carbon trading is phased in beginning in 2000 (EIA, 1999c), achieving the CEF Advanced scenario levels of reduction requires a $63/tonne carbon permit price, which results in a GDP loss (including both transitional and long-term macroeconomic costs) of $39 billion. This is equal to the median of the range predicted by the seven models described in EMF-16 (Weyant and Hill, 1999). Based on the EIA study (1998c) that models carbon trading beginning in 2005, the CEF Advanced scenario levels of reduction would require a $66/tonne carbon permit price. This results in a GDP loss (including both transitional and long-term macroeconomic costs) ranging from $47 billion to $74 billion (in 1997$). The lower estimate occurs when revenues are recycled using payroll tax reductions, and the higher estimate occurs with revenue recycling through personal tax rebates, which do not correct pre-existing distortions in taxes.

As with the long-term macroeconomic costs described in the previous paragraphs, these findings show that even in the transition period, potential GDP losses can be mitigated – and indeed potential GDP gains may result – when revenue recycling is used to stimulate investment. In 2010, the net direct savings are of the same order of magnitude as the macroeconomic (transitional plus long-term) costs. Over the following decade, the net direct savings grow as energy-efficient technologies gain market shares, while the long-term macroeconomic impacts remain steady and the transitional costs decline.

Macroeconomic Indicators. A range of macroeconomic indicators associated with the two policy scenarios is provided in Table 1.20. For simplicity, these assume that GDP grows in the Moderate and Advanced scenarios at the same pace as in the BAU forecast.

Table 1.20 Macroeconomic Indicators

			2010			2020		
	1990	1997	BAU	Mod.	Adv.	BAU	Mod.	Adv.
GDP (billion 1997$)	6136 (1992$)	8171	11,123	11,123 (0%)	11,123[a] (0%)	13,128	13,128 (0%)	13,128[a] (0%)
Energy/GDP Ratio (kBtu/1997$)	13.7 (1992$)	11.5	9.9	9.6 (-4%)	8.9 (-10%)	9.1	8.4 (-7%)	7.4 (-20%)
Carbon/GDP Ratio (gC/1997$)	219 (1992$)	181	159	151 (-6%)	132 (-17%)	147	133 (-10%)	103 (-29%)

Note: BAU = Business-As-Usual; Mod. = Moderate; Adv. = Advanced. Numbers in parentheses represent the percentage change compared with BAU.

[a]As noted in the section on "Macroeconomic Effects," there is great uncertainty regarding the GDP levels that would result from Advanced scenario policies (ranging from an increase of $14 billion to a decrease of $44 billion, relative to the BAU). For the purposes of this table, we have assumed the same GDP levels as in the BAU forecast.

One of the macroeconomic indicators reflects the energy productivity of the U.S. economy: the energy/GDP ratio. An expanded portrayal of this indicator is provided in Fig. 1.13 in terms of U.S. energy use in kBtu/GDP in 1997$. This figure shows the historic reduction in energy intensity of the U.S. economy from 1973–74 (the OPEC oil embargo) through 1986 (when energy prices began a period of

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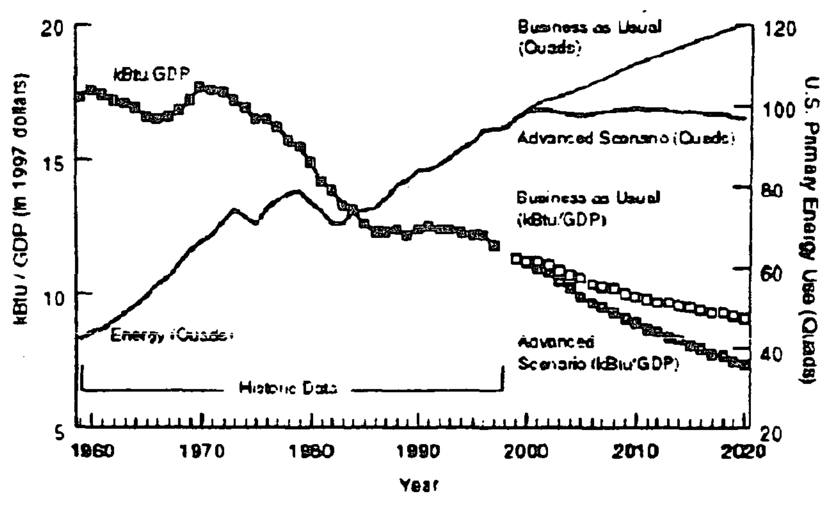
decline that has continued to today). The EIA AEO99 Reference case calls for a continuing improvement in this indicator as the result of a GDP growth rate that outpaces the increase in energy use. The Advanced scenario projects even larger energy productivity gains, especially in the second decade of the twenty-first century. This is a result of the leveling off of U.S. energy consumption at 97 quads in 2020 in the Advanced scenario, compared with the Reference case forecast of 119 quads in 2020.

Sectoral and Regional Impacts. Many sectors of the economy and regions of the United States would benefit from a transition to the type of clean energy future characterized in this study's two policy scenarios. For example, the growth of strong domestic wind and bioenergy industries could bring new employment opportunities to many regions and could lead to a revitalization of the economies of rural America. A wide range of other business opportunities would thrive under the Advanced scenario. Specific sectors likely to see positive impacts on output include:

- energy service companies, contractors, and consultants,
- light-weight materials and fuel cell manufacturing,
- nuclear energy services industry,
- wind turbine manufacturers and biomass producers and processors, and
- electronic sensors and controls and advanced battery manufacturers.

Fig. 1.13 Energy/GDP Ratios



Financial institution business should expand along with the growth in third-party energy service companies, since many manufacturing companies or building owners may prefer to lower their debt-equity ratios through third-party investors when undertaking energy efficiency measures.

The enhanced energy-technology innovation envisioned from the doubling of RD&D budgets in the Advanced scenario could lead to a stronger domestic economy through international cooperation. The development of advanced energy technologies could help expand the market share of U.S. companies in the vast global market for efficient and clean energy technologies. It could also enhance long-term markets for other U.S. exports by building the energy basis for sustainable prosperity in developing and transitional economies. Both of these goals are highlighted in the recent report from the PCAST Panel on

International Cooperation in Energy Research. Development, Demonstration, and Deployment (PCAST. 1999).

The reduction of coal consumption in the Advanced scenario by 30% in 2010 and by nearly 50% in 2020 (relative to BAU) would have major negative consequences for the coal industry. Stricter policies to reduce SO_2 are anticipated to have a smaller negative impact on coal production in western states because of its lower sulfur content and its increasingly lower mining costs (EPA, 1999). Policies to reduce CO_2, on the other hand, are anticipated to have a smaller negative impact on coal production in Northern Appalachia and the Midwest because these mines are closer to coal markets and do not require long-haul, carbon-intensive transportation (EIA, 1998c).

Unequal regional impacts of CO_2 policies on the electricity industry are also anticipated because of regional differences in the resources used to generate electricity. In particular, interior states would suffer greater economic hardship than coastal regions based on the interior region's greater dependence on coal for electricity. Coastal regions have more readily available nuclear and hydroelectric power (Resourcedata International, Inc., 1999).

The reduced demand for coal would also adversely affect the transportation sectors (i.e., rail and barge) that draw sizeable fractions of their business from hauling coal. The viability of some rail links and barge routes would be weakened by the reduced freight.

Similarly, the 10 to 20% reduction in petroleum consumption in the Advanced scenario would dampen demand for petroleum products from the domestic refining industry. This could further challenge the U.S. oil industry's ability to compete in world markets and to expand its production quickly in the event of oil supply shocks.

At a broader scale, cost-effective energy-efficiency measures free up real resources that otherwise would be needed for energy production. Because the energy-efficiency measures are cost-effective, a net surplus output remains for increased consumer and business investment spending. The increased consumer and business investment spending are the sources of general benefits to most sectors in the economy (Hanson and Laitner, 2000).

1.5 SENSITIVITY ANALYSIS

This section analyzes a range of alternative policies to systematically assess the opportunities and consequences of a variety of futures other than the BAU, Moderate, and Advanced scenarios described in the rest of the report. These alternative scenarios are important for several reasons. First, they reflect the highly unpredictable nature of political and consumer views and they highlight the diversity of policy alternatives. Second, they characterize the impact of uncertainties in parameter values and model assumptions.

Many types of uncertainties influence the CEF scenarios. Some of these uncertainties can be captured through quantitative sensitivity analyses, in which one or more key input assumptions are varied and the results studied. Other uncertainties are more difficult to capture – e.g., uncertainties in the specification of basic data and underlying assumptions, in the realism of the models and related forecasting approaches, and in the assessment of impacts of policies. Recognizing that sensitivity analysis captures only a portion of the uncertainty, we have carried out a range of sensitivities on a number of important variables. These are described in detail in subsequent chapters. To illustrate the approach, the following box summarizes a selection of sensitivity cases, including (1) higher natural gas prices, (2) shorter duration of the renewable

Results of Selected Sensitivity Cases

High Natural Gas Prices
By assuming limited technological progress in gas drilling, exploration, and recovery, natural gas prices in the electric sector were increased by 12% above the BAU scenario for 2020. The major impact is a reduction in natural gas consumption for electricity generation of about 12%. About three-quarters of the natural gas is replaced by coal in both the BAU and Advanced scenarios. The result is an increase in carbon emissions by between 6 and 10 MtC in the two cases, respectively. By also assuming that demand reduction policies were not implemented, natural gas prices were increased further to 26% over the BAU forecast for 2020. Coal increases make up two-thirds of the gas reduction. Biomass, geothermal, and wind make up 8%, 5%, and 4% of the lost gas generation, respectively.

High Natural Gas and Petroleum Prices
The EIA's "High World Oil Prices" (EIA, 1998a) were added to the high natural gas price sensitivity (described above) to model a future in which both natural gas and petroleum prices rise significantly. In this sensitivity, world oil prices increase from $19 per barrel in 1997 to $27 in 2010 and $29 in 2020. When this energy price trajectory is added to the standard Advanced scenario, light-duty vehicle miles of travel drop by 2% (by 2005) and the efficiency of the light-duty fleet increases by 2 to 3% compared to the standard Advanced scenario. The result is a significant decrease in carbon emissions from transportation. This is offset slightly by an increase in carbon emissions in the electric sector caused by a shift from natural gas to coal generation resulting from the higher natural gas prices and fuel switching from oil to electricity in buildings and industry.

Renewable Energy Policy and Cost Sensitivities
In this sensitivity, the renewable portfolio standard (RPS) was terminated in the Advanced scenario in 2004, four years ahead of schedule. This causes wind generation in the Advanced scenario to fall from 159 to 97 TWh in 2020. (It is 9 TWh in the BAU in 2020.) This results in an increase in carbon emissions in the Advanced scenario of 20 MtC in 2020. An increase in the projected capital costs for wind and biomass of 20 to 25% in 2020 has the same effect as early termination of the RPS.

No Diesel Penetration in Light-Duty Vehicles
The Advanced scenario has a penetration of 2.2 million high-efficiency diesels in 2010 and 3.1 million in 2020. We simulated a case in which there is no diesel penetration in light-duty vehicles. The effect was to reduce fuel economy for new light-duty vehicles from 41.9 to 40.5 mpg in the Advanced case in 2020. (This compares with a projected fuel economy of 30.5 mpg in the BAU in 2020.) The net effect is an increase in energy use of 0.5 quads in the Advanced scenario in 2020, or about 10 MtC. The absence of diesels has such a small effect on energy and carbon emissions because other efficient technologies (e.g., fuel cells) are assumed to be available to replace the diesels.

Higher Cost of Advanced Fossil Fuel Technology
Sensitivity analyses were conducted to examine a less optimistic future for the cost and performance of natural gas and integrated gasification combined cycle plants. (For example, capital costs for natural gas combined cycle plants were assumed to be 17 to 30% higher, depending on the scenario.) The results show a decline in carbon emissions (6 MtC for the Moderate and 3 MtC for the Advanced scenarios), resulting from replacement of the fossil energy generation by renewable and nuclear power. With higher cost advanced technologies, the market price for SO_2 credits increases slightly, as do electricity prices (by 1 to 2 mills per kWh). Because of the availability of advanced technologies for renewables and combustion turbines and the continued availability of relicensed nuclear plants as backstops, less R&D success for combined cycle technologies does not have a major impact on the overall results.

Table 1.21 Summary of Sensitivity Cases

	Domestic Carbon Trading System	Moderate Demand and Supply-Side Policies	Advanced Demand-Side Policies[a]	Advanced Supply-Side Policies[b]	Advanced Demand and Supply-Side Policies
2010:					
No Carbon Trading	**BAU Scenario:**	**Moderate Scenario:**			
Primary Energy (Quads)	110.3	106.5	102.9	109.0	103.3
Carbon Emissions (MtC)	1769	1684	1634	1714	1619
Carbon Emissions (MtC) from Electric Generators	645	597	589	604	575
$25/tC					
Primary Energy (Quads)	109.1	104.9	100.7	107.5	101.0
Carbon Emissions (MtC)	1720	1625	1556	1652	1539
Carbon Emissions (MtC) from Electric Generators	608	555	534	557	515
$50/tC					**Advanced Scenario:**
Primary Energy (Quads)	107.5	103.2	99.1	106.0	99.3
Carbon Emissions (MtC)	1663	1548	1504	1579	1463
Carbon Emissions (MtC) from Electric Generators	562	491	493	496	456
2020:					
No Carbon Trading	**BAU Scenario:**	**Moderate Scenario:**			
Primary Energy (Quads)	119.8	110.1	101.9	112.6	100.9
Carbon Emissions (MtC)	1922	1740	1602	1748	1568
Carbon Emissions (MtC) from Electric Generators	709	623	584	593	550
$25/tC	118.5	108.8	99.8	112.1	98.8
Primary Energy (Quads)	1842	1651	1490	1684	1472
Carbon Emissions (MtC)	645	551	500	547	482
Carbon Emissions (MtC) from Electric Generators					
$50/tC					**Advanced Scenario:**
Primary Energy (Quads)	116.5	107.6	98.3	110.8	96.8
Carbon Emissions (MtC)	1755	1546	1426	1562	1347
Carbon Emissions (MtC) from Electric Generators	571	461	443	440	374

[a]The advanced demand-side policies are those policies that are defined for the end-use sectors in the Advanced scenario (excluding the domestic cap and trade system).
[b]The advanced supply-side policies are those policies that are defined for the electricity sector in the Advanced scenario (excluding the domestic cap and trade system).

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portfolio standard or higher cost of renewable energy technology, (3) no penetration of light-duty diesel engines, and (4) higher cost of advanced fossil fuel technologies.

Overall, the results show impacts on the order of 3 to 20 MtC in 2020 for each of the sensitivities. These results are to be compared with the reduction in carbon emissions in 2020 of approximately 180 MtC in going from BAU to the Moderate scenario, and a reduction of 565 MtC in going to the Advanced scenario. In short, each of the particular sensitivities analyzed has an impact on carbon emissions that is less than 4% of the reduction achieved in moving from BAU to the Advanced scenario.

In the following section, the results of system-wide variations in policies are presented – comparing and contrasting demand-side versus supply-side policies and examining cases that rely strictly on domestic carbon trading. The demand-side policies are those defined for the three end-use sectors in the Advanced scenario (excluding the domestic carbon trading system). The supply-side policies are those defined for the electricity sector in the Advanced scenario (excluding the domestic carbon trading system). Two values of the carbon permit price were assessed: $25/tC and $50/tC. Twelve sensitivity cases were defined by combining various of these categories of policies, as shown in Table 1.21. The Advanced scenario is the combination of all three categories of policies, with the $50/tC carbon permit price, and the BAU scenario is the absence of any of these policies. Results are summarized for both 2010 and 2020 in Table 1.21. Additional tables in Appendix D-5 provide more detailed results for each of these sensitivities.

1.5.1 Demand-Side Policies

Efforts to promote energy efficiency have been a cornerstone of U.S. energy policy since the OPEC oil embargo of 1973–74. These efforts have been viewed favorably by a majority of the public (Bonneville Power Administration, 1999; Sustainable Energy Coalition, 1999) and have produced well-documented, positive impacts (Chapter 2). Thus it is plausible to imagine a future in which politicians and the public support a vigorous push to improve energy efficiency. This scenario could result, for instance from an increased awareness of the link between energy use and a range of negative environmental consequences. Or it could be precipitated by a rise in energy prices. Our analysis indicates that a push on energy efficiency, by itself, could produce significant reductions in energy use and proportionate cuts in carbon emissions.

When the demand-side policies from the Advanced scenario are modeled separately (i.e., without supply-side policies and without a domestic carbon trading system), energy use in 2010 grows to only 103.1 quads, a 7% decrease relative to BAU. During the second decade of demand-side policies, accelerated strides in the performance and deployment of efficient technologies cause the historic energy use to "turn the bend" and decline, dropping to 102.2 quads by 2020. This is a 15% decrease from the BAU forecast and is 77% of the Advanced scenario's energy reductions.

The drop in carbon emissions from the demand-side scenario is comparable to the drop in energy use. When demand-side policies are modeled separately, carbon emissions in 2010 grow to only 1641 MtC, 7% lower than the BAU forecast of 1,771 MtC. During the second decade of demand-side policies, further efficiency investments cause carbon emissions to decline slightly (as with energy use), decreasing to 1609 MtC by 2020. This reduction is 16% of the BAU and is 55% of the Advanced scenario's carbon emission reductions.

Almost no further energy reductions – and only a modest decrease in carbon emissions – result from adding supply-side policies to the demand-side scenario, in either 2010 or 2020. This finding is not surprising since the supply-side policies focus on encouraging the production and use of clean energy options. Also, it highlights how the success of demand-side policies can make it more difficult for low-carbon energy options to penetrate the market, partly because reduced demand restricts the need for new capacity.

In contrast, adding carbon trading to the demand-side scenario significantly reduces both energy consumption and carbon emissions. In both 2010 and 2020, energy use decreases by an additional 2 quads with a $25/t carbon permit price and by an additional 4 quads with a $50/t carbon permit price. Coupling these two types of policies brings the energy and carbon reductions to within 90% of the reductions produced by the Advanced scenario.

1.5.2 Supply-Side Policies

One can imagine a future in which the United States implements an energy policy that focuses primarily on the production of cleaner energy through a variety of supply-side policies. This might result, for instance, from the rise in popularity of green power programs. Or it could result from a political preference for dealing with the smaller number of energy producers rather than expanding programs dealing with the large number of energy end-users.

To model this type of scenario, we look at the impacts of the Advanced scenario's supply-side policies in the absence of demand-side interventions and without a domestic carbon trading system. When these supply-side policies are modeled, the impacts on energy use are minimal, ranging from a 1% decrease from BAU in 2010 to a 6% decrease in 2020. Carbon reductions are somewhat more significant, ranging from a 3% decrease from BAU in 2010 to a 9% decrease in 2020. Both of these impacts are much smaller than for the demand-side scenario.

Looking specifically at carbon emissions from electric generators, a more noteworthy carbon impact is indicated. A decrease of only 2% in electricity demand in 2010 relative to the BAU forecast – presumably due to slightly higher electricity prices, yields a 6% decrease in carbon emissions from electric generators. Similarly, electricity demand decreases by just 9% in 2020 relative to the BAU, but carbon emissions from electric generators decrease by 16%. Thus the reduced demand is not the principal driver; the more significant effect is from switching to low-carbon sources of electricity. Comparable decreases are achieved in the demand-side scenario, but the cause is the significant decline in electricity consumption.

Adding demand-side policies to the supply-side scenario produces a substantial drop in overall energy use and carbon emissions. The impact on carbon emissions from electric generators, however, is relatively small since the supply-side policies have already significantly reduced these by shifting electricity generation to cleaner fuels.

Adding a domestic carbon trading to the supply-side scenario results in only a modest decrease in energy use, but it has a significant dampening impact on carbon emissions. The $25/t carbon permit price on its own cuts carbon emissions to 7% and 12% below the BAU forecast in 2010 and 2020, respectively. For electric generators, carbon emissions drop even more significantly, to 14% and 23% below the BAU in 2010 and 2020. At $50/tC, the carbon permit price has an even more dramatic effect on carbon emissions from electric generators, achieving 80% of the reduction in the electric sector in the Advanced scenario (without any additional demand-side policies).

1.5.3 Carbon Trading Policy

Many analysts have argued for the merits of tackling the global climate change challenge by creating a domestic carbon trading program, as was done to reduce SO_2 emissions from electric generators. Trading programs could motivate innovative and low-cost actions to reduce CO_2 emissions, as well as the emissions of other greenhouse gases such as CH_4, N_2O, HFC, PFC, and SF_6. Thus it is plausible to imagine a future in which the nation implements a domestic carbon trading policy as its primary approach to carbon mitigation.

Compared with the demand- and supply-side cases, a trading case alone where carbon acquires a value of $25/t has the least impact on energy use and carbon emissions. At a value of $50/tC, the carbon trading case still reduces energy use and carbon emissions less than the demand-side scenario. Energy use drops by only 2% in both 2010 and 2020 relative to BAU (to 107.5 and 116.5 quads in 2020 compared with BAU forecasts of 110.3 and 119.8 quads). Carbon emissions decrease by only 6% to 9% relative to BAU (to 1663 and 1755 MtC in 2020 compared with BAU forecasts of 1769 and 1022 MtC).

Compared with the supply-side case, the carbon trading case with a value of $50/tC is more effective at reducing energy use and carbon emissions in the first decade, but it is less effective in the second decade. The carbon trading system is assumed to be announced in 2002 and operational beginning in 2005. From then on, energy prices take on a proportionately higher value. The supply-side policies are more gradual. The RPS, for instance, is not fully in effect until 2010. Also, restrictions on particulate emissions (modeled as an SO_2 ceiling) are not implemented until 2010 and then are enacted over the following decade in incremental steps.

The further reductions from adding demand-side policies to the carbon trading case are much greater than the incremental reductions from adding supply-side policies. In fact, of the various combinations shown in Table 1.21, coupling demand-side policies with carbon trading at $50/tC comes the closest to achieving the energy and carbon reductions of the Advanced scenario.

1.5.4 Summary

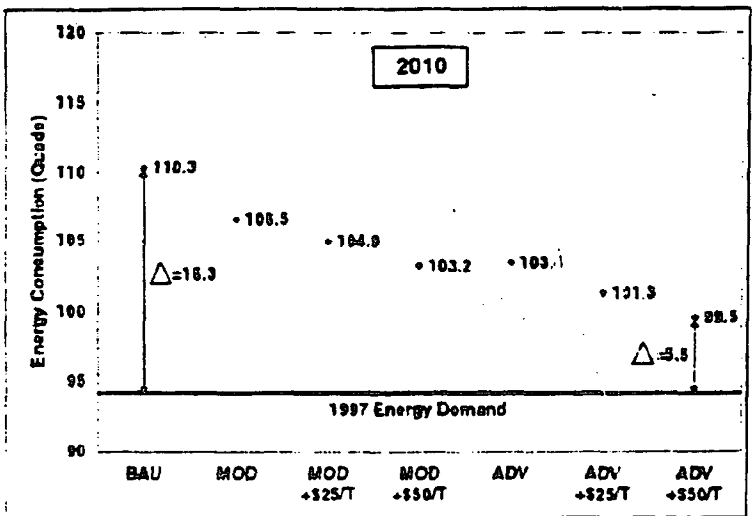
Among the three categories of policies, the demand-side policies produce the greatest energy and carbon reductions (Fig. 1.14 and 1.15). They dampen energy use and carbon emissions in approximately equal proportions. Supply-side policies and the domestic carbon trading policy, on the other hand, principally reduce carbon emissions in the electricity sector. However, neither of these sets of policies is able to stabilize (or reduce) carbon emissions during the 20-year period. Adding a domestic carbon trading system to the demand-side policies gets to within 90% of the Advanced scenario's energy and carbon reductions. This is the most effective combination of two policy categories, bringing energy use and carbon emissions in 2020 down to below 1997 levels. In sum, the opportunities and consequences of each of these sets of policies varies considerably, and the value of each depends intimately upon the specific goals of the policy intervention – for example, short-term vs. long-term impacts and energy vs. carbon reductions.

Because our scenarios extend only to 2020, it is not possible to estimate the longer term benefits of different policy clusters. For instance, what is the full cost of a policy scenario limited to demand-side options if it means delaying the development of environmentally attractive supply-side options? Would future U.S. export markets for supply-side technologies be diminished? Would the U.S. be less prepared to add clean power if, a compelling need were to unexpectedly emerge? Such longer term considerations suggest that a diversified portfolio of demand- and supply-side policies is advantageous.

1.6 COMPARISONS ACROSS STUDIES

This section compares the results of the CEF analysis with those of other major carbon mitigation scenarios that employ engineering-economic (i.e., "bottoms up") methodologies. The goal of these comparisons is to explain the divergence of modeling results by comparing the assumptions and methodologies of each study. The policy pathways that are modeled, the base and target years, and the baseline assumptions about economic growth and future energy prices can all affect results, including estimates of future energy consumption and carbon emission levels, rates of market penetration of key technologies, and the estimated costs associated with these scenarios.

Fig. 1.14 Sensitivity Cases for the Year 2010



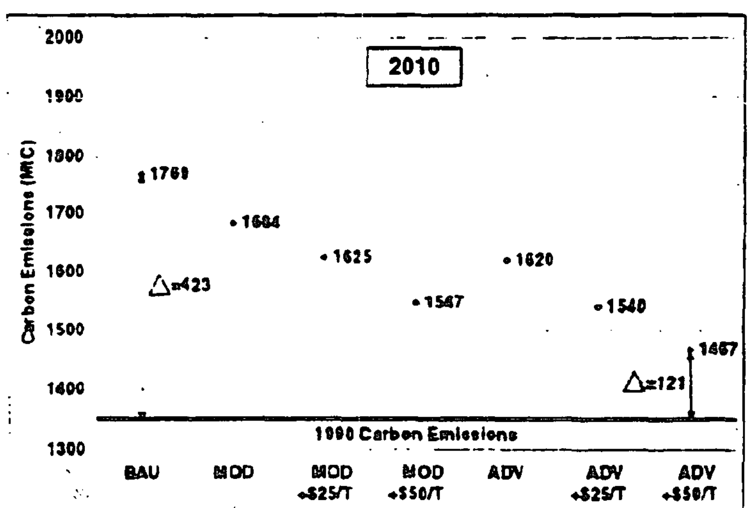


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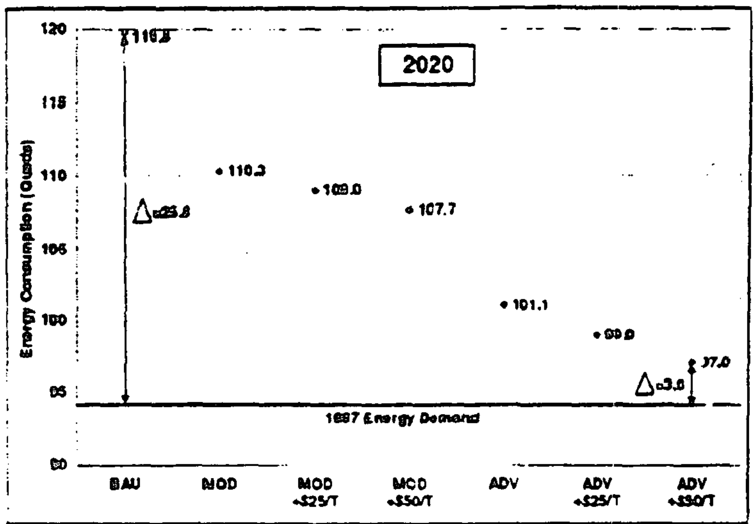
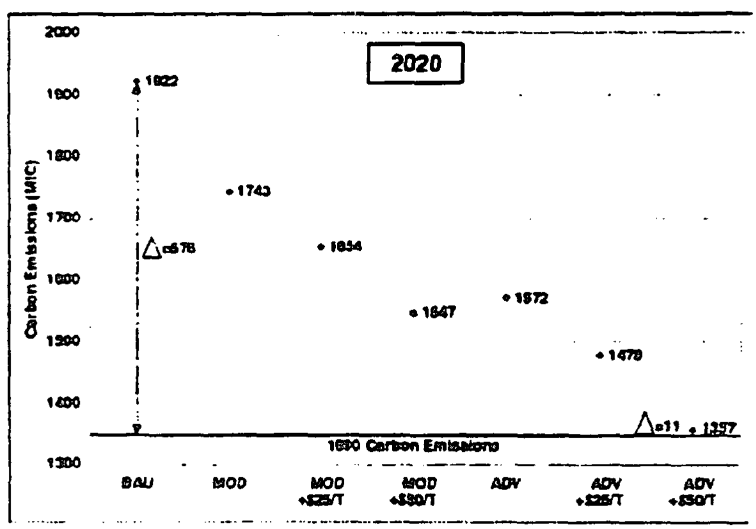
Fig. 1.15 Sensitivity Cases for the Year 2020





Additional studies have used general equilibrium. "top-down" modeling to estimate the costs of achieving various levels of carbon reduction in the United States. These include studies by WEFA (1998). analyses using the Pacific Northwest National Laboratory's Second Generation Model (Edmonds et al., 1992). studies using MIT's Emissions Prediction and Policy Analysis Model (Jacoby et al., 1997), analysis by Manne and Richels (1997) sponsored by the Electric Power Research Institute, and analysis by Standard and Poors DRI (1998). Detailed comparisons are not provided with these studies because of the differences in basic methodology. However, the reader can find a lucid comparison of their projections and cost estimates for achieving the Kyoto Protocol goals in EIA's *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity* (1998c, chapter 7).

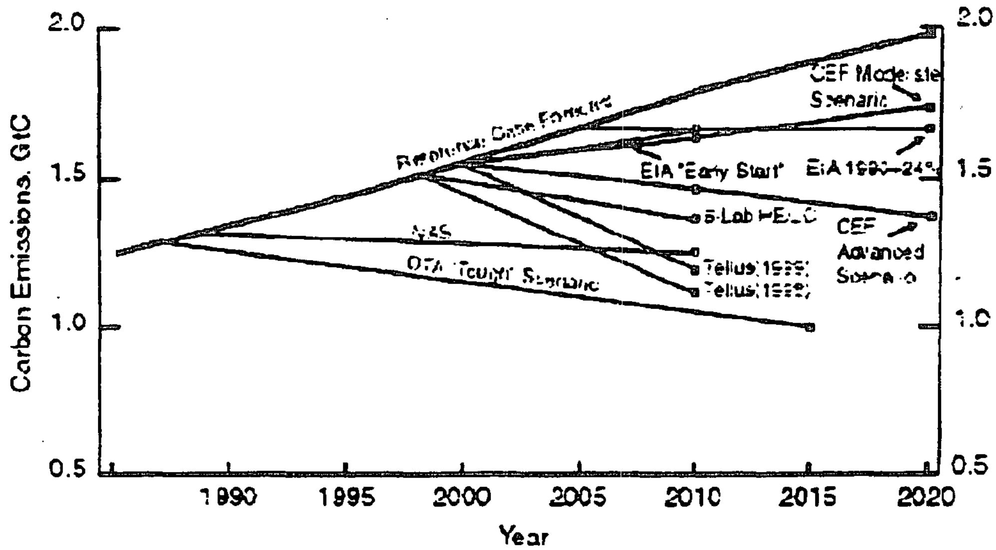
The following engineering-economic studies are examined in the following pages:

- *Changing by Degrees: Steps to Reduce Greenhouse Gases*, by the Office of Technology Assessment (OTA, 1991);
- *Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base* by the National Academy of Sciences (NAS, 1992);
- Interlaboratory Working Group. *Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy-Efficient and Low-Carbon Technologies by 2010 and Beyond*–also known as "The Five-Lab Study" (1997);
- *Policies and Measures to Reduce CO_2 Emissions in the United States: An Analysis of Options for 2005 and 2010* by Tellus Institute (1998);
- Bernow, S., et al. (1999) *America's Global Warming Solutions*, by Tellus Institute and Stockholm Environment Institute[16];
- *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity*, by the Energy Information Administration (EIA, 1998c); and
- *Analysis of the Impacts of an Early Start for Compliance with the Kyoto Protocol* by the Energy Information Administration (EIA, 1999c).

Each of these studies describes at least one "low-cost" carbon reduction scenario. To keep the comparisons manageable, only one scenario from each study is described. The scenario chosen in each case is the one that produces the largest carbon reductions while maintaining low costs (i.e., annual costs generally less than $100 billion). These include the "tough" scenario from OTA (1991), the high-efficiency/low-carbon case from the Five-Lab study, the "climate protection" scenario from the 1998 and 1999 Tellus studies, and the EIA (1998c and 1999c) scenarios that reduce carbon emissions to 24% above 1990 levels. The variation in carbon reduction levels across these scenarios is shown in Fig. 1.16. To facilitate these cross-study comparisons, this figure portrays each scenario's carbon reductions relative to EIA's AEO99 Reference case (EIA, 1999a). Differences in the assumptions and methodologies used by these studies that help to explain variations across their findings are summarized study-by-study in the following paragraphs. For a more detailed, parameter-by-parameter comparison of many of these studies, see Brown et al. (1998).

[16] The Tellus Institute reports reflect an effort among leading non-governmental energy organizations that was begun with *America's Energy Choices* in 1991. The series of reports includes *Energy Innovations: A Prosperous Path to a Clean Environment* by five national environmental organizations (Alliance to Save Energy, et al., 1997).

Fig. 1.16 A Selection of Low-Cost Engineering-Economic Scenarios



The 1991 report by the Office of Technology Assessment (OTA) titled *Changing by Degrees* (Office of Technology Assessment, U.S. Congress, 1991) analyzed the potential for energy efficiency to reduce carbon emissions by the year 2015, starting with the base year of 1987. Its **"tough" scenario** results in a 20% to 35% emissions reduction relative to 1987 levels, or emissions levels of 850 to 1,000 MtC/year in 2015. The CEF study's carbon reductions are considerably less than OTA's "tough" case. However, the annual rate of decrease in carbon emissions is similar, as can be seen by the parallel positioning of their trajectories in Fig. 1.16. The large difference between their endpoints is due partly to OTA's 13-year "jumpstart."

The tough scenario achieved its reductions at an estimated net annual cost ranging from -$28 billion to $212 billion (in 1997$). Residential building efficiency improvements are seen as the least-cost options and are estimated to generate net savings in both the pessimistic and optimistic cases. Energy-efficient technologies for commercial buildings and for transportation are seen as saving or costing money, depending on the assumptions. Altogether, these three end-use efficiency "stair-steps" in the supply curve account for more than 450 MtC of reductions in the year 2015. The savings from the first three steps are offset by the net costs represented by the two remaining steps – industrial efficiency and electric generators. These two options are estimated to deliver more than 400 MtC of reductions. This study differs from the CEF Study in its view that industrial efficiency technologies have net costs, even under the most optimistic assumptions.

The **NAS scenario** (National Academy of Sciences, 1992) included energy conservation technologies that had either a positive economic return or that had a cost of less than $2.85 (in 1997$) per tonne of carbon. Electric utility technology options play a negligible role. Altogether, NAS concluded that energy conservation technologies offered the potential to reduce carbon emissions by 463 MtC over a 20-year period, with more than half of these reductions arising from cost-effective investments in building energy efficiency. The CEF Advanced scenario describes bigger reductions overall (575 MtC over a 20-year period). However, only 369 MtC of these reductions come from energy efficiency improvements. A key reason that the NAS estimate is higher is that it did not use stock turnover periods to constrain the introduction of new technologies. Another reason is that it did not employ any type of "participation fraction" to limit the portion of purchases that actually buy optimum-efficiency equipment. Rather, the NAS study focused on the full technical potential of a suite of energy conservation technologies.

The NAS study estimated that it could realize this potential at a net benefit to the economy ranging from $14 billion to $116 billion per year (in 1989$). This net benefit results from adherence to the low-cost guidelines for including individual technologies. Power plant upgrades constitute the only supply-side technology option that does not exceed the NAS definition of a low-cost technology for reducing carbon emissions. These upgrades include 3% efficiency improvements to existing coal plants, 5% efficiency improvements to hydroelectric plants, and a 5% increase in the average capacity factor of existing nuclear power plants. In contrast, new electricity supply technologies that emit no carbon are estimated to require high implementation costs. They are therefore not part of the potential emission reduction estimated by the NAS study, thereby keeping costs low.

The pace of carbon reductions in the Five-Lab study's **"high-efficiency/low-carbon" scenario** is similar to the pace of reductions in the Advanced scenario, as documented by the parallel carbon reduction trajectories shown in Fig. 1.15. However, in 2010 both the carbon and energy reductions in the CEF study's Advanced scenario are less than those of the Five-Lab study's HE/LC case. This difference is largely due to the distinct timeframes of each study. The Five-Lab study's scenarios used a variation of the EIA AEO97 Reference case as its baseline and assumed that a national focus on efficient and clean energy technologies would begin in 1998. In contrast, the CEF study uses a variation of the AEO99 Reference case as its baseline and therefore is working against a 5% higher level of energy use and carbon emissions in 2010. In addition, it assumes that new policies begin in 2000, which allows only 10 years, instead of 12, to produce impacts by 2010. These two differences make it more difficult to devise low-cost strategies to bring down future energy use and carbon emissions to historic levels.

Sector-specific differences also exist in the energy savings modeled by the CEF and Five-Lab studies. Specifically, the CEF study shows lower savings for the transportation sector and higher savings for both buildings and industry. In the Advanced scenario, 20 years are required for the transportation sector to deliver energy reductions comparable to those achieved in the other two sectors. The Five-Lab study showed less of a lag partly because it had two more years in which to generate results.

Carbon emissions from electricity production in the HE/LC case are somewhat higher than in the Advanced scenario in 2010. This is due primarily to the greater use of wind energy and the relicensing of more nuclear plants in the Advanced scenario. These potential carbon reductions are somewhat offset by the Advanced scenario's smaller introduction of biomass cofiring, hydropower, and fossil plant efficiency improvements, compared with the HE/LC case. In contrast to the electricity sector, the end-use sectors in the HE/LC case generate greater carbon reductions than in the Advanced scenario. This is partly because the impacts of fuel cells in buildings and combined heat and power in industry are not included in the CEF bottom-line estimates, and ethanol displaces less gasoline in the Advanced scenario. In the Five-Lab study, savings from lower energy bills exceed the incremental technology investment costs and the cost of administering the programs and policies required to motivate these investments. The same is true for the CEF study, if the recycled revenues from the domestic carbon trading system are used to offset higher energy prices, as was implicitly assumed in the Five-Lab study.

The Tellus Institute's 1998 **"climate protection" scenario** modeled the carbon emission reductions from a vigorous set of RD&D and deployment policies. Compared to the policies modeled in the Advanced scenario, these policies are more aggressive. For instance they include stricter appliance and buildings standards, increased CAFE standards, a carbon content standard for transportation fuels, incentives for more rapid investment in new manufacturing equipment in industry, and a 10% "unconstrained" renewable portfolio standard in the electric utility sector. The result is an estimated decrease in carbon emissions of 593 MtC in 2010. This is approximately the same level of reduction that is achieved by the CEF Advanced scenario in 2020. The reductions are particularly strong in the transportation sector due to the aggressive policies of the climate protection scenario. It foresees the potential to reduce petroleum use by 2.2% per year. In contrast, the CEF study estimates growth in petroleum use through 2010, and reductions during the second decade only after sufficient R&D-generated improvements have materialized.

The **"climate protection" scenario** produced by the Tellus Institute in 1999 models many of the same policies as in its 1998 climate protection scenario. Again, these are generally more aggressive than the policies modeled in the CEF study's Advanced scenario and include:

- a cap and trade system to reduce the carbon intensity of the electric sector by 40% in 2010,
- incentives for biomass cofiring and district energy systems with cogeneration,
- stricter appliance and building standards,
- a carbon content standard for motor fuels to achieve a 10% reduction by 2010,
- a 10% unconstrained renewable portfolio standard, and
- facilitation of high-speed intercity rail development and intermodal freight movement.

The result is a rapid decline in carbon emissions to 1,150 MtC in 2010.

The 1998 climate protection scenario estimates net annual benefits of $87 per tonne of reduced carbon, for a total annual savings of $52 billion (in 1997$). The net annualized savings of the 1999 climate protection scenario is estimated to be $43 billion (in $1996) in 2010. A substantial portion of this scenario's carbon reductions comes from a 28% decrease in petroleum use, relative to the BAU scenario. This sizeable reduction reflects a set of policies to decrease vehicle miles traveled and to shift the nation toward more efficient transportation modes. Such policies are not considered in the Advanced scenario of the CEF study, although they are discussed in detail in Appendix E-2.

The **1990+24% scenario** described in *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity* (EIA, 1998c), is driven by a single policy instrument: a domestic carbon trading system. In this scenario, emissions in 2010 are limited by a cap defined as 24% above 1990 levels. (EIA also models scenarios that reduce carbon emissions to +9%, -3%, and -7%. These other cases are not described here because their costs are significantly higher.) It is assumed that the domestic carbon trading system is phased in beginning in 2005. At the 1990+24% cap (i.e., a carbon reduction of 123 MtC in 2010), carbon permits are estimated to trade at $67 per tonne (in $1996) in 2010. The annual macroeconomic costs to the economy are estimated to be $56 to $88 billion ($1992) between 2008 and 2012. This range reflects two different revenue-recycling schemes (either a social security tax rebate or a personal income tax rebate).

The introduction of carbon prices in 2005 in the 1990+24% scenario lowers the demand for energy services due to both the direct effect of higher energy prices on energy markets and the indirect effect of higher energy prices on the economy. There is also greater adoption of more efficient equipment and increased use of low-carbon fuels. U.S. coal consumption is significantly lower, while petroleum consumption decreases by a modest 2%. Thus, the analysis suggests that a small increase in oil prices from the domestic carbon trading system would have a minimal impact on vehicle efficiencies.

Consumption of natural gas, nuclear power, and renewable energy is higher, primarily for electricity generation.

In EIA's **"Early Start" scenario** (EIA, 1999c), it is assumed that a domestic carbon trading program is phased in beginning in 2000. This earlier start date smooths the transition of the economy to carbon reduction targets in 2008-2012. Other assumptions of the analysis are the same as in the EIA study described above (EIA, 1998c). The earlier start date reduces the carbon prices in 2010 from $67 (1996$) to $62 per MtC in the 1990+24% case. With the early start, actual GDP begins to rebound back toward its level in the Reference case sooner, and the recovery is smoother than in the case with a 2005 start date. Thus, the early start case involves a tradeoff. Its peak impacts are less severe, but they occur earlier than with the 2005 start. Net present value calculations show that the cumulative discounted impacts are larger in the early start cases.

The primary differences between these two EIA analyses and the present study are that the 1990+24% scenarios achieve their carbon reductions through a domestic carbon trading system, that is modeled as a carbon tax. We have seen in our analysis that carbon permits are effective in producing fuel switching in the electric utility sector, from coal to natural gas, but have relatively little impact on energy demand. Because of the low demand elasticity in the end-use sectors, EIA has had to apply a high carbon tax to obtain demand reductions. In contrast, the CEF study (and most of the other studies examined here) has used policies – such as appliance standards and voluntary agreements – to achieve demand reductions, and thus has not needed such high carbon permit prices. The EIA study also did not assume increased RD&D programs, while the CEF study assumes significantly increased RD&D resources, with resulting technology improvements in all sectors of the economy, especially in the transportation.

1.7 STUDY LIMITATIONS AND REMAINING ANALYSIS NEEDS

The objective of this CEF study is to develop scenarios that show how energy efficiency and clean energy technologies can address U.S. energy and environmental challenges while enabling continued economic growth. To meet this objective within our resources, we have restricted the scope of the CEF study. These limitations, and the need for further analysis, are described in the following paragraphs.

Perhaps the most significant limitation of the study is its focus on domestic carbon dioxide emissions. This focus results from these facts:

- Although the United States faces many energy and environmental issues, climate change could be the most challenging.
- Many of the policies and technologies that address carbon emissions have co-benefits such as improved air quality, security of energy supplies, and energy productivity.
- Carbon dioxide emissions from fossil fuel combustion represent 83% of U.S. emissions of greenhouse gases.
- While global climate change is an international issue, and international trading of carbon permits may become a reality, the potential for domestic carbon emission reductions can be evaluated largely independently of the international trading opportunities and is relevant to the international debate.

This focus on carbon emissions means that while we have included some policies directed at other issues (e.g., electric sector restructuring), we have not examined many policies relevant to non-CO_2 greenhouse gas emissions, carbon sink development, local air pollution emissions, or international carbon trading or export market opportunities.

In spite of the long-term nature of the global climate change problem, we elected to constrain the study's modeling to a near-term (2020) timeframe to better represent specific policy opportunities and impacts. This timeframe is also consistent with the use of NEMS, which extends only through 2020. One result of "truncating" our analysis at 2020 is that the modeling is not responsive to needs and conditions that emerge in subsequent years. This is not a limitation of the BAU forecast, but it is a limitation of the CEF scenarios. These scenarios could be improved if circumstances after 2020 could be foreseen (e.g., breakthrough technologies, more or less severe environmental conditions, export market developments, etc.) and factored into the design of policies and programs.

Because of the long lifetimes of power plants, refineries, and many other energy investments, decisions made over the next two decades will have far-reaching implications for subsequent decades and may not be optimal for the long run. In addition, the RD&D investments of the next few decades will determine which long-term options become available after 2020 and which are foreclosed. The impact of short-term decisions over the longer term is illustrated vividly by the six global energy scenarios developed for the next century by Nakicenovic, Grubler, and McDonald (1998), which are discussed in Chapter 8.

Although we have examined the direct costs and benefits of the policies included in the different scenarios, we have not assessed the cost of no policies (i.e., the cost of inaction). The study also does not assess the cost of policies to promote low-cost adaptation to climate change (e.g., strengthening physical infrastructures, emergency preparedness programs, and improved air conditioning technologies). An entirely different study would be required to assess the costs of a changing global climate.

The study is also limited in terms of methodology. As discussed in Section 3.7, "Remaining Analysis Needs," a major methodological weakness is our limited ability to analyze non-fiscal policies. These include information and technical assistance programs, demonstration projects, and voluntary agreements. More detailed documentation of program impacts is needed so that analyses such as the CEF study can be better grounded, and future policies and programs can benefit better from past experiences. Modeling the results of R&D programs also proved difficult. We cannot forecast with precision, we can only illustrate by example, the kinds of improvements in technologies over time that can be the determining factor in the acceptance of many clean energy technologies. Resource limitations also prevented this study from analyzing markets at the disaggregated level of detail required for some technologies to be accurately assessed, such as combined heat and power, building shell/equipment interactions, and distributed generation.

The CEF study is also methodologically limited in its assessment of the macroeconomic impacts of policies. This is particularly problematic for policies involving large transfer payments, such as domestic carbon trading with its redistribution impacts, transition costs, and equity issues.

Given these limitations of scope and methodology, caution should be used when applying the CEF study results. First, the study consists of a set of scenarios, not forecasts. The scenarios are distinguished by a range of public perceptions of the severity of the global climate change problem. If the public does not perceive the problem as extremely serious, these scenarios will not materialize. Second, it is not possible in a study of this nature to conceive of all the mechanisms that energy markets will find to deal with the problem. In general, modeling is poorly suited to anticipating the market's capacity to innovate. In particular, studies by Porter and others strongly suggest that, given flexibility and policy signals that "steer" rather than "row" (precisely the kind that are difficult to model), markets will innovate without incurring substantial price penalties (Porter and van Linde, 1995). Thus it is likely that we overestimate the cost of reducing U.S. carbon emissions.

Similarly, not all policy opportunities have been identified. Inasmuch as better opportunities will emerge, the policies of this study should be taken more as well-documented possibilities than as recommendations. Finally, while we identify near-term technology and policy opportunities, these should not be pursued to the exclusion of technologies and policies that will help us address the longer term beyond 2020.

Many of the CEF study's limitation could be improved with a modest amount of further analysis. These analyses could include the following:

- modeling the impacts of non-fiscal policies;
- improved modeling of macroeconomic impacts of policies;
- improved modeling of distributed power generation, such as fuel cells in buildings and combined heat and power in industry;
- expansion of the modeling capabilities to include a fuller range of air pollutants, so that co-control policies (e.g., air quality and carbon reduction policies) can be more easily analyzed; and
- better characterization of the impacts of uncertainties.

The development of models with longer timeframes, finer geographic disaggregation, and a broader array of international considerations would likely require a more significant amount of additional analysis.

..8 CONCLUSIONS

This analysis documents the important role that policies can play in stimulating the development and market penetration of efficient and clean energy technologies. These technologies, in turn, could help the United States meet a wide array of challenges, including global climate change, energy supply vulnerabilities, air pollution, and economic competitiveness. Our assessment suggests that the incremental technology and policy costs required to implement these technologies would be less than the energy cost savings from the more efficient use of energy throughout the economy in combination with the carbon permit transfer payments.

This report has developed a variety of scenarios. None of them – including the BAU scenario – is a prediction of the future. They all attempt to characterize the results of different assumptions about the future on the energy system (demand, supply, and price) and, to a lesser degree, the economy.

In the discussion that follows, we present our conclusions approximately in order of increasing uncertainty, as we describe what is needed to achieve reductions in carbon emissions and other pollutants in the 2010 to 2020 timeframe. All of the conclusions are, of necessity, tinged by the uncertainty that is inherent in any discussion of the future.

It is clear that a baseline built on current approaches to energy policy in this nation will result in substantial increases in carbon and other pollutant emissions in 2010 and 2020. The BAU case shows increases in carbon emissions of 31% and 43% above 1990 levels in 2010 and 2020, respectively. Although many different futures based on a continuation of current economic and policy trends are possible, virtually all of them would show substantial increases in carbon emissions. Thus we conclude that, without major shifts in policy and/or in the economic environment, the United States will be much further from stabilizing its carbon emissions if today's trends continue.

The Moderate scenario shows what a considerable effort to increase efficiency could achieve. The authors believe that the scenario demonstrates a range of policies and technologies that are conceivable with a modest shift in the present political context. One view of the Moderate scenario, which shows an increase in energy demand of 27% and 31% above 1990 levels in 2010 and 2020, respectively (an energy reduction of 4% and 8% from BAU in those years), is that it is a modest effort to curb demand growth. Others, contemplating the policies and technologies that need to emerge to make this case happen, may view it as a more significant departure from current trends and policies. The authors view this case as one in which uncertainty about technologies and the likelihood of policies to bring them into the market is relatively modest. That is, in all end-use sectors, the technologies with favorable economics to achieve the demand reductions are available. The greatest uncertainty is the willingness of the nation to adopt policies to encourage them. The second greatest uncertainty is the likely effectiveness of the policies and, therefore, the aggressiveness with which they would need to be pursued. In all analyses of this scenario, we observe a favorable direct economic impact.

Another type of measure to reduce carbon emissions is a direct cap on emissions, resulting in a carbon permit value. We have analyzed $25/tC and $50/tC cases and focus on the $50/t case here. If we apply $50/tC to the BAU case, carbon emissions are reduced by 24% and 30% in 2010 and 2020, respectively. Two very different types of uncertainties relating to this reduction. First is the issue of whether and under what circumstances a policy leading to an increase in energy prices, through a domestic carbon trading system, would be adopted. Such a charge is difficult to imagine in the present political environment. It would require a substantial recognition of the importance to the nation of reducing carbon emissions and a willingness to commit resources and effort to do so. The second set of uncertainties relates to the modeling. For example, we have analyzed the economics of retirement of coal-fired plants and their replacement by natural gas-fired plants under different carbon permit prices. These studies are based on costs averaged across a large number of plants and do not necessarily reflect the real-world costs of individual plants. Future work could show greater or lesser replacement of coal-fired power plants at a $50/tC charge. Our analysis suggests that the direct costs of this domestic carbon trading system on the economy would be small (defined as less than the net savings to the economy of the Moderate scenario).

The CEF-NEMS analysis estimates that the measures identified in the Moderate scenario combined with a cap on carbon that resulted in a $50/tC charge would lead to an increase in carbon emissions above 1990 levels of 15% in both 2010 and 2020. We believe there is less uncertainty in the technology or the economics of this case compared with the political feasibility of implementing the policies (e.g., increasing federal budgets for energy efficiency programs and energy technology R&D; implementing selected energy efficiency policies and/or achieving voluntary agreements with industry; and establishing a carbon cap equivalent to a $50/tC charge).

While there is of necessity some uncertainty in domestic supply of natural gas and its cost, the moderate case with a $50/tC charge has a lower natural gas demand than the BAU. Thus the uncertainty of gas availability at low prices is reduced in this case relative to BAU. This realization makes clear the importance of combining energy efficiency programs, which make more natural gas available, with supply policies that increase use of natural gas.

The Advanced scenario, by combining much more aggressive policies and pursuing advanced R&D goals much more actively, shows carbon emission reductions during the second decade of our analysis period. Are these scenarios achievable? What are the preconditions for success, or a degree of success, in achieving them? If they can be achieved, are they affordable?

These questions have no simple answers. The authors of the report view the cases as plausible – that is, nothing in them violates our knowledge of energy technologies or markets. Of the considerable uncertainties, first and foremost is political feasibility. Even more than the Moderate scenario with a carbon permit price, the Advanced scenario requires a dramatic change in political will. Very active market policies, with substantial federal funding, along with regulatory policies, commitment by industry on energy efficiency well beyond present practice, and greatly increased R&D are all prerequisites. There is little to suggest that such fundamental policy and budget changes are conceivable in the present political environment.

The issue here is not likelihood in the present political environment but feasibility in a different one. If for whatever reason – clear evidence of climate change, new scientific findings, international pressures – the nation did commit to a path of significant carbon reductions, then how plausible is a case such as our Advanced scenario and what are the major uncertainties and barriers to achieving the CEF-NEMS modeled results?

We first discuss three large areas of uncertainty. In many cases, technology is not presently available to achieve the Advanced scenario results. The scenario requires substantial progress toward more efficient vehicles. A combination of advanced diesels with greatly lowered emissions, fuel cell hybrids, reduced-cost alcohol fuels, gasoline hybrids, and electric vehicles will need to be commercial and affordable before 2010. Similarly, costs for key renewable energy sources such as wind and biomass co-firing must be significantly reduced over the same time period. Important improvements in energy-efficient technologies – either cost or performance – are needed for both buildings and industry as well; success in these sectors also depends strongly on program implementation. It is not certain that these technological improvements will occur in the timeframe suggested. It is also possible that technology innovation in response to the combined set of policies described in the study plus similar or more aggressive policies enacted in other countries and not analyzed, could lead to greater technical progress than assumed. If the country – government and private sector – invests in the R&D substantially (we assume a doubling), the authors believe that the technology improvements required for the Advanced case are plausible.

The second area concerns the effectiveness of the policies. This is tied closely with the success in technology R&D. If the R&D is successful, and the technologies are available and cost-effective, then the policies need far less aggressive a push. For example, if advanced vehicle design makes 60 mpg cars (and even light-duty vehicles) affordable without degrading performance, then achieving either a voluntary agreement or mandatory standards on fuel economy is far less difficult than under conditions of technological uncertainty. In a world in which the goal of reducing carbon emissions is widely accepted, the consumer is far more likely to trade acceleration for fuel economy, thus making fuel efficiency agreements or standards easier to adopt. Nonetheless, even in a world in which there is strong agreement among many parties agree to reduce greenhouse gas emissions, there remain uncertainties about the efficacy of the policies. Particularly in buildings and in industry, it remains possible that market barriers to energy efficiency will be more stubborn than expected and/or that the real costs of implementing energy efficiency will be higher than estimated. Again, R&D interacts with policies: a successful R&D effort produces technologies that make policy easier to implement.

A related policy issue concerns the transition to an Advanced scenario. The biggest transition issue concerns the movement away from coal. The coal industry would be dramatically affected by the policies and measures that bring about the Advanced scenario: coal production is down 50% from the BAU case in 2020 (down 40% from 1997 levels). This would dramatically and adversely affect the coal industry and its related transportation modes (rail and barge). Other industries – natural gas, renewables, and providers of energy efficiency – would clearly gain.

The final area concerns the cost of the Advanced scenario. The cost results are critical to the plausibility of the scenario. If the scenario saves consumers and society money, then the policies underlying it become more plausible than if there is a substantial net cost to society. The results suggest that society might have benefits of tens of billions of dollars per year by 2020. This estimate depends in large measure on our estimates of the costs and performance of the technologies and, to a lesser extent, of the policies. The technologies could be more expensive than we expect, or the policies could be more costly. (They

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could also be less costly.) It is also worth repeating that these costs depend on advances in technology combined with smart and efficient policies; without these, the costs are necessarily much higher.

In summary, a variety of viewpoints are possible in the Advanced scenario. The authors believe that it could happen only with dramatic changes in government policy and national will (affecting both consumers and industry). Even with these dramatic changes, there remain important uncertainties. Will the technology advance as much as now appears plausible? Will the advances take place in the timeframe that we anticipate? Will the policies work as well as we expect? To some, the likelihood of "yes" is high, and the Advanced scenario is highly plausible given the transformation of the policy environment. Others who look in detail at the technologies and policies enumerated in the report may feel that a substantial portion of the reductions in energy use and emissions in going from the Moderate to the Advanced scenario is highly plausible – again assuming the technology R&D investment and the willingness to pursue policies. There will be those who are much more pessimistic about technology and policy and who believe that little, if any, of the results of the Advanced scenario are likely. The authors of this report have a range of views about these results, but in all cases find themselves in either the first or second of these three groups: we believe that, with the sufficient commitment, the United States could achieve all or a substantial portion of the Advanced scenario and at a negligible cost (or benefit) to the economy.

Climate change is but one of the concerns that U.S. energy policy must address. This study identifies a set of policy pathways that could significantly accelerate the development and deployment of cost-effective energy technologies. By targeting clean energy technologies, these policies offer the potential for multiple benefits: greenhouse gas reductions, energy bill savings, balance-of-payment benefits, enhanced security through energy diversity, and improved air quality. These multiple benefits are produced by moving forward on many fronts – on policies to remove market and organizational barriers, programs to facilitate deployment, and technology development. These are all key ingredients of a clean energy future.

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6

by [illegible]

1-4

	Solar* Insolation per day (kWh/m^2)	Wind (MW)	Geothermal	Biomass
Alabama	4.9	-		
Alaska	3.0	N/A		
Arizona	6.4	2,793		
Arkansas	5.1	9,754		
California	5.6	32,063		
Colorado	5.8	219,003		
Connecticut	4.4	4,409		
Delaware	4.6	2,127		
Florida	5.2	-		
Georgia	5.1	447		
Hawaii	5.6	N/A		
Idaho	5.1	25,414		
Illinois	4.6	46,864		
Indiana	4.4	191		
Iowa	4.7	379,650		
Kansas	5.3	722,389		
Kentucky	4.5	340		
Louisiana	5.0	-		
Maine	4.4	3,537		
Maryland	4.6	2,467		
Massachusetts	4.6	15,149		
Michigan	4.2	32,417		
Minnesota	4.4	412,691		
Mississippi	5.0	-		
Missouri	4.9	35,990		
Montana	4.7	430,584		
Nebraska	5.1	586,652		
Nevada	5.9	8,336		
New Hampshire	4.6	3,034		
New Jersey	4.6	6,635		
New Mexico	6.2	130,272		
New York	4.2	43,972		
North Carolina	5.0	2,396		
North Dakota	4.7	613,022		
Ohio	4.2	2,602		
Oklahoma	5.3	468,608		
Oregon	4.3	20,621		
Pennsylvania	4.3	28,958		
Rhode Island	4.5	369		
South Carolina	5.1	291		
South Dakota	5.0	518,393		
Tennessee	4.8	1,042		
Texas	5.4	722,460		
Utah	5.6	8,741		
Vermont	4.3	3,098		
Virginia	4.9	5,784		

18312

Washington	4.0	19,275
West Virginia	4.3	4,154
Wisconsin	4.5	39,953
Wyoming	5.4	365,132

*The solar insolation is the mid point of the highest insolation range covering a significant portion of the s

2-4

Solar & wind Ref.
by State

3-4

tates population as shown on the NREL average annual solar insolation for flat-plate set at latitude plu 1

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my state

4-4

5 degrees.

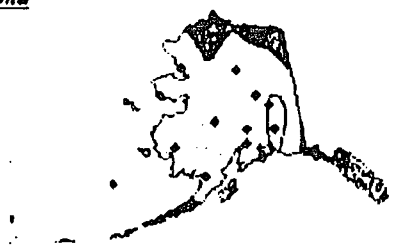
18315

DOE019-0282

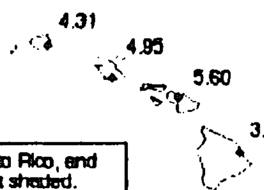
Average Daily Solar Radiation Per Month

ANNUAL

Alaska

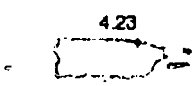


Hawaii



Hawaii, Puerto Rico, and Guam are not shaded.

San Juan, PR



Guam, PI

North-South Axis Tracking Concentrator Tilted at Latitude

Collector Orientation

One-axis tracking parabolic trough with a horizontal north-south axis and tilted from the horizontal at an angle equal to the site's latitude

This map shows the general trends in the amount of solar radiation received in the United States and its territories. It is a spatial interpolation of solar radiation values derived from the 1961-1990 National Solar Radiation Data Base (NSRDB). The dots on the map represent the 239 sites of the NSRDB.

Maps of average values are produced by averaging all 30 years of data for each site. Maps of maximum and minimum values are composites of specific months and years for which each site achieved its maximum or minimum amounts of solar radiation.

Though useful for identifying general trends, this map should be used with caution for site-specific resource evaluations because variations in solar radiation not reflected in the maps can exist, introducing uncertainty into resource estimates.

Maps are not drawn to scale.

NREL

National Renewable Energy Laboratory
Resource Assessment Program

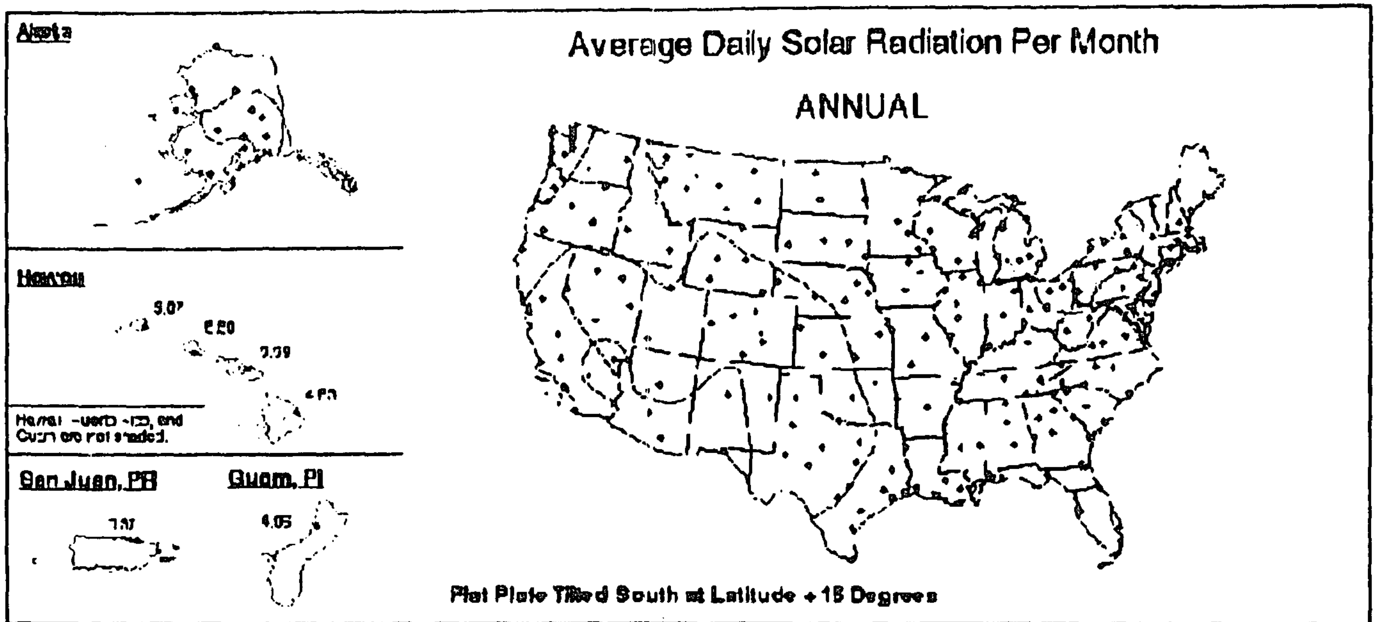
kWh/m²/day

- 10 to 14
- 8 to 10
- 7 to 8
- 6 to 7
- 5 to 6
- 4 to 5
- 3 to 4
- 2 to 3
- 0 to 2
- none

C1XLA13-52

DOE019-0283

18316



Collector Orientation

Flat-plate collector facing south at fixed tilt equal to the latitude of the site plus 15 degrees. To optimize performance in the winter, this tilt angle is recommended.

[illegible] United States and its territories. It is a spatial interpolation of solar radiation values derived from the 1961-1990 National Solar Radiation Data Base (NSRDB). The data [illegible] NSRDB.

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[illegible]

NREL

National Renewable Energy Laboratory
Resource Assessment Program

kWh/m²/day

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- 8 to 10
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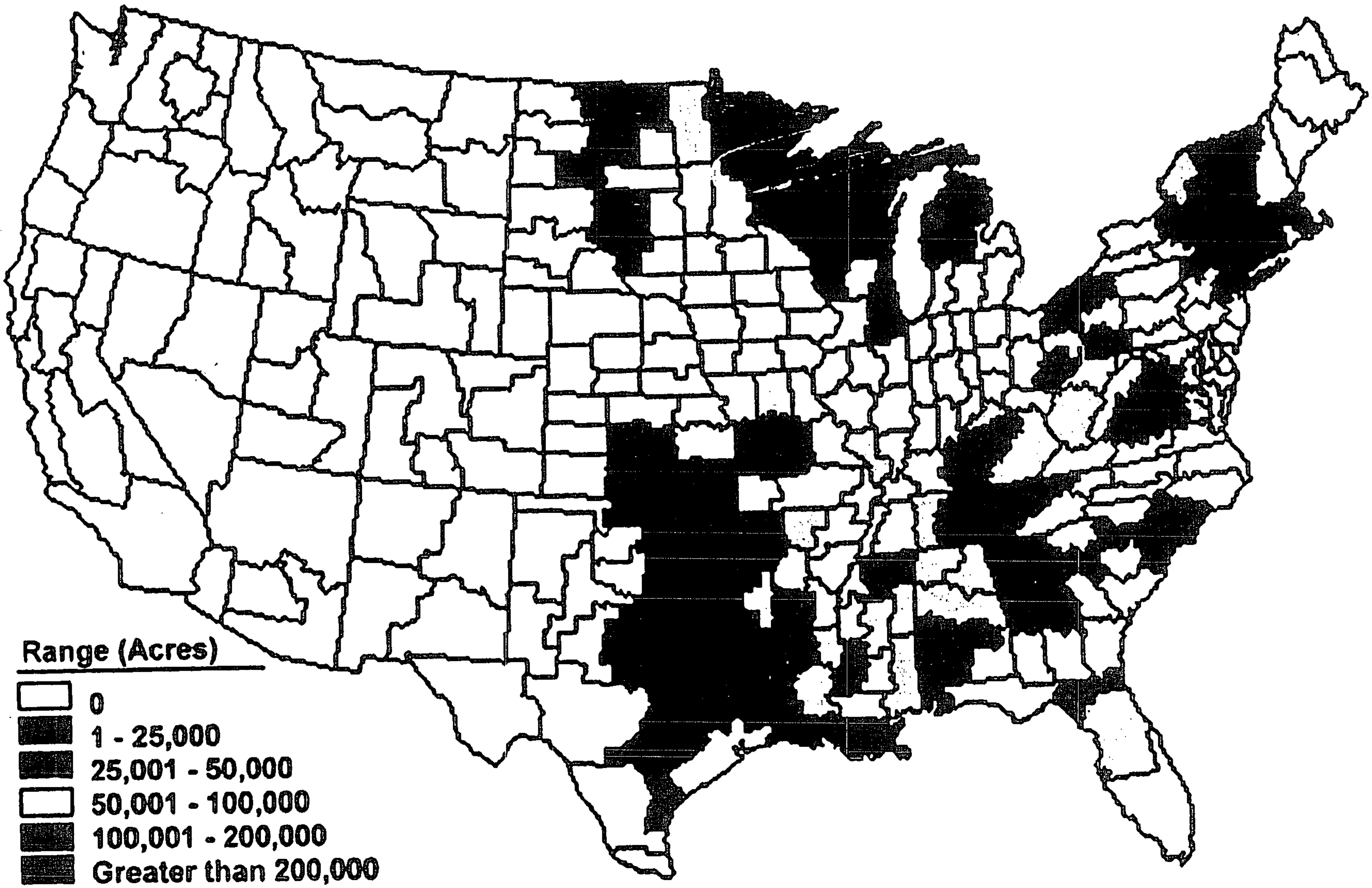
- 5 to 6
- 4 to 5
- 3 to 4
- 2 to 3
- 0 to 2
- none

DOE019-0284

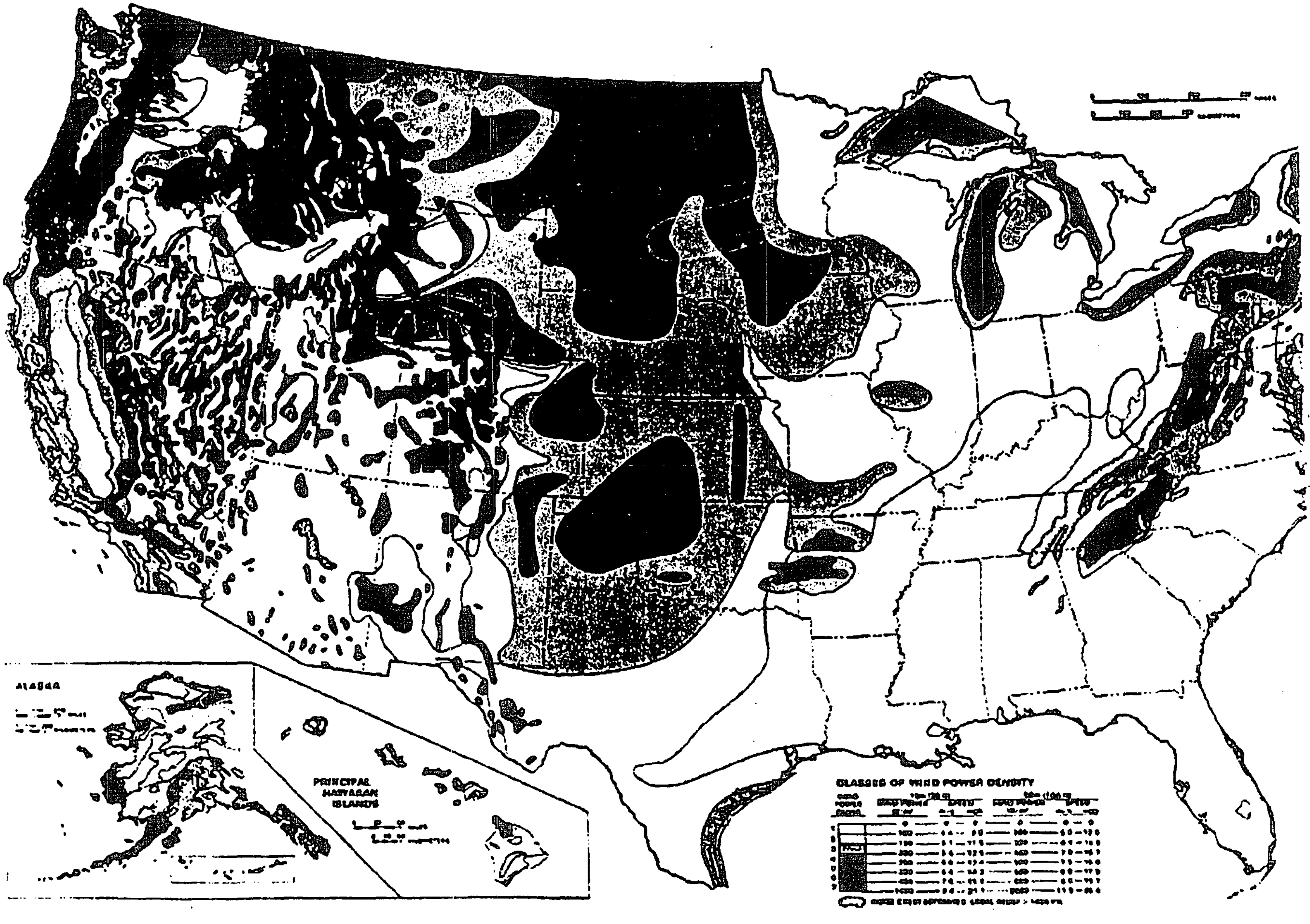
18317

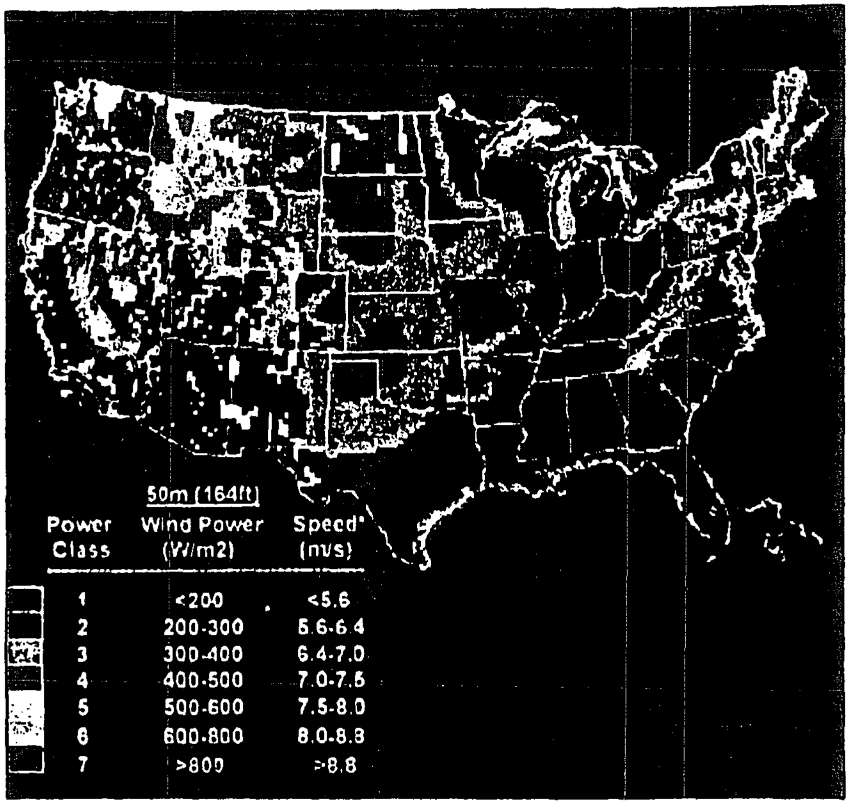


DOE019-0285

18318

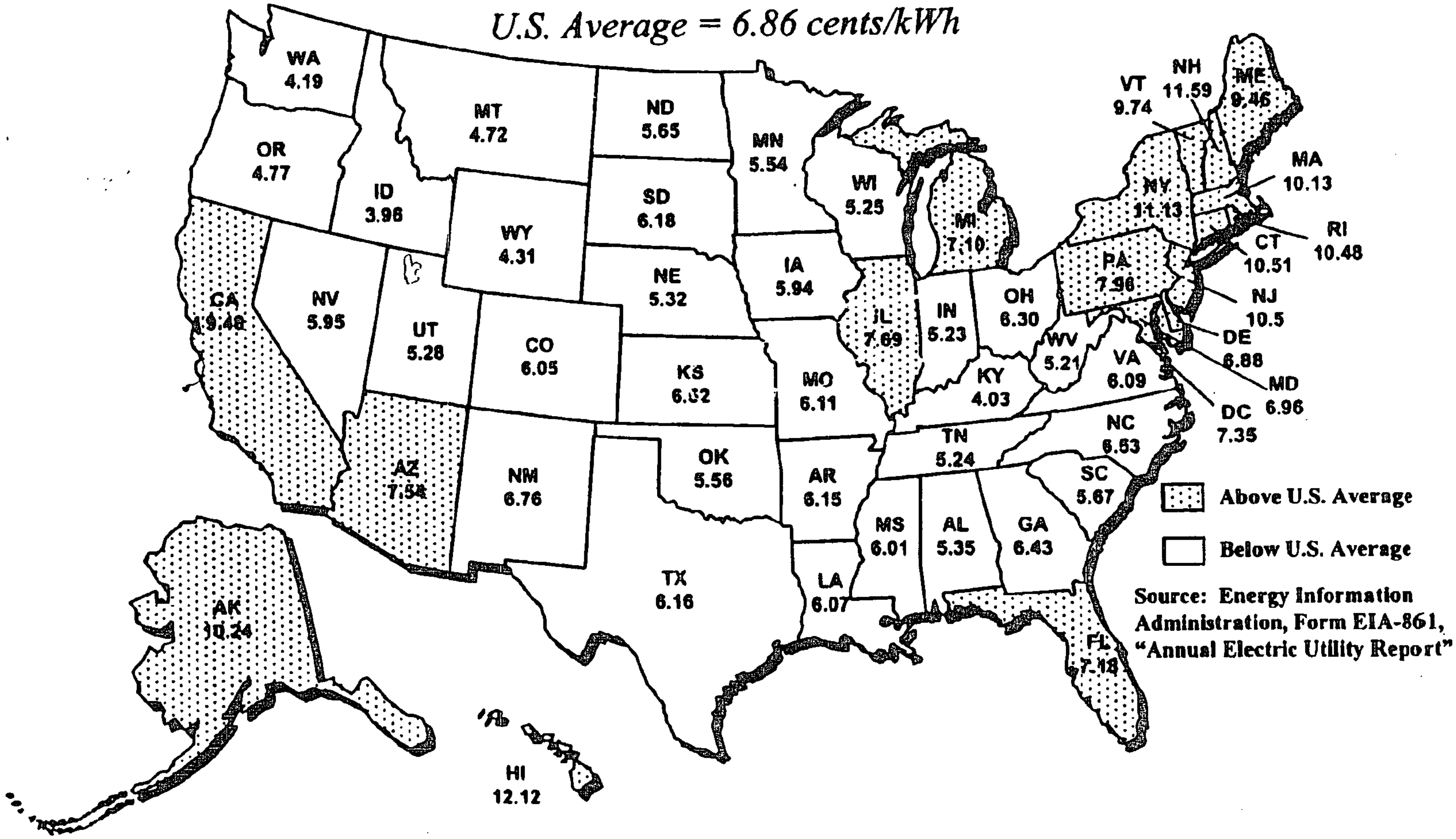
UNITED STATES ANNUAL AVERAGE WIND POWER



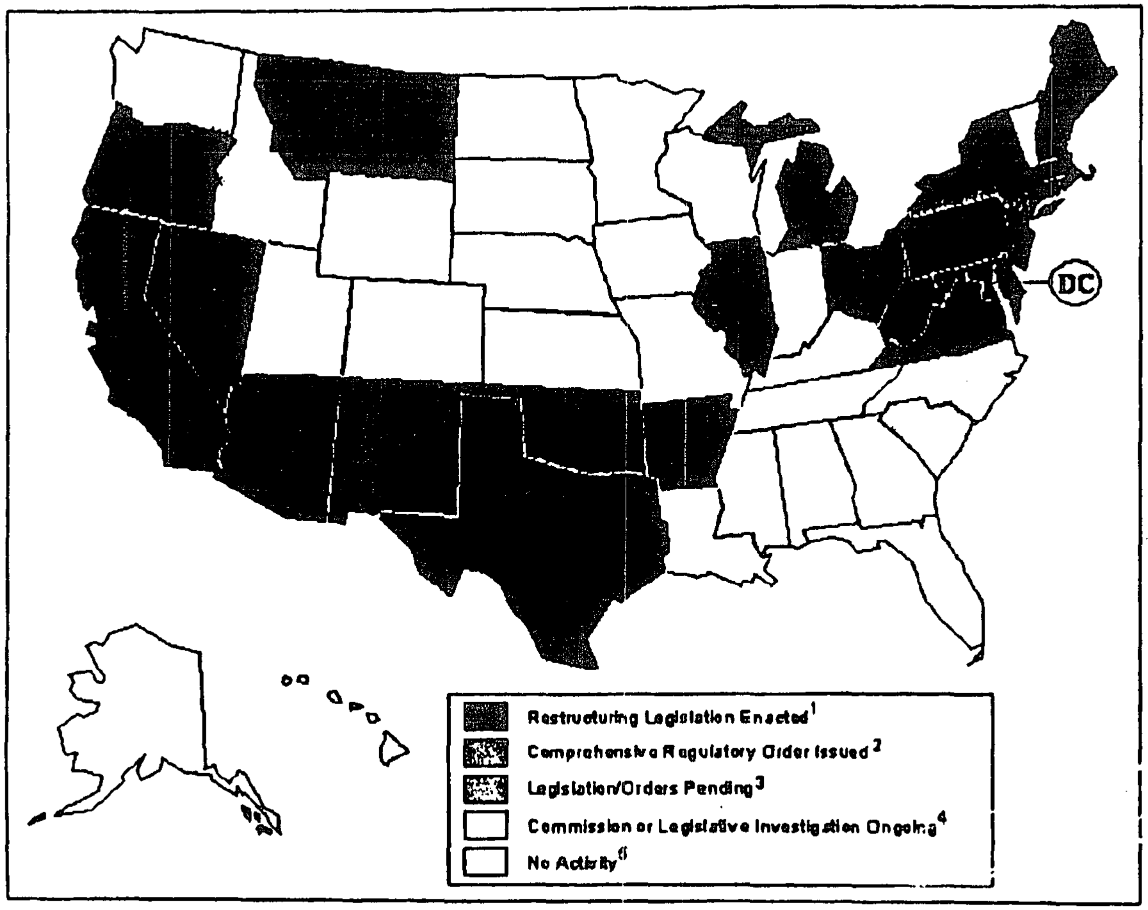

50m (164ft)
Power Class
Wind Power (W/m2)
Speed* (m/s)
1 <200 <5.6
2 200-300 5.6-6.4
3 300-400 6.4-7.0
4 400-500 7.0-7.5
5 500-600 7.5-8.0
6 600-800 8.0-8.8
7 >800 >8.8

1996 Price of Electricity in the U.S.

U.S. Average = 6.86 cents/kWh



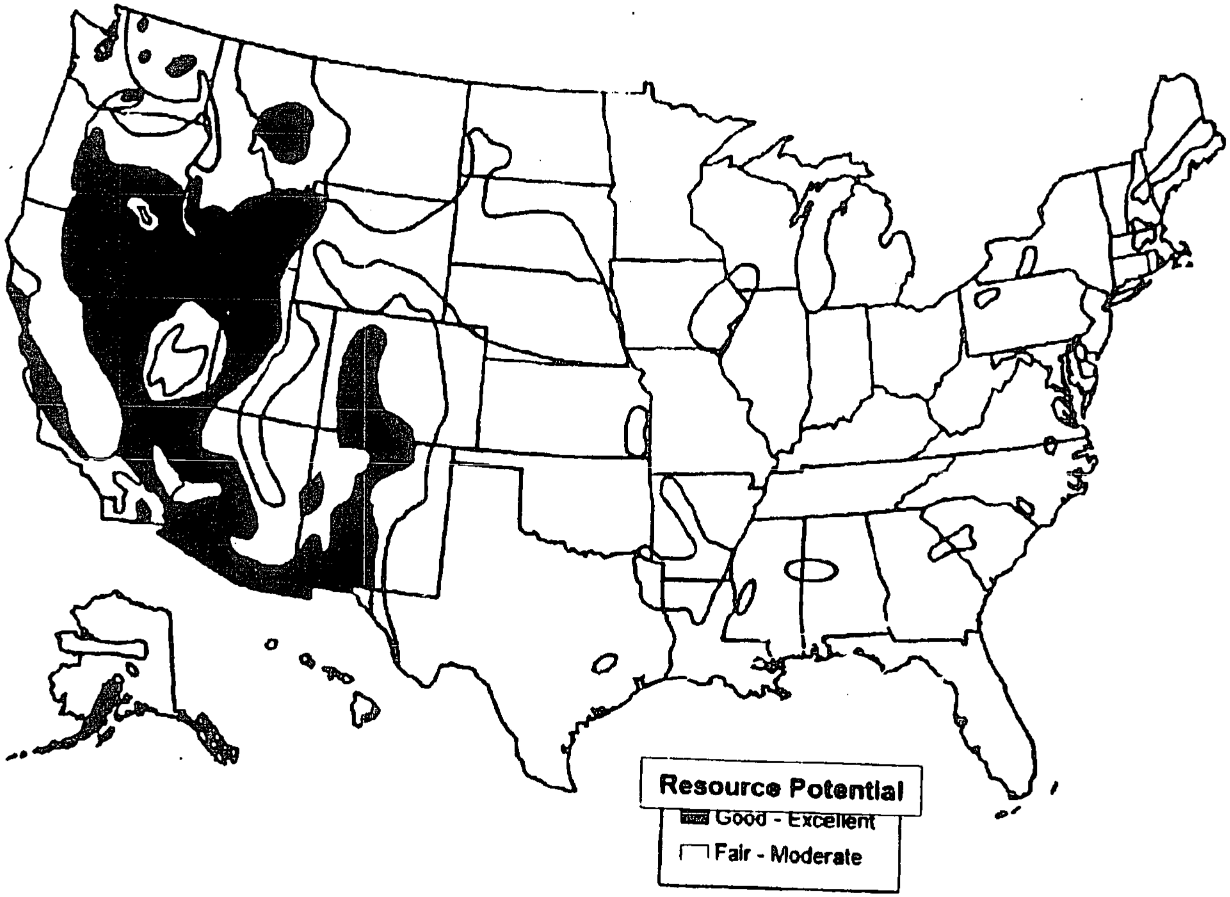
Source: Energy Information Administration, Form EIA-861, "Annual Electric Utility Report"



DOE019-0289

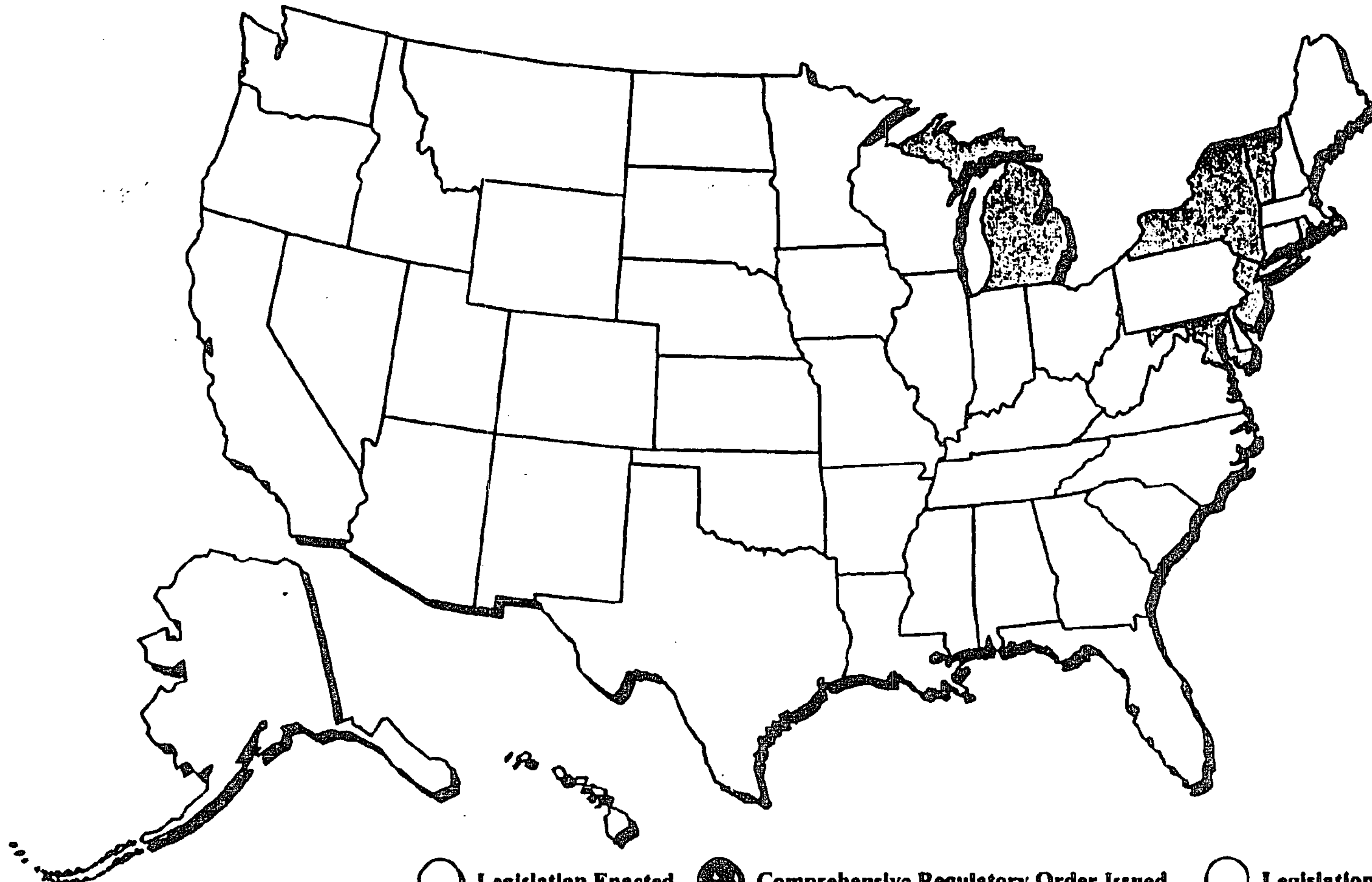
18322

Geothermal Energy Potential



map 1

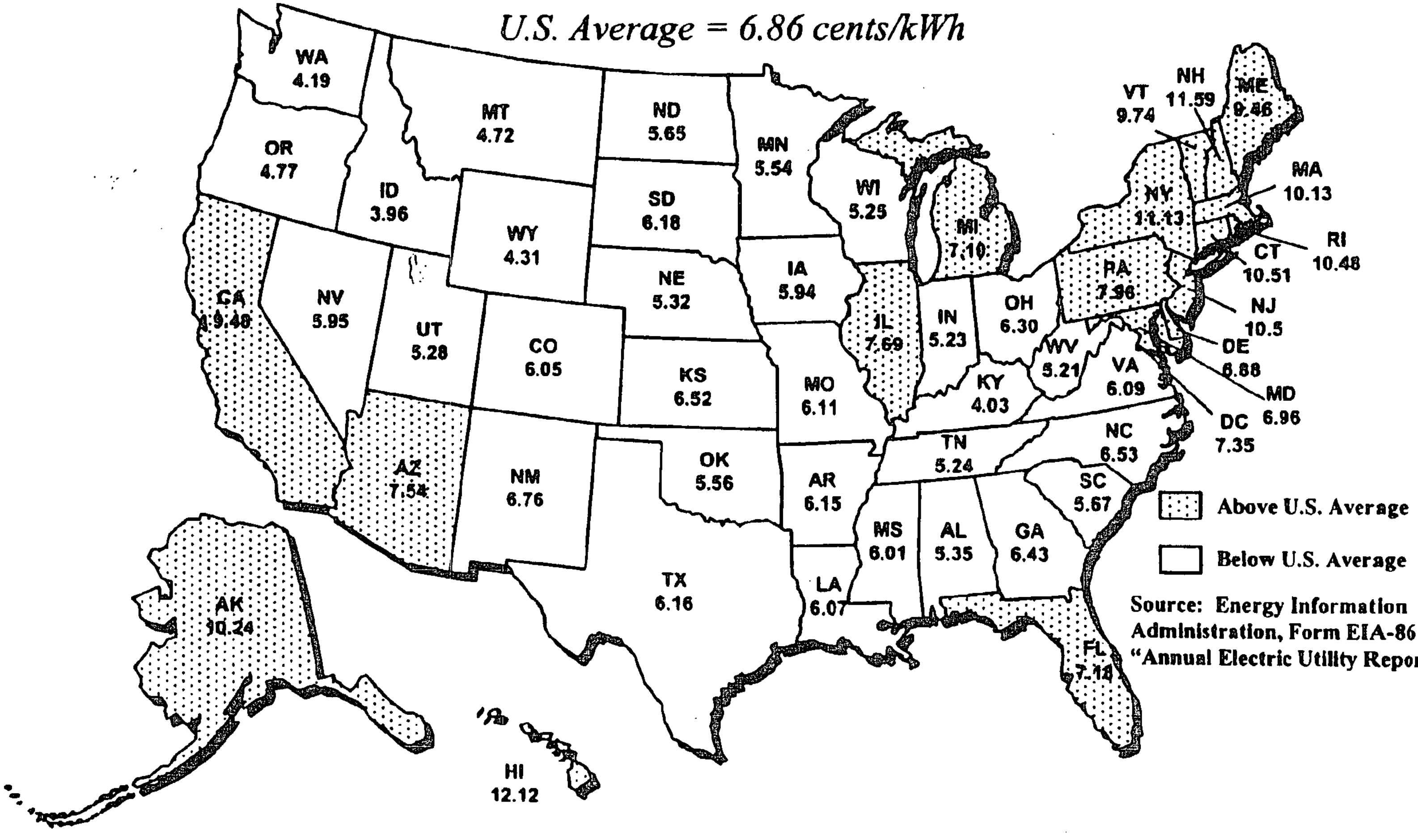
Overview of State Restructuring Actions



Source: EERE/EIA State-by-State Utility Restructuring Database, 1/99

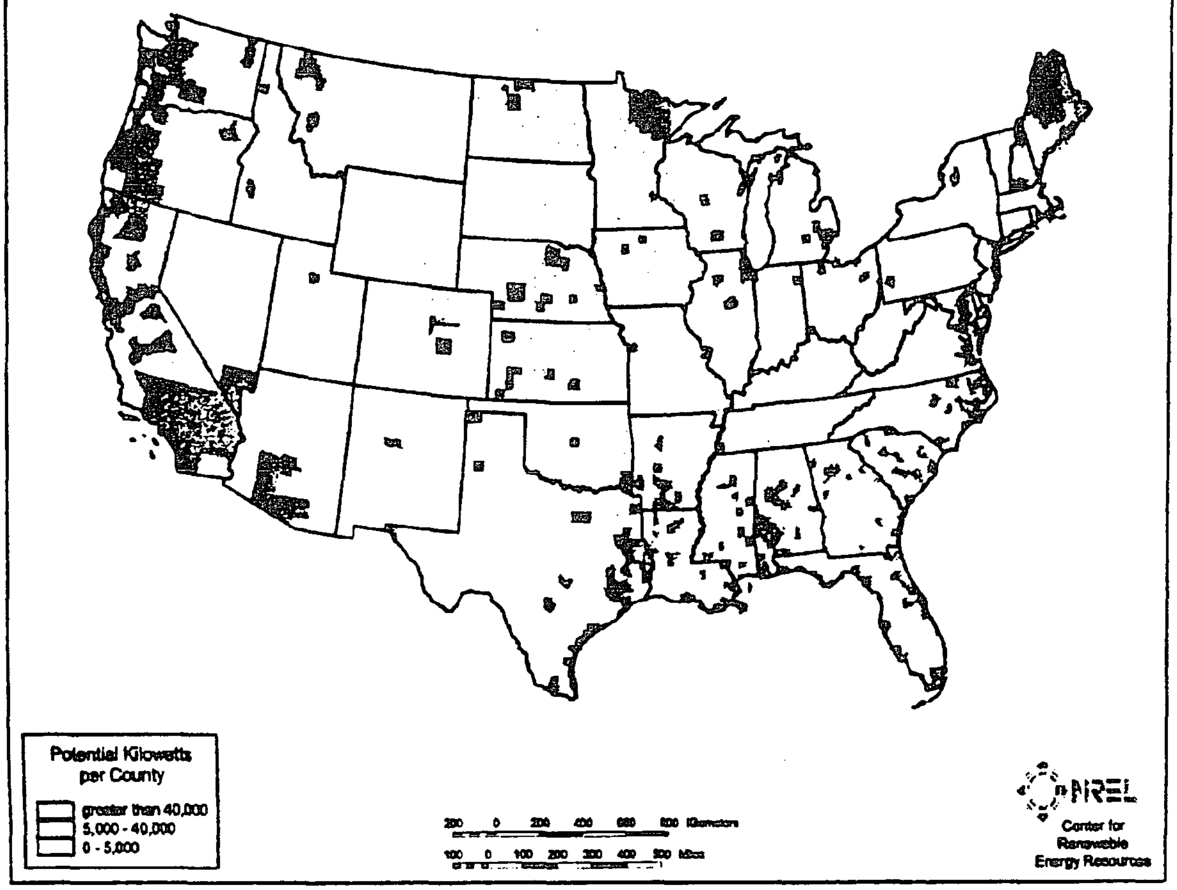
1996 Price of Electricity in the U.S.

U.S. Average = 6.86 cents/kWh



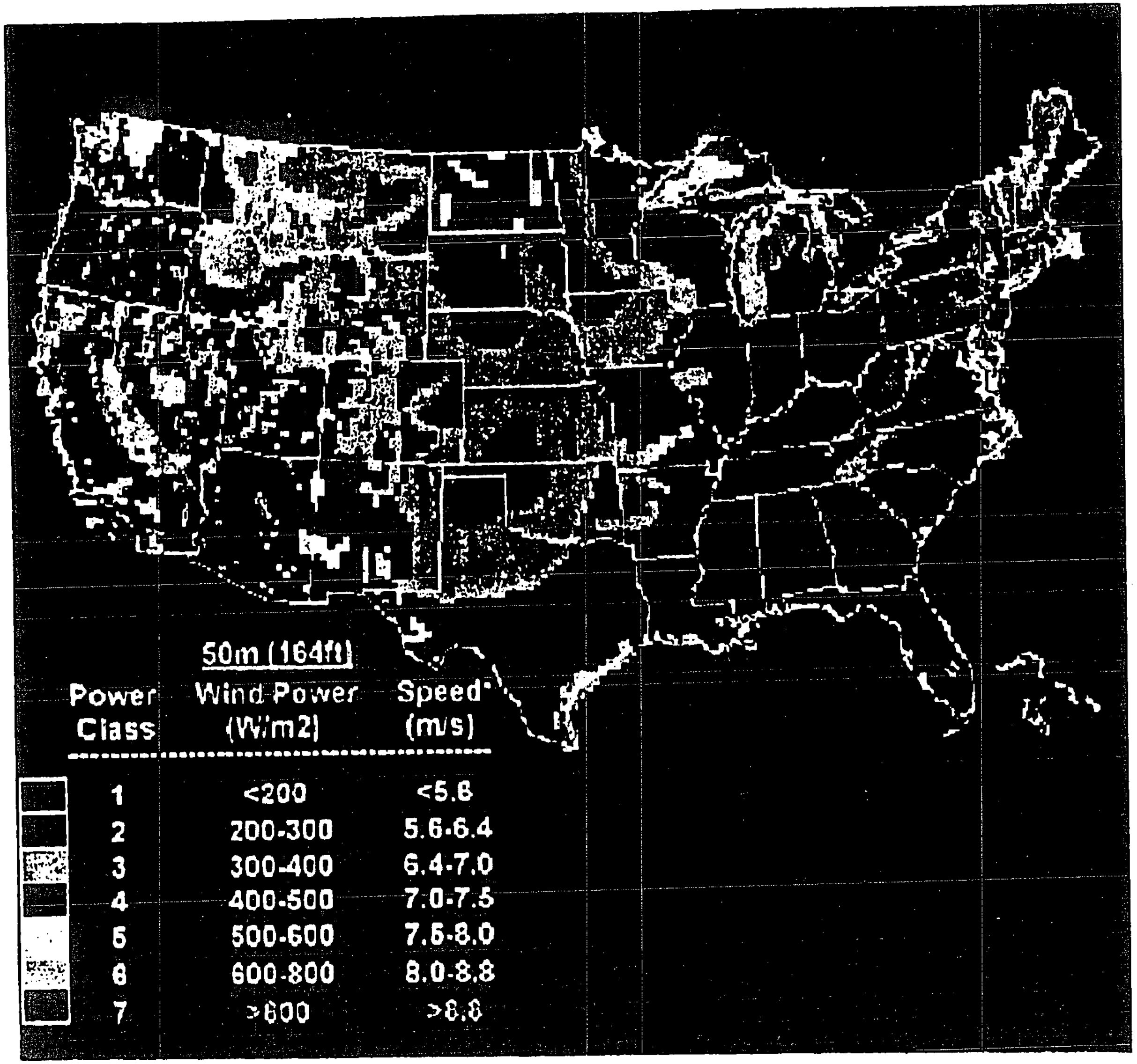
Source: Energy Information Administration, Form EIA-861, "Annual Electric Utility Report"

Biomass and Biofuels Resource Potential



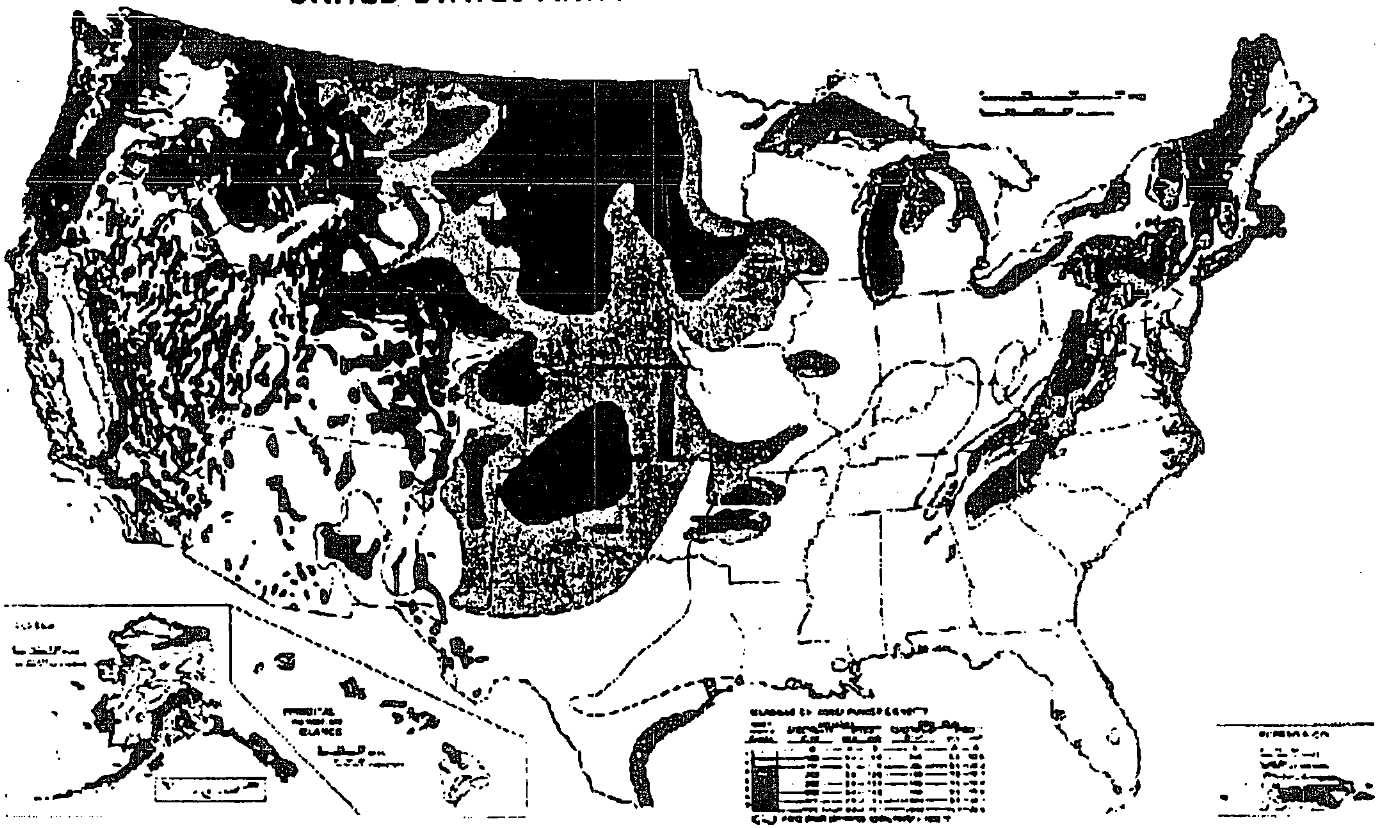
18326

DOE019-0293



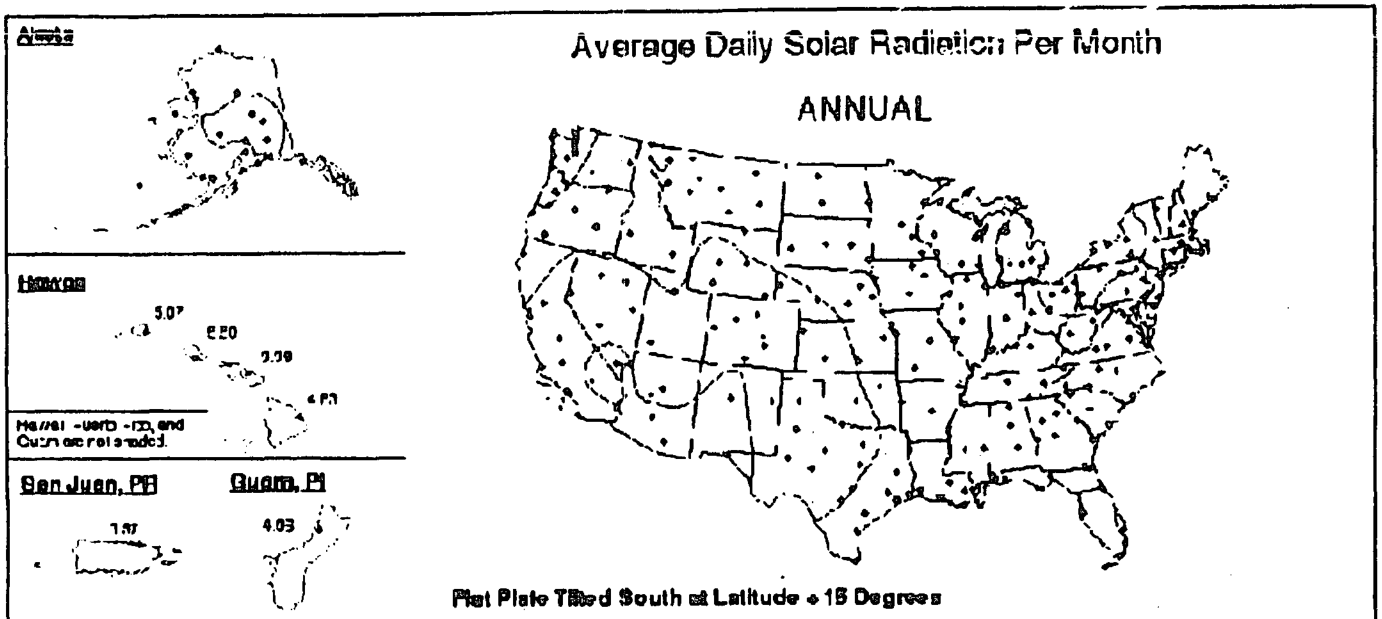
50m (164ft)
Power Class
Wind Power (W/m2)
Speed* (m/s)
1 <200 <5.6
2 200-300 5.6-6.4
3 300-400 6.4-7.0
4 400-500 7.0-7.5
5 500-600 7.5-8.0
6 600-800 8.0-8.8
7 >800 >8.8

UNITED STATES ANNUAL AVERAGE WIND POWER



Average Daily Solar Radiation Per Month

ANNUAL



Flat Plate Tilted South at Latitude + 15 Degrees

Collector Orientation

Flat-plate collector facing south at fixed tilt equal to the latitude of the site plus 15 degrees. To optimize performance in the winter, this tilt angle is recommended.

This map shows the general trends in the amount of solar radiation received in the United States and its territories. It is a spatial interpolation of solar radiation values derived from the 1961-1990 National Solar Radiation Data Base (NSRDB). The data [illegible] 239 sites in the NSRDB.

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[illegible]

NREL

National Renewable Energy Laboratory
Resource Assessment Program

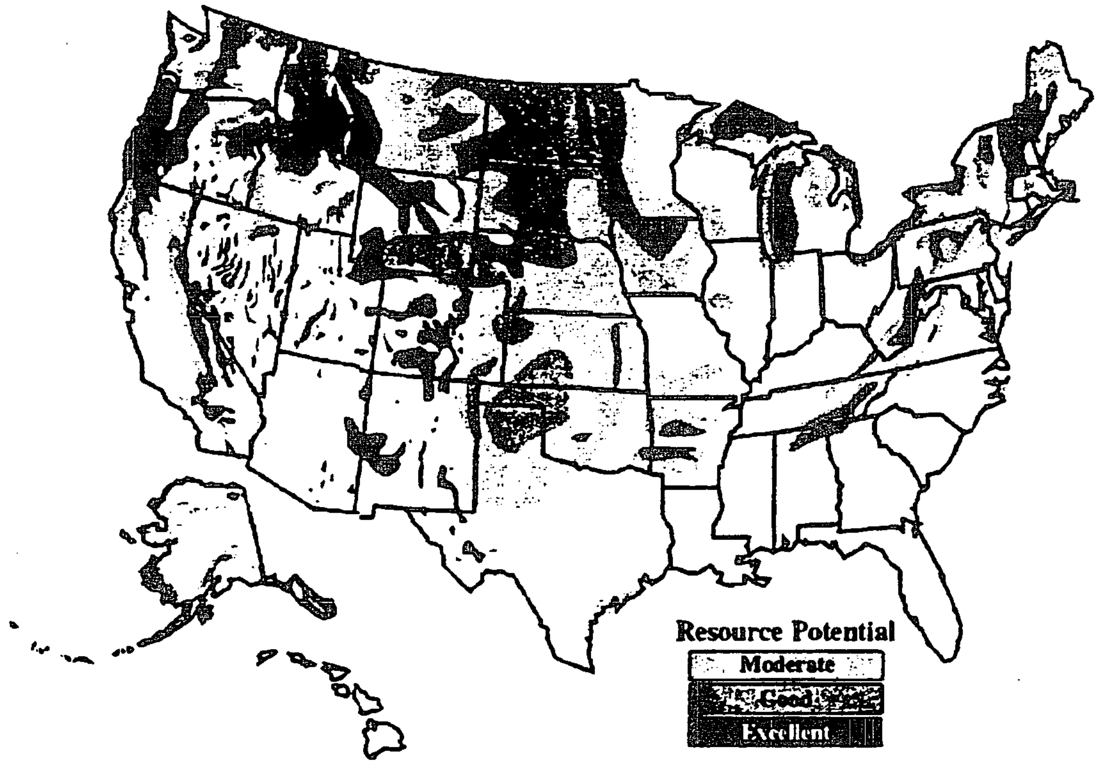
kWh/m²/day

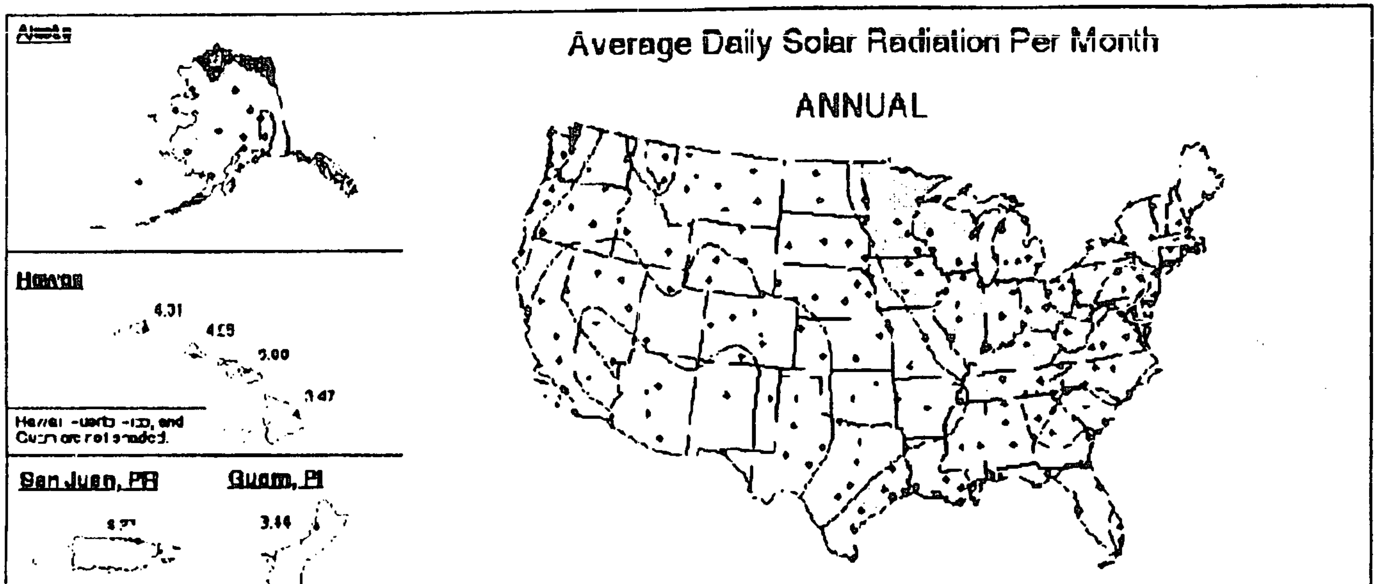
- 10 to 14
- 8 to 10
- 7 to 8
- 6 to 7
- 5 to 6
- 4 to 5
- 3 to 4
- 2 to 3
- 0 to 2
- none

[illegible]

DOE019-0296

18329


Resource Potential
Moderate
Good
Excellent



North-South Axis Tracking Concentrator Tilted at Latitude

Collector Orientation

One axis tracking parabolic trough with a horizontal north-south axis and tilted from the horizontal at an angle equal to the site's latitude

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[illegible]

NREL
National Renewable Energy Laboratory
Resource Assessment Program

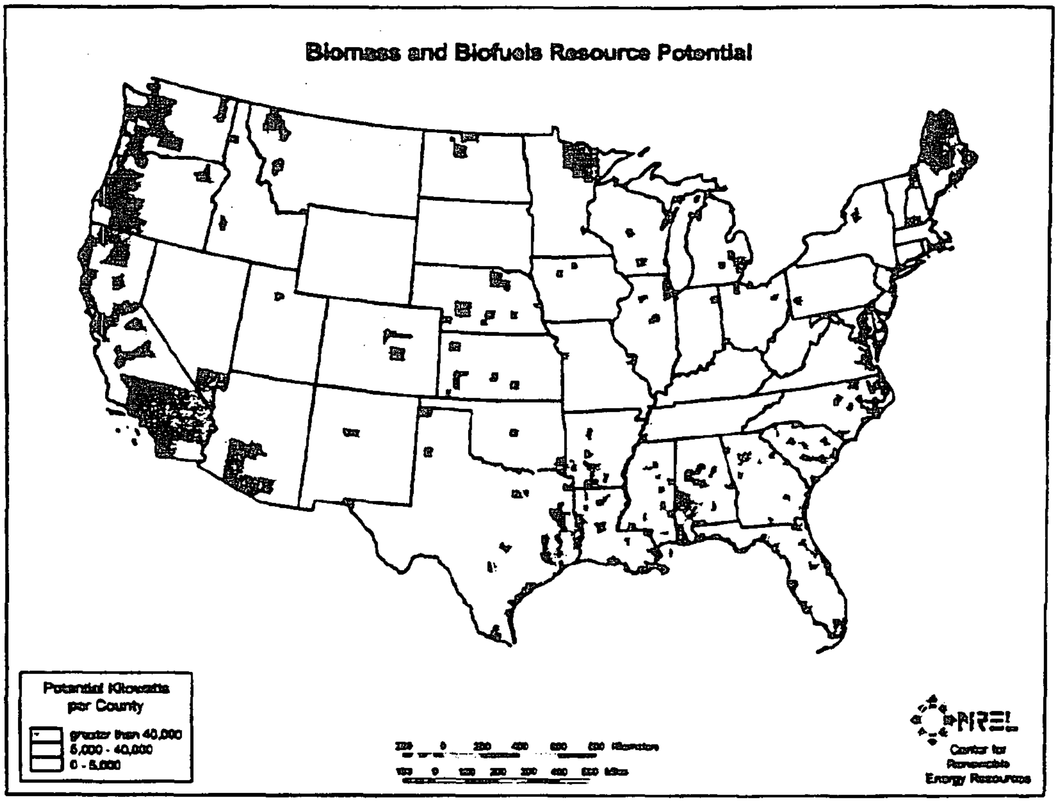
kWh/m²/day
10 to 14
8 to 10
7 to 8
6 to 7
5 to 6
4 to 5
3 to 4
2 to 3
0 to 2
none

C1Y 8-3-02

DOE019-0298

18331

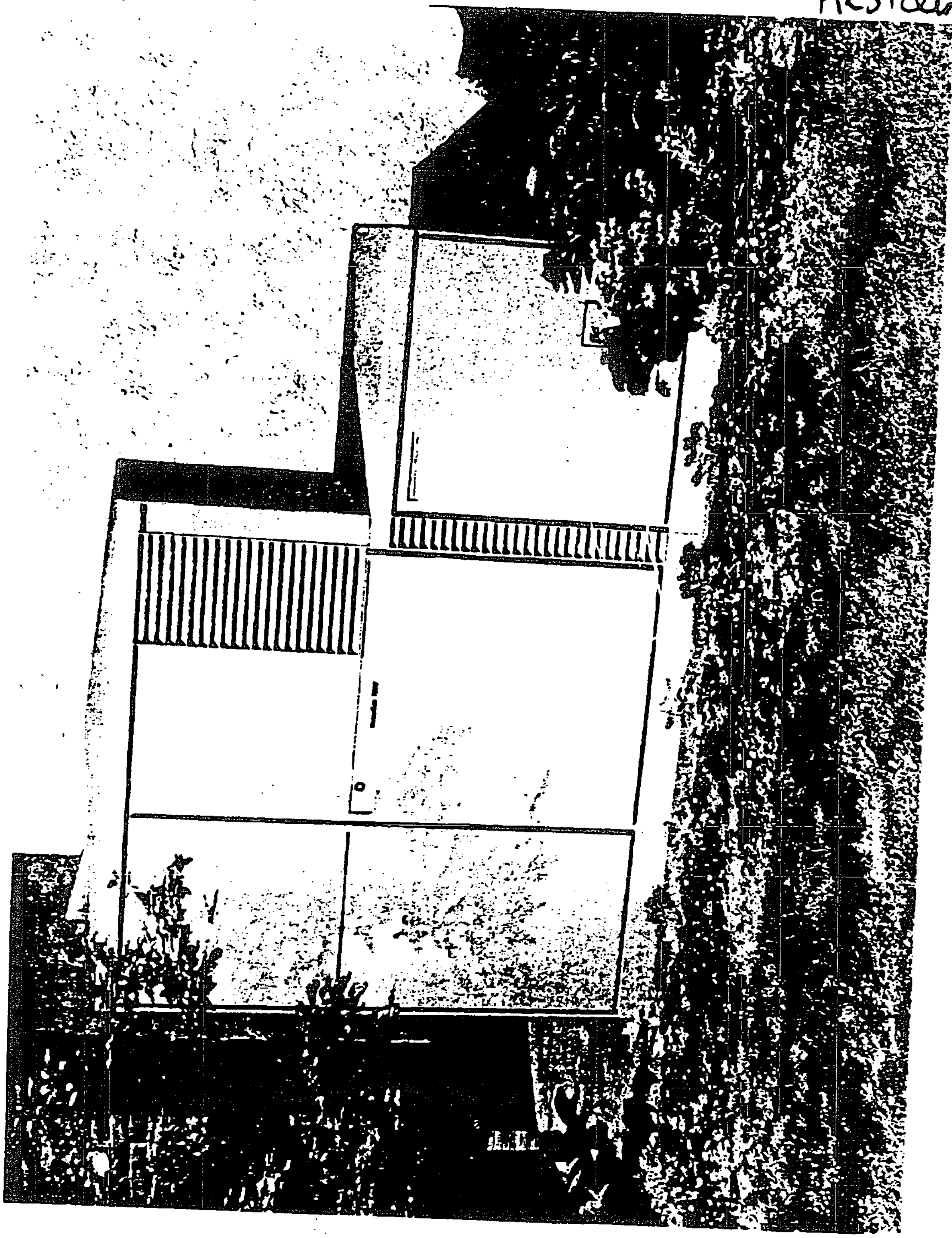
Department of Energy
Regional Support Offices
(RSO)



Biomass and Biofuels Resource Potential
Potential Kilowatts per County
greater than 40,000
5,000 - 40,000
0 - 5,000
NREL
Center for Renewable Energy Resources

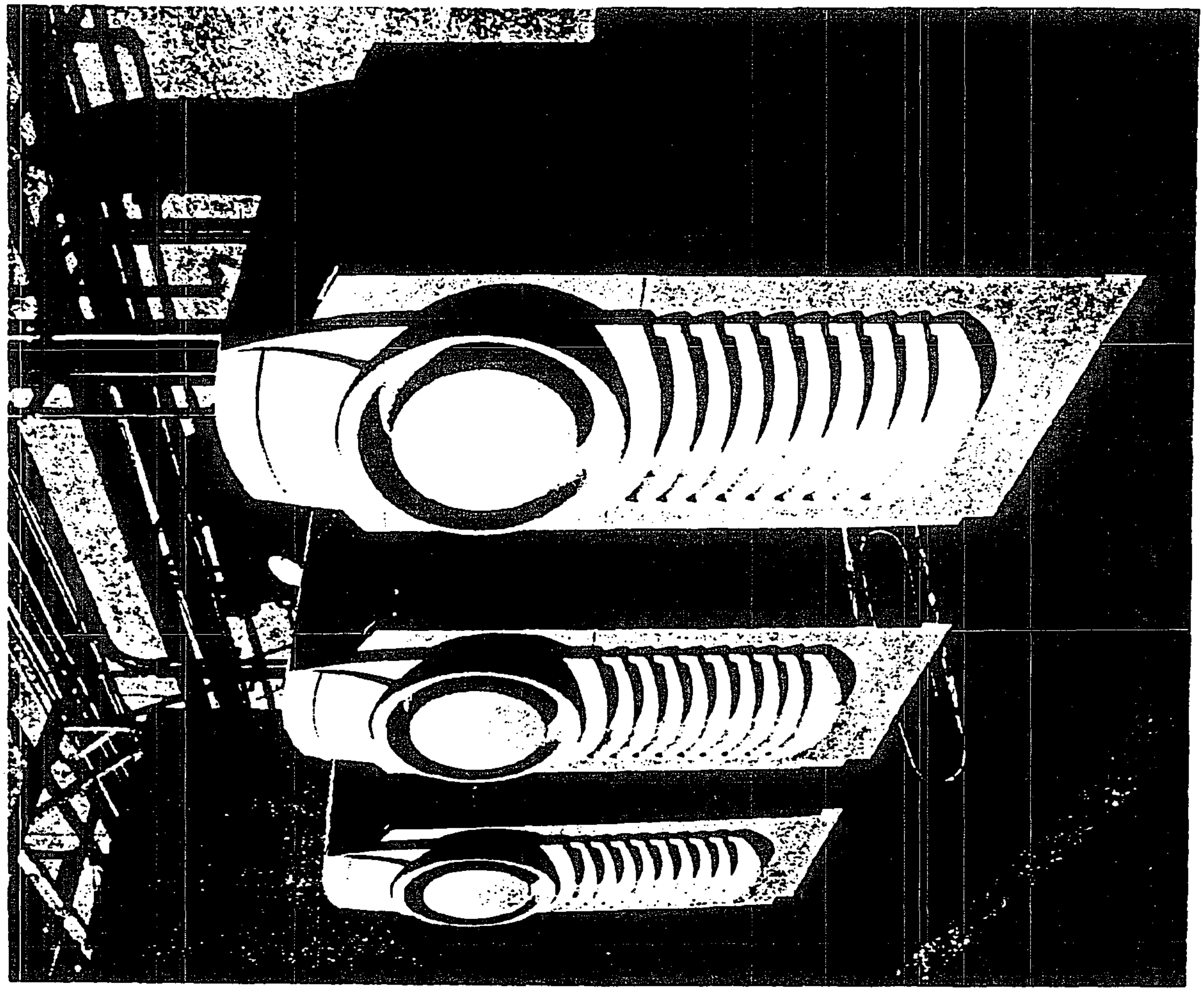
18333

Membrane Fuel Cell Installation, Residence



18334

DOE019-0301



18335

DOE019-0302

9

It's Time for a National Energy Policy Reality Check

A review of the current energy policy debate

from a taxpayer and consumer perspective

Prepared by

Glenn R. Schleede*

June 21, 2001

*Energy Market & Policy Analysis, Inc, Reston, VA 20195-1875; Phone 703 709-2213; Fax 703 709-2214; Email: EMPAInc@aol.com

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