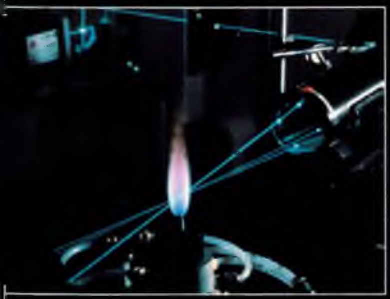
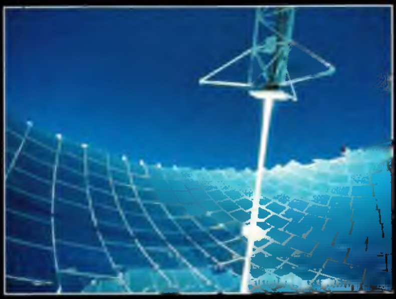
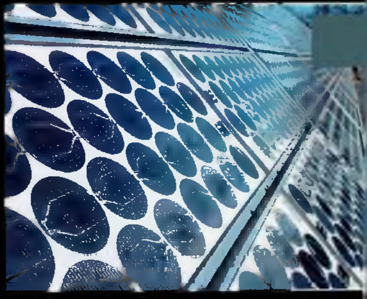
NATIONAL ENERGY STRATEGY

First Edition
1991/1992



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National Energy Strategy

Powerful Ideas for America

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Washington, D.C.
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National Energy Strategy

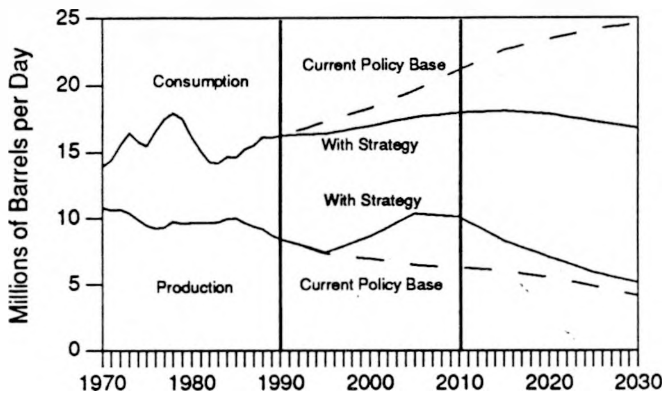
Errata

Page 119, the fifth approach in the Goals and Approaches table should read as follows:

- Extend the 10-percent investment tax credit for solar and geothermal

Page C–22, Figure C–21 should be replaced by the following graph:

Figure C–21. Oil Consumption and Production
National Energy Strategy Scenario



Executive Summary

A National Strategy: How We Expect to Produce and Use Energy in the Future

How We Expect To Produce and Use Energy in the Future

The National Energy Strategy lays the foundation for a more efficient, less vulnerable, and environmentally sustainable energy future. It defines international, commercial, regulatory, and technological policy tools that will substantially diversify U.S. sources of energy supplies and offer more flexibility and efficiency in the way energy is transformed and used. Specifically, it will spur more efficiency and competition throughout the energy sector, expand the fuel and technology choices available to the Nation, improve U.S. research and development (R&D), and support the international leadership the United States exercises in energy, economic, security, and environmental policy.

The objective of the National Energy Strategy, as established by President Bush in July 1989, is—

> achieving balance among our increasing need for energy at reasonable prices, our commitment to a safer, healthier environment, our determination to maintain an economy second to none, and our goal to reduce dependence by ourselves and our friends and allies on potentially unreliable energy suppliers.

The President directed that "a keystone of this strategy" be continuing the successful policy of market reliance. Wherever possible, markets should be allowed to determine prices, quantities, and technology choices. In specific instances where markets cannot or do not work efficiently, government action should be aimed at removing or overcoming barriers to efficient market operation.

The goals of a healthy environment and reduced dependence on insecure suppliers represent national security, foreign policy, and social benefits to which markets are unlikely to give adequate weight. Hence, government must act, alone or in concert with private markets, to incorporate appropriately these considerations. However, regulations and other government interventions are extremely blunt tools that always impose unforeseen costs by reducing the flexibility of the economy. Therefore, government intervention in markets must be justified by rigorous cost-benefit analysis and rely to the maximum possible extent on economic incentives to allow the economy to achieve our energy security and environmental goals at the lowest possible cost.

This is the framework we used to evaluate the proposals for this Strategy that were submitted by people and organizations all across the country. These submissions were essential to building a National Energy Strategy that fully addresses the energy challenges and opportunities before us.

The Strategy also builds upon a number of Bush Administration initiatives. These include the following: (1) the 1990 revisions to the Clean Air Act; (2) natural gas wellhead decontrol legislation in 1989; (3) incentives provided to domestic renewable and fossil energy producers in the fiscal year 1991 budget agreement; (4) the unprecedented international consensus forged in the wake of the Persian Gulf crisis; (5) the fiscal year 1991 and 1992 realignments of the Department of Energy's research and program priorities; (6) the Administration's domestic energy supply and demand measures adopted in response to the Iraqi oil disruption; and (7) the science and mathematics education initiatives by the Secretary of Energy.

Future energy use will be more efficient because of the market-driven use of new technology and because of ongoing public and private sector efforts to promote energy efficiency (for example, State efforts to promote integrated resource planning). We estimate that under current policies,[1] the

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1. The "Current Policy Base" case depicts a hypothetical energy future based on the very unlikely scenario of no change to, or a "frozen," current energy policy, including the effects of existing laws except for the Clean Air Act Amendments of 1990. Projected energy effects of these amendments are included in "With Strategy" results unless separately indicated. The purpose of the Current Policy Base case is not to forecast, but to provide a reference, something to measure from. A more detailed explanation of the Current Policy Base case is contained in Appendix C.

amount of energy used in the United States to create a unit of gross national product (GNP) will decrease by almost 12 percent in the year 2000 and slightly more than 20 percent in the year 2010 over today's energy-efficiency levels. This represents a savings of more than 13 quads[2] of energy in 2000 and almost 30 quads in 2010.

The challenge of the National Energy Strategy is twofold: (1) to reinforce these current policy measures to make sure that the progress we believe is probable is actually achieved; and (2) to accomplish even greater improvements in energy efficiency, in security, and in the reduction of energy environmental impacts than would be achieved by current policies alone. To meet these challenges, the Strategy calls for action by Federal, State, and local governments and by domestic and international energy producers and consumers. This National Energy Strategy provides a roadmap to a more secure and cleaner energy future through greater energy and economic efficiency and new technology.

Achieving Greater Energy Security

Much of the oil on which we and the rest of the world depend is produced in politically volatile regions of the globe. The oil fields of the Persian Gulf alone provide one-fourth of the oil the world presently consumes. They contain nearly two-thirds of the world's proved oil reserves.

For nearly 20 years, U.S. Administrations have sought to balance the economic benefits of using low-priced imported oil with the foreign policy risks and the security costs of ensuring oil's free flow. These two decades have shown that *sudden*, dramatic changes in world oil prices are far more harmful to the United States and other nations than a persistent but gradual rise in price—even if the *average* price over the long term in both sets of circumstances is identical. Popular opinion aside, our vulnerability to price shocks is not determined by how much oil we import. Our vulnerability to oil price shocks is more directly linked to: (1) how oil dependent our economy is; (2) our capacity for switching to alternative fuels; (3) reserve oil stocks around the world; and (4) the spare worldwide oil production capacity that can be quickly brought on line.

The contrasting experiences of Great Britain and Japan in 1980, after the Iranian revolution triggered an increase in oil prices to more than $40 per barrel, offer a classic example of how oil imports alone are an inadequate gauge of "oil vulnerability." Great Britain was almost totally self-sufficient in oil, but it suffered economically *more* from the oil-price shock than most countries.[3] Japan, which did (and still does) import *all* the oil it uses, experienced only a slowing of its economic growth to a very respectable 3.4 percent from 5.3 percent before the shock.

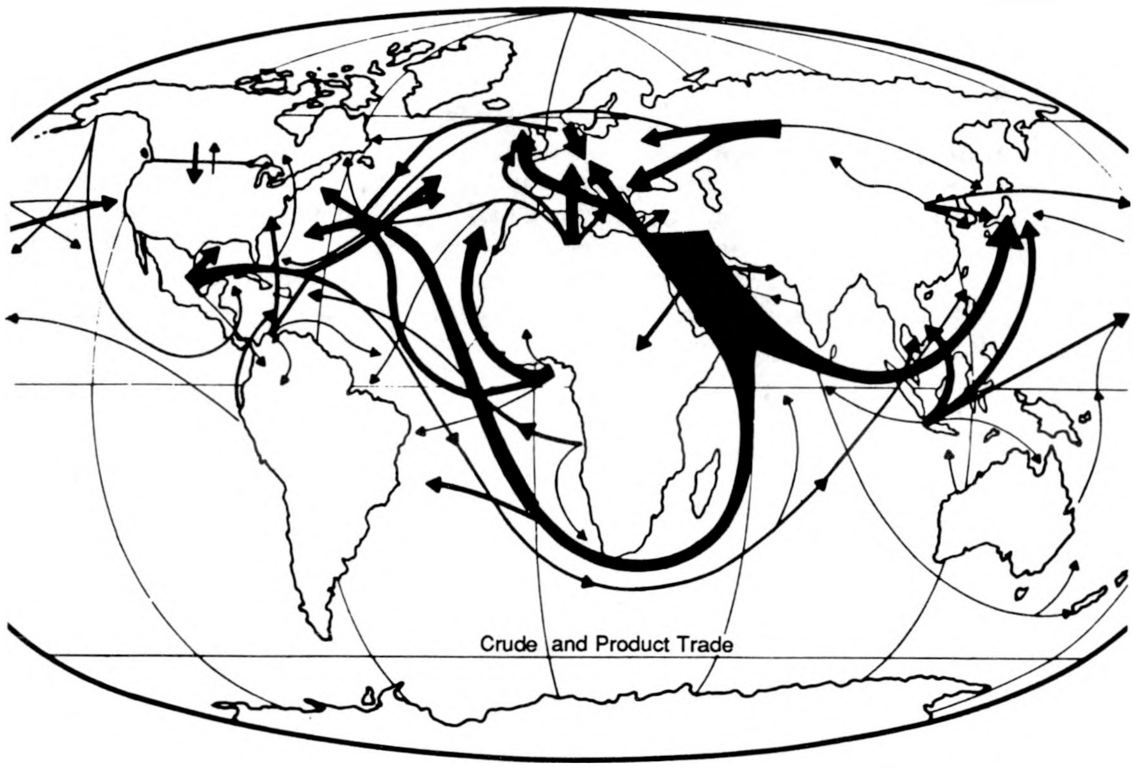
In short, as Figure 1 illustrates, we are part of a complex and *inter*dependent world oil and refined-petroleum products market. Products flow to where the demand is greatest, as reflected by the highest price. Any increase in the world price of oil, brought about by any event, in any place, would raise the price of U.S. oil and the price of oil to our allies and trading partners, regardless of the degree of our import dependence. Recognizing our energy *inter*dependence allows us to focus our efforts on those things that will enhance global energy security and, by so doing, enhance America's security.

The National Energy Strategy review confirmed that no feasible combination of domestic or international energy policy options can make us completely invulnerable to oil supply disruptions during the foreseeable future. Indeed, it revealed that our Nation and the world are likely to depend *more* on Middle East oil suppliers under any realistic scenario for the foreseeable future. Nevertheless, if fully implemented, the National Energy Strategy *will* make our country less prone to economic damage from violent fluctuations in either the supply or the price of petroleum.

2. A "quad" (1 quadrillion British thermal units, or Btu) is a standard unit used in comparing large amounts of energy derived from diverse sources, or used in differing applications—based on converting the respective total energy contents into heat equivalents. For example, 1 quad is roughly equal to the energy contained in the oil that would be used in 1 year if daily consumption were 500,000 barrels.

3. British GNP growth moved from +2.4 percent prior to the shock to -2.0 percent after the shock.

Figure 1. World Petroleum Market
Complex and Interdependent



Source: U.S. Department of Energy

No single policy tool can substantially increase America's energy security. The basic vulnerability involves oil, but reducing this vulnerability requires a broad array of actions: maintaining adequate strategic reserves; increasing the efficiency of our entire fleet of cars, trucks, trains, planes, and buses; increasing U.S. petroleum production in an environmentally sensitive manner; further deregulation of the natural gas industry; and using alternative transportation fuels.

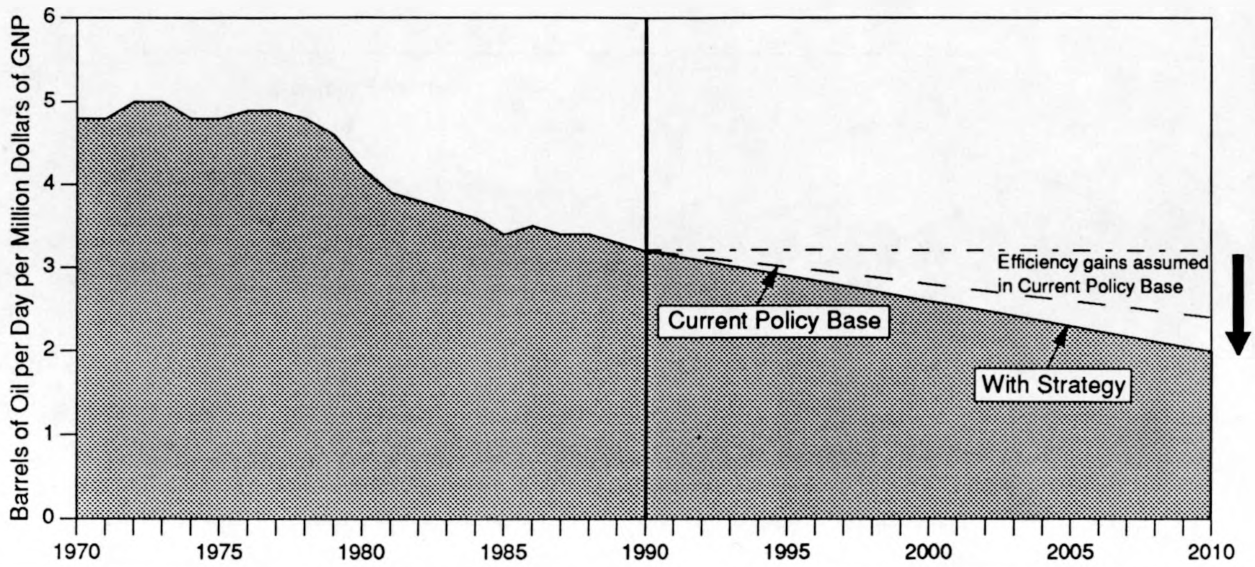
Since our vulnerability cannot be completely eliminated, it is not in our interest to adopt measures that reduce imports but impose high economic or environmental costs. Policy measures should be chosen that balance economic, environmental, and energy security objectives.

The National Energy Strategy aims to diversify the sources of oil supply *outside* the Persian Gulf by encouraging environmentally sensitive production in the United States (including certain areas of the Outer Continental Shelf (OCS) and the Arctic National Wildlife Refuge (ANWR)), other parts of the Western Hemisphere, Europe, and Asia and to further develop and maintain contingency mechanisms (including strategic oil reserves and stocks) and excess world production capacity.

Simultaneously, as Figure 2 illustrates, the National Energy Strategy would reduce the importance of oil to the U.S. economy—through conservation, efficiency improvements, and oil displacement by the use of improved technologies and alternative fuels.

National Energy Strategy initiatives are expected to decrease U.S. oil consumption by 1.3 million barrels per day below projected year-2000 levels and by 3.4 million barrels per day below projections for the year 2010—largely because of

Figure 2. Reduced Exposure to Oil Price Shocks



displacement of oil by alternative fuels in vehicles. As alternative fuels (compressed natural gas, electricity, and alcohol from natural gas, biomass, and coal) and the technologies to use them become more cost-competitive, they will become available across the country to a large and growing fleet of fuel-flexible and dedicated alternative-fuel vehicles and gradually erode petroleum's dominant role in the transportation sector. The effects of these initiatives on total U.S. oil consumption is shown in Figure 3.[4]

As shown in Figure 4, the Department of Energy estimates that Strategy initiatives could increase domestic oil production by 1.8 million barrels per day above the levels projected for the year 2000—largely because of the use of advanced oil recovery technology made possible by new investments in Federal and private-sector R&D, and by environmentally responsible development of promising areas like ANWR and OCS. By 2010, domestic oil production could be augmented by 3.8 million barrels per day.

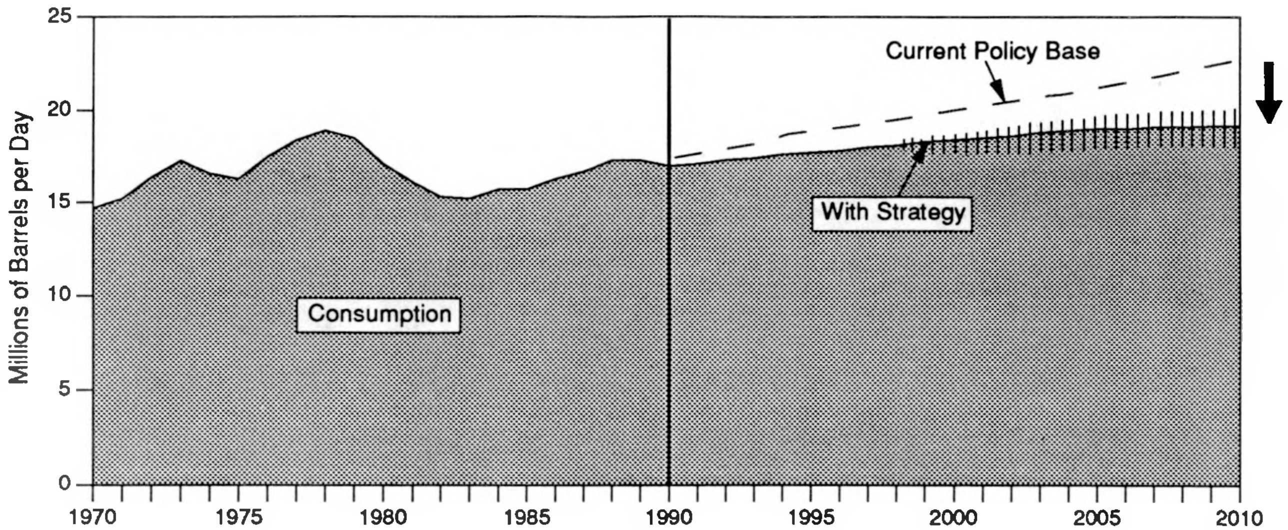
As Figures 3 and 4 illustrate, the National Energy Strategy embodies a sustainable, *balanced* approach to increasing supply and reducing demand. This first National Energy Strategy will be adjusted over time as technologies, markets, and knowledge change.

The Strategy is not specifically targeted at the problems of the moment. With regard to the short term, the Strategy builds upon a decade of energy market deregulation that has allowed the rapid and appropriate market response to the Iraqi crisis. In addition, the Strategic Petroleum Reserve, used as part of a coordinated international response, has demonstrated its capability to effectively address shortrun oil market disruptions.

Some will suggest that this progress in enhancing our energy security is not enough, that we should embark on measures such as oil import fees; large taxes on gasoline; subsidies for the production of liquid fuels from coal, shale, and natural gas; broadly mandated use of alternative transportation fuels; and sharply higher fuel-efficiency standards that would compel the use of smaller, possibly less safe, cars. These and other similar measures were *all* carefully examined in the development of the National Energy Strategy. Oil imports could be reduced substantially, depending on the level, type, and phase-in of subsidy, taxation, or mandate. But the cost would be very high—in higher prices to American consumers, lost

4. This and following Strategy charts reflect the inherent uncertainty of projecting future impacts.

Figure 3. Effects of the National Energy Strategy on U.S. Oil Consumption



jobs, and less competitive U.S. industries. Moreover, as the experience of Great Britain in 1979 pointed out, these tax, subsidy, and mandate measures would *not* necessarily shield the U.S. economy from the effects of future world oil market disruptions, not even if the United States were to eliminate virtually all oil imports. The economic impacts depend more on *price*, as set by the world market, than on the level of our imports.

What does the Strategy offer instead? A balanced program of greater energy efficiency, use of alternative fuels, and the environmentally responsible development of all U.S. energy resources.

Increasing Energy and Economic Efficiency

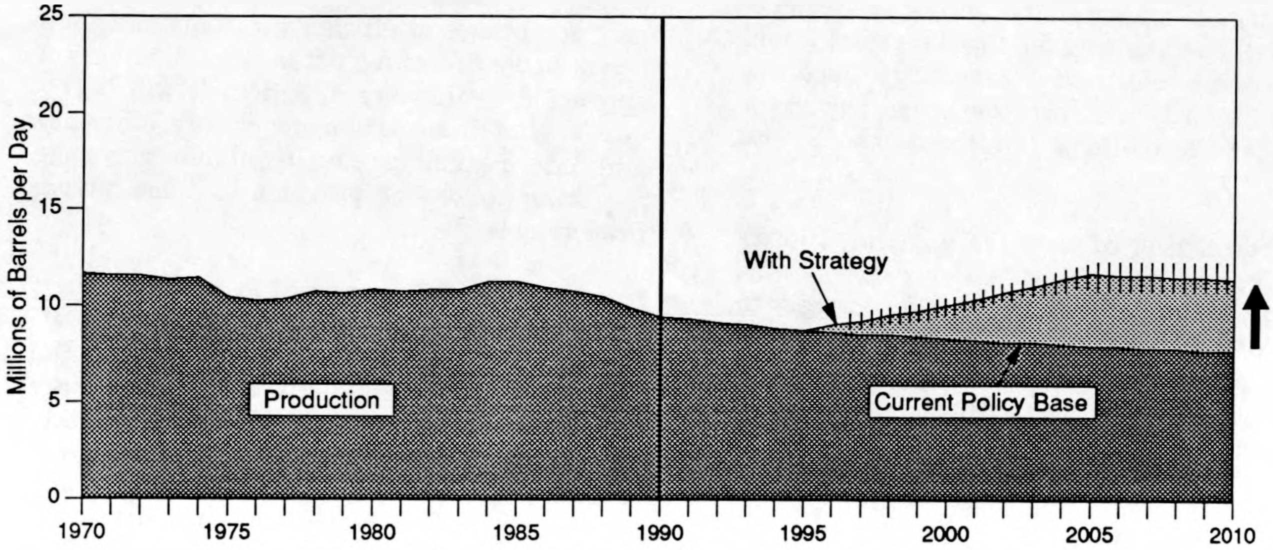
This National Energy Strategy reflects a National commitment to greater efficiency in every element of energy production and use. Greater energy efficiency can reduce energy costs to consumers, enhance environmental quality, maintain and enhance our standard of living, increase our freedom and energy security, and promote a strong economy. A common feature of every new technology supported in this National Energy Strategy is its potential to more efficiently transform energy raw materials into the energy services we need. Under this heading are the National Energy Strategy initiatives designed to increase the efficiency with which we use energy, in the generation and use of electricity, in our residences and offices, in the industrial sector, and in transportation.

Increasing Efficiency in Electricity Generation and Use

The United States is becoming increasingly electrified. By 2010, we project that 41 percent of our primary energy will be consumed in electricity generation, up from 36 percent today. Accordingly, it is extremely important that we produce, distribute, and consume electricity as efficiently and as cleanly as possible.

About 700,000 megawatts (MW) of electric generating capacity is now installed in the United States. For most of this century, U.S. electricity demand has increased at roughly the same rate as GNP. Even with aggressive conservation and efficiency efforts, and assuming that the existing 700,000 MW is maintained through refurbishment and replacement, we will need about 200,000 MW *more than the present total* to meet the electricity requirements of a growing U.S. economy in 2010.

Figure 4. Effects of the National Energy Strategy on U.S. Oil Production



The Federal-State regulatory regime that governs investment decisions in electricity supply and demand will profoundly influence the types of new capacity to be built, who will build it, what technology and fuels are used, and what the full consumer and environmental consequences will be.

These new capacity decisions are further complicated by the difficulty in finding sites for new generating and transmission facilities of *any* kind in many parts of the country. Moreover, outmoded legislation (some from half a century ago) unnecessarily prevents some of the most able builders and operators of electric powerplants from engaging in the wholesale electricity generation business.

Specifically in the electricity area, the National Energy Strategy will:

- **Amend the Public Utility Holding Company Act of 1935 (PUHCA).** Reform would allow builders of powerplants to build, own, and operate powerplants in more than one area, while ensuring continued protection of consumer interests.

- **Expand Integrated Resource Planning (IRP).** IRP is a process for meeting consumer electricity needs by demand reduction or supply addition, whichever is most cost-effective. The existing IRP Program at the Department of Energy will be expanded to provide more accurate and timely information and analytical tools to consumers, utilities, and State commissions. In addition, the Department will promote IRP by the Federal power marketing administrations (PMA's), and work with the Federal Energy Regulatory Commission (FERC) to foster IRP through FERC's regulation of wholesale power markets.

- **Provide Tax-Free Treatment of Utility Efficiency Discounts.** The Internal Revenue Service will treat as exempt from Federal taxation utility bill discounts that electricity consumers receive for investments they make in energy efficiency.

- **Reduce Federal Subsidies for PMA Electricity.** Require Federal power marketing administrations to sell power at rates that will cover Government costs. Not only will electricity conservation be enhanced, but Federal receipts will increase with minimum impact on PMA rates.

- **Expand Access to Electricity Transmission for Wholesale Buyers and Sellers.** Existing policies and programs under the Federal Power Act will be reviewed to ensure that transmission services and facilities are adequate for the emerging competitive generation market. Expansion of transmission access and promotion of efficient pricing for these services would use existing electricity generation facilities most efficiently and provide lower electricity prices for the Nation's industries, shops, and homes.

- **Improve Siting of New Generating Plants and Transmission Lines.** Joint efforts with State and regional authorities are necessary to develop mechanisms to promote the timely, efficient siting of electricity generation and transmission facilities without jeopardizing public participation and environmental protection.

Increasing Residential and Commercial Energy Efficiency

In residential and commercial buildings, the National Energy Strategy seeks to maintain or enhance comfort, indoor air quality, and affordability, while reducing energy use. The National Energy Strategy proposes the following actions:

- **Expand Research and Development.** The Department of Energy is significantly expanding its support for R&D on a wide range of more energy-efficient building technologies. Working together with private industry, universities, and other organizations, the Department will continue its efforts to accelerate the development and use of such technologies.

- **Continue Support of State and Utility Programs.** The Department of Energy and other Federal agencies will continue to provide assistance to States and utilities in their efforts to improve energy efficiency in residential and commercial buildings. These efforts include the weatherization of homes occupied by low-income households, the retrofit of institutional buildings, incentives for the purchase of energy-efficient appliances, and a wide range of consumer information programs.

- **Expand Use of Mortgage Financing Incentives for Residential Energy Efficiency.** To encourage the more widespread use of mortgage financing for energy efficiency, the Departments of Energy and of Housing and Urban Development will increase financial and technical support to develop and encourage the voluntary acceptance of efficiency ratings and their use in home financing. After at least 5 years of support for voluntary adoption, it will be required that information on energy efficiency and information on the available mortgage financing options be provided to home buyers prior to sale.

- **Improve the Efficiency of Public Housing.** The Department of Housing and Urban Development, with technical support from the Department of Energy, will establish energy indicators to identify public housing projects where significant savings can be achieved, develop innovative incentives for managers and tenants to use energy more efficiently, and more thoroughly monitor and evaluate the savings from significant energy-related investments.

- **Set Cost-Effective Appliance and Equipment Standards and Provide Information to Consumers Through a Labeling Program.** The Department of Energy has established efficiency labeling and standards for 13 categories of residential appliances and for fluorescent lighting system ballasts. The Administration will support legislation to require energy-efficiency labeling for certain other types of equipment, including light bulbs.

- **Develop and Encourage Use of Building Efficiency Standards.** The Administration will strengthen building energy-efficiency standards by providing technical assistance to State and local governments to promulgate and implement these standards. All new buildings subsidized by Federal funds or federally insured mortgages will be required to meet cost-effective energy-efficiency standards, which, at a minimum, are equivalent to the standards or codes currently recognized by major national organizations.

- **Improve Federal Energy Efficiency.** The Administration will issue and implement an Executive order directing Federal agencies to continue and strengthen their efforts to improve the efficiency and management of energy use in Federal buildings and other facilities.

Increasing Industrial Energy Efficiency

The National Energy Strategy seeks to improve energy efficiency and flexibility in the industrial sector, thereby reducing petroleum use and overall production costs. Industrial waste generation is targeted through support of increased waste recycling and measures to increase our ability to use wastes as feedstocks.

The National Energy Strategy proposes the following actions:

- **Increase Funding for Industrial Process Efficiency Research and Development.** Funding for cost-shared R&D projects to improve industrial energy efficiency and productivity will be increased. These efforts will concentrate on major energy-using industries and processes.

- **Minimize Industrial Waste.** Industrial R&D funding will be increased to sponsor cost-shared projects with industry to minimize industrial wastes. Reducing the generation of wastes and using wastes as feedstocks improve the competitiveness of industry and reduce the consumption of oil. In addition, improved energy and material efficiency reduces the cost of pollution control. Process innovations, modification of feedstocks and products, and recycling promise substantial payoffs.

- **Expand and Develop Energy Audits.** States and utilities will be encouraged to expand or develop programs to speed up adoption and use of existing improved energy-using technologies. Many cost-effective opportunities to reduce industrial use of energy currently exist. Audits of manufacturing plants can identify opportunities to improve efficiency. Current industrial energy use audit programs are being expanded.

- **Examine Regulatory Policy.** Federal regulatory programs will be examined in cooperation with the Environmental Protection Agency to ensure that the use of waste minimization technologies is encouraged. New legislation or modification of regulations will be proposed where needed.

Increasing Transportation Energy Efficiency

The National Energy Strategy seeks to reduce the amount of energy we use to move people and goods by improving the efficiency of *all* the vehicles on the road, and by increasing the overall efficiency of the transportation system itself.

Specifically, the National Energy Strategy will:

- **Expand Efforts To Develop Advanced Technologies.** Advanced transportation technologies—including gas turbines, electric vehicles, fuel cells, and low-heat rejection diesel engines in the mid-term, and intelligent vehicle-highway systems, magnetic-levitation and other high-speed trains, and advanced air traffic control systems in the long-term—can save significant energy in the transportation sector.

- **Accelerate Scrappage of Older Cars.** Older vehicles have higher emissions and, generally, lower fuel economy than new cars. This initiative will promote State and local government and private-sector programs that offer a "bounty" for older cars of a designated model year. Implementation of the Clean Air Act Amendments of 1990 will provide the opportunity to encourage State and local governments and the private sector to establish such programs.

- **Evaluate Corporate Average Fuel Economy (CAFE) Program.** A comprehensive analysis of feasible fuel economy levels, considering safety, technology, economics, and the impacts of the new Clean Air Act Amendments and other recent regulatory requirements will be undertaken. Should these studies warrant them, changes to the current standards will be considered, including the following: providing credit trading and averaging among manufacturers; eliminating distinctions between import and domestic vehicles; revising noncompliance penalties; and establishing alternative forms of corporate average fuel economy standards (for example, standards based on vehicle size). These changes may permit cost-effective improvements in vehicle fuel economy without compromising highway safety.

- **Improve Consumer Information on Fuel Economy and System Efficiency.** Additional efforts will be undertaken to increase the distribution of the Gas Mileage Guide, encouraging Americans to "drive smart" and adopt more energy-efficient driving and commuting habits. A year-long advertising campaign will inform the public about simple, common-sense measures that can help reduce oil use. The cooperative efforts with private foundations and educational institutions will be expanded to promote greater awareness of energy-efficiency opportunities.

- **Promote Mass Transit and Ride Sharing.** A series of measures will be implemented to encourage increased use of carpools, vanpools, and mass transit. These measures will include the ability of employers to provide increased tax-free transit subsidies, increased availability of high-occupancy vehicle right-of-way, and improved public transportation services.

Securing Future Energy Supplies

Oil

For the foreseeable future, oil will remain a critical fuel for the United States and all other industrialized nations. In addition to the measures previously discussed that will make the U.S. economy less dependent on oil, the National Energy Strategy proposes initiatives to (1) reduce the economic consequences of disruptions in world oil markets, and (2) increase domestic oil and petroleum product supplies.

Measures To Reduce Impact of Oil Market Disruptions

- **Increase Oil Production in Countries Outside the Persian Gulf.** Barriers to investment in petroleum development will be addressed on a priority basis, thereby increasing and diversifying world production capacity.

- **Improve Emergency Preparedness.** Expand the Strategic Petroleum Reserve (SPR) to 1 billion barrels, and test Gulf Coast refined-product reserves.

- **Diversify Transportation Fuels.** To reduce the dependence of the transportation sector on oil, the Strategy will (1) remove the limit on CAFE credits that can be earned by manufacturing vehicles capable of operating on alternative fuels, (2) accelerate the purchase of alternative-fuel vehicles for the Federal fleet, and (3) require the use of alternative fuels in car, truck, and bus fleets. These measures will complement aggressive R&D efforts to improve the technologies for the production and use of alternative fuels.

Measures To Increase Domestic Production

- **Open Access to Environmentally Responsible Development of the Coastal Plain of the Arctic National Wildlife Refuge and to Certain Offshore Areas.** ANWR and offshore areas are potentially major sources of domestic oil and gas production, both now and for the future.

- **Facilitate Environmentally Responsible Development of New Alaskan North Slope Resources.** Five major discovered fields on the Alaskan North Slope are undeveloped. These fields could add an estimated 1 billion barrels of recoverable oil and condensate to domestic oil production over the next several decades.

- **Lease Elk Hills Reserve.** Operation of the producing Elk Hills Reserve field by market-driven private companies will lead to increased oil and natural gas production at lower costs.

- **Deregulate Oil Pipelines.** Eliminating oil pipeline regulation, except for pipelines not subject to competition, will reduce consumer costs and encourage the most efficient use of the oil pipeline system.

- **Implement Oil and Gas Tax Incentives.** The oil and natural gas tax measures enacted in 1990 as part of the budget reconciliation legislation[5] will raise production by about 400,000 barrels per day oil equivalent by the year 2000.

- **Promote Horizontal Well Drilling.** Increased levels of domestic production will be encouraged by removing State regulatory barriers to horizontal drilling and by facilitating transfer of horizontal drilling technology.

- **Increase Production of California Heavy Oil.** Lack of demand in the United States for California heavy oil and the existing prohibition against export of this oil are inhibiting California heavy oil production. Access to export markets would increase California heavy oil production, further diversifying world oil production and providing capital for investment in additional domestic production.

- **Evaluate Effects of Environmental Regulations on Domestic Refining Capacity.** The Department of Energy has commissioned the National Petroleum Council to conduct a two-phase study. The first phase will produce a report by June 1991 that will address the capabilities of the U.S. refining industry to meet consumer needs, considering especially the requirements of the Clean Air Act Amendments of 1990. The second phase, to be completed in 1992, will provide analysis of the time and investments necessary to meet new environmental regulations, and their effects on petroleum product supply and prices.

Natural Gas

Natural gas is a domestically abundant source of clean energy. All price controls on natural gas at the wellhead will be eliminated by January 1993, under the Wellhead Decontrol Act of 1989. The natural gas industry, however, continues to be hampered by inefficient and outmoded regulation. This regulation, initially designed to protect the consumer, frequently has the opposite impact.

The National Energy Strategy will remove regulation, except where necessary to protect consumers, while enabling all segments of the industry to expand by taking advantage of market opportunities. If fully implemented, the National Energy Strategy measures would increase U.S. consumption of natural gas by almost 1 trillion cubic feet (approximately 5 percent) over what it would have been in the year 2000 under pre-Strategy policies.

Specifically, the National Energy Strategy will:

- **Expedite Gas Pipeline Construction.** New natural gas pipelines could be built under several options, including shortening or eliminating the process for obtaining a certificate of public convenience and necessity from FERC. Pipelines constructed under this approach would still have to comply with all applicable State and Federal environmental laws, but would not be subjected to delay by competitors.

- **Streamline the National Environmental Policy Act Process Associated With Natural Gas Pipeline Construction.** FERC would be the sole agency responsible for administering National Environmental Policy Act (NEPA) environmental reviews of proposals to build new natural gas pipelines. FERC would still be required to consult and solicit comments from other agencies, but other agencies would not be allowed to delay the approval process by failing to meet deadlines or by preparing independent NEPA documents.

- **Deregulate Pipeline Sales Rates.** Unless a pipeline is found to have market power in the sale of natural gas, the price at which a pipeline sells natural gas would be deregulated if the pipeline provides comparable transportation and other services to all customers, regardless of whether they are purchasing gas from the pipeline or from other sources.

- **Reform Natural Gas Pipeline Rate Design.** The traditional pricing structure for pipeline services would be reformed to ensure that existing pipeline and storage facilities are operated efficiently. Rate reform initiatives would include exempting natural gas pipelines from rate regulation except for pipelines found to have market power in their transportation

5. The measures are a tax credit for enhanced oil recovery, a 2-year extension of the section 29 credit, modifications to the percentage depletion rules, and alternative minimum tax relief for independent producers.

function, promoting incentive regulation for pipelines found to have market power in their transportation functions, authorizing capacity holders to resell capacity rights, and allowing greater pricing and contracting flexibility for new pipelines.

- **Improve Access to Natural Gas Pipeline Transportation Services.** Remaining impediments to third-party use of pipeline facilities on an open-access basis would be removed by promoting the use of pricing mechanisms rather than government rules to balance supply and demand. Efficient pricing would be facilitated by unbundling transportation, marketing, gas purchasing, and storage services. Transportation services should be offered to those purchasing gas from other suppliers comparable to those provided by the pipeline when it is the seller of gas.

- **Eliminate the Department of Energy's Import and Export Regulation.** The Department of Energy would end its regulatory oversight of natural gas import and export transactions.

- **Encourage the Use of Natural Gas as an Alternative Transportation Fuel.** Through accelerated purchases of alternative-fuel vehicles for the Federal fleet and through a nationwide private-fleet alternative-fuel program, the National Energy Strategy will expand market opportunities for natural gas as a transportation fuel.

Coal

If we as a nation are to benefit in the future from our enormous, low-cost coal reserves, a variety of efforts are necessary to (1) develop and demonstrate new "clean coal" technologies; (2) reduce uncertainty over environmental regulation and allow electric powerplants (which use more than four-fifths of all the coal consumed in the United States) maximum flexibility in their actions to comply with the Clean Air Act Amendments of 1990; (3) provide regulatory incentives to offset financial risks in commercial deployment of new clean coal technology; (4) reduce the cost, investment risks, and environmental impacts of producing liquid fuels from coal; and (5) confront head-on the need to reduce carbon dioxide emissions associated with the use of coal.

New clean coal technologies can substantially improve efficiency and reduce emissions from powerplants. Until they are proven at commercial scale, however, their use entails more risk for utilities than conventional technologies. This additional risk could make it difficult for these new technologies to enter the marketplace quickly, especially given the tight deadlines of the Clean Air Act Amendments of 1990. The Clean Coal Technology Program, the single largest technology development program in the Department of Energy, is designed to help overcome this risk by offering the Federal Government as a financial partner in demonstrating worthy projects.

By promoting the export of clean coal technologies, the National Energy Strategy will also help other nations (especially in Eastern Europe and the developing world) to achieve common goals: a cleaner environment and less dependence on oil.

Specifically, the National Energy Strategy will:

- **Accelerate Use of Clean Coal Technology.** The Administration will encourage State regulatory authorities to act in concert with appropriate Federal agencies and provide regulatory incentives for utilities to invest in projects using innovative clean coal technologies. The object of the regulatory incentives would be to offset the additional risks associated with investment in technologies that are not fully proven on a commercial scale.

- **Clarify Applicability of the Clean Air Act's Prevention of Significant Deterioration (PSD) and "New Source Review" Provisions to Existing Powerplants.** Current PSD and new-source-review policy discourages certain types of maintenance, repair, and fuel-switching activities by deeming these actions to be "modifications," thus subjecting an existing powerplant that undertakes such an activity to stringent "new source" and PSD requirements. This policy will be altered by Environmental Protection Agency administrative action (and, if necessary, by new legislation) to clarify what changes in plant equipment or operation should trigger PSD and new source review.

- **Create Favorable Export Climate for U.S. Coal and Coal Technology.** To improve the climate for coal-related exports, the National Energy Strategy will improve the visibility of U.S. firms and their products by establishing an information clearinghouse and closer liaison with U.S. representatives in other countries. Interagency coordination of Federal programs pertinent to these exports will be strengthened. Current programs and policies for facilitating the financing of coal-related projects abroad will be reviewed and improved.

- **Remove Barriers to Construction of Coal Slurry Pipelines.** Coal slurry pipelines, using a mixture of water and coal, can compete effectively with railroads and barges as a low-cost way to transport coal, but proposed pipelines must obtain rights-of-way to cross competing railroad lines. They also raise water use concerns in areas where water is scarce. The Administration supports legislation to grant Federal eminent domain to applicants that have satisfied regional and State water use concerns.

Nuclear Power

Nuclear power can cleanly and safely meet a substantial portion of the additional base-load electricity generating capacity the United States will require by 2030 if (1) the operating lifetimes of existing nuclear plants are extended (where this can be done safely with appropriate Federal oversight and technical support), and (2) utility executives once again consider the "nuclear option" technically, politically, and economically feasible when new capacity is planned.

The State-Federal impasse on construction of a high-level nuclear waste repository, an impossibly cumbersome nuclear licensing process, and the loss of full public confidence in our ability to manage civilian nuclear power technology have all contributed to the hiatus in the construction of new nuclear capacity. The National Energy Strategy proposes a number of measures to address these issues that would, if implemented, increase nuclear power generation in 2010 by almost 10 percent and in 2020 by more than double that in the Current Policy Base case projection.

Specifically, the National Energy Strategy will:

- **Reform the Nuclear Power Licensing Process.** The licensing process for new nuclear powerplants must be reformed by legislation to provide for early resolution of technical and institutional issues such as emergency planning prior to construction. The duration of and uncertainty associated with the postconstruction hearing must be reduced while improving the public's opportunity to address valid safety questions during the licensing process. The Administration also supports renewing the licenses of existing nuclear plants, where this can be done safely.

- **Manage Properly and Dispose of High-Level Nuclear Waste.** All Federal agencies must fully support the Department of Energy's efforts under current law to site and license a permanent waste repository and a monitored retrievable storage facility. Federal agencies also must assist the Nuclear Waste Negotiator's efforts to identify potential hosts for these facilities. In addition, Federal legislation should be enacted that, while preserving existing due-process and regulatory requirements, will ensure that the Nation's need for facilities to isolate high-level waste is met in a timely manner. Finally, the Department of Energy will consider alternatives to current Federal management of the high-level radioactive waste program, including management by a federally chartered, independent corporation.

- **Develop New, Passively Safe Designs.** The Department of Energy is working toward Nuclear Regulatory Commission certification for two "next generation" light-water reactors (with simplified designs and better engineered safety systems) and two more advanced light-water reactors (incorporating the concept of "passive safety") by 1995. The Department also will continue R&D on other advanced nuclear systems that show promise.

Standard reactor designs, combined with licensing reform and improved construction management, could reduce the cost of nuclear-generated electricity by as much as one-third. *Without* successful implementation of the Strategy initiatives, the contribution of nuclear power to our electricity supply could decline substantially after 2010. *With* the Strategy initiatives, nuclear power could be generating, safely and cleanly, at least 21 percent of our total electricity needs by the year 2030.

Renewable Resources

Public comment received during development of the National Energy Strategy revealed virtually unanimous support for the development and use of renewable energy resources because of their environmental and energy security advantages. As a result of this overwhelming interest and support, extensive analytical efforts have been made to better understand the potential of each renewable energy resource and the barriers—technological, marketplace, or otherwise—that might block renewable energy resources from achieving their full potential.

This analysis leads to several important conclusions. First of all, renewables can play a larger role in meeting our energy needs. The fraction of our energy supplied by renewables has been increasing, and that increase is projected to continue. Second, we can accelerate the growth in renewable supplies over the next 40 years without resorting to permanent subsidies or mandates. This is because several renewable technologies are on the verge of successful commercialization into the mainstream energy marketplace. These technologies have experienced significant technical progress over the past 10 years. Their commercialization does not require scientific breakthroughs. What is needed is the opportunity to translate R&D progress to practice, removal of market barriers to renewables, and continued, *focused* R&D to realize the full potential of these technologies.

Adding renewable technologies to the menu of available energy choices can contribute to a growing economy—domestically, by spurring competition and innovation, and internationally, by contributing to the balance of trade through the export of new products and technologies. Renewable technologies represent an important opportunity, but not a panacea for the U.S. energy economy. Their long-term contribution is predicated on overcoming remaining technical and cost barriers, mainly through intensified R&D.

The National Energy Strategy's renewable energy initiatives are based on these conclusions and on a clear understanding of the contributions that renewable energy can and cannot be expected to make. For example, given policies to address existing regulatory barriers and market imperfections, solar thermal or photovoltaic electricity technologies can compete today to provide electricity generation in remote locations and for peaking purposes. In addition, wind, geothermal, and biomass energy systems already can make limited contributions to meeting base and intermediate electrical loads. However, additional technical progress is needed to reduce the costs and enhance the competitiveness of renewable electric options, particularly for base-load applications.

Finally, the National Energy Strategy is based on the premise that for renewables, as for other emerging technologies, investment in R&D to increase technology performance and reduce costs is a more appropriate role for the Federal Government than is using taxes or regulations to subsidize or mandate the use of particular technologies.

Specifically, the National Energy Strategy will support renewable energy electricity and transportation fuel technologies through eight measures:

Electricity

- **Extend Investment Tax Credits for Emerging Renewable Technologies.** The investment tax credit for renewable energy technologies will be extended through 1992.

- **Amend PURPA To Extend Benefits to Larger Renewable Facilities.** The Public Utility Regulatory Policies Act of 1978 (PURPA) should be amended to remove permanently the qualifying size limit imposed on small power producers, but only in States that use competitive procurement programs for new electricity generating facilities.

- **Expand Efforts To Develop Advanced Renewable Technologies.** R&D programs for renewable energy technologies will be expanded in partnership with industry, utilities, and States to improve performance and lower costs.

- **Amend PURPA To Allow More Flexibility in Renewable Plant Design.** In addition to legislative removal of the size cap, PURPA should be amended to ease its restrictions on the percentage mix of renewable resources and other fuels qualifying small power producers are allowed to use, but only in States that use competitive procurement programs for new electricity generating facilities.

- **Reform Hydropower Regulation.** FERC should be designated as the sole decision-making agency for non-Federal projects at existing dams while ensuring the disciplined, nonduplicative participation of State and other Federal agencies. FERC should not regulate small hydro projects (up to 5 MW). These actions are intended primarily to replace outdated equipment, facilitate relicensing, and promote construction of additional capacity at *existing* hydroelectric facilities.

- **Convert Municipal Solid Waste to Energy.** The Department of Energy will work with the Environmental Protection Agency, States, local jurisdictions, and industry to collect and disseminate information and to conduct research on technologies to integrate waste-to-energy systems into comprehensive waste management programs.

These measures would increase renewable electricity generation in the year 2000 by 14 percent, and in 2010, by 16 percent as compared with the Current Policy Base case projections.

Transportation Fuels

- **Support Ethanol and ETBE.** The ethanol and ethyl tertiary butyl ether (ETBE) tax credits passed in 1990 as part of the budget reconciliation legislation will support the use of ethanol and the ethanol-based additive ETBE as transportation fuel components over the next decade.

- **Develop New Energy Crops.** An accelerated program carried out by the Departments of Energy and Agriculture will aim to develop "energy crops"—nonfood feedstocks for liquid fuels—and the technology to use these feedstocks to produce cost-competitive transportation fuels by the year 2000.

- **Develop and Use Cost-Competitive Alternative Fuels and Technologies.** The National Energy Strategy alternative fuel initiatives will provide greater incentives for manufacturers to produce alternative-fuel vehicles and use them in Federal and private fleets. Combined with provisions in the Clean Air Act Amendments of 1990, the Strategy will provide significant new market opportunities for renewable alternative fuels and electric vehicles.

Fusion Energy

For the longer term, the National Energy Strategy looks to fusion energy as an important source of electricity-generating capacity. The Department of Energy will continue to pursue safe and environmentally sound approaches to fusion energy, pursuing both the magnetic confinement and the inertial confinement concepts for the foreseeable future. International collaboration will become an even more important element of the magnetic fusion energy program and will be incorporated into the inertial fusion energy program to the fullest practical extent. The current National Energy Strategy goal is to have an operating demonstration plant (using either technique) by about 2025 and an operating commercial powerplant by 2040.

Enhanced Research and Development for Energy Security

Any meaningful effort to ensure future energy supplies must address the role of advanced technology. The National Energy Strategy deems three areas of technology development particularly vital:

- Technologies to reduce the transportation sector's near-total reliance on oil, by making oil use more efficient, by introducing alternative fuels and technology, or by diversifying travel modes;

- Technologies that increase the environmentally protective production of domestic energy resources; and

- Technologies that improve energy efficiency and increase the range of economical, clean technology choices.

A major element of the National Energy Strategy will be increased investment in advanced energy technology R&D. The fiscal year 1992 budget includes $903 million, an increase of $227 million, or 34 percent above the fiscal year 1991 budget, to support the Strategy's R&D initiatives governmentwide. The budget proposes $653 million for Department of Energy National Energy Strategy-related R&D, an increase of $134 million, or 26 percent. Over the 5-year period 1992 through 1996, the Department of Energy would invest $3.5 billion in National Energy Strategy R&D initiatives discussed in this section. This initiative looks to a future where alternative technologies are available to reduce energy consumption and increase fuel-flexibility.

To ensure that the R&D efforts pursue useful goals and result in ultimate commercialization of the technologies, the National Energy Strategy R&D initiatives will utilize industry cost-sharing and will be carried out as joint government-industry programs in which industry participants have a significant say in the nature, organization, and locus of research efforts.

A brief description of the major initiatives follows:

- **Advanced Transportation Fuels From Biomass.** Accelerate research, development, and demonstration of new feedstocks and conversion technologies to provide initial commercialization of cost-competitive alcohol fuels by the year 2000.

- **Vehicle Propulsion Technologies.** Enhance R&D on gas turbine engines, low-heat-rejection diesel engines for use in heavy-duty trucks, and on fuel-cell vehicles to produce cost-effective alternatives over the long term.

- **Electric Vehicle Technology.** Expand R&D on batteries and electric vehicles, in conjunction with an industry-led consortium that has just been formed.

- **Aeronautical Technologies.** Enhance long-term R&D on new, more energy-efficient aircraft technologies.

- **High-Speed Rail and Magnetic Levitation.** The Department of Transportation, the Department of Energy, and the Corps of Engineers will pursue high-speed rail technologies and the National Maglev Initiative, to explore alternatives for both long-distance automobile travel and short-haul air travel.

- **Intelligent Vehicle-Highway Systems (IVHS).** The Department of Transportation, a number of States, and the auto industry will work cooperatively to advance IVHS technology in the United States. IVHS has the potential to reduce congestion, improve traffic flow, reduce idling at traffic signals, and allow drivers to choose more efficient routes to their destinations, all of which can improve the energy efficiency of transportation.

- **Telecommuting.** R&D on faster, easier-to-use computer networks and software can help make telecommuting more widespread.

- **Air Traffic Control Systems.** The Federal Aviation Administration's Air Traffic Control System can enhance its efficiency and performance, with a significant impact on fuel use.

- **Advanced Oil Recovery Technologies.** Enhance R&D on technologies that will permit greater production of the two-thirds of known U.S. oil reserves not normally recovered using present production techniques.

- **Industrial Technologies.** Accelerate R&D for improved industrial processes and equipment and for alternative fuels and feedstocks.

- **Advanced Light-Water Nuclear Reactors.** Advanced light-water nuclear reactors will incorporate major advances in design, including passive safety features. The Department of Energy is currently supporting first-of-a-kind engineering work that will assist companies in their efforts to have the Nuclear Regulatory Commission certify the new standardized designs.

- **Advanced Nuclear Reactor Concepts.** Advanced nuclear reactor concepts will have safety features that go beyond the standardized designs currently envisioned. Researchers have demonstrated that both high-temperature gas-cooled reactors and liquid-metal reactors can shut themselves down safely under conditions that would be extremely serious for present-day reactors. The Department of Energy continues R&D support for both of these advanced concepts.

In addition to these specific initiatives, a national awards program will be created, offering large cash prizes for major innovations in energy technologies that can reduce U.S. oil vulnerability. The program will set forth specific energy-related technological challenges and award prizes for meeting those challenges.

By 2030, these R&D initiatives could save between 5 million and 8 million barrels per day of oil, depending on the success of the proposed R&D programs. They will improve U.S. competitiveness in world markets and help make this Nation a cleaner, safer, more desirable place than ever in which to live and work.

Enhancing Environmental Quality

Concern for the environment runs throughout the National Energy Strategy and is reflected in all the initiatives previously discussed. Reasonable and sustainable energy policies will benefit both the environment and the economy. The keys are advanced technology and improved energy use practices that can help us maintain adequate supplies of affordable energy while enhancing the quality of our environment.

Motivating our technology and resource choices must be an improved understanding of total fuel-cycle costs of all energy sources. Total fuel cycle costs are the entire costs of producing, transporting, dispensing, and using a given energy resource, including the costs of health and environment impacts. Existing analytical tools are not capable of doing this with any reasonable precision; however, developing and sharing the capability to make such total fuel-cycle cost assessments is a National Energy Strategy priority. Building on what we know now, the National Energy Strategy proposes action that will improve public health; enhance the quality of our air, water, and land; and protect the global environment.

Energy and the Quality of Our Air, Water, and Land

In air quality, the National Energy Strategy seeks to reduce energy-related emissions to achieve and maintain the National Ambient Air Quality Standards for carbon monoxide and ozone; to develop cost-effective, flexible control strategies to reduce energy-related emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x); and to ensure that other air-quality concerns are incorporated into policies for energy supply and use.

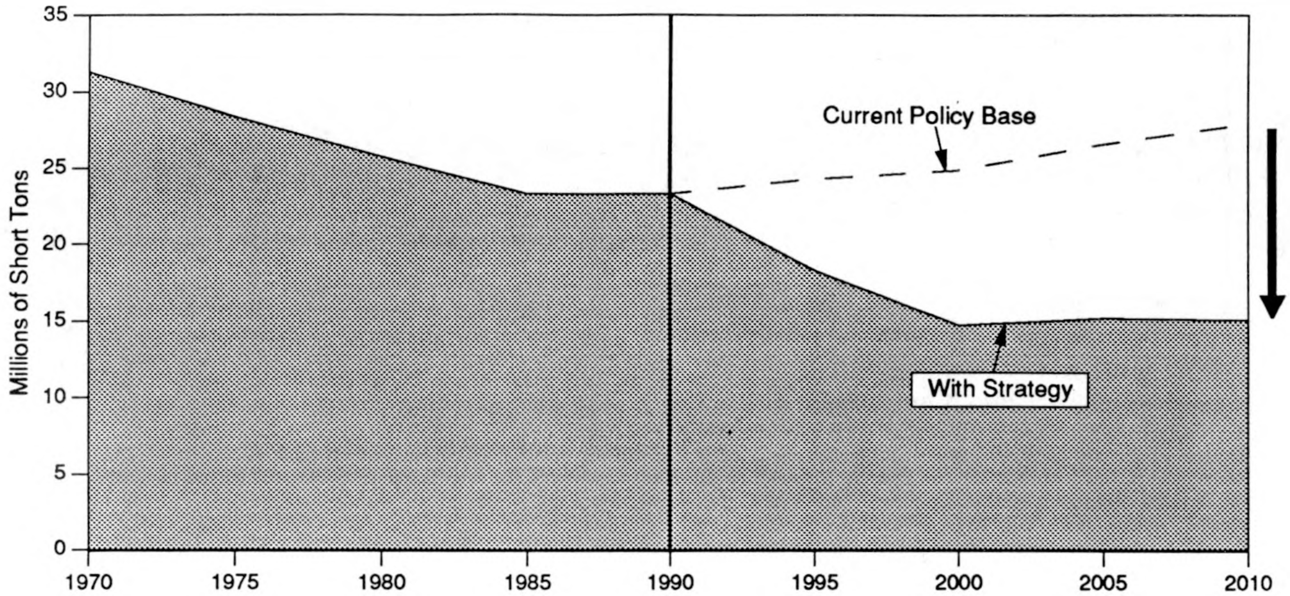
In waste management, the National Energy Strategy seeks to develop technologies, procedures, and safeguards to ensure that wastes are treated, stored, and disposed of in a manner that protects human health and the environment. The Strategy supports efforts to develop cost-effective, environmentally sound techniques to reduce the quantity, persistence, and toxicity of energy-related and other industrial wastes.

In water and land use, the National Energy Strategy seeks to ensure that activities associated with energy production and use protect surface-water and groundwater resources. Improved procedures to incorporate environmental concerns into energy facility siting and land use will also be developed and implemented.

The 1990 Clean Air Act Amendments, which are an integral component of the National Energy Strategy, will limit the major air pollutants from powerplants, vehicles, and industry. In many cases, pollutants will be reduced from current levels—despite economic growth and increased use of energy.

As Figures 5 and 6 illustrate for air emissions, National Energy Strategy initiatives (coupled with existing Department of Energy R&D programs—such as the development of alternative fuels for transportation, clean coal technologies, and improvements in energy efficiency) should reduce air and water pollutants and waste even

Figure 5. Reduced Emissions of Sulfur Dioxide



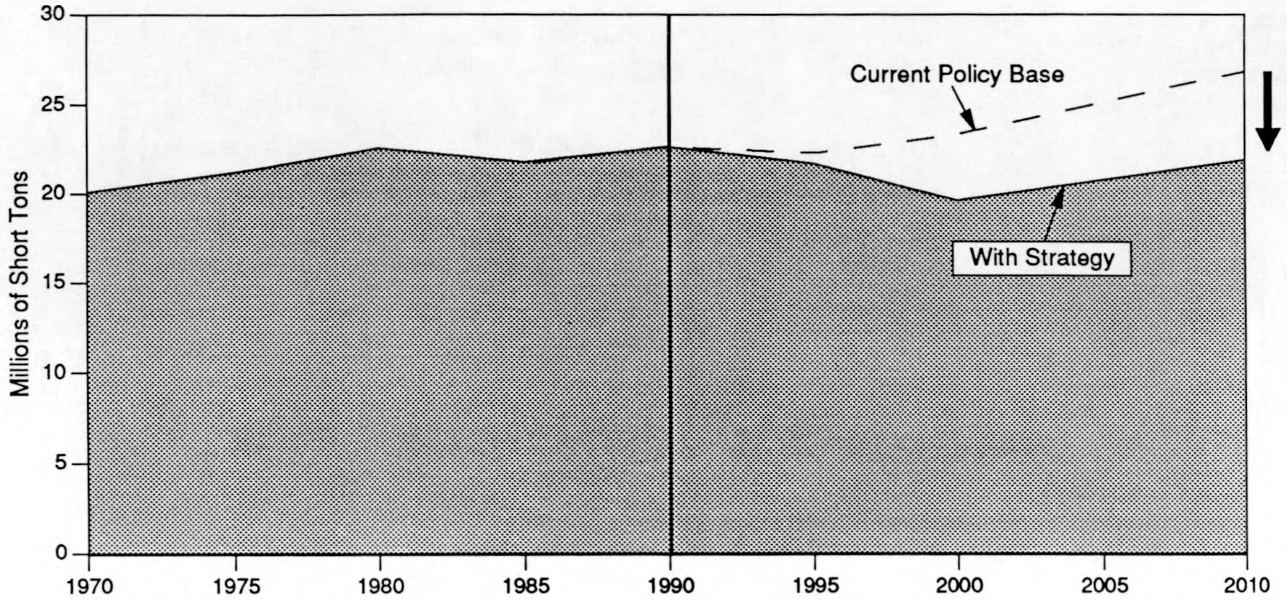
further from projected levels. For example, while advanced propulsion technologies will significantly increase efficiency, they should also reduce vehicle pollutant emissions by as much as 90 percent. National Energy Strategy measures are expected to reduce emissions of SO_2 by 12 million tons and NO_x by 5 million tons in the year 2010.

The Clean Air Act Amendments of 1990 and the National Energy Strategy are estimated to reduce SO_2 emissions by 40 percent, NO_x by 25 percent, and volatile organic compound emissions by 30 percent from the projected levels of emissions in 2030, based on policies that were in place prior to 1990. In addition, the Strategy includes a pledge to develop new technologies that minimize wastes. It also recognizes that current inefficiencies in the way wastes are regulated contribute to the problem and should be eliminated.

The National Energy Strategy proposes the following actions to better harmonize energy and environmental objectives and protect our air, land, and water:

- **Use Market Mechanisms.** Make maximum use of market-based mechanisms (informed by full fuel-cycle cost analyses) to most effectively protect the environment, minimize costs, and provide the flexibility necessary to maintain ample energy supplies.
- **Increase Efficiency.** Increase efficiency in every phase of energy production, transformation, and use.
- **Increase the Use of Natural Gas.** Increase the availability and use of natural gas.
- **Develop Cost-Competitive Renewable Energy Supplies.** Increase R&D and investment incentives for renewable energy technologies.
- **Develop and Use Alternative Transportation Fuels.** Develop and promote the use of cleaner transportation fuels, including reformulated gasoline.
- **Develop and Use Clean Coal Technologies.** Develop and facilitate the use of clean coal technologies.
- **Improve Energy Impact Assessments.** Improve analyses of the effects of environmental regulation on energy supply and demand.

Figure 6. Reduced Emissions of Nitrogen Oxides



- **Improve Siting Processes.** Drawing on State model programs, improve the processes used to site energy facilities, including refineries.

- **Minimize Wastes.** Develop cost-effective, environmentally sensitive techniques to reduce energy-related and other industrial wastes and improve environmental restoration.

One goal of these measures is to protect and enhance environmental quality while minimizing the projected costs of environmental regulation in this country (now more than $100 billion per year and growing) through more efficient management of environmental compliance.

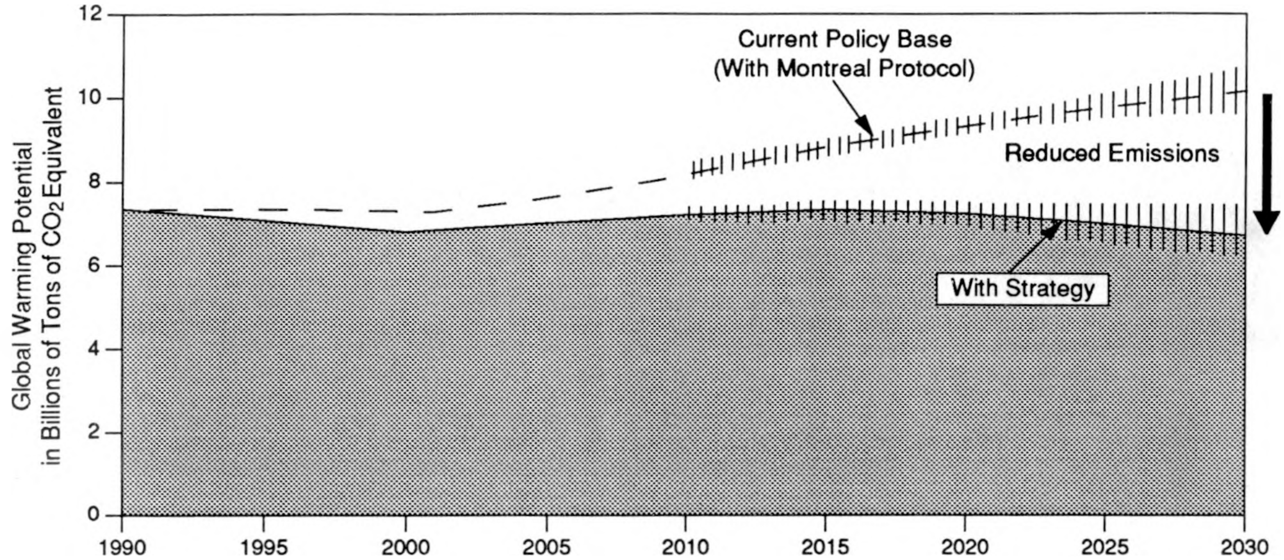
Energy and Global Environmental Issues

Despite large uncertainties regarding potential climate change, there is sufficient credible scientific concern to start acting to curb the buildup of so-called greenhouse gases—several of which are related to the production and use of energy. These gases include carbon dioxide, carbon monoxide, methane, and chlorofluorocarbons. Figure 7 illustrates the greenhouse gas emission reductions that would be produced by the National Energy Strategy. These reductions are achieved by: (1) greater use of renewable energy and nuclear power and improved energy efficiency in both the electricity and the transportation sectors; and (2) other actions already taken by the United States (for example, the Clean Air Act Amendments of 1990). With all of these initiatives, the United States' contribution to potential global warming would, in the National Energy Strategy scenario, remain at or below present levels for the foreseeable future. While the accuracy of any future projections diminishes as the time horizon under consideration lengthens, the National Energy Strategy will significantly reduce greenhouse gas emissions relative to any current policy baseline.

The National Energy Strategy actions are consistent with the recommendations of the United Nations' Intergovernmental Panel on Climate Change. Under its precepts, this country has taken a lead in adopting prudent strategies to reduce greenhouse gases that are also justified on grounds other than climate change (for example, reforestation, greater energy efficiency, and reducing the emission of chlorofluorocarbons and other substances that deplete the Earth's protective ozone layer).

Taken together, these actions both reduce emissions from the sources of greenhouse gases and

Figure 7. Reduced Potential for Global Warming



Note: Global Warming Potential (GWP)—Unit of 100-year global warming potential measured in billion metric tons of CO_2 equivalents. Greenhouse gases vary in their atmospheric lifetimes and in their ability to absorb and reradiate heat. This chart is based on converting the projected volumes of greenhouse gases to one common measure, Global Warming Potential. If indirect gases that form tropospheric ozone (nitrogen oxides and volatile organic compounds) were to be included, a slightly lower GWP for the National Energy Strategy scenario would result.

enhance sinks (such as trees) that absorb gases. Considering both sources and sinks of all greenhouse gases allows for a comprehensive approach to the climate change issue, including scientific and economic research, monitoring, technology development, and action plan development.

Fortifying Foundations

Fundamental Science and Engineering Research

The key to new knowledge and innovation in energy is basic science and research. Of course, there must also be *focused* R&D—both to advance new technologies and to better understand existing technologies.

A major part of the National Energy Strategy is to expose and expand the role that science and technology can play in achieving U.S. objectives for energy security, economic growth, and enhanced environmental quality. History is full of instances where technology revolutionized both our energy sources and our effectiveness in putting them to human service. New insights about geology, new extraction techniques, and the exploration of new geographical frontiers more than once have "restocked" domestic petroleum reserves, notwithstanding declarations that those reserves were about to be exhausted. During the 1980's, new technology helped to break the one-to-one relationship that had long existed between total primary energy consumption and economic growth.

The private sector is primarily responsible for developing and commercializing technology, but the Federal Government has a critical role in basic and applied scientific research. The extensive system of national research laboratories and Federal support of academic and private research can profoundly influence the focus, scope, and pace of energy technology development.

Accordingly, the National Energy Strategy seeks to maintain U.S. preeminence in fundamental science and engineering research, sharpen the focus of Strategy-related research in energy science and technology, and promote excellence and productivity throughout the U.S. research establishment. The following areas are particularly important:

- **Maintain Basic Research Portfolio.** Maintain a balanced and diverse Federal portfolio of research investments in fundamental science and engineering research, estimated to be in excess of $11 billion annually across 10 Federal agencies.

- **Establish Federal Research and Development Priorities.** Establish a continuing interagency review of energy-related applied Federal R&D, estimated to be approximately $3 billion in annual investments across seven Federal agencies, to identify top-priority technical opportunities and ensure that research investments support key Strategy goals and technical objectives.

- **Encourage Industrial Research.** Encourage industry to increase its energy research investments through financial incentives for research consortia, permanent tax credits for research and experimentation investments, increased use of personnel exchanges, and prizes and awards.

- **Strengthen University Research.** Strengthen individual investigator capabilities, increase cost sharing in funding proposals, and upgrade university equipment and instrumentation.

- **Maintain User Facilities.** Ensure the viability of top-priority, world-class research facilities that are available to university and private investigators, and explore alternative means for supporting them in the longer term.

- **International Collaboration.** Pursue bilateral and multilateral international agreements to construct and operate high-cost, long-term experimental research facilities.

Technology Transfer

In the area of technology transfer, the National Energy Strategy seeks to: (1) increase the use of joint industry-government efforts in R&D and in the commercialization of new technologies; (2) increase the participation of the Federal Government in the technology transfer process; and (3) accelerate the process of transferring technology to private industry and commerce in order to enhance U.S. competitiveness.

The National Energy Strategy proposes the following actions:

- **Increase Industry Participation.** Increase industry participation in R&D and in the commercialization of new technologies by making the 20-percent tax credit for industrial research and experimentation permanent and by encouraging collaborative, cost-shared R&D.

- **Ensure Adequate Protection for Intellectual Property.** Provide copyright protection for technical data and software, both at home and abroad. Broaden the National Cooperative Research Act of 1984 to include certain types of product development activities, and reform product liability laws. Revise classification policies to improve industrial access to laboratories and facilities that could contribute to enhancing U.S. competitiveness, while continuing to protect national security interests. Finally, revise Federal procurement regulations and practices to promote greater efficiency and innovation.

- **Promote Technology Exports.** Improve the coordination of Federal agencies in export promotion efforts, particularly for Eastern Europe and developing countries.

- **Increase the Participation of the Federal Government in Technology Transfer.** Develop and implement comprehensive agency policies supporting technology transfer as a fundamental mission of the Federal Government. Provide adequate funding for technology transfer, including support for cost-shared programs that help demonstrate the technical feasibility of generic, enabling technologies and that provide technical assistance for the development of spinoff applications by industry.

- **Accelerate the Technology Transfer Process.** Improve delivery of technology transfer services nationwide through careful reform of the infrastructure. Ensure that Federal approval for procurement and technology transfer activities are sufficiently speedy and flexible.

Education: Investing in Human Resources

Without a population literate in math and science, we cannot expect to develop, manage, or properly use the new energy technologies we will need to provide a secure, clean energy future for all Americans. It is for these reasons that the National Energy Strategy contains key recommendations for improving math, science, technology, and engineering education. The Federal role—a modest but critical 6 percent of total funding at the precollege level—must be integrated with those of the States and the private sector to achieve the best results. Special emphasis must be placed on recruiting women and underrepresented minorities into the technical work force, to recruiting and preparing qualified math and science teachers for our schools, and to broadening the base of "science literacy" among the U.S. public.

The President and the Governors provided a framework for achieving excellence in U.S. education following the Charlottesville Education Summit. This part of our "national strategy" has already been well publicized, and it includes the goal that "by the year 2000, U.S. students will be first in the world in science and mathematics achievement."

The Secretary of Energy chairs the Committee on Education and Human Resources of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET-CEHR). This 16-agency group prepared the first coordinated report and budget for direct Federal spending on math, science, and engineering education, which accompanied the President's fiscal year 1992 budget submission to Congress.

The National Energy Strategy seeks to increase Americans' understanding of the role of energy in their lives, and its attendant costs and benefits, and to ensure a reliable supply of highly skilled scientists, engineers, and technicians in energy-related fields. The National Energy Strategy emphasizes the need to:

- Improve precollege mathematics and science education in support of the National Education Goals.
- Encourage precollege reform through government agencies and school partnerships.
- Strengthen and update the math and science curriculum.
- Promote positive images of mathematics and the sciences.
- Initiate and expand incentives for careers as mathematics and science teachers.
- Make math and science teachers full partners in the scientific community.
- Maintain close linkages with the States and the private sector through FCCSET-CEHR.
- Support public science literacy through mass media and parent-child programs.
- Continue to assist energy education through development of materials and school curricula.
- Broaden public science literacy programs.
- Provide fellowships and equipment to colleges.
- Provide technical and on-the-job training.
- Increase programs relating to undergraduate curriculum and materials development in the sciences.
- Support the increased participation of all population groups, including women, minorities, and the disabled, in science and technology careers.

Conclusion

In sum, the National Energy Strategy addresses the range of institutional and regulatory barriers preventing the best use of all of our Nation's energy resources—supply and demand, intellectual and physical. The implementation of this Strategy is inherently a shared responsibility. Working together at all levels of government and with the American people, we can achieve a cleaner, more productive, and more secure energy future.

Prologue

Why Energy Matters

Why Energy Matters

Energy is closely linked to economic prosperity—at home and abroad. The linkage exists for all countries, but particularly for the United States. Our country is not only the world's largest energy *consumer*, but also the second largest energy *producer*.

Energy is woven into the fabric of our daily activities and is a major factor underlying the strength of our economy. The fact that the United States represents less than 5 percent of the world's population, but produces one-fourth of global economic output testifies to the strength of our economy and the high standard of living we enjoy. Energy lies at the heart of this productivity.

The United States' pattern of energy use is commensurate with its large land area, low population density, and significant indigenous resources. Most nations do not have comparable characteristics, except for countries like Canada and Australia, whose energy consumption patterns are similar to those of the United States. The entire infrastructure of our cities, highways, and industries was developed with abundant and relatively inexpensive energy sources. Differences in how Americans use energy compared to other nations are due largely to a multitude of physical, cultural, and structural differences rather than to technological advantage.

Our geographically dispersed population requires us to drive farther for commerce and leisure than do people in most other countries. Our transportation networks are the most extensive in the world, giving us the choice necessary to meet the requirements of our economic life. Differences in residential energy use can be largely traced to different climate conditions, living arrangements, and household conveniences. Compared with other nations, U.S. residents have greater personal space in homes and offices, a greater number of single-family homes, better heating and cooling systems, and a wider range of labor-saving appliances.

The U.S. economy, the largest in the world, produces a vast array of products and services. Industrial energy use is affected by the mix of goods and services produced as well as how energy is used to produce them. Our economy includes certain energy-intensive industries that account for much of our industrial energy use. Nine of our most energy-intensive industries account for 70 percent of industrial energy use but less than 15 percent of the economic value of industrial output. Our historical economic strength has been due in part to low energy costs as a factor of production.

The National Energy Strategy is based on a careful consideration of U.S. energy consumption and supply patterns. These are discussed in this section of the Strategy Report as a prologue to the rest.

How America Uses Energy

Energy is needed to produce goods and services in the four basic sectors of our economy: residential buildings, commercial buildings, industry, and transportation. In addition to energy used directly by these sectors, large amounts of energy are used to produce electricity—which feeds back into numerous end-uses.

- Much U.S. energy use is geared directly to productive economic efforts (industry and business combined).
- Our continuing national dependence on oil arises from the use of motor fuels to transport people and products.
- Oil represents only a very small portion (about 5 percent) of the energy consumed to produce our electricity.
- Petroleum (distillate fuel oil) has gradually been "backed out" of residential and commercial uses. Today only a few regions of the United States still use fuel oil extensively for space

and water heating, notably New England and the Middle Atlantic States—where, until recently, fuel oil prices remained competitive with electricity and natural gas.

- Many renewable energy resources (such as solar, wind, and geothermal power) have increased their respective contributions to the U.S. economy by very large percentages in recent years; but—except for biomass and hydroelectricity—they still offer very little input in absolute terms. (Biomass includes wood-burning in home fireplaces and the use of wood wastes by the lumber and paper industries).

Over the past two decades, Americans have learned to use energy more efficiently. The United States uses about 10 percent more energy today than it did in 1973, yet there are more than 20 million more homes, 50 million more vehicles, and the gross national product is 50 percent higher. As energy prices increased during the 1970's, Americans purchased more fuel-efficient cars and appliances, caulked and weatherstripped their homes, and adjusted thermostats. Businesses replaced heating and cooling equipment, adopted more efficient manufacturing processes, and switched fuels when possible. At the same time, the economy as a whole shifted from energy-intensive industries toward less intensive goods and services.

Transportation

A little more than one-quarter of our Nation's energy is used to transport people and goods. Virtually all of this energy consists of petroleum products used to power automobiles, trucks, ships, airplanes, and trains. Almost 90 percent of all passenger traffic and more than 20 percent of all freight traffic in the United States moves on highways. In all, the transportation sector accounts for about *two-thirds* of all petroleum use in the United States.

Industry

Industry accounts for more than one-third of our national energy consumption, relying on a mix of fuels to produce the myriad products and services the United States provides for the world. Most of this use can be traced to nine energy-intensive industries, such as steelmaking, that make extensive use of energy in the production process. Petroleum in industry is used as a fuel as well as a raw material in the manufacture of products, including plastics and synthetic fabrics. Petroleum and natural gas continue to be our major industrial fuels, together accounting for roughly three-fourths of direct consumption.

Industry is more flexible than the other end-use sectors in adjusting its energy consumption and switching fuels when market conditions dictate. As a result of rising energy prices and economic conditions in the late 1970's and early 1980's, industry became more energy-efficient, using less energy to produce more goods and services.

Residential

Two-thirds of the 90 million U.S. households live in single-family homes. These "stand-alone" houses—the envy of apartment dwellers around the world—will almost always be somewhat more energy-intensive than multiple-family structures. And the relatively small size of U.S. families will always distort the significance of statistics about "average" energy use per dwelling unit. In a similar vein, the 110 million refrigerators and the more than 30 million home freezers in this country tend to be individually larger (as well as far more plentiful) than those in other countries—using more energy, but providing far more convenience.

Heating accounts for the largest portion of energy used in our homes. More than half of all primary energy used in the residential sector goes to heating rooms and making hot water; air-conditioning accounts for another 5 percent of consumption. Major appliances (refrigerators, freezers, ranges, and ovens) are responsible for one-fifth of residential consumption.

Commercial

Electricity supplies nearly 70 percent of the energy used by the commercial buildings sector. Much of the recent growth in electricity use can be attributed to increasing use of air-conditioners in commercial buildings, which partly reflects the population growth in southern regions of the

United States. Besides electricity, natural gas is the other major fuel used in commercial buildings.

The diversity of building types found in the commercial sector and the variety of functions they perform create a broad range of energy needs. Office buildings, hospitals, schools, warehouses, hotels, and restaurants all require energy for different needs. In addition, about 8 percent of commercial energy goes for street lighting and miscellaneous public services.

Regional Variations

There are striking differences in both the *amounts* and the *types* of energy used within different regions of the country, and even within neighboring States. Preferred *sources* of energy are often those that are most readily available from States' own natural resources or those of neighboring States. Texas and California are the Nation's largest consumers of natural gas and petroleum. Ohio and Pennsylvania use the most coal.

Energy use varies greatly from State to State, with some States using more than 4 1/2 times as much per capita as others. The five States in which total energy consumption per capita was highest in 1988 (the last complete year for which such breakdowns are available) are Alaska, Wyoming, Louisiana, Texas, and North Dakota. All are subject to extremes in temperature, all are "spread out," and most have energy production as an important industry. The economic health of each one depends on types of industry whose very nature *requires* large investments of energy to operate—so that roughly half to two-thirds of all the energy they use is absorbed in their respective industrial sectors.

How America Produces Energy

America's natural energy resources are extensive and diverse; coal, oil, natural gas, and uranium are all found in appreciable quantities within U.S. boundaries. Figure 8 shows the regional diversity of the large U.S. fossil resource base. Renewable resources are available in quantities without practical limits, subject to the limitations of the technologies that use them. The combination of all resources (together with some net imports) provides energy for a wide range of uses in transportation, residential and commercial buildings, and industry. Although most fuels produced from U.S. resources are used domestically, considerable amounts of some (such as coal) are also exported.

Like any other enterprise, the production of energy is linked not only to consumer demand, but also to a host of other factors: the availability of resources, the cost of production, government licensing and regulation, competition in the marketplace, and economic incentives. The reliability of some energy producers is also highly responsive to world events.

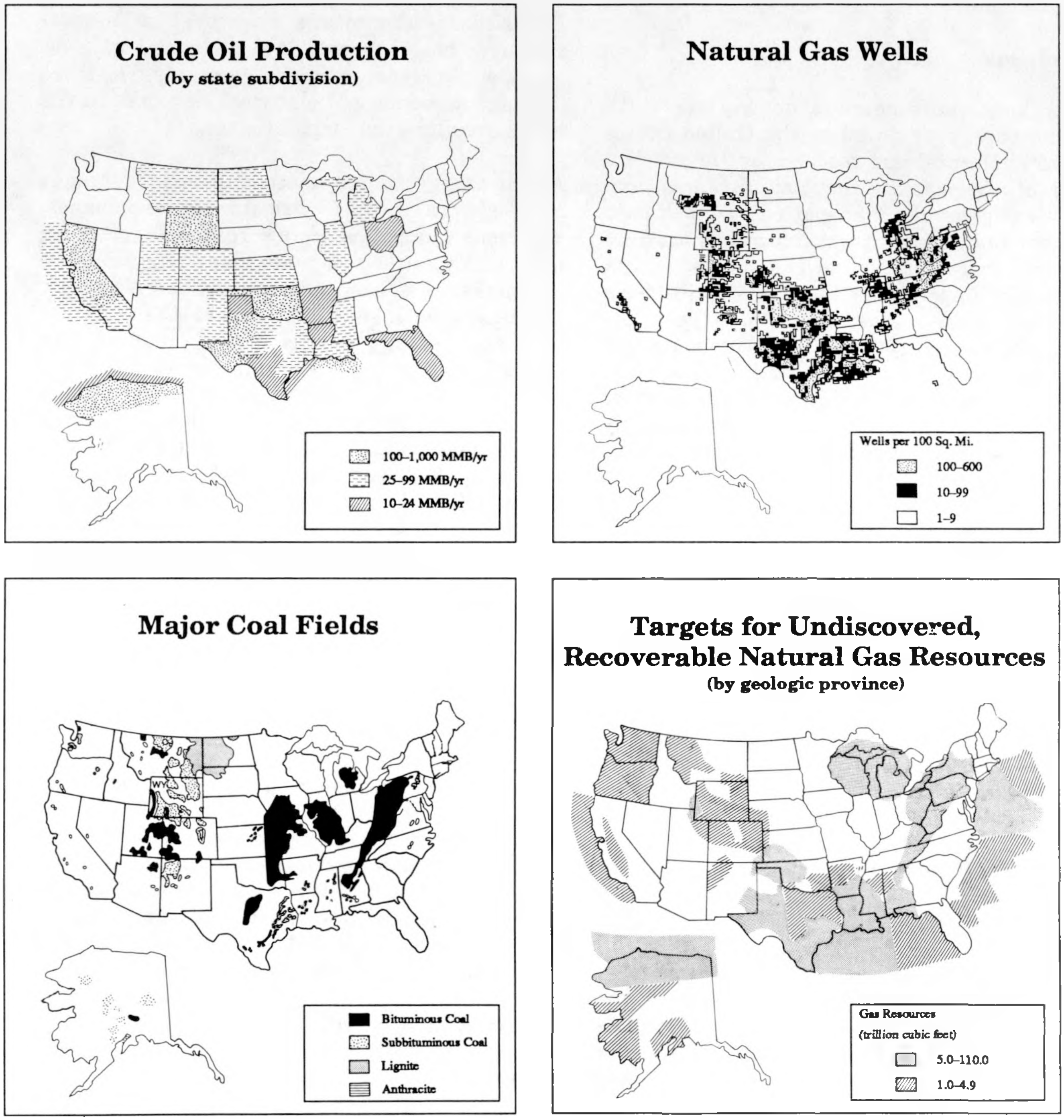
Oil and Refinery Products

Domestic oil production now accounts for about one-fourth of all the energy produced in the United States every year. In 1989, more than 6 billion barrels of refined oil products (such as gasoline, jet fuel, motor oil, and fuel oil) were supplied to U.S. consumers. There are currently more than 200 operating oil refineries in the United States, with a combined capacity to produce almost 16 million barrels of refined products every day.

The production of crude oil and refined products is greatly influenced by international events, particularly those affecting Middle Eastern nations. In the years following the oil-price shocks of the 1970's, extraordinary increases in oil exploration and development in this country and around the world expanded supplies. By 1986, the supply of petroleum was sufficiently abundant to cause a price collapse. With falling prices came a decrease in more expensive domestic production and an increase in imports, a trend which generally continues today. In 1990, domestic production of crude oil fell for the fifth consecutive year—to its lowest level in 25 years. Oil refineries have also undergone considerable changes in response to the economics of oil; between 1980 and 1989, a substantial number of operable refineries in the United States were shut down. These refineries were typically small and operated by independents. Downstream processing capacity increased during the same period, resulting in increased ability to produce more light products per barrel of crude oil.

In 1989, 42 percent of the crude petroleum used in the United States was imported. Much of the oil on which we and the rest of the world depend is

Figure 8. Focal Points of U.S. Domestic Energy Supply Show Rich Base, Help Explain Regional Diversity



produced in politically volatile regions of the globe. The oil fields of the Persian Gulf area, which represent nearly two-thirds of known global oil reserves, now supply one-quarter of the oil the world consumes.

Natural Gas

Natural gas accounts for approximately one-fourth of all the energy produced in the United States every year. Natural gas reserves are found in a number of areas across the United States, and supplies are generally transported by pipeline to consumers. Domestic production currently provides the largest source of natural gas supply, with a small portion imported from Canada and Algeria to supply certain markets with high peak demands. While industry is the largest consumer of natural gas produced in the United States, residential and commercial buildings also account for a significant portion, with natural gas currently supplying about 50 percent of the energy used by the residential sector.

Coal

Coal represents the Nation's most abundant fossil energy resource; proved U.S. coal reserves are also the largest in the world. Coal now provides more than one-third of all the primary energy *produced* in this country and supplies nearly one-fourth of all the energy we *use*. Almost nine-tenths of domestic use of coal goes into generating electricity. Major coal fields are located all over the United States, with heavy concentrations in the southeastern, midwestern, and western States. Roughly 10 percent of the billion tons of coal now mined here each year is exported.

Nuclear Energy

Nuclear energy is currently the source of about 20 percent of the electricity generated in the United States. Since 1974, nuclear power facilities have accounted for about one-third of the new generating capacity added to meet the growing demand for electricity. No new nuclear powerplants are currently scheduled for construction beyond what is already under way or completed, primarily because of concerns over regulatory uncertainty, economics, nuclear waste disposal, and safety issues.

Electricity

Electricity is the means by which our natural resources are converted into a clean, highly diverse, easily transported energy supply. The three largest interconnected electrical networks in the world are all in the United States.

As an energy source, electricity is in a unique category. To meet electrical energy demands, enormous quantities of raw resources (oil, coal, natural gas, nuclear, or renewable energy) must be consumed. The energy consumed for electricity production is, in fact, far greater than the net amount of energy that is finally produced. For example, for every 1 kilowatthour of electricity delivered, between 2 and 3 kilowatthours worth of coal must be consumed. This is caused by energy losses inherent in the generation and delivery of electricity. Coal currently provides more than 55 percent of the U.S. electrical energy supply; most of the remainder is produced by nuclear, hydropower, and natural gas.

Renewable Energy

Renewable energy resources, which include hydropower, solar, biomass, wind, and geothermal energy, currently provide almost 10 percent of the primary energy produced in the United States every year. Hydropower is the most widely used renewable energy source, producing about 9 percent of the electricity generated in the United States last year. Although more than half of the renewable energy produced in the United States is used for generating electricity, it is also used for transportation fuels, industrial process heat (for example; wood waste in the paper industry), and for heating buildings and hot water.

Overarching Principles

These patterns of energy production and use, combined with sharp variations between the different parts of our Nation, underscore the wisdom of basing a National Energy Strategy on the self-adjusting mechanisms of competition and free-market principles.

Increasing Energy and Economic Efficiency

Electricity Generation and Use

Residential Energy Use

Commercial Energy Use

Industrial Energy Use

Transportation Energy Use

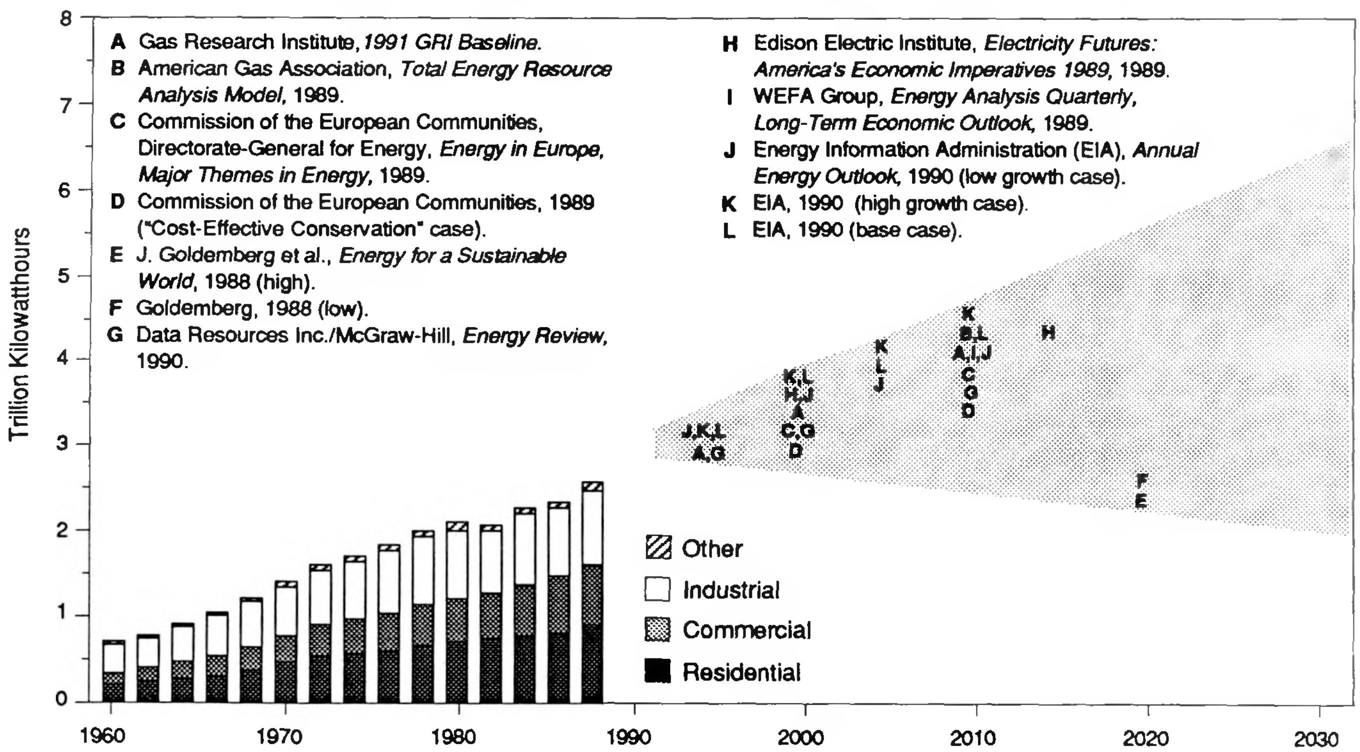
Electricity Generation and Use

Modern life is unthinkable without reliable electric power. The generation, transmission, and use of electricity sustains our economic productivity, elicits technological and scientific innovation, and profoundly influences the quality of our environment. More than one-third of the total energy used in the United States goes to the generation of electricity. Demand for electricity has historically risen in tandem with the gross national product (GNP), and this trend is expected to continue for the foreseeable future.

Modern homes, offices, and factories depend on electricity for lighting, heating, cooling, telecommunications, and product processing. These services and others, vital to the economy, also represent a substantial commitment of the Nation's income. In 1989, consumers spent more than $160 billion on electric utility services. For the future, it is expected that $100 billion to $200 billion in new capital investment will be needed over the next 10 years to meet the Nation's growing electricity needs.

Market inefficiencies in the electricity sector are well documented. Federal, State, and local regulations have been used since the earliest days of the industry to correct for the natural monopoly status of electric utilities. The Administration believes that regulation of any industry is justified only

Figure 9. Projections of U.S. Demand for Electricity



Note: Differences in projections are caused, in part, by varying assumptions concerning energy prices, economic growth, consumer and producer behavior, and rates of technological change, including replacement of capital stock. The shaded area represents an envelope bracketing these differences.

Goals and Approaches—Electricity Generation and Use

Goal	Approach
Encourage efficiency and flexibility in electricity supply and demand choices	• Alter Federal and State regulation of the electricity industry to permit more competition and to produce and use electricity more efficiently
Promote diversity of electricity technology and fuel choices	• Pursue research, development, and demonstration activities to improve performance of electric technologies and to use clean, abundant domestic energy resources at competitive costs

where significant market power by industry participants is shown to exist. It is still accepted generally that transmission and distribution of electricity are natural monopolies and should remain regulated, albeit more flexibly, but recent developments (such as competitive bidding programs in which nonutility suppliers compete to provide new electricity resources) have challenged the idea that the generating portion of the industry needs the same degree and type of regulation. The traditional regulatory framework is undergoing some stress as it strives to keep pace with changing market forces.

The Clean Air Act Amendments of 1990 and other efforts to safeguard and improve environmental quality will profoundly affect hundreds of investment decisions in the electric utility sector. Electricity producers will be investing billions of dollars over the next two decades to comply with new and emerging environmental laws and regulations. The universe of investors will expand to include new firms that are entering the power generation business under a variety of competitive approaches aimed at obtaining new capacity at least cost. Electric utilities and regulators are also developing new ways of evaluating and comparing techniques to invest in electricity conservation and efficiency. In the face of all these changes, the National Energy Strategy seeks, among other things, to clarify the respective roles that Federal and State governments are likely to play in fostering the development of a competitive electric utility industry.

Although U.S. demand for electricity is increasing, there is also growing opposition to building any kind of new electricity generation or transmission facility. The National Energy Strategy addresses the need to reconcile public concern for environmental quality with society's requirement for reliable and economic electricity.

Figure 9 highlights the uncertainty associated with trying to project the amounts of electricity-generating capacity likely to be needed in the future. The projections of U.S. demand through 2030 can vary by more than a factor of 3.

Such widely varying projections indicate the intrinsic difficulty of long-term demand forecasting; and they suggest that, ideally, the electricity industry (and electricity users) should be able to respond flexibly to a wide range of circumstances. A diversity of generating technologies and energy sources can help to provide flexibility in responding to changing conditions in the economy. Furthermore, electricity markets will be able to operate more efficiently if some existing regulatory barriers to competition and other technological uncertainties are removed.

Goals and Approaches

Competitive markets ensure economic efficiency and provide the flexibility necessary to manage uncertainty. Although electricity markets are and will continue to be extensively regulated, National Energy Strategy proposals will change regulation to permit enhanced competition in the electric power industry.

In addition to encouraging competition, the Strategy calls for reforms to regulations that unnecessarily impede the development of electricity resources and that reduce the ability of providers of electricity to respond to changing conditions. Public participation and environmental safeguards will be maintained while duplicative or inefficient regulatory procedures are eliminated.

The National Energy Strategy supports the rapid development and commercialization of new and innovative electricity-generating technologies, such as solar, wind, geothermal, clean coal, and advanced nuclear, together with hydroelectric and natural gas. These technologies will benefit consumers in several ways. For example, improving the engineering efficiency of the generating process can lower electricity costs directly, while reducing the need for auxiliary environmental or safety facilities can lower electricity costs indirectly. Lower costs promote a robust economy and increase the competitiveness of U.S. industry. In addition, these technologies make use of abundant domestic energy supplies and employ American technical know-how.

The National Energy Strategy proposes to achieve electricity goals through two distinct but related processes. The first involves the reform of statutes and regulations that, while individually desirable, have collectively reduced the ability of regulators to balance national energy and nonenergy public policy requirements. The regulatory regime that has emerged does not fully reflect current market conditions or the state of available technology.

The second process involves research, development, and demonstration activities that contribute new technologies to the electric power industry. These technologies will increase the efficiency and diversity of resources used in electricity generation and will contribute to the Nation's environmental, global competitiveness, and energy security objectives.

The National Energy Strategy does not seek to select favored resources, fuels, or technologies. Rather, it intends to define and rectify regulatory barriers and market imperfections. Markets must ultimately determine the most economic mix of electricity supply and demand resources. This is difficult but necessary in industries such as electricity where regulation plays a major role.

This section of the National Energy Strategy report focuses on actions relating to regulatory reform of the electricity industry. Actions concerning electricity generation and efficiency technologies, such as renewables, nuclear, and clean coal, are discussed in their respective sections.

The National Energy Strategy goals and approaches related to electricity are set out in the table on page 31. In reality, most of the Strategy's electricity actions help achieve more than one goal. New technologies, for example, not only promote U.S. global competitiveness but also help maintain diverse fuel choices and enhance environmental quality.

Policies presented in this and other sections that address the Strategy's electricity goals are listed below. They include policies for regulatory reform and for research and development and technology transfer. Legislative and regulatory reform policies include the following:

- Modifying the Public Utility Holding Company Act (PUHCA) to remove impediments to greater competition.
- Reforming the Public Utility Regulatory Policies Act (PURPA) to remove certain size and fuel-use restrictions on small power producers.
- Utilizing existing Federal Energy Regulatory Commission (FERC) and Department of Energy authority to properly price electricity-transmission services and to expand access to transmission facilities.
- Providing Federal support for State integrated resource planning programs.
- Phasing out Federal power marketing administration (PMA) debt subsidies.
- Streamlining hydroelectric power regulation.
- Reforming the nuclear power licensing process.
- Developing a comprehensive solution to the high-level radioactive waste management problem.

Technology development and demonstration policies include the following:

- Providing Federal support for research, development, and demonstration of energy technologies.
- Resolving environmental concerns that impede the use of municipal-solid-waste-to-energy technologies.
- Developing methods to compare the full social costs of supply and demand fuels and technologies used in meeting electricity requirements.

Expected Results

Figure 10 shows an estimate of the impact of the National Energy Strategy on the electricity sector. Following through on the Strategy is expected to reduce the demand for fuels used to generate electricity in 2030 by about 7 quads and to increase the range of fuels and technologies available for electricity generation.

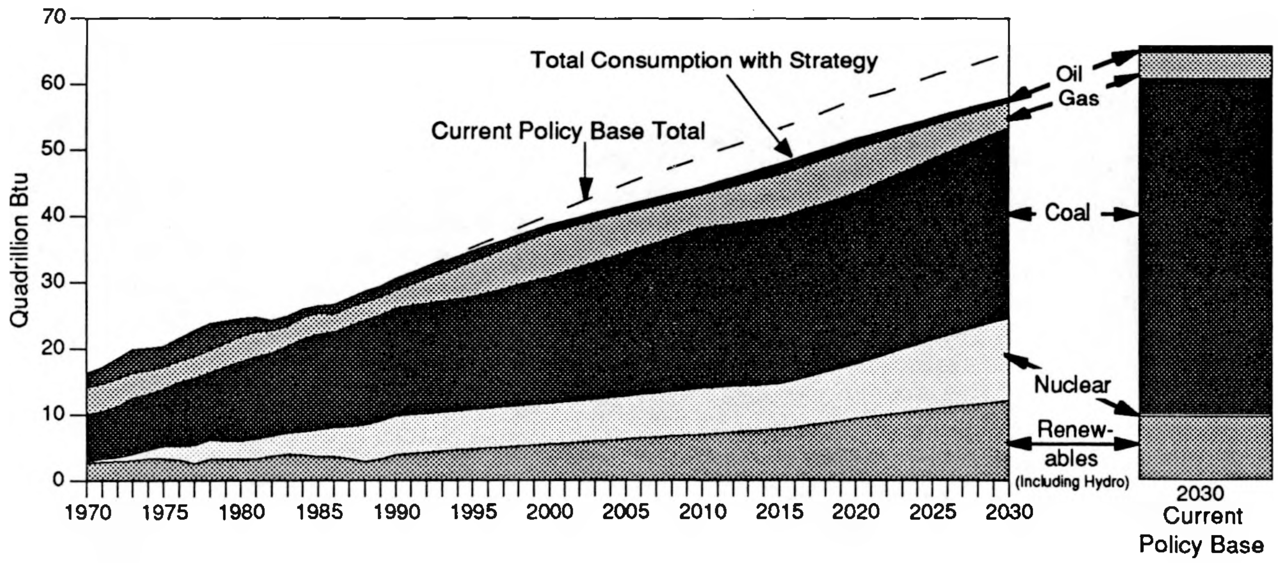
The Strategy's intent is to encourage competition and increase technological choice in the electricity sector. Figure 10 shows that in the absence of Strategy actions, efficiency gains would be minimal. Coal-fired generation would expand dramatically while nuclear generation would all but disappear by 2030. Further, oil-fired generation would increase, and renewable energy use would experience only moderate growth.

Under the National Energy Strategy, coal for electricity generation—while remaining a major generation fuel—will decrease relative to the current policy reference case, and nuclear generation will provide major increments of supply after about 2015. In addition, reliance on renewable sources will increase while dependence on oil for electricity generation will decrease. The National Energy Strategy will assure a more fuel-diverse, secure, and environmentally sensitive electricity sector.

Efficiency and Flexibility in Electricity Supply and Demand Choices

The National Energy Strategy aims to substantially reform the regulation of the electric power industry. The Strategy calls for legislative and regulatory actions to permit more competition in the industry, reduce consumer costs, and promote flexibility and efficiency in the way electricity is produced and used.

Figure 10. National Energy Strategy Projected Changes in the Mix of Fuels Used To Generate Electricity



Electricity is supplied by several types of public and private entities that are subject to many Federal, State, and local regulations. The principal policies affecting electricity supply and demand are the province of State regulatory agencies. Thus, to be effective, Federal policies must be developed cooperatively with these State authorities. The Strategy directs attention to aspects of Federal regulations that limit the flexibility of State regulators and utilities to ensure optimal investments.

The National Energy Strategy addresses several obstacles to improving efficiency and flexibility in electricity supply and demand choices. These obstacles include Federal and State regulations that artificially restrain participation in the market by capable builders and operators of electric powerplants, barriers to increased conservation and supply efficiency, inadequate access to transmission facilities, difficulty in siting new plants and transmission lines, and conflicts between State and Federal jurisdictional authorities.

Public Utility Holding Company Act

Competition among wholesale electricity suppliers was not a practical possibility in 1935, when Congress enacted the Public Utility Holding Company Act. The industry structure imposed by PUHCA implicitly assumes that electricity will be generated by the local utility. However, electric utilities vary widely in their ability to minimize the costs of constructing new powerplants. Thus the act, as written, is a major obstacle to relying upon the most efficient firms to build and operate the new generating capacity that will be needed over the next several decades.

Since 1935, the Nation's electricity supply system has been integrated into large regional networks. The passage of the Public Utility Regulatory Policies Act in 1978 led to limited competition among a small group of wholesale suppliers. The experience gained through PURPA suggests strongly that greater competition among wholesale suppliers is both feasible and likely to be beneficial. Electricity would cost less, and utilities would have more flexibility in dealing with uncertainty in the pace of electricity demand growth.

The National Energy Strategy calls for modification of PUHCA to allow businesses to build, own, and operate powerplants for wholesaling electricity in more than one geographic area. This will help develop electricity supplies and stimulate competitive market efficiencies that are not available under the traditional single-supplier approach. Over the long term, the modification of PUHCA is expected to have a powerful effect on the efficiency of the Nation's energy markets.

The Administration's approach to the amendment of PUHCA would not force State regulatory authorities or utilities to turn to competitive procurement of new generating capacity. Those that choose to rely on the traditional practice of having the local utility build new capacity under cost-of-service regulation will be free to do so. At the same time, States and utilities that are interested in competitive procurement—and there are many—will be able to draw from a much broader pool of potential suppliers. The prospective suppliers, in turn, would be able to use virtually any fuel source or generation technology as long as environmental, safety, and siting requirements are met.

PUHCA was enacted to prevent utilities from using complex corporate structures to evade regulatory oversight at the expense of investors and consumers. The National Energy Strategy recognizes the need to continue protecting investor and consumer interests. The Strategy recommends that PUHCA be amended to allow competition in wholesale electricity markets while protecting consumers and investors through a combination of market forces and watchdog regulation by Federal and State agencies.

Amendment of PUHCA in this balanced manner can lead to many benefits, including lower capital costs for new generating capacity, a wider range of generating technologies, improved generating efficiencies, lower electricity prices, reduced risks to consumers of cost overruns for new generating capacity, increased investment opportunities overseas, and export of goods and services by the U.S. electric supply industry.

Access to Electricity Transmission

Although competition is developing in electricity generation, electricity transmission remains a monopoly service. Therefore, continued regulation of both price and obligation to serve is necessary unless changing technologies permit markets to operate without regulation. Even so, there is substantial debate about the ability of transmission facility owners and of Federal and State regulators to ensure the most efficient use of existing transmission facilities and to provide for the necessary expansion of the electricity transmission network.

Where there is market power, access to transmission lines can be denied to wholesale power buyers and sellers by the owners of the lines, or the owners can offer access at a price so high that access is effectively denied. Owners may deny access to protect their own position in the wholesale generation market. With some exceptions, the Federal Government cannot under current law directly require owners to provide access. It can, however, set bulk power and transmission prices. Pricing policy is the most important of several Government policy instruments that can indirectly affect the access policy of transmission owners.

Limited access to transmission facilities inhibits the efficient use of current generating capacity and hinders construction of new capacity. In particular, limited access impedes development of competitively supplied generation resources. Moreover, transmission planning and construction procedures generally do not adequately consider regional electricity requirements. In addition, the Federal Energy Regulatory Commission's authority to require transmission access and regional cooperation is limited.

Increased access to electric transmission facilities for wholesale power buyers and sellers would increase economic efficiency by facilitating procurement of the lowest cost resources from both utility and nonutility suppliers. Greater access to transmission facilities also would increase competition in wholesale markets and ensure that the Nation's industries, shops, and residences have access to electricity at the lowest reasonable cost.

FERC has been exploring its authority over transmission access in specific cases. While these do not comprise a distinct access and pricing policy, the direction of Commission decisions has been toward more open access.

FERC has permitted some companies to sell electricity at wholesale without cost-of-service price regulation and has permitted other companies to merge—provided certain transmission access conditions are met. So far, however, the Commission has exercised this conditioning authority under limited circumstances. Features of the Federal Power Act that might permit the Commission to condition or require access in a wider variety of cases have not yet been fully explored or legally tested.

Under the National Energy Strategy, the Administration supports full utilization of Department of Energy and FERC authorities to encourage more open access to electric transmission facilities for traditional utility and other suppliers of electric power, while maintaining reliability standards. The Administration also supports efforts by FERC to promote efficient pricing of transmission services. These actions will help to develop a competitive generation sector and to increase the flexibility of providers of electricity.

Under the Federal Power Act, FERC can establish policies that promote these objectives. The Strategy recommends that FERC review its existing policies and programs and reexamine its authority under the Federal Power Act to ensure that transmission services and facilities are adequate for the emerging competitive generation market. If experience shows that FERC's authority is inadequate, then the Strategy recommends legislative expansion of FERC's authority.

Integrated Resource Planning

Future demand for electricity services is most likely to be met through a wide variety of investments in new generation capacity and in programs and technologies that reduce consumption. Regulators and utilities will need to be able to determine which of these investments are most likely to provide the greatest net social benefits to consumers.

In the last decade, public utility commissions in a number of States have experimented with a variety of planning instruments designed to compare the costs and benefits of electricity supply and demand options. These instruments, variously known as least cost utility planning or integrated resource planning (IRP), continue to be refined in light of new knowledge about the full costs of fuel cycles, consumer response to utility investments in conservation, and technological innovation.

Utilities in at least 31 States have begun to develop IRP programs. Many of these programs are quite new, and many are only now addressing the regulatory changes necessary to implement IRP procedures. IRP processes have been valuable in pointing out discrepancies in Federal and State taxation and regulatory treatment of energy demand and supply investments.

The National Energy Strategy is based on the premise that investments in electricity conservation and efficiency should be allowed to compete fairly with electricity supply options. An efficient electricity market is a National Energy Strategy goal. That goal is best achieved by giving consumers and producers appropriate incentives to make efficient consumption and production decisions, and by facilitating competition among providers of both electricity generation and demand reduction services. IRP is intended to provide a framework for creating such incentives and fostering such competition.

No single approach to IRP is appropriate, because utility costs, pricing policies, and other characteristics vary widely. States and utilities are best able to determine the approach most responsive to local needs. For example, district heating and cooling technologies and ground-source heat pumps offer the potential of substantial savings in some regions. The Federal Government can assist this process by pursuing research in this area and testing promising concepts in publicly owned systems.

The National Energy Strategy will foster increased use of IRP processes. The existing Department of Energy IRP Program will be expanded to provide accurate and timely information and analytical tools to consumers, utilities, and State commissions. The program will provide financial assistance, technical data, and evaluation criteria that will help States and utilities to build effective IRP programs.

Increased Federal support and State implementation of IRP activities are expected to reduce electricity demand by about 45,000 megawatts (MW) of generating capacity in 2010 and 90,000 MW in 2030. This represents about a 7-percent reduction in necessary generating capacity compared with the current policy reference case. The net economic benefit is estimated to be about $35 billion for the 1990–2030 period.

Federal Power Marketing Administrations and Integrated Resource Planning

The Federal power marketing administrations sell at wholesale to local utilities the electric power that is produced at Federal hydroelectric (and other) generating facilities. These local facilities are primarily cooperative, municipal, and public power district utilities, which in turn, serve about 24 percent of the Nation's electricity consumers. The PMA's already encourage IRP among their customer utilities through technical assistance programs.

The National Energy Strategy would have the PMA's intensify these efforts. Encouragement of electricity efficiency and conservation by these Federal entities will help stretch the use of this clean energy resource.

Federal Energy Regulatory Commission and Integrated Resource Planning

FERC regulates wholesale electricity transactions representing more than 20 percent of utility sales. Moreover, actions by FERC affect the activities of State regulatory commissions.

The National Energy Strategy encourages FERC to use its existing regulatory authority to promote the use of IRP in wholesale electric power markets. FERC authority over wholesale transactions may inadvertently discourage IRP activities at the State level. While development and implementation of IRP programs are primarily State activities, DOE will encourage FERC to promote IRP in its wholesale ratemaking by taking the following actions:

- Establishing a policy to make clear that its approval of rates for wholesale power transactions does not prevent a State commission from disallowing recovery of a portion of the rate at the retail level if the State commission determines that the transaction is not consistent with the State's IRP program.

- Encouraging regional cooperation and coordination of wholesale suppliers' generation and transmission planning, siting, and construction activities.

- Encouraging transmission transactions (wheeling) for third-party suppliers.

- Instituting efficient pricing policies for short- and long-term wholesale power transactions that both reduce aggregate regional electricity supply costs and provide adequate incentive to suppliers to expand generation and transmission capacities.

Federal Tax Treatment of Efficiency Investments

Federal tax policies affect the cost and profitability of investments in electricity conservation and efficiency. Many electric utilities provide cash payments to their customers to encourage participation in demand-side reduction programs. These direct payments are taxable under existing Federal tax law. Taxation of these payments reduces their value to customers and thereby reduces participation in demand-side management activities. However, other types of incentives provided by utilities are not taxable.

The National Energy Strategy supports activities that encourage consumer participation in cost-effective demand-side management and other electricity-efficiency programs. Therefore, the Strategy calls for the Internal Revenue Service to issue a Technical Advice Memorandum that clarifies the tax treatment of these programs. This memorandum will state that:

- Utility rate discounts (or nonrefundable credits to utility bills) received by any customer (residential, commercial, or industrial) to encourage participation in demand-side reduction programs are not taxable income.

- Direct payments by utilities to customers that are industrial or commercial firms for making efficiency investments are taxable income. These firms may depreciate the full cost of investments funded, in part, by such payments, including that portion reimbursed by the utility direct payment.

- Direct payments by utilities to residential customers are taxable income.

- Direct payments by utilities to industrial, commercial, or residential customers will be treated by the Internal Revenue Service as a purchase of an intangible asset by those utilities.

Phaseout of Federal Subsidies to the Power Marketing Administrations

Federal policies traditionally have provided lower electricity prices and preferential treatment to some classes of utilities and their customers. By phasing out this special treatment, all of the country's electric utilities would be put on a more equal footing, and the true cost of producing power at Federal facilities would be more accurately reflected in prices received for that power. The inequities arising from some customers or regions of the country receiving preferential treatment would also be ended. A principal example of this policy is the debt repayment practices for the PMA's.

Under current policy, the PMA's are allowed to sell power at a price that does not cover the Federal Government's cost of providing it. The PMA's are allowed to repay loans at interest rates far below the Government's costs of borrowing money. This below-cost financing has cost the U.S. treasury more than $4 billion to date.

Historically, these subsidies and special treatment by the Federal Government were intended to achieve certain desirable social goals such as accelerating electrification and promoting economic development of rural areas where private enterprise would not be profitable. These goals have, for the most part, been achieved.

Today, these policies discourage energy conservation and efficiency by underpricing electricity. This, in turn, increases demand for electricity and for more Federal hydroelectric dams. It is essential that Federal power be sold at prices that at least cover the costs of providing it. Therefore, the Administration supports elimination of PMA debt subsidies. Adopting this policy will make other Federal efforts aimed at conserving electricity and other forms of energy more effective.

Siting New Generating Plants and Transmission Lines

State and local siting and environmental reviews do not always incorporate regional and national needs. In addition, the uncertain and often conflicting and cumbersome regulatory oversight of generation and transmission facilities inhibits development of new electricity resources.

The National Energy Strategy supports improved cooperation and coordination among Federal and State regulatory agencies. This cooperation would reduce licensing and siting delays and better incorporate regional and national electricity requirements into decision mechanisms. In this regard. FERC will seek improved cooperation with State regulatory commissions. The Department of Energy intends to maintain a liaison with the National Association of Regulatory Utility Commissioners to facilitate information flows and discussions between State and Federal officials.

In addition, the Strategy calls for the review and modification of Federal licensing procedures for non-Federal hydroelectric facilities, including exemption of certain small-scale facilities from Federal regulation. The details of these actions are presented in the section on renewable energy.

Regulation by State and Federal Agencies

The earlier discussion regarding reform of PUHCA addressed Federal regulatory impediments to developing competition in the electricity generation sector. However, the electricity industry also is subject to a myriad of Federal and State regulations regarding such issues as environmental impacts and pricing of electricity services. These regulations often overlap and contradict each other, thereby imposing undue burdens and restrictions on the electricity industry.

Most jurisdiction over electric utility planning, siting, and system expansion activities lies with State commissions. State and local agencies are also primarily responsible for retail activities. However, the Federal Government has a legitimate interest in ensuring that national energy goals are reflected in State and local regulatory processes, and FERC has a special responsibility to oversee the adequacy of facilities used for wholesaling electricity in interstate commerce, recognizing that often the same facilities are used for retail and wholesale services.

The National Energy Strategy calls for reconsidering the current division of regulatory authority over electric utilities between Federal and State agencies, in order to define more clearly their respective authorities and to minimize inconsistencies.

To facilitate efficient use and timely expansion of electricity facilities, the Strategy supports improved coordination and cooperation among the various Federal, State, and local regulatory agencies. It supports policies to reduce regulatory impediments to the efficient operation and expansion of electricity generation and transmission facilities. To achieve these objectives, the Strategy supports the following actions as set out in other sections of this discussion and in other sections of this report:

- Amending PUHCA in a way that ensures adequate State authority to protect consumers' interests.
- Amending the Public Utility Regulatory Policies Act to ease size and fuel use restrictions for those new entrants that win a bid under a State-approved competitive bidding program.
- Encouraging FERC-National Association of Regulatory Utility Commissioners cooperation to resolve regulatory issues.
- Providing assistance to State IRP programs to increase production and end-use efficiency.

- Transferring to the States the main responsibility for licensing of small non-Federal hydroelectric facilities.

Diversity of Electricity Technology and Fuel Choices

Maintaining a diversity of electricity fuel choices has become more difficult. Because electricity can be generated remotely from the location of its use, the environmental and safety effects of electricity generation can be separated geographically from the location of electricity consumption. This has contributed to the "not-in-my-backyard syndrome," where local opponents to new resources see the negative aspects of facilities but not the benefits.

The National Energy Strategy calls for developing energy resources in an environmentally sound manner. It also supports environmental and safety regulatory policies that do not unduly impede the use of diverse fuels for generating electricity. These policies are intended to balance the Nation's environmental needs and electricity requirements. Many of the actions designed to ensure energy diversity are discussed in the sections on natural gas, coal, nuclear power, and renewable energy.

A well-developed U.S. economy depends on adequate, reliable, and competitively priced electricity supplies. Because of this dependence, Federal policies are needed that support research, development, and demonstration of new electricity technologies to hold down electricity costs, assist in minimizing our dependence on imported energy sources, and improve the environmental performance of energy facilities. Support for these activities also helps U.S. companies compete effectively in providing electricity generation (and other energy) services in export markets.

The National Energy Strategy process identified several factors that inhibit development and commercialization of new energy technologies. Regulatory policies can discourage utility commercialization of new risky technologies. In addition, insufficient research and development expenditures cause lengthy delays in the successful development of new supply- and demand-side resource technologies. National Energy Strategy actions to rectify these conditions are presented in the sections on technology transfer and fundamental science and engineering research. The Strategy also supports actions in the following areas:

- Advanced clean coal, renewable, waste-to-energy, and nuclear generation technology.

- Advanced electrical transmission, distribution, and storage technology.

- Efficient appliances and equipment.

- Technology for energy-efficiency applications in buildings and industry.

Residential Energy Use

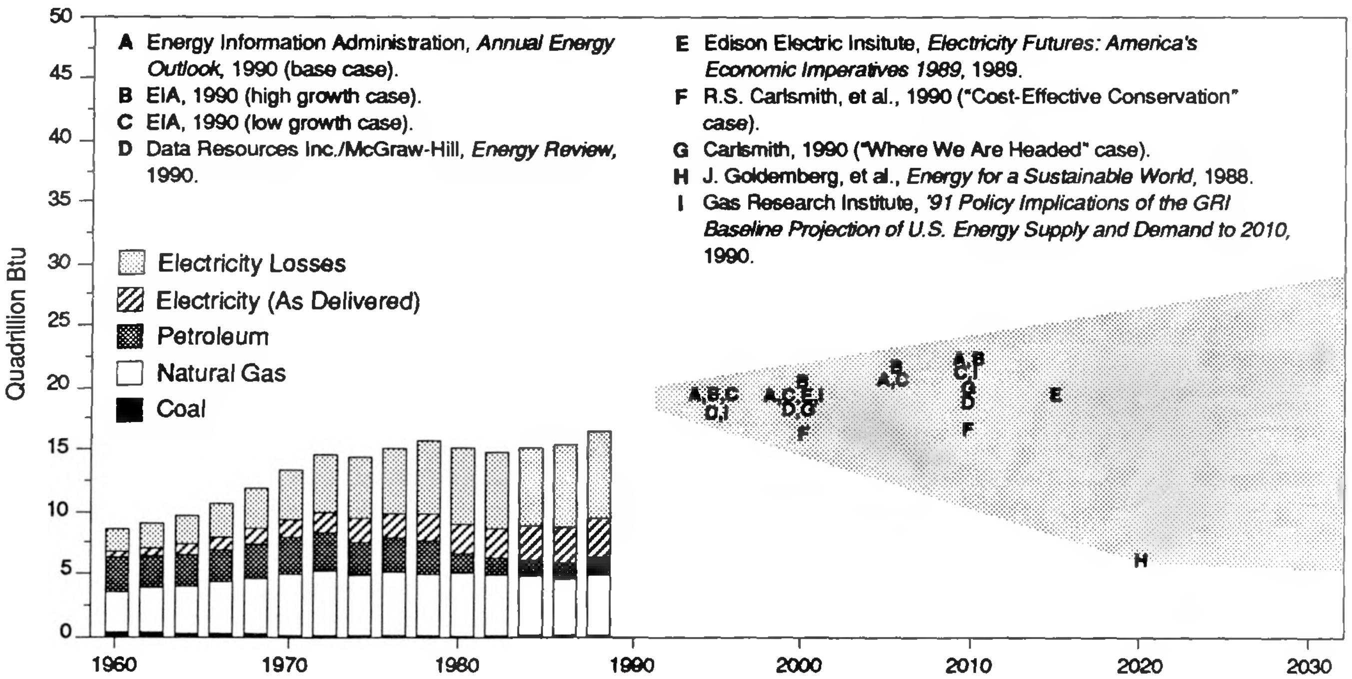
Today, households use about one-fifth of the primary energy consumed annually in the United States (including the energy required to produce electricity and deliver it to final users). Figure 11 shows historical trends in residential primary energy by fuel type, as well as a range of projections from recent studies.

Each year, Americans pay almost $100 billion in home energy bills for heating, cooling, refrigeration, cooking, and other conveniences and amenities, such as home entertainment. Energy costs can be a heavy burden on the monthly budgets of low-income households. Future energy price increases may increase the need—and the opportunities—for all households to invest in more efficient energy use and in solar and other renewable sources of energy.

The table on the facing page summarizes the goals of the National Energy Strategy directed at residential energy use and the approaches used by the Federal Government in pursuit of these goals. Success of the efforts envisioned by the National Energy Strategy should make it possible to provide affordable energy services and increased amenities while continuing to reduce energy use per household.

Where and how people live are important determinants of energy use. For example, two-thirds of the 90 million households in the United States occupy

Figure 11. Projections of U.S. Energy Consumption—Residential Sector



Notes: Historical comparison data excludes wood.
Differences in projections are caused, in part, by varying assumptions concerning energy prices, economic growth, consumer and producer behavior, and rates of technological change, including replacement of capital stock. The shaded area represents an envelope bracketing these differences.

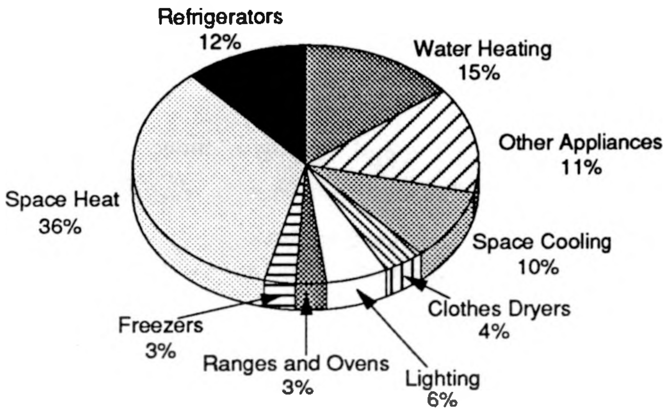
Goals and Approaches—Residential Energy Use

Goal	Approach
Develop new, marketable technologies to increase energy efficiency and expand use of renewable energy within homes	• Increase support for research and development to— – Reduce costs and improve performance of residential energy technologies – Develop methods of measuring and improving indoor comfort and environmental quality
Make full use of cost-effective energy-efficiency and renewable-energy technologies	• Increase energy efficiency of new housing by— – Providing technical information and assistance to industry, utilities, and State and local governments – Assisting State and local governments in adopting and enforcing Federal energy-efficiency standards through local building codes – Requiring new federally subsidized homes and new manufactured housing to conform to more stringent energy-efficiency standards • Retrofit existing residences by— – Supporting home energy ratings and the use of energy-efficiency criteria in mortgage loans – Helping States to implement effective programs to retrofit housing occupied by low-income households – Demonstrating exemplary energy management in federally supported public housing – Retrofitting existing federally owned housing • Improve the energy efficiency of residential appliances by using existing authority to update residential appliance efficiency standards to keep pace with new technology

single-family homes, which use more energy than apartments or mobile homes. In the South, houses may use more energy for cooling than for space heating; the opposite is true in the northern tier of States. Housing growth has been rapid in the Sun Belt, where electricity is used very commonly for both space heating and water heating. Electric heating (but not air-conditioning) is also common in the Pacific Northwest, thanks to a history in that region of relatively low-cost, federally subsidized hydropower. Oil heat, still widespread in the Northeast and in parts of the Midwest, is much less common in other areas. Notwithstanding these regional differences, space heating accounts for the largest single share of primary energy use in the residential sector for the country as a whole—followed by water heating, refrigeration, air-conditioning, and lighting, in that order (Figure 12).

Between 1962 and 1986, onsite energy use per household dropped by about one-third. This resulted from a number of factors, including the improved efficiency of new homes and appliances, homeowner investments in energy-saving measures for existing housing (such as better insulation), the population shift to warmer climates, and behavioral changes. During the same period there has been a general shift from fuel to electricity for space and water heating; and the use of

Figure 12. Residential Consumption of Primary Energy by End-Use, 1987



Source: Department of Energy, Conservation and Renewable Energy staff estimates, based on Energy Information Administration, *Household Energy Consumption and Expenditures*, 1987.

air-conditioning has increased. Because there is a substantial amount of energy involved in producing and delivering electricity to end-users, more *primary* energy per household is now required.

Many near-term technical options for residential energy conservation exist: to improve the efficiency of new houses, to "retrofit" existing residences (and heating or cooling systems), and to replace older, inefficient appliances. Over the long term, new technical opportunities should become available, including commercial application of new types of building materials; factory-based production of structural components or entire homes; advanced equipment and controls for lighting, space heating and cooling, water heating, and household appliances; and more effective use of landscaping and site design to temper the "microclimates" in residential neighborhoods. Besides saving money for consumers in the long run, many of these residential energy technologies can make U.S. homes more comfortable and improve air quality within them. From a broader perspective, they can contribute to the overall efficiency, reliability, and environmental acceptability of the Nation's electric and gas utility systems.

Although many consumers responded to the higher energy prices of the 1970's and early 1980's by adopting energy-efficient measures and practices, a number of institutional and market barriers limited their responses. Our stock of housing and appliances is still far less energy efficient than would be economically optimal.

Some of the more significant market barriers to greater energy efficiency for the residential sector include these:

- **Traditional Energy Price Regulation.** Utility rates set for electricity and natural gas do not always reflect the full costs to the economy or society—or even to the utility itself—of supplying energy under various conditions. This leads individual consumers to undervalue investments in energy efficiency and renewable resources. For residential customers in particular, the high cost of electronic meters has generally prevented utilities from instituting electricity rates that vary by time of use to reflect actual utility system costs more accurately.

- **Lack of Customer Incentives.** Market mechanisms often fail to induce the adoption of an economical energy-saving measure in situations where those who must pay for it cannot count on receiving its economic benefits. Homebuilders often find it difficult to recoup the costs of energy-efficient features because they lack an accurate, credible method for comparing homes and relating energy performance to dollar savings for the buyer. Similarly, owners of rental buildings may be reluctant to invest in energy-saving measures if the tenant (rather than the landlord) benefits exclusively from the lower utility bills.

- **First-Cost Bias.** Builders and home buyers both have a strong tendency to minimize the "up front" cost of a residential property, even at the expense of attractive potential savings in the future. This tendency has been reinforced by mortgage loan practices that fail to consider the lower *total* cost of owning an energy-efficient home when energy expenses are added to mortgage and tax payments.

- **Low Incomes of Some Energy Users.** Low-income households are often unable to finance desirable improvements in energy efficiency, no matter how short the "payback time." Federal and State weatherization assistance programs (supplemented by utility programs in some areas) have reached more than 2 million low-income housing units over the past 10 years.

- **Absence of Credible Data Sources.** For many new and some established energy technologies, even professional architects and engineers may be reluctant to invest in energy-saving measures without reliable data on actual performance and costs. The same concerns are shared by many utility program managers, mortgage lenders, and individual energy consumers.

- **Industry Fragmentation.** The homebuilding industry is split among a large number of small firms, subcontractors, and suppliers of equipment and parts; this makes it difficult to generate and sustain support for any sort of large-scale, industry-sponsored program of research and development. Strong ups and downs in the market for new homes also reinforce a general reluctance to risk innovative designs, products, or construction techniques.

- **Difficulties of Code Enforcement.** Even where States or localities have adopted requirements for energy efficiency as part of their building codes, enforcement is often hampered by complex code provisions and a lack of resources to train builders, provide design assistance, or even to check plans and inspect actual building sites unless serious health and safety violations are at issue.

- **Public-Sector Constraints.** By definition, publicly owned and assisted housing is more insulated from market forces. The Federal Government owns and operates tens of thousands of housing units and provides financial support to millions of other units. More than 1 million of these are owned and operated by local housing authorities, yet many housing authorities lack both the financial resources and the appropriate management incentives to improve energy efficiency. This situation is beginning to change, as the Department of Housing and Urban Development and the Department of Energy work together on initiatives for improved efficiency in public housing and other types of federally aided housing.

- **Slow Turnover.** Many of the foregoing problems are exacerbated by the customarily long lifetimes of most residential structures and of the heating and cooling systems that serve them. Thus, an initial decision on design, construction, rehabilitation, or appliance purchase that fails to take advantage of cost-effective energy efficiencies will represent a lost opportunity for many years to come.

The market's response to energy prices will continue to be a powerful factor in improving efficiency. However, there is also a role for effective Federal leadership—in cooperation with private industry, utilities, and State and local governments—to help overcome specific market barriers and to help ensure that cost-effective energy-efficient and renewable-energy technologies are applied wherever they can be.

Goals and Approaches

As summarized in the table on page 41, the National Energy Strategy for the residential sector is multifaceted, relying mainly on market forces but also providing Federal leadership to reach two main goals: (1) improvements in the availability and economics of new energy-efficient and renewable-energy technologies and (2) increased adoption of cost-effective investments in energy-efficiency and renewable-energy technologies.

Existing Federal policies and programs include research and development on new technologies, providing consumers and businesses with reliable information on residential energy technologies, and development of test procedures and mandatory efficiency standards for new home appliances. Federal energy guidelines are incorporated in State and local building codes (and represent required efficiency levels in new federally owned housing). The Federal Government supports State and local government programs (especially those directed at low-income households), assists utilities that invest in energy-efficiency programs and services, and promotes sound energy management in public housing supported by the Federal Government. The National Energy Strategy recognizes the continuing need for these efforts and also identifies several areas where Federal support can be strengthened. The Strategy's energy goals and approaches for the residential sector are described in detail below.

Expected Results

Under the Current Policy Base case, residential primary energy use is projected to grow by about 7 quads (40 percent) between 1990 and 2030. This scenario assumes that average energy intensity in the residential stock would remain about constant while the number of housing units would increase by about 40 percent. It also assumes a continuation of the market barriers that have limited cost-effective investments in residential energy efficiency.

State and local adoption and vigorous enforcement of the Federal building standards, including new industry efforts in quality control, could save up to 0.2 quad per year by 2010. Retrofits and other energy management improvements in public housing could save up to 0.02 quad, and up to 0.1 quad might be saved by 2010 in new and existing homes because of home buyer and builder responses to mortgage loans that give proper credit for energy cost savings. Effective implementation of integrated resource planning by electric utilities, which is discussed under "Electricity Generation and Use," could also help to slow the growth in residential electricity demand while improving system load factors.

Even with these actions, there will remain opportunities for further increases in residential energy efficiency. Achieving more of this potential for energy efficiency and renewable sources in the residential sector depends on actions by a large number of consumers, businesses, and institutions outside the Federal Government; however, many look to the Federal Government for leadership. The National Energy Strategy's commitment to Federal activities now under way and to new actions, coupled with an aggressive, well-planned Federal research, development, and demonstration program in buildings energy technology, can help point the way to a future in which reliable energy services are provided at greatly reduced costs and with a positive impact on the quality of home environments.

Advanced Technologies

Several of the market barriers described above have inhibited the development of residential energy technologies. Significant advances in energy efficiency and in the performance of renewable energy technologies appear technically feasible and potentially economically viable, but do not yet receive sufficient research and development support from private industry.

Expanded Research and Development

The Department of Energy will significantly increase its present level of support for research, development, and of promising new energy-efficient and renewable technologies, design practices, and advanced materials and construction methods. The Department will continue to collaborate with industry, utilities, and States in cosponsoring research and in promoting commercial application of new technologies through utility-sponsored incentive programs, demonstrations in federally owned residential buildings, and technical support to State programs, such as the Weatherization Assistance Program, to encourage these programs to take advantage of proven new technologies.

These expanded research and development efforts can build on a solid base of past Department of Energy- and industry-sponsored research on residential efficiency and renewable-energy technologies sponsored by the Department of Energy and industry. The following are areas of ongoing research that have already produced some useful results:

- New building designs and construction methods that make cost-effective use of direct solar gains, better insulation, low-heat-loss windows, building thermal mass, and measures to reduce air leakage through the building envelope and heating and cooling ducts.

- Energy-efficient appliances and equipment, such as improved refrigerators, furnaces, heat pumps, and air-conditioners.

- High-quality fluorescent lights to replace some standard incandescent bulbs in homes.

- High-performance materials for building and equipment applications, including low-emissivity glass, prototypes for evacuated panels and other advanced insulation concepts, and replacements for conventional refrigerants and foam insulation that contain ozone-depleting chlorofluorocarbon compounds.

- Industrialized housing techniques, ranging from factory-assembled window, wall, and roof components to complete panels or building modules. (Factory-based production is a growing trend in the U.S. housing industry, resulting in cost-effective application of new materials, improved product quality, and reduced onsite construction time and costs; energy-saving features are an added bonus.)

- More effective techniques for retrofitting existing residential buildings, including replacement of inefficient boiler burners and controls, improved techniques for insulating buildings and sealing air leaks, and advanced controls for home appliances to optimize the timing of both thermal and electrical loads.

- Landscaping and site design techniques that can reduce cooling and heating loads by tempering the "microclimate" around houses.

Indoor Air-Quality Research

To ensure that improved energy efficiency enhances, rather than harms, indoor air quality, the Federal Government will continue its support of research and other efforts in this area, including investigation of the sources of indoor air pollution, practical methods for evaluating indoor air quality in the field, and cost-effective means of mitigating air-quality problems in both new and existing homes.

Some energy-saving measures, if not properly designed and implemented, may worsen the quality of indoor air. For example, measures that save energy by sealing air leaks can also eliminate too much of the fresh air needed to dilute indoor pollutants. Also, volatile chemicals may evaporate from foam insulation that is not properly manufactured. Once these problems are properly understood and diagnosed, there are often reliable technical solutions. For example, well-designed mechanical ventilation systems, often with heat recovery to reduce space- or water-heating costs, can actually improve indoor air quality in homes, compared with uncontrolled air infiltration through the building shell or the sporadic opening of windows.

There are other examples of energy-efficiency measures that can make strong contributions to indoor air quality, thermal comfort, and other positive features of the home environment. For example, replacing older gas appliances with new, energy-efficient models may also remove some leaky or poorly adjusted gas-burning equipment from the stock, and repairing leaks in the building envelope and warm-air ducts in basement and crawl-space areas may help to reduce the amount of radon that is drawn into some houses from naturally occurring soil and groundwater sources.

Energy-efficiency measures need not interfere with achieving a high-quality, healthy, safe, and pleasant home environment. Buildings-related research and development by the Department of Energy, the Environmental Protection Agency, and other agencies, as well as industry- and utility-sponsored research, will continue to emphasize indoor environmental quality. The results are already being incorporated in the residential energy-efficiency standards developed by the Department of Energy and the American Society of Heating, Refrigerating, and Air Conditioning Engineers, and in utility-sponsored retrofit programs.

Cost-Effective Investments in Energy Services

While relying primarily on the private market, the National Energy Strategy also recognizes that market forces alone sometimes fail to produce the most economical outcome for consumers, because of poor information, gaps in the industry infrastructure, other costs to society not reflected in prices (externalities), or other constraints. Thus, there is a need for selected Federal efforts that encourage the application of cost-effective technologies.

Nearly one-half of the primary energy consumed in residences is used for heating and cooling

(Figure 12). Improving the thermal efficiencies of building shells, windows, and air ducts could reduce the energy consumed for these purposes by 20 to 40 percent in new homes. To achieve this potential, the Federal Government currently supports energy-efficient new housing in several ways.

Building Efficiency Standards and Guidelines

The Department of Energy, the Department of Housing and Urban Development, and other Federal agencies develop and implement energy-efficiency standards for new residential buildings. The Department of Energy standards are developed in collaboration with the American Society of Heating, Refrigerating, and Air Conditioning Engineers and other industry and professional groups. The standards provide a basis for State and local governments to incorporate energy requirements into their own building codes. Virtually every State now has some energy provision in its statewide or local building codes; about 60 percent rely on the Department of Energy standards for technical guidance, although many of these are now out of date. By law, the current Department of Energy standards are mandatory for new federally owned housing, such as military base housing. Department of Housing and Urban Development energy standards apply to manufactured housing and to new homes with Federal Housing Administration-insured mortgage loans. The Department of Energy, the Department of Housing and Urban Development, and other Federal agencies also provide reliable information on home energy efficiency for builders, buyers, and lenders.

As part of its ongoing efforts, the Department of Energy periodically updates its Federal building standards to reflect changing technologies and market conditions. The Department of Energy will work with the Department of Housing and Urban Development and other Federal agencies to strengthen the energy-efficiency standards for new manufactured housing and for all federally assisted new housing, including housing financed with federally guaranteed mortgage loans (Federal Housing Administration, Veterans' Administration, and Farmers Home Administration). Additional Federal technical and financial assistance will be made available to help State and local governments, as well as industry and building-code organizations, to update their energy-efficiency code provisions and to ensure cost-effective compliance.

Home Energy Ratings and Mortgage Financing

In cooperation with States, utilities, and the real estate and finance industries, the Department of Energy will develop and disseminate reliable techniques for rating the energy performances of both new and existing homes. In cooperation with the Department of Housing and Urban Development, lending institutions, the real estate industry, and national loan-underwriting organizations, the Department of Energy will encourage incorporation of this information in home "energy labels" and in mortgage lending practices, so that both the loan amounts and the buyer-qualifying rules fully reflect the value of lower energy operating costs. The Government will require institutions to provide such information to home buyers, after allowing at least 5 years for voluntary adoption.

Retrofit of Existing Residences

Several Federal, State, and utility programs support the retrofitting of existing homes, especially those occupied by low-income households. An important source of Federal funds is the Low-Income Home Energy Assistance Program under the Department of Health and Human Services. Recent legislation allows States to use up to 25 percent of the grants they receive under this program for low-income weatherization.

The Federal Government also provides technical assistance to a range of State and utility programs that provide consumer incentives and services for retrofitting existing housing. With respect to utilities, the Department of Energy supports State regulatory authorities (and utilities themselves) in designing programs and evaluating results. Department-funded data and analyses help States and utilities to modify their resource plans to better reflect the potential benefits of "demand-side management" resources. The Department will significantly expand this technical support. (These and related actions are described under "Electricity Generation and Use.")

In the case of federally owned or supported housing, for many years Federal agencies have undertaken significant capital and management improvements to increase energy efficiency. With respect to federally supported public housing, the Department of Housing and Urban Development and the Department of Energy have recently expanded a cooperative effort to assist local housing authorities in selecting energy-saving investments and improved operating practices. These efforts will be strengthened further by additional actions, including the establishment of energy indicators to identify public housing projects where significant savings can be achieved and the development of innovative incentives for managers and tenants to conserve. The Department of Housing and Urban Development will also more thoroughly monitor and evaluate the effects of energy-related capital investments. For federally owned housing, a new Executive order will improve the Government's ongoing energy management efforts.

Appliance Efficiency Labeling and Standards

About 80 percent of all residential primary energy is consumed by major home appliances and equipment, such as refrigerators, freezers, water heaters, furnaces, and air-conditioners. Because the energy efficiency of most new products can be significantly improved and because such products are usually replaced every 15 years or less, there is a very large potential here for energy savings. For this reason, the Federal Government has mandated standard testing, energy-efficiency labeling, and minimum efficiency standards for all new residential appliances and equipment in certain categories. Under current law, the Department of Energy and the Federal Trade Commission regulate the testing and labeling of covered appliances and equipment and the Department periodically updates the efficiency standards.

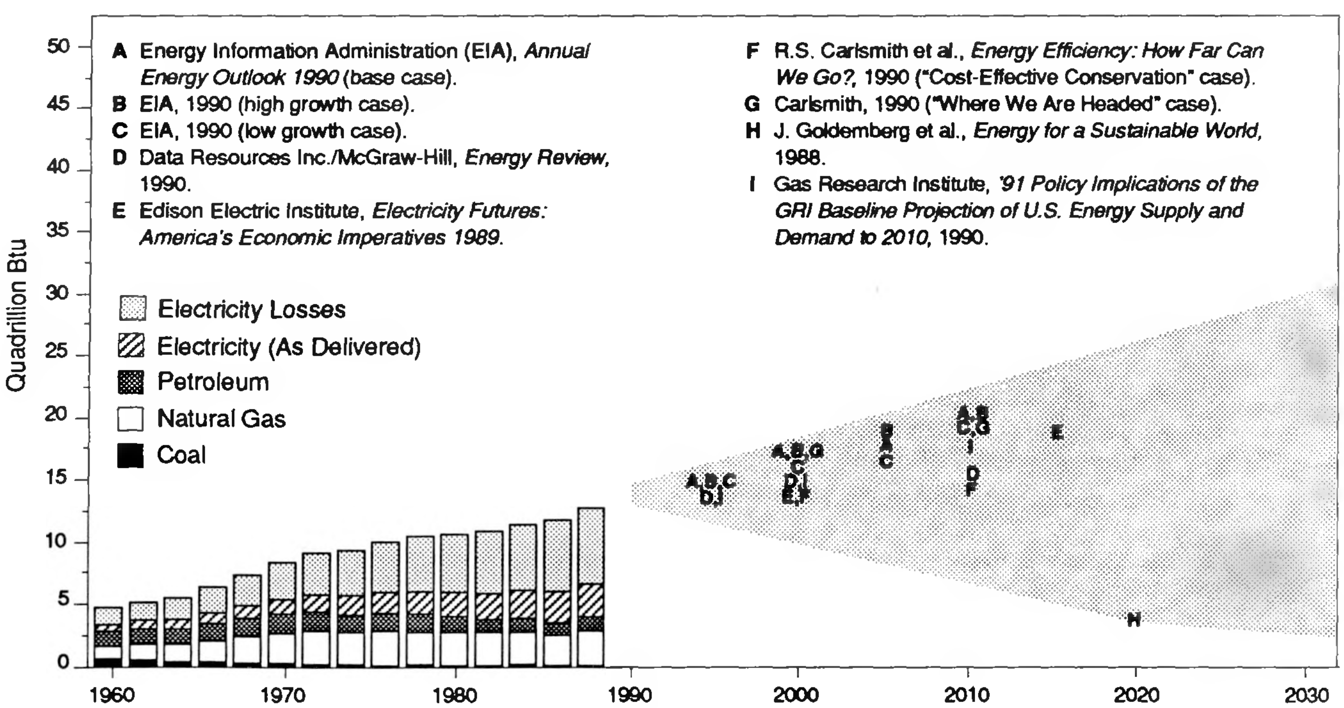
Appliance efficiency standards are effective in removing the least efficient models from the market, but they do little to accelerate introduction of very efficient new models. Continuing improvements in the average efficiency of new appliances can benefit from research and development sponsored by the Department of Energy and industry. States and utilities can help make it profitable for manufacturers to develop and introduce state-of-the-art appliances, and utility financial incentives can encourage consumers to replace older, inefficient appliances with the best new units on the market.

Commercial Energy Use

In the United States over the past three decades, economic growth, technological developments, and the transition to a service-oriented economy have greatly expanded the amount of commercial floorspace and introduced many new energy uses. As indicated in Figure 13, total use of primary energy for this end-use sector has increased faster than in any other since 1972, and, according to some projections, this trend could continue. (For statistical purposes, "commercial buildings" include nonresidential government-owned and nonprofit institutional buildings, which together account for more than 30 percent of total energy use in this sector. Street lighting and certain other supporting services—including some district heating—are also included in the "commercial energy use" category.)

Commercial buildings are obviously diverse in both structural type and function. They range from hospitals and restaurants (with very high intensities of energy use) to warehouses (which generally use relatively little energy per square foot). All together, the commercial sector today accounts annually for more than 13 quads (15 percent) of the Nation's primary energy use, with about two-thirds of the sector's total consisting of end-use electricity plus the energy required to generate and deliver it. Building owners and tenants spend about $70 billion per year for energy. Future growth in this sector's demand for electricity could be a major contributor to the supply problems faced by utilities in some regions.

Figure 13. Projections of U.S. Energy Consumption—Commercial Sector



Note: Differences in projections are caused, in part, by varying assumptions concerning energy prices, economic growth, consumer and producer behavior, and rates of technological change, including replacement of capital stock. The shaded area represents an envelope bracketing these differences.

Goals and Approaches—Commercial Energy Use

Goal	Approach
Develop new, commercially viable technologies to increase energy efficiency and expand use of renewable energy	• Increase support for research and development to— – Reduce costs and improve performance of commercial-building energy technologies, including lighting systems, windows, heating and cooling equipment, and design techniques – Develop methods of measuring and improving indoor comfort and environmental quality
Make full use of cost-effective energy-efficiency and renewable-energy technologies	• Provide information and technical assistance to— – Support industry, utilities, and State and local governments in developing and implementing effective programs, including adoption of Federal efficiency guidelines in local building codes – Extend Federal performance testing and labeling to lighting products and other equipment – Accelerate commercial application of new technologies • Implement efficiency guidelines and standards where needed for— – Lighting ballasts – New buildings • Exercise Federal leadership by— – Increasing energy efficiency in Federal building design, operation, and procurement through improved management – Using Federal facilities to test promising new technologies

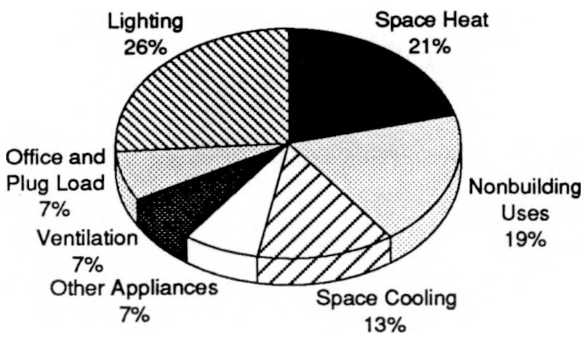
Efficiency improvements in recent years have resulted in a slight decline in the overall intensity of end-use commercial energy, but electricity is being applied more intensively each year. When electricity generating and distribution losses are included, lighting is now the largest single form of commercial energy consumption (26 percent of primary energy use), followed by space heating and cooling (Figure 14). Office equipment (such as computers, printers, and copiers) now accounts for about 7 percent of primary energy use; but it is a major source of growth in electricity demand and has become more significant than lighting in some new office buildings.

Air-conditioning for commercial buildings contributes to sharp peaks in the demand for electricity on hot summer days, forcing utilities to maintain high generating capacities just to satisfy occasional short-term requirements. To cover the costs of plants to meet this peak demand, electricity rates for commercial customers often include additional, "demand" charges or are based on time-of-use—with the highest rates during periods of peak demand.

The table above summarizes the goals of the National Energy Strategy directed at commercial energy use and the approaches used by the Federal Government to accelerate the development and application of more efficient and economical energy technologies for this sector.

Even though commercial floorspace continues to grow, much of the effect on total demand for energy services could be offset by developing and deploying cost-effective new technologies to improve the energy efficiency of building envelopes,

Figure 14. Commercial-Sector Consumption of Primary Energy by End-Use, 1990



Source: Department of Energy, Office of Conservation and Renewable Energy, staff estimates, based on DOE/EIA Commercial PC-AEO Forecasting Model.

equipment, and controls. Using solar energy and other renewable sources to satisfy at least part of the energy requirements here would also reduce the demand for conventional fuels—resulting in a variety of benefits discussed elsewhere in this report. There is great potential for making commercial buildings more energy efficient and shifting to renewable energy sources, but an array of market barriers are inhibiting the realization of this potential.

There are impressive technical opportunities to use energy more efficiently and effectively in both existing and new commercial buildings, but many of the same obstacles that discourage such efforts in other end-use sectors apply here as well:

- Regulated energy prices that may not reflect the full costs of new energy supply.
- The difficulty of reflecting environmental and other noneconomic benefits in private financial decisions.
- The large number of individual decisions and actions required to make a significant impact nationwide.
- The fragmented nature of the building industry, which contributes to a reluctance or inability to invest in long-term, generic research and development.

Some obstacles apply more specifically to the commercial sector:

- The small fraction of total business expenses—and thus management attention—devoted to the energy costs of buildings.
- The related tendency of building owners and tenants to focus mainly on occupant comfort and productivity—and to be wary of any change that might disrupt traditional building operations.
- The lack of incentives for owners of leased buildings (about one-third of the commercial stock) to invest in energy efficiency when it is usually the tenants who benefit from lower utility bills.
- The large number of actors responsible for a building's energy performance—ranging from the architect and the design engineer to the contractor, developer, lender, leasing agent, building manager, and, of course, the final occupants.
- Limitations on capital available to invest in energy-saving features (private developers often require paybacks of 1 to 3 years for measures that may last many times longer, and year-to-year budget constraints at all levels of government hamper investments in cost-effective measures within government-owned facilities).
- Budget limitations on State and local government enforcement of energy provisions within building codes—not to mention the necessary but discouraging complexities of some energy-efficiency requirements.
- The slow turnover in commercial buildings and major energy-using equipment.

Goals and Approaches

Recognizing the many obstacles to the economically efficient allocation of resources within the commercial buildings sector, the National Energy Strategy takes a multifaceted approach to increasing energy efficiency and the use of renewable energy resources in this area. Government policies are needed to improve market mechanisms' effectiveness in ensuring the efficient use of energy and other resources in the commercial sector, to provide additional support for technology development, and, in some areas, to ensure that cost-effective investments are made. The National Energy Strategy has two primary goals for the commercial sector: accelerating the development of new energy technologies and increasing cost-effective investment in commercial-sector energy services.

Through an accelerated program of Federal research and development in partnership with other industry, utility, and public-sector research organizations, new energy-efficiency and renewable-energy technologies will be developed that are reliable, that are commercially competitive, and that meet energy service needs while maintaining or enhancing indoor environmental quality, occupant comfort, and productivity in commercial buildings. In addition, the Federal Government would encourage the full use of cost-effective energy-efficiency and renewable-energy technologies by removing specific market barriers to such investments and by undertaking selective actions to encourage or require cost-effective energy service investments.

Expected Results

According to the economic and other modeling assumptions in the Current Policy Base case, annual primary energy use in commercial buildings is likely to increase by about 12 quads between 1990 and 2030. Contributing factors would include rapid growth in commercial floorspace; demand for new energy services, such as computers and office automation; and a continued trend toward all-electric buildings. This Current Policy Base case assumes continuation of the market failures that have limited cost-effective investments up to now.

By continuing to strengthen the efficiency standards applied to federally owned and assisted new buildings and by providing the technical assistance necessary for State and local governments to implement these standards through their building codes, it is estimated that primary energy demand could be reduced by 0.2 quad in 2010. Extending the Federal testing and labeling program for appliances to nonresidential equipment could contribute further savings by providing information to purchasers. In addition, the Federal Government will achieve additional gains in energy efficiency and cost savings by continuing to invest in cost-effective measures and practices in its own facilities.

Even greater savings could be achieved, although these will depend on actions outside the direct control of the Federal Government: market-driven responses by private industry and consumers and actions by utilities and government agencies at the State and local levels. However, the Federal Government can still affect the outcome by providing effective support, technical expertise, and leadership by example. Over the longer term, the Federal Government can also help lead the way to a transition from the Nation's present dependence on depletable energy sources to a primary reliance on renewable resources, coupled with highly efficient commercial building envelopes, equipment, and controls. Because of the long lead times involved, work should begin now on both the advanced technologies and the "delivery systems" and expertise needed to install, operate, and maintain them. Federal research, development, and demonstration efforts can all help build the foundation for an affordable and sustainable energy future.

Advanced Technologies

A number of the obstacles described above have inhibited the development of commercial-building energy technologies. As in the residential sector, significant advances in energy efficiency and in the performance of renewable energy technologies appear technically feasible and potentially economically viable, but they do not yet receive sufficient research and development support from private industry.

Expanded Research and Development

In partnership with private industry, utilities, and States, an expanded Federal research and development program will accelerate the development and commercialization of new, cost-effective technologies for energy efficiency and renewable-energy use in commercial buildings. The Department of Energy will seek cost-sharing arrangements, using consortia with industry, utilities, universities, and States for research and development and timely application of new commercial-sector technologies. It will get industry and universities more involved in the planning and conduct of research and development.

During the past decade, federally supported research and development has contributed to numerous energy-efficient products and systems, although many are not yet in widespread commercial use. For example, natural-gas-fired furnaces and boilers with electric ignition and condensing heat exchangers are 10 to 30 percent more efficient than standard equipment. New designs for commercial-building heat pumps and chillers with variable speed and output require up to 25 percent less electricity than systems now in place. Federal research and development efforts have contributed to major efficiency gains in fluorescent lighting ballasts and high-performance window coatings. Federal agencies have also cooperated with industry in an accelerated search for energy-efficient alternatives to use of chlorofluorocarbons in refrigeration systems and foam insulation. These and many other technologies offer considerable promise for the future. Future developments could include cost-effective passive and active solar technologies for heating and cooling; advanced controls for lighting and for heating, ventilation, and air-conditioning systems; "smart" windows, with optical properties that can adjust to balance heat gains and losses and availability of daylight; building-scale photovoltaics; high-efficiency office equipment; and district heating and cooling systems that use thermal storage and advanced, low-pollution cogeneration.

The National Energy Strategy envisions a significant increase in the current Federal commitment to commercial-building research and development. Federal funds can be highly leveraged by coordinating research planning and execution with the research, development, and demonstration programs of industry, utilities, and State and local governments.

Speeding the development of new, improved energy-efficiency technologies will not, by itself, ensure their immediate acceptance by the market. Full and prompt commercial deployment will require further actions to address the specific market barriers cited above.

Indoor Air-Quality Research

Another important component of the research and development effort is aimed at maintaining or improving the indoor environmental quality of energy-efficient commercial buildings (also see "Energy and the Quality of Air, Land, and Water"). Given the potential costs of a disruption in commercial services or other adverse effects on employee productivity, businesses continue to emphasize that energy-saving measures must not degrade the quality of the environment in offices, stores, or other commercial buildings. Fortunately, many of the same design and control strategies that contribute to energy efficiency can also help to mitigate or eliminate indoor air-quality problems, discomfort, and poor lighting quality. For example, well-balanced air distribution systems not only provide the proper amount of outside fresh air to dilute indoor air pollutant sources but also can help eliminate uncomfortable warm and cold spots in different zones of commercial buildings. Where there are localized or infrequent pollutant sources, such as copy machines or people crowded into meeting rooms, new types of sensors and controls can regulate the amount of fresh (heated or cooled) air routed to these spaces. Hospitals, restaurants, and other commercial buildings with special requirements for large amounts of outside air can use heat recovery systems to reduce their heating and cooling energy needs. Finally, careful selection and placement of lighting equipment, combined with effective use of daylighting and proper interior design, can produce high-quality lighting while greatly reducing energy requirements for lights and their associated cooling loads.

The Department of Energy will continue to cooperate with the Environmental Protection Agency and other Federal and non-Federal agencies on research to better understand the sources of indoor air pollutants, techniques to measure the various dimensions of indoor environmental quality, the relationship of the indoor environment to human health and productivity, and the development and demonstration of new technologies that couple energy efficiency with indoor environmental quality.

Cost-Effective Investments in Energy Services

"Market conditioning" activities can encourage cost-effective public and private investments in commercial-sector energy services. While relying primarily on market mechanisms, the Federal Government can accelerate deployment of new energy technologies through information and technical assistance efforts, efficiency guidelines and standards, and aggressive energy management within Federal facilities.

Information and Technical Assistance

The Department of Energy will seek congressional authority to extend the residential equipment testing and labeling program to selected nonresidential equipment, including lighting equipment and controls, commercial space-conditioning equipment and controls, office equipment, and small (under 25 horsepower) electric motors. This program would allow architects and engineers to make sound technical judgments when specifying equipment for new buildings and would provide contractors and building managers with a more reliable basis for comparing investments in replacement equipment. Federal technical and financial assistance to States, local governments, and utilities will promote utility-sponsored incentive programs, new energy services for customers, and other measures to ensure that efficiency and renewable energy sources are considered fully reliable components of utility resource planning.

Of special importance are Federal efforts to strengthen the "infrastructure" for delivering new products and services related to efficiency and renewable energy sources. These efforts will include support for basic skills training, professional education, and assurance of reliable data and analysis tools for tracking progress and guiding future decisions in both the private and the public sectors.

Efficiency Guidelines and Standards

Where information and incentive strategies fail to achieve optimal levels of investment in efficiency and renewables, the Department of Energy will use its existing authority to continue promulgating and updating efficiency standards for new federally owned or assisted commercial buildings and for implementation through State and local energy codes. The Federal Government will also expand its efforts to assist local agencies and builders in code updating and compliance, to provide improved design tools for architects, and to support industry efforts to improve quality control in construction, start-up "commissioning" of new buildings, and long-term building operation and maintenance.

Federal Leadership

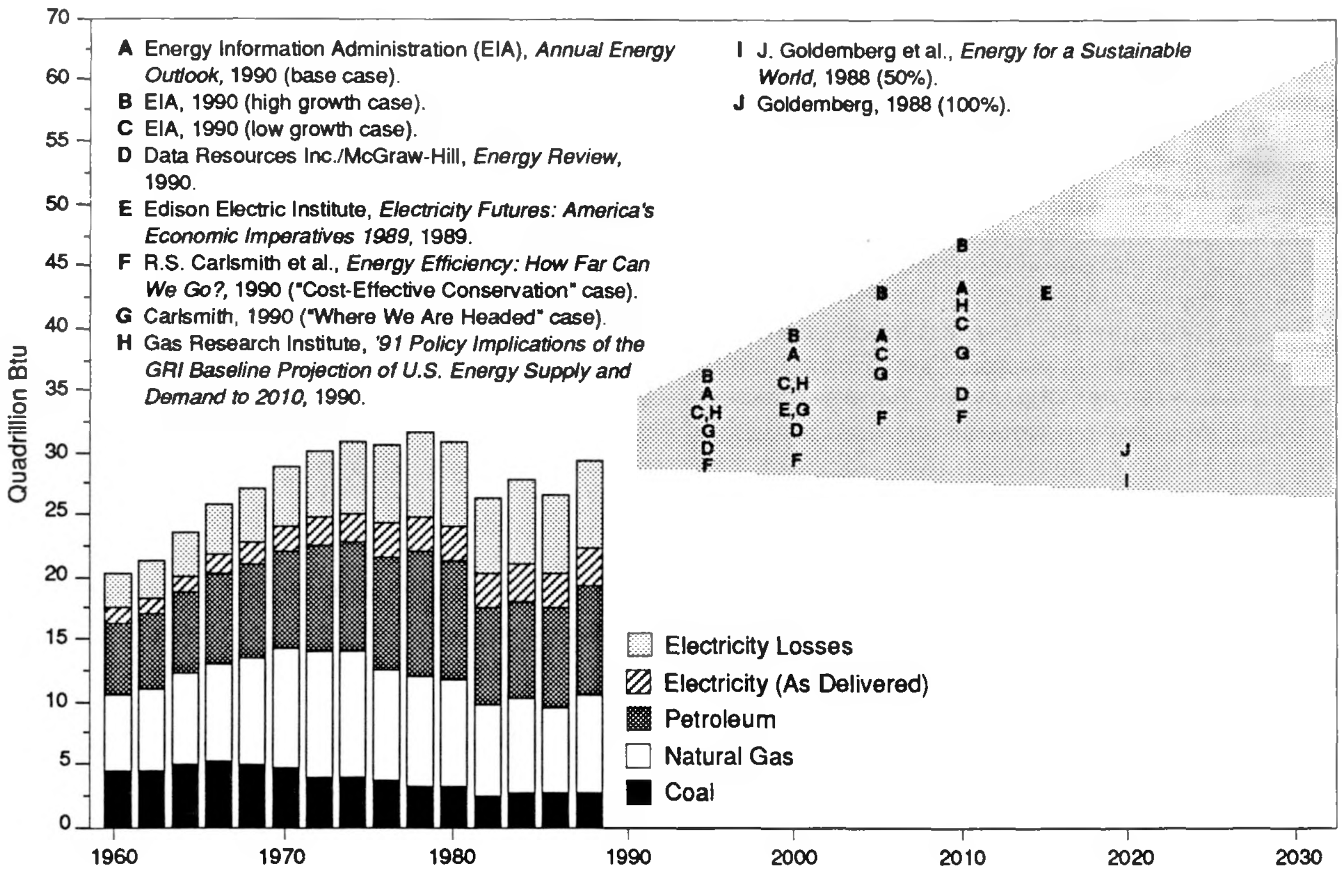
The Government's own purchasing power will be used, under a new Executive order, to establish a Federal leadership role in energy management. The Department of Energy will support continuing interagency efforts to use third-party financing, utility conservation incentives, performance-based contracting, and improved criteria for energy cost-effectiveness in Federal procurement and leasing practices. Federal support for State and utility programs of financial and technical assistance will encourage States, local governments, and other institutional building owners, such as schools and hospitals, to make optimal use of available energy technologies.

Industrial Energy Use

The industrial sector accounts for approximately one-fourth of all U.S. petroleum consumption, but more than half of this is used as feedstocks for such material as plastics and petrochemicals. Excluding fuels used as nonenergy feedstocks (but including the energy used to produce and deliver electricity), the industrial sector accounted for 36 percent of all primary energy consumption in this country during 1989.

When "industry" is cited as an energy-consuming sector, this includes not only manufacturing and processing but also mining and agriculture. Energy consumption by manufacturers is approximately 80 percent of the consumption of the entire industrial sector, and 70 percent of nonfeedstock manufacturing energy use is attributable to four energy-intensive industrial sectors, which are petroleum and coal products, chemicals, primary metals, and pulp and paper.

Figure 15. Projections of U.S. Energy Consumption—Industrial Sector



Note: Differences in projections are caused, in part, by varying assumptions concerning energy prices, economic growth, consumer and producer behavior, and rates of technological change, including replacement of capital stock. The shaded area represents an envelope bracketing these differences.

Goals and Approaches—Industrial Energy Use

Goal	Approach
Improve energy efficiency and fuel-flexibility in the industrial sector	• Conduct aggressive cost-shared Government-industry research and development programs aimed initially at industrial processes in energy-intensive industries
Encourage cost-effective measures to reduce energy costs	• Conduct energy audits of manufacturing plants to accelerate adoption of existing cost-effective measures
Reduce industrial waste generation, increase recycling of wastes, and increase use of plant- and consumer-generated wastes as process feedstocks	• Conduct aggressive research and development on technology and techniques to reduce the rate of waste generation and to allow wastes to be used as resources

Figure 15 shows historical industrial use of primary energy and a range of projections for future use in the United States. Between 1973 and 1989, the value of goods and services produced in the United States grew by 50 percent, yet industrial energy use decreased by 6 percent. Figure 16 illustrates the drop from 1973 to 1985 in primary industrial energy use "intensity," the measure of energy use per dollar of industrial output. About half of this change in energy intensity was due to efficiency improvements made by industry in response to energy prices. The other half was due to structural shifts in U.S. demand—away from the products of energy-intensive industries, and away from producing energy-intensive goods (such as automobiles) domestically to importing them.

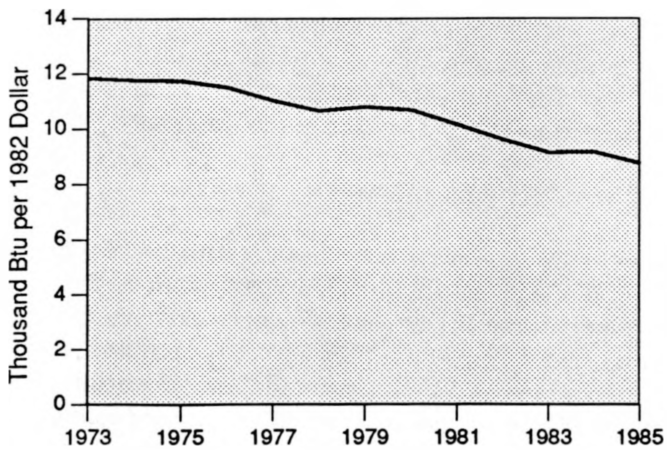
The industrial sector becomes more energy efficient as older equipment and facilities are replaced. During the last 15 years, increased energy prices have accelerated this turnover and retooling process.

In Figure 15, historical energy consumption by industry is disaggregated by fuel type. By 1989, electricity and electrical system energy losses were one-third of industrial primary energy, followed by petroleum and natural gas, with about 28 percent each.

Newer equipment and facilities have given U.S. industry additional fuel-flexibility and improved emissions control. To the extent that manufacturers can switch from one fuel to another in response to price differentials, fuel-flexibility in industrial processes adds to cost effectiveness.

Current industrial practices produce more than 600 million tons of solid hazardous wastes each year, along with millions of tons of waste gases that contain chemicals worth about $500 million per year. The Environmental Protection Agency estimates that approximately 11 billion tons of nonhazardous solid wastes and wastewaters are also produced each year. These waste streams,

Figure 16. Industrial Primary Energy Consumption per Dollar of Industrial Output, 1973–1985



Source: Energy Information Administration, *Energy Conservation Indicators 1986 Annual Report*, February 1988.

containing potential feedstock sources, present industry with serious environmental problems and growing disposal costs. Counting only the costs of meeting enforced regulations, industry currently spends about $46 billion per year on pollution controls. Transforming these wastes into usable feedstocks could reduce the Nation's requirements for primary energy while concurrently improving environmental quality.

The industrial sector does not face the same barriers to greater energy efficiency and fuel-flexibility faced by the other energy end-use sectors. As mentioned under "Residential Energy Use" and "Commercial Energy Use," there is often a difference in those two sectors between those who pay for the energy efficiency improvement and those who reap its benefits. While the industrialist both pays for the energy efficiency improvement and reaps its benefits, efficiency research and development remain underfunded. It is difficult for any single firm to finance and conduct the efficiency research and development necessary when the benefits of that research are soon adopted by other firms.

There are research and development opportunities, such as advanced dual-fired industrial boiler design. These opportunities, if fulfilled, would provide energy benefits across several industry segments. However, no one firm has the incentive to finance them.

Thus, Government has a role in providing research and development in new energy-efficient and fuel-flexible technologies to be available for application by industry when energy prices increase. Ensuring a continuous stream of new efficient and fuel-flexible technologies is key to U.S. industries remaining cost-competitive in global markets.

Goals and Approaches

As shown in the table on page 55, the National Energy Strategy establishes three goals for industrial energy use: (1) encourage increased energy efficiency and fuel-flexibility in the industrial sector to reduce petroleum dependence, (2) encourage cost-effective measures to reduce energy costs, and (3) reduce industrial waste generation, increase recycling of wastes, and increase the use of plant- and consumer-generated wastes as process feedstocks. The goals are interrelated; fuel-efficiency and fuel-flexibility improvements are implicit in waste minimization goals.

Expected Results

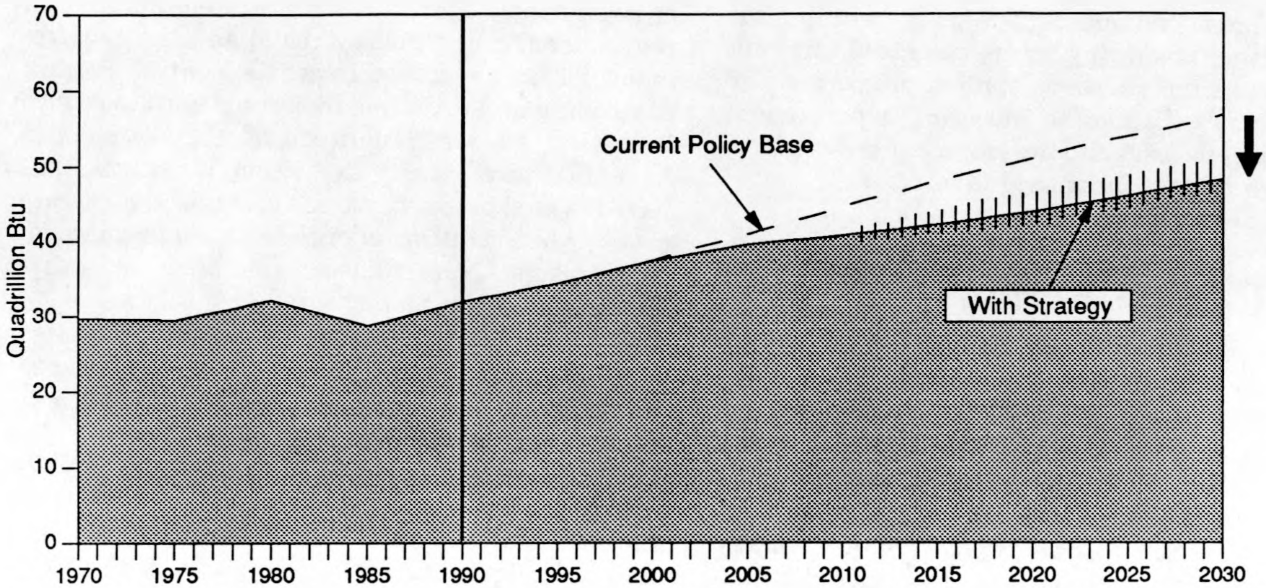
The National Energy Strategy's cost-shared research and development projects will lead to reduced industrial energy consumption. The "Current Policy Base" and "With Strategy" cases shown in Figure 17 are model-based projections and are the Department of Energy's best estimates of future energy consumption. The cross-hatched area surrounding the "With Strategy" case line represents the uncertainty range of the model projections.

Based on these estimates, industrial energy use, including electricity losses, would be about 55 quads in 2030 without the National Energy Strategy actions. With the actions, the industrial sector, on average, would be 5 percent more energy efficient in 2005, 10 percent more efficient in 2010, and more than 15 percent more efficient in 2030. In aggregate, about 9 quads of primary energy, including electricity losses, could be saved by 2030, as shown in Figure 17.

Energy Efficiency and Fuel-Flexibility

Implementation of the National Energy Strategy will improve energy efficiency and fuel-flexibility by increasing support for research, development, and demonstration, using industry-Government cost sharing, and by increasing information and technology dissemination efforts through the Energy Analysis and Diagnostic Centers and other outreach projects. Industrial energy research and development will stress reduction of waste energy in industry and advanced industrial processes. Increasing energy audits of industrial plants through the Energy Analysis and Diagnostic Centers will reduce energy use and help disseminate the results of Government and industry research and development.

Figure 17. Industrial Primary Energy Use



Research and Development on Waste Energy Reduction

The Department of Energy will increase its support of research and development on equipment that will improve energy conversion efficiency, recover energy from industrial waste heat, and provide higher temperature structural materials and related technical information that supports these advances. Opportunities exist in all industries to develop technologies that deliver energy services to industrial processes at higher efficiencies and with greater fuel-flexibility than at present. Energy that is wasted in the manufacturing process can be captured and used, thereby reducing energy requirements to produce goods and services and increasing plant production. Therefore, savings are achieved from lower energy costs and more efficient plant utilization. The Nation will also derive substantial environmental benefits by reducing the energy that it requires to produce goods and services.

Department of Energy research and development support will stress advanced chemical and mechanical heat pumps; process heat exchangers and ceramic recuperators; advanced materials such as continuous fiber-ceramic composites; advanced combustion systems for industry; and industrial cogeneration technology. These technologies will address a mix of near-, mid-, and long-term opportunities to save energy in the industrial sector. Research and development will be carried out through innovative cost-sharing arrangements with industry.

Research and Development on Industrial Processes

The Department of Energy will increase its support of research and development on new industrial processes that offer significant opportunities for improving energy efficiency and increasing industry's flexibility in using alternative fuels—particularly, renewable fuels. The development of new industrial processes, from raw material to final product, presents another major opportunity for industry to improve its energy efficiency and fuel-flexibility. Opportunities to save energy by redefining the production process exist within specific industries, such as steelmaking, as well as within process steps that cut across industries, such as separations technology.

The Department of Energy supports the development of new industrial processes for advanced steelmaking, sensors and controls, improved membranes for separation systems, and process electrolysis. Department research and development focuses on technologies that offer energy savings and fuel-flexibility in the near, mid-, and long terms. The Department of Energy will pursue cooperative cost-sharing arrangements to carry out Federal research and development programs. The Government will also be pursuing a permanent 25-percent research and development tax credit to encourage private industrial investment.

Energy Audits

Opportunities to save energy in industry are not necessarily limited to the application of advanced technology. Often, existing technology can be applied more effectively to reduce energy use with no loss of performance. Good standard operating and maintenance practices, for example, offer cost-effective measures for industries to save energy and improve productivity. Energy audits of industrial facilities often reveal simple ways to cut energy use quickly, with very small capital investment.

Energy Analysis and Diagnostic Centers, operated by universities for the Department of Energy, have performed more than 2,800 preliminary plant energy audits for small- and medium-sized companies. The Department's expansion plan calls for adding 3 universities in fiscal year 1992 to the 18 already participating. In addition to helping smaller firms improve their energy efficiency, this program provides hands-on audit training for engineering students. The Department will encourage similar private-sector programs, such as utility-conducted industrial audits performed as part of a demand-side management program.

Waste Reduction, Waste Recycling, and Use of Wastes as Feedstocks

The reduction of waste generation is an important strategy to control costs and improve productivity. Potentially dischargeable waste is not produced and therefore does not require treatment and disposal. Waste reduction ensures that more raw material becomes product, thereby reducing energy requirements, saving natural resources, and lessening environmental impacts. After wastes are reduced to their technical minimums, industry may use or convert unavoidable wastes to feedstocks or fuels. If use or conversion is impossible, it may treat wastes and release them into the environment. More restrictive environmental regulations, rising energy costs, and the requirement for more economic waste control require developing and investing in technologies to reduce industrial wastes. Hundreds of U.S. companies have instituted waste reduction measures that have lowered production costs and raised corporate profits while reducing energy use and environmental impacts. Nevertheless, cost-effective waste minimization can be increased.

Incomplete knowledge of the most advanced waste management practices is an important obstacle to more effective waste management. There are a wide variety of production processes that require individualized waste management strategies. In addition, implementation of new waste management techniques may require regulatory changes.

The Government will continue to rely on private industry to make economic choices on waste management alternatives. However, to overcome the lack of advanced waste reduction and utilization technology, information barriers, and regulatory deficiencies, the following actions are required: support research and development on advanced process technology that reduces wastes, support research and development on waste use and conversion technology, determine which regulatory changes may help foster improved waste management without compromising environmental quality, and develop an outreach program.

Research and Development on Waste Reduction Technologies

The Department of Energy will increase funding of cost-shared research and technology development directed specifically at industrial waste reduction. Long-term waste solutions often involve redesign of major portions of an industrial process that may require significant research and development, and many small- and medium-sized companies do not have the necessary resources. Even firms that have sufficient resources must evaluate the relative merits of developing new production technology versus product-related research and development.

The Department, in close coordination with industry, will target the cost-shared effort to key areas with potential for substantial energy reduction. Other criteria will include opportunities to reduce environmental impacts, to increase overall industrial productivity, and to save natural resources. Initially, the Department will target chemical processes because of the large amounts of wastes that they produce and the large investments that are being made in pollution control activities ($4.2 billion in 1988). Additional industries, such as the petroleum industry and the pulp and paper industry, will follow as additional analysis is done on their waste reduction opportunities and needs.

Research and Development on Waste Use and Conversion

The Federal Government will increase its support for research and development on the innovative mechanical, biochemical, and thermochemical processes that industry needs to convert industrial wastes economically into feedstocks or fuels. All industries produce wastes at every stage, from raw material input through product distribution and servicing. Many opportunities exist for profitable recovery and conversion of some of these wastes rather than payment of continuing and generally escalating costs for their environmentally sound disposal. However, the lack of cost-effective recovery techniques to use the materials and energy content of industrial wastes efficiently limits their use.

The Department of Energy will focus on techniques for improved recovery of metals and other materials from auto scrap, recovery of useful products from waste tires, recovery of adhesives and other useful materials from wood wastes, recovery of high-value products from food wastes, and separation and collection of useful gaseous materials. Solar technologies will be developed to decontaminate wastewater and destroy hazardous industrial chemicals. The Department will pursue near-, mid-, and long-term research and development objectives through cost-sharing with industry. Though strongly market oriented and well connected to the ultimate industrial users of the technology, the Department's approach in this area emphasizes bringing capabilities of the National Laboratories to bear on the complex technical issues involved.

Industrial Waste Regulation Reform

The Department of Energy and the Environmental Protection Agency will determine the extent to which existing regulatory programs discourage investment in innovative waste and pollutant minimization technologies. The evaluation will include input from private industry on existing regulatory barriers and potential solutions. The Department and the Agency will then suggest legislative or regulatory changes to encourage waste minimization investments.

Waste Outreach Program Development

The lack of good data, worker information programs, and auditing procedures may create significant barriers to widespread adoption of waste reduction practices. The Department of Energy will develop a coordinated outreach program to communicate research results, provide technical information and advice, and disseminate industrial waste stream data to the industrial sector. This effort will be coordinated with the Environmental Protection Agency, as well as with leading industry groups with interest in waste reduction and use.

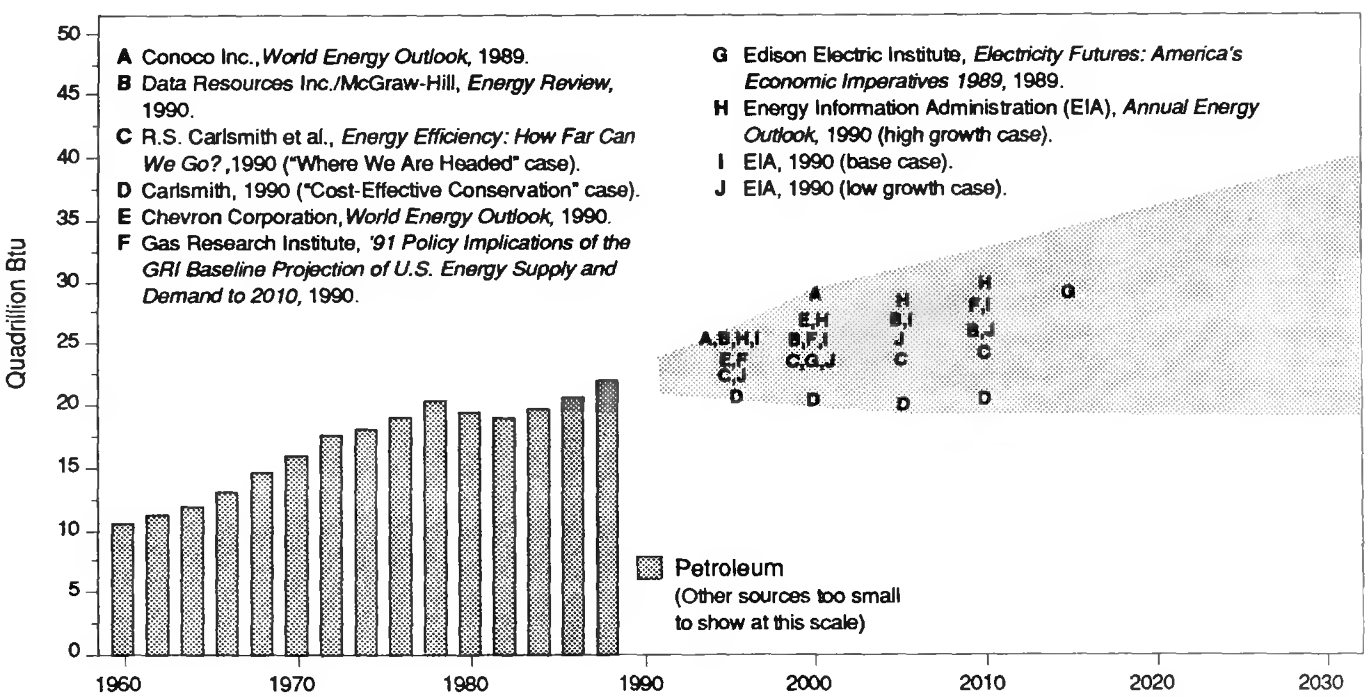
Transportation Energy Use

The efficient transportation of people, goods, and services is essential to the economic and social vitality of the Nation. But the U.S. transportation sector's near-total dependence on oil also shapes the Nation's energy security and environmental concerns. U.S. use of energy for transportation has been growing rapidly in the past few years. Since 1976, the amount of oil that the Nation uses for transportation alone has exceeded its domestic oil production. In 1990, the transportation sector accounted for about two-thirds of all U.S. petroleum use and about one-fourth of total U.S. energy consumption—at a cost of about $200 billion.

The National Energy Strategy will guide the United States into a future in which the transportation sector will use less oil than it does today—while maintaining a high standard of mobility and a diversity of transportation choices for all Americans. Advanced propulsion technologies and alternative fuels can be expected to significantly increase efficiency and reduce pollution without sacrificing safety and comfort.

Between 1960 and 1989, U.S. transportation's demand for energy grew rapidly, averaging 2.5 percent per year (Figure 18). As indicated in Figure 19, the Current Policy Base case projects continued annual growth in transportation energy demand between 1990 and the year 2010 at 1.7 percent overall, and 1.3 percent for light-duty vehicles (principally, passenger cars).

Figure 18. Projections of U.S. Energy Consumption—Transportation Sector



Note: Differences in projections are caused, in part, by varying assumptions concerning energy prices, economic growth, consumer and producer behavior, and rates of technological change, including replacement of capital stock. The shaded area represents an envelope bracketing these differences.

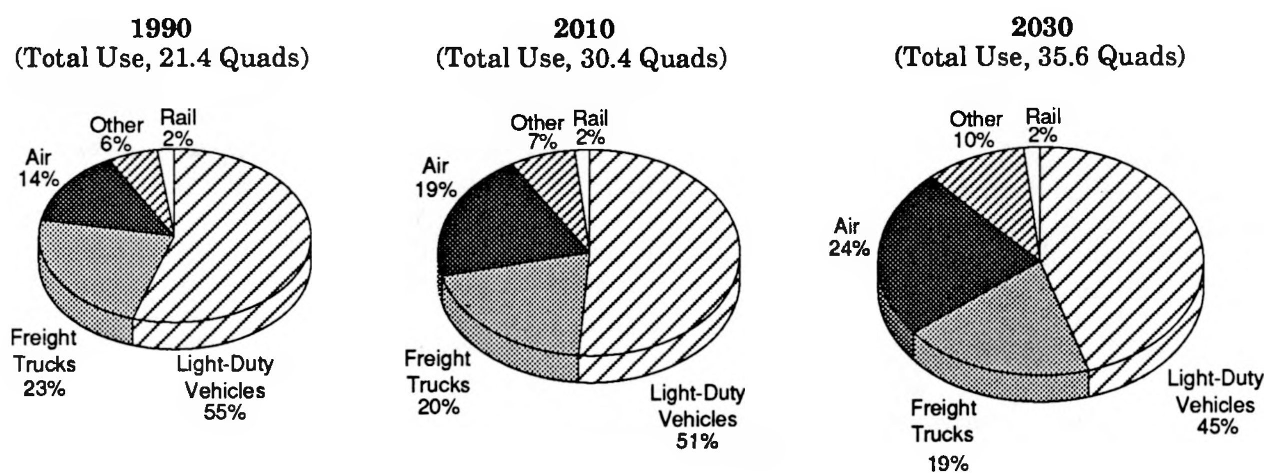
Goals and Approaches—Transportation

Goal	Approach
Reduce transportation energy demand by cost-effectively improving fleet fuel efficiency	• Get less efficient, highly polluting vehicles off the road • Expand research and development programs to accelerate the commercialization of advanced clean, energy-efficient propulsion systems in major transportation modes • Assess new-car fuel-efficiency potential within safety, emissions, and market limitations
Improve transportation energy supply through use of cost-effective alternative transportation fuels	• Provide incentives and requirements for use of alternative-fuel vehicles • Stimulate use of alternative fuels from nonpetroleum sources • Accelerate research and development of new feedstocks and conversion processes for domestically produced biofuels
Increase efficiency of the overall transportation system	• Promote use of mass transit and ride sharing for efficient use of the existing transportation system • Conduct research and development programs on long-term alternative transportation systems

Higher demand for jet fuel and diesel fuel, closely related to economic growth and shifts in personal travel and freight mode choices, would be responsible for much of the projected increase in transportation fuel use. Energy consumption by aircraft is anticipated to more than double between 1990 and 2030, *and* energy consumption by heavy trucks and marine craft is expected to rise more than 80 and 75 percent, respectively, over the same period (Figure 19).

Fuel demand by light-duty vehicles (passenger cars and light trucks), however, is expected to increase by only 45 percent by 2030 (Figure 19). Nonetheless, light-duty vehicles are likely to remain the largest future users of oil in the

Figure 19. Oil Use in the Transportation Sector (by Mode)



transportation sector, even though the shares consumed by freight trucks, aircraft, and marine craft are expected to increase sharply. Light trucks have shown less average improvement in fuel economy than have automobiles, and many households have shifted from automobiles to light trucks for personal transportation.

In addition to dominating U.S. oil consumption, the transportation system is a major contributor to urban air pollution. The 1990 revisions to the Clean Air Act—an integral part of the National Energy Strategy—address this problem by placing increasingly stringent emission requirements on motor vehicles, intensifying programs for vehicle inspection and maintenance, mandating vapor recovery systems, directing the use of "clean" fleet vehicles in some areas, and requiring changes in diesel fuel and gasoline composition—including the use of oxygenates (alcohols and ethers).

The use of oxygenates in gasoline is not new. In recent years, U.S. gasoline has included increasing amounts of alcohols and ethers, but they still constitute a minor component in terms of overall fuel volume. In 1988, about 834 *million* gallons of ethanol and 390 *million* gallons of methanol (converted into methyl tertiary butyl ether, or MTBE) were blended into some of the 112 *billion* gallons of gasoline used in the United States. Over the next decade, implementation of the Clean Air Act is expected to accelerate the use of alcohols and ethers in gasoline in areas that have not attained certain minimal clean air standards, displacing a minimum of 200,000 to 300,000 barrels per day of oil use.

Goals and Approaches

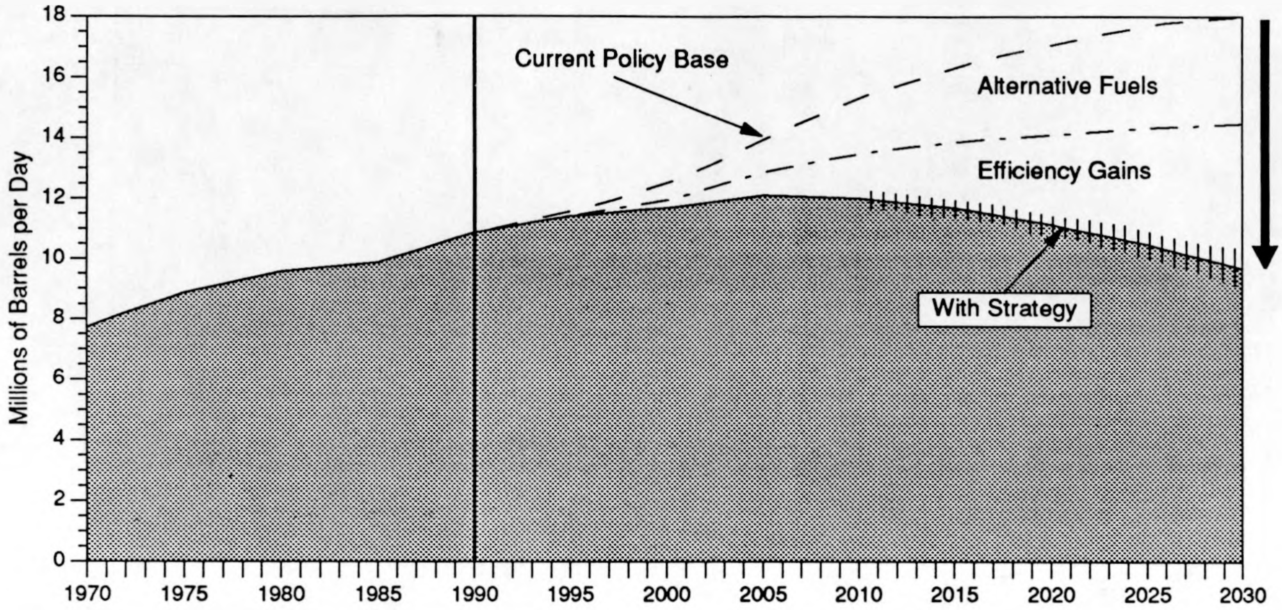
The National Energy Strategy provides for specific actions for the near term, regulatory and technology actions for the midterm, and advanced technology development programs with high potential for saving energy for the long term. The Strategy's policy actions will enable consumers and producers to use the market to make transportation choices that are more efficient and less dependent on oil. These actions will include getting inefficient vehicles off the road and removing obstacles to the introduction of alternative fuels. Where there are technological constraints on actions, the Federal Government will direct enhanced research and development efforts at removing those constraints and expanding the portfolio of future cost-competitive alternatives. The Strategy also includes strengthening of programs to enable industry and the Federal Government and its laboratories to work together more effectively through expanded research and development consortia, joint ventures, cooperative research and development agreements, and other arrangements. These and other techniques can help focus research and development on industry needs for commercialization and will accelerate technology transfer. The Government will also strengthen cooperative interagency efforts, such as Department of Energy-Department of Agriculture research on new energy crops.

Expected Results

The National Energy Strategy provides for transportation energy-efficiency improvements and use of alternative transportation fuels that should allow continued growth in travel but require less petroleum than is used today. Implementation of the Strategy will reduce U.S. reliance on oil (Figure 20). We have made these estimates while recognizing that they depend on several assumptions about the future behavior of individuals and firms. Nonetheless, such estimates are useful to help put into perspective the potential significance of the measures being proposed in the National Energy Strategy. The alternative-fuel and energy-efficiency initiatives included in the National Energy Strategy and the Clean Air Act Amendments of 1990 are expected to reduce U.S. oil imports by about 2 million barrels per day by 2005 and 3.5 million barrels per day by 2010. Estimates of oil import reductions range up to 8 million barrels per day by 2030.

The National Energy Strategy's alternative-fuel initiatives will result in a wide variety of alternative fuels that will penetrate and reshape the transportation infrastructure, becoming available across the country to a large and growing fleet of flexible-fuel and dedicated alternative-fuel vehicles. These fuels include natural gas, ethanol, methanol, liquefied petroleum gas, and electricity. However, we do anticipate that Department of Energy research will foster an alternative-fuel industry that increasingly relies on domestically produced alternative fuels produced from biomass

Figure 20. Demand for Oil in the Transportation Sector



feedstocks. With successful research and development, biofuels production facilities will offer attractive investments for private industry at levels that are reasonable given current industry patterns. Domestically produced nonfood energy crops could also increase agricultural diversity and invigorate rural areas while enhancing U.S. energy security.

As shown in Figure 21, the National Energy Strategy will cause increasing displacement of imported petroleum by use of alternative fuels, estimated to be the equivalent of 3.8 million barrels per day by 2030 (this includes 0.4 to 0.6 million barrels per day of oil equivalent of oxygenates in reformulated gasoline resulting from the Clean Air Act Amendments). Significant production of domestic biofuels will begin around 2010, rising to about 50 percent of total alternative-fuel use by 2030.[1]

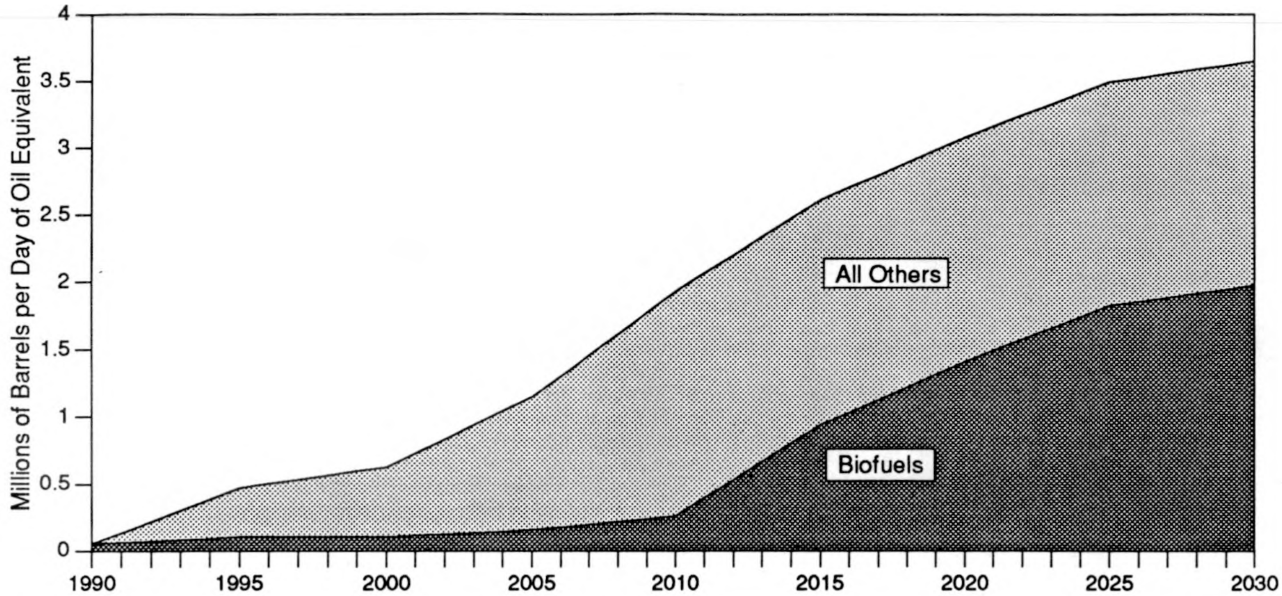
Taken together, improvements in efficiency and increased reliance on alternative fuels are expected to reduce toxic emissions and emissions of greenhouse gases. With successful research and development and enhanced public education, advances in all transportation modes could bring greater efficiency to the overall system. With a consistent vision and commitment, the United States can increase transportation efficiency and fuel choice and reduce air pollution while maintaining the mobility and freedom of transportation choice that the public demands.

Fleet Fuel Efficiency

The largest group of energy consumers in transportation is light-duty vehicles (automobiles and light trucks), which use about 6.5 million barrels per day of oil and account for 60 percent of all transportation energy use (Figure 19). The fuel economy of light-duty vehicles has improved significantly over the past 15 years. For example, new-car fuel economy has more than doubled since 1973. However, increases in travel during the same period have been so great that aggregate light-duty-vehicle fuel use has increased. Fuel use by heavy trucks (which are under no fuel economy regulations) has increased dramatically; overall total highway energy consumption is responsible for about 75 percent of transportation energy use.

1. The greater use of alternative fuels is due to the alternative-fuel options in the mid- and long term and the availability of advanced nonpetroleum vehicle technologies brought about in part by the transportation research and development options in the long term.

Figure 21. Displacement of Oil From Alternative Fuels



Both because of the dominance of energy use by highway vehicles and because of the longer time (13 years or more) that such vehicles remain a part of the transportation stock, it is important to focus on increasing the efficiency of the whole fleet.

Because of significant gains in vehicle efficiency during the past decade and because of low petroleum prices, fuel costs currently represent a small proportion (15 to 20 percent) of total operating costs over a motor vehicle's lifetime. This relatively low fuel cost has dampened consumer interest in more fuel-efficient vehicles, despite the availability in the U.S. market of a wide range of vehicles with very high fuel efficiency. Even when consumers are interested in fuel economy, they must make extra efforts to obtain comprehensive comparative information. (A recent Argonne National Laboratory study found that many motorists are not aware of the Gas Mileage Guide and that dealers do not always provide it.) In the absence of predictable consumer demand, the development of new transportation technologies can be costly and risky, especially to U.S. industry. Nevertheless, energy-efficient technologies benefit the Nation by reducing oil imports and improving air quality—benefits that are broadly distributed and that do not just accrue to the manufacturers that bear the risk of developing the technology or to the individual users of the vehicles.

The National Energy Strategy takes three approaches to meeting the goal of greater fleet efficiency: (1) getting inefficient vehicles off the road and initiating a comprehensive assessment of efficiency, safety, and emission standards for light-duty vehicles; (2) accelerating research and development activities that are most likely to lead to the manufacture of more energy-efficient, fuel-diverse, and environmentally improved transportation systems; and (3) improving the effectiveness of consumer response to transportation efficiency.

An enhanced research and development effort is expected to accelerate the development of new efficient, fuel-diverse automobile technologies. This midterm approach could bring new automotive technologies to the marketplace during the mid- to late 1990's. The Department of Energy will work with vehicle and component manufacturers on key technologies that include the following:

- Automotive gas turbines
- Advanced diesel engines
- High-performance batteries

- High-performance electric vehicles
- High-temperature ceramic materials
- Friction-reducing technologies

By increasing the near-term budget for these programs and focusing on the critical performance and cost parameters, the Federal Government could hasten the introduction of these technologies into the marketplace, with the attendant benefits of reduced petroleum consumption and a decline in vehicle emissions. In addition, manufacturers and consumers could have an expanded range of engine and vehicle technologies to meet their specific travel needs.

Vehicle Scrappage

Significant accomplishments have been made in improving the efficiency of new vehicles, bringing the average new-car tested mileage up from 15.8 miles per gallon in 1975 to 28.1 miles per gallon today. Nevertheless, overall transportation consumption of oil is rising because older, less efficient cars still constitute a portion of all U.S. cars and because people are driving more. The Federal Government will provide incentives to State and local governments and private parties to establish programs that would result in the scrappage of the oldest and dirtiest vehicles still in use. These incentives take the form of emission compliance credits that would alleviate the need to undertake more costly measures to meet clean air requirements. We estimate that such programs could remove 2 million old and inefficient cars by the year 2000. Early retirement of these gas-guzzling vehicles could lead to savings of 10,000 to 15,000 barrels per day of oil. Nationwide, ozone and smog-producing emissions could be reduced 1 to 2 percent. These emission reductions would have an even greater effect since the program is focused on urban areas with relatively poor air quality.

Fuel Economy Standards

The current corporate average fuel economy law contains several provisions that limit its effectiveness and equity. For example, corporate average fuel economy requirements do not account for the ranges of vehicle types that manufacturers produce. A producer of primarily compact and subcompact vehicles must merely meet the same standard that applies to a full-line producer or a producer that specializes in luxury cars. Consequently, the standards do not require equal efforts by different manufacturers. The corporate average fuel economy requirements contain "import" and "domestic" fleet requirements that are arbitrarily defined and that do not conform to the current practice of the U.S. automobile industry, which is increasingly integrated into an international industry in terms of product design and manufacture. Furthermore, current standards do not address safety problems arising from reliance on smaller and smaller vehicles.

The Department of Transportation will sponsor a study to determine feasible fuel economy levels for the next decade and determine costs to manufacturers and consumers. The study will account for the requirements of the Clean Air Act Amendments of 1990. Because the 1990 Amendments impose significant new emission and warranty standards on light-duty vehicles, the study must assess the effect of these requirements on the automobile industry's ability to further improve fuel economy. The study will also consider the impacts of safety requirements and the economic health and capabilities of the auto industry. After this study, the Government will have the information it needs to evaluate changes that would affect vehicles produced in the mid- to late 1990's. Changes to the current standards would be considered, such as providing credit trading and averaging among manufacturers, eliminating distinctions between import and domestic vehicles that can adversely affect full-line manufacturers, revising noncompliance penalties, and establishing alternative forms of corporate average fuel economy standards, for example, standards based on vehicle size. These improvements may permit cost-effective improvements in vehicle fuel economy without compromising highway safety.

The National Energy Strategy does not include a recommendation to increase corporate average fuel economy (CAFE) standards. The more measured approach adopted by the Strategy is taken for two reasons: First, the effect of the 1990 Amendments' emission requirements on the automobile industry's financial and engineering capabilities is not now fully understood. Before proceeding with additional fuel economy requirements, it is important to assess all of the regulatory requirements facing the automobile industry in the 1990's and beyond, including those related to emissions, safety, and fuel efficiency. In addition, the Administration believes that a full understanding of all important beneficial and detrimental effects is required, including impacts on safety, increased vehicle miles of travel, and increased automobile emissions. Second, new fuel economy requirements would not have any appreciable effect on U.S. oil demand until after 2000.

The Administration believes that there is no particular urgency to move precipitously on fuel-efficiency policies that are not reasonably expected to impact new vehicle production before 1995. The most appropriate near-term focus of attention is believed to be the efficiency of the total fleet already on the road and initiation of the long-term process of alternative fuels introduction.

Vehicle Propulsion Technologies

The Federal Government will enhance research and development on batteries and electric vehicles to move initial commercialization of electric vehicles up to the mid-1990's. Electric vehicles are an environmentally attractive alternative to conventional vehicles, especially in urban areas. Research could accelerate the development of battery concepts that could improve both near-term and long-term commercial competitiveness for electric vehicles. Efficient, durable, and safe batteries that can provide acceptable driving ranges for urban travel are essential for widespread market acceptance of electric vehicle technology. A consortium of vehicle manufacturers, battery developers, and utilities, along with the Department of Energy, is being formed to support an aggressive research and development program to make major advances in battery technology. The program will focus on extending electric vehicles' driving range on a single charge up to 200 miles, increasing battery specific energy and specific power, and improving electric propulsion technology.

The Government will enhance research and development on gas turbine engines. Compared with conventional gasoline engines, ceramic gas turbine engines could be 30 to 40 percent more efficient, could operate with high performance with a variety of alternative fuels, could have very low emissions, and could have reduced maintenance requirements. Worldwide, eight vehicle manufacturers have extensive research programs on gas turbine technology; the Department of Energy is working on the technology with the U.S. auto industry. An accelerated research and development program could reduce the time necessary to complete development and move the anticipated commercialization date from 2002 to the mid-1990's. The advanced gas turbine could also be used in long-haul trucking.

The Government will also enhance research and development on low-heat-rejection diesel engines for use in heavy-duty trucks, using temperature-resistant ceramic parts to achieve up to 22 percent more efficiency than conventional diesel engines. Continued research and development on ceramic material design, processing, and testing is critical to both gas turbine and low-heat-rejection diesel engine research.

The Department of Energy will accelerate research and development on fuel cell vehicles to produce cost-effective alternatives over the long term. Originally developed as power supplies for electric utilities and space stations, fuel cells are now being applied to transportation. Fuel cell technology could improve fuel economy 70 to 80 percent over conventional engines and could reduce noise. In addition, fuel-cell-powered vehicles would provide an ultraclean vehicle technology for areas that have not attained Federal ozone standards, alleviating the need for such areas to undertake more costly attainment strategies. Several fuel cell concepts, such as the proton exchange membrane, are being investigated. Possible applications in urban buses appear very attractive, although they are not commercially viable at this time.

Aeronautic Technologies

The Federal Government will enhance long-term research and development on new aircraft technologies, such as composite materials, advanced wing designs, and fly-by-light control systems, to increase energy efficiency by 30 to 60 percent over that of current commercial aircraft. In 1989, U.S. air carriers logged 446 billion passenger revenue miles, consuming about 1 million barrels per day of jet fuel and aviation gasoline; general aviation aircraft consumed an additional 0.07 million barrels per day. World air travel is expected to double in the next 10 years and to continue sustained growth of over 5 percent annually thereafter. Enhanced research and development are necessary to minimize the effects of these increases on fuel demand.

Role of Consumers in Improving Fuel Economy and System Efficiency

The Environmental Protection Agency, the Department of Transportation, and the Department of Energy will continue to provide fuel economy information through the Federal Fuel Economy Information Program. Future transportation efficiency ultimately depends on the purchase decisions and transportation behavior of consumers. To help them buy the most fuel-efficient vehicles, the Government will work to ensure that they have early access to comprehensive, comparative information before they make their purchase decisions. The Federal Fuel Economy Information Program is responsible for the mileage labels required on new cars and the publication of the Gas Mileage Guide. These efforts provide substantial benefits at very low cost, encouraging purchases of more efficient vehicles. Use of the Gas Mileage Guide is estimated to have saved 200,000 barrels of oil in 1989—savings which will continue over the lives of the vehicles. Because surveys have found that the guide is not used as much as it would be if there were greater awareness of it, the Government will undertake additional efforts to increase its distribution and augment its effectiveness.

The Department of Energy has taken an aggressive role in encouraging the public to "drive smart" and adopt more energy-efficient driving and commuting habits. An extensive advertising campaign was launched in September 1990 to let the public know about simple, common-sense measures that can help reduce oil use and dependence on imported oil. Such measures as keeping tires properly inflated, driving slower, and using public transportation or carpools not only save oil but also save money at the gas pump. Federal and State outreach efforts will have to expand to improve fuel efficiency in the other transportation modes.

In conjunction with the Science and Education Initiative, the Federal Government also will expand its cooperative efforts with private foundations and educational institutions to promote greater awareness of energy efficiency.

Alternative Transportation Fuels

The development of alternative transportation fuels is driven by national concerns about growing U.S. dependence on imported oil and declining urban air quality. Increasing the supply of cost-competitive alternative fuels addresses these concerns and contributes to economic efficiency.

Use of alternative fuels is hampered by a variety of structural, technological, and economic obstacles. Because of Federal and State subsidies that overcome the cost difference between gasoline and domestically produced ethanol, ethanol is already used as a blending agent in almost 10 percent of all U.S. gasoline. However, the use of such alternative fuels as ethanol, methanol, natural gas, propane, and electricity is in a relatively undeveloped stage because of factors that are specific to each alternative fuel and because of factors that are common to all these fuels. These common factors include the limited U.S. fuel distribution infrastructure and the difficulty of introducing alternative-fuel vehicles to the general public until alternative fuels are widely available. Conversely, it is difficult to introduce widespread fuel distribution for a vehicle fleet that has not yet materialized. In addition, some alternative-fuel vehicles are much more expensive than their gasoline counterparts, and the performance does not always compare well with that of a gasoline counterpart. Some alternative fuels are more expensive than gasoline, and some require changes in how vehicles are refueled (or recharged). Notwithstanding recent interest in alternative fuels, researchers' experience with advanced alternative-fuel vehicles is relatively limited, and they need additional data on such vehicles' performance, fuel economy, and emissions, especially for optimized vehicles in daily real-world service.

In concert with research and development programs to develop engines that can use alternative fuels, Federal support for use of nonpetroleum fuels will require efforts to improve the understanding of the fuels, reduce the fuels' costs, and supplement the programs as needed with policies and incentives to bring alternative fuels into the market. Domestically produced fuels, such as natural gas, ethanol, and some methanol, can help reduce energy imports. Natural-gas-based liquid fuels, such as methanol, can be a bridge to domestically produced renewable fuels, further reducing U.S. dependence on imported oil. The National Energy Strategy will speed the introduction of alternative fuels and alternative-fuel vehicles between 1995 and 2010. The Government will undertake several concurrent actions to meet this goal, encouraging vehicle manufacturing, access to vehicle refueling, and new fuel supplies.

Incentive for Alternative-Fuel Vehicles

The Administration supports eliminating the 1.2-mile-per-gallon cap on corporate average fuel economy credits for alternative-fuel-flexible or dual-fuel vehicles. The Alternative Motor Fuel Act of 1988 provides corporate average fuel economy credits for vehicles operated on either alcohol or natural gas. Dedicated alternative-fuel vehicles receive an unlimited fuel economy credit, but they may be limited to niche markets. Production of flexible- or dual-fuel vehicles, however, results in a corporate average fuel economy credit that is limited to 1.2 miles per gallon initially and then declines to 0.9 miles per gallon. This incentive is unlikely to stimulate the manufacture of more than a few hundred thousand flexible-fuel vehicles per year. As a consequence, fuel economy credits for alternative-fuel vehicles would have little effect on energy use for at least two decades. Removing the cap on corporate average fuel economy credits for flexible- and dual-fuel vehicles should provide a significant incentive for manufacturers to produce vehicles that could operate on alcohol or natural gas, as well as conventional fuels, establishing the capacity for a large market for future U.S. alternative-fuel production and distribution.

Federal Alternative-Fuel Fleet

The Federal Government will accelerate its purchase of new alternative-fuel vehicles. The Government purchases 44,000 light-duty vehicles per year and operates a civilian fleet of 200,000 cars and light trucks. Large enough annual Federal purchases, especially if done in cooperation with State and local initiatives, would increase incentives for auto manufacturers to produce a wider variety of optimized alternative-fuel vehicles that use a range of alternative fuels, including natural gas, ethanol, methanol, liquefied petroleum gas, and electricity. Large Federal purchases also would encourage manufacturers to produce vehicles that meet Federal and State fleet specifications.

Alternative-Fuel Fleets

The Clean Air Act Amendments of 1990 provide significant new requirements for the use of clean-fuel vehicles. The Federal Government supports a modification of the clean-fuel-fleet concept to ensure use of alternative transportation fuels (which are not required by the Clean Air Act Amendments' clean-fuel-fleet program) and to expand the program nationwide.

The 1990 Amendments require that, in 22 urban areas, fleets of 10 or more cars and light-to-medium trucks meet stricter emissions standards. These fleets would, under this proposed initiative, be required to purchase alternative-fuel vehicles starting in 1995 (10 percent, growing to 90 percent by 2000). These purchase requirements would also be extended to heavy trucks (excluding over-the-road class 8 trucks) and to all other urban areas. However, in urban areas not covered by requirements of the 1990 Amendments, only fleets of 20 or more vehicles would be affected. Bus fleets would be required to begin purchase of alternative-fuel buses in 2000.

This program will emphasize use of public refueling so as to not require fleet operators to install refueling facilities that are not cost-effective. Combined with the incentive to encourage manufacture of alternative-fuel vehicles and the increased purchase of alternative-fuel vehicles by the Federal fleet, these alternative-fuel fleet requirements are expected to stimulate the widespread introduction of alternative-fuel vehicles and the availability of alternative fuels at public refueling stations.

Data on Alternative Fuels and Vehicles

The Federal Government will accelerate efforts started under the Alternative Motor Fuels Act of 1988 and give them additional support. Because alternative-fuel vehicles are only now being tested in significant numbers under real-world conditions, data on their performance, fuel economy, and emissions are incomplete. Specific areas where additional data and analysis are needed are environmental emissions from vehicles using alternative fuels, full fuel-cycle costs of alternative fuels compared with fossil fuels, and agricultural impacts stemming from large-scale biomass production. The newly established Alternative Fuels Data Center at the Solar Energy Research Institute will collect and analyze data on alternative fuels utilization from Federal and State fleets. The Alternative Fuels Utilization Program will encourage research on improving the costs, efficiency, and performance of alternative-fuel vehicles.

Ethanol Tax Credits

Tax credits for ethanol were renewed in the 1990 Budget Reconciliation Bill, ensuring that domestically produced ethanol can continue to play an important part in meeting the Clean Air Act Amendments of 1990's new emissions requirements for vehicles. Expansion of use of alcohol fuels as additives for reformulated gasoline could help meet emissions requirements even before significant market penetration by flexible-fuel or dedicated alcohol vehicles, further increasing the ability of the transportation infrastructure to accommodate alternative fuels.

Advanced Transportation Fuels From Biomass

The Federal Government will accelerate research and development of new feedstocks and conversion technologies to ensure commercial readiness of cost-competitive alcohol fuels by the year 2000. Domestically produced liquid fuels from biomass, particularly from nonfood agricultural products, could provide the Nation with significant energy security benefits while strengthening its rural economies. Clean-burning alcohol fuels produced from nonfood biomass constitute a renewable and sustainable alternative for dwindling domestic petroleum reserves. Alcohol fuels can be used as blends in today's vehicles, and they can be used in pure form in flexible-fuel vehicles or dedicated alcohol vehicles powered by internal combustion engines, new gas turbines, or fuel cells.

The costs of producing alcohol fuels from biomass have dropped significantly, reducing the plant gate price of ethanol from $3.60 per gallon in 1980 to $1.27 per gallon in 1990, which is equivalent to a wholesale gasoline price of $1.65 per gallon, taking into account ethanol's lower energy content per gallon. For comparison purposes, the average wholesale price of gasoline (excluding taxes) was about $0.76 per gallon in 1989. This progress has come through successful research and development on improved alcohol yields, faster production systems, increased alcohol concentrations, and improved enzymes and microbial systems. Accelerated research on enzymatic hydrolysis technologies for ethanol production is expected to reduce ethanol's price even further. As researchers come to understand and perfect enzymatic conversion processes for ethanol, they will shift their emphasis toward combining the separate steps into an integrated process through development of continuous processing and construction of a process development unit and a semicommercial engineering development unit. Early, limited introduction of these new technologies, using low-cost feedstocks, such as municipal and agricultural wastes, may be possible.

Methanol from biomass cost about $2.50 per gallon on a gasoline equivalent basis in 1980, but research on advanced gasifiers has brought the cost down to about $1.15 per gallon. Methanol costs are expected to decrease due to future improvements in gasification technology, synthesis gas conditioning, gas product cleanup, and increased Federal support for pilot-plant testing.

Cooperative Department of Energy-Department of Agriculture feedstock and alternative-fuel research is expected to accelerate development of diverse energy crops for both ethanol and methanol. Additional research on oilseeds and microalgae may yield new feedstocks for diesel fuel and oils from biomass. Research on advanced genetic technology to enhance energy content and maximize desirable feedstock components of such crops as fast-growing poplar trees and perennial grasses could help improve productivity and reduce costs.

Attainment of cost goals through accelerated research and development could bring ethanol and methanol to commercial readiness by the year 2000 under Current Policy Base case oil prices, leading to alcohol production of 5 to 8 quads (2.5 million to 4 million barrels per day) by 2030. Using renewable biomass, transportation will contribute significantly less to greenhouse gas emissions. The Government will encourage expanded industry participation, with emphasis on the introduction and commercialization of alcohol fuel production technologies, development and testing of flexible-fuel and dedicated alternative-fuel vehicles, and evolution of the transportation infrastructure.

Alternative Fuels From Coal

The Department of Energy's Coal Liquefaction Program supports basic and applied research to develop the scientific and engineering knowledge base that industry needs to bring economically competitive and environmentally acceptable advanced technology for the manufacture of synthetic liquid fuels from coal into the marketplace when needed. Using today's technologies, the cost of producing such liquids in small test plants is currently estimated to be equivalent to $35 to $40 per barrel of oil. The goal of the Department's program is to demonstrate cost improvements at its test facilities over the next 5 years. The National Research Council identified $30 per barrel (at the test facility level) as a reasonable cost goal for the next 5 to 10 years. Even if this objective were met, however, additional effort may be needed to address issues associated with replicating test-plant performance at a larger scale facility.

Coal liquefaction produces a complete spectrum of liquid fuels that could be used in the existing U.S. transportation infrastructure. The Department focuses its efforts upon the two different and distinct approaches to producing liquid fuels from coal: direct and indirect. Direct liquefaction processes combine hydrogen with the complex organic chemical structures found in coal to produce liquid components. Indirect liquefaction involves coal gasification to produce synthesis gas (a mixture of carbon monoxide and hydrogen), followed by catalytic conversion of the synthesis gas to liquids. Each approach has unique characteristics that make it a candidate for commercial development when market conditions are appropriate.

Integration of Alternative-Fuel Initiatives With 1990 Clean Air Act Amendments

The Clean Air Act Amendments of 1990 were not intended to be an energy policy, but because of their major impact on the energy industry, they will have very significant effects on energy use. While some of the new requirements will cause slight increases in U.S. energy use, others will substantially reduce U.S. oil imports. The most important of these requirements concerns the use of alternative fuels in transportation.

The Clean Air Act Amendments require that a substantial proportion (about 25 percent) of all U.S. gasoline contain oxygenates by 1995. About 250 thousand barrels per day of oil displacement is expected to occur because of this requirement. Further, there are substantial incentives for areas that have not attained clean air standards to "opt in to" the reformulated gasoline requirements. By the year 2000, reformulated gasoline is expected to essentially replace conventional gasoline, resulting in about 700,000 barrels per day of oil displacement.

Another important Clean Air Act Amendments program is the California Clean Car Pilot Program. Combined with the State's leadership in introducing alternative-fuel vehicles, by 2005, the program is expected to displace 100,000 barrels per day of oil use.

Several National Energy Strategy alternative-fuel options were designed to work with the Clean Air Act Amendments of 1990. As was described above, the National Energy Strategy proposes to modify programs affecting fleets and buses and provide incentives for the production of alternative-fuel vehicles. In combination with the Clean Air Act Amendments, these proposals are expected to result in significant displacement of U.S. oil demand by alternative transportation fuels. This displacement is estimated to be about 1.5 million barrels per day by 2005 and 2 million barrels per day by 2010. Therefore, the National Energy Strategy and the Clean Air Act Amendments would work together to provide additional energy security benefits and enhance the environmental benefits that the Clean Air Act Amendments would otherwise provide.

Public Education, Technology Transfer

The Department of Energy will continue to sponsor student competitions, such as the Methanol Challenge, the Natural Gas Challenge, the Sunrayce, the Junior Solar Sprint, and newly introduced competitions to bring new ideas to the forefront and to encourage the Nation's young scientists and engineers to pursue careers in advanced transportation technologies. Through cost sharing on research and demonstration projects, the Department of Energy, the Department of Agriculture, and industry will develop laboratory technologies into commercial and competitive processes. Significant public and industry participation can help ensure that new data on alternative fuels and improved analysis are widely available.

Efficiency of the Overall Transportation System

Historically, most of the United States' activities to improve fuel efficiency have focused on personal transportation in light-duty vehicles. The use of more efficient vehicles and alternative fuels will go a long way toward easing U.S. dependence on petroleum, but these changes should not be introduced in isolation; rather, they should be part of a larger effort to improve the overall efficiency of the Nation's transportation system. Continued growth in urban travel, intercity travel, and freight transport provides an impetus for the Nation to conduct research and development activities in areas where there could be high payoffs in reducing congestion, reducing the energy intensity in both passenger and freight transportation, and improving the efficiency of the existing transportation system. The National Energy Strategy's goal is to move people and goods as efficiently and conveniently as possible, using the most appropriate technologies for various transportation requirements.

Obstacles to achieving better overall transportation system efficiency exist at both the individual and the broader societal levels. When individuals make decisions on how to meet their transportation needs, they look at the costs and benefits of various options. Government action can affect this efficient decisionmaking process by promoting or failing to promote different transportation modes. When State and local planners make decisions about transportation systems, they may be limited to the solutions of the past. In the long term, their adoption of new ways of meeting transportation needs will depend on researchers' abilities to design new technologies and to approach old problems in new ways. Focusing only on improving the efficiencies of current systems is absolutely vital, but may be an obstacle to pursuing other long-term options. The Administration's proposed Surface Transportation Reauthorization Bill has a number of features that are complementary to the National Energy Strategy, such as providing funding for an efficient National Highway System, providing funding flexibility between highway and transit projects in urban and rural areas, providing a higher Federal match for operational improvements, and allowing States to conduct operational tests of congestion pricing on specific Federal-aid routes in air-quality nonattainment areas.

The National Energy Strategy does not include a tax on gasoline beyond the recently enacted 5-cent-per-gallon motor fuel tax increase. Analysis of the gasoline tax showed that very high taxes were required in order to stimulate significant reductions in oil demand. For example, a 50-cent-per-gallon motor fuel tax was estimated to reduce oil imports by less than 500,000 barrels per day. At the same time, depending on the corresponding macroeconomic and monetary factors, significant gross national product losses were estimated to result from a large motor fuel tax increase. Lastly, the economic consequences of this tax would fall most heavily on these least able to bear them. While households with over $50,000 annual income would experience only a 1-percent loss of income from a 50-cent-per-gallon tax, households with incomes below $10,000 would experience a 5-percent loss.

Mass Transit and Ride Sharing

The Federal Government will encourage the use of mass transit in place of private, single-occupancy motor vehicles for commuting by increasing the amount of tax-free transit benefits that employers may provide to employees. In addition, the Administration will implement a series of measures to encourage increased use of carpools, vanpools, and transit, including increased availability of high-occupancy-vehicle (HOV) right-of-way and improved public transportation services. Studies and demonstration projects, such as those performed by the Urban Mass Transportation Administration, have consistently shown that mass transportation, carpools, vanpools, and HOV lanes are the quickest, cheapest ways to improve transportation energy use and reduce commuter congestion. As part of a long-term effort to improve system efficiency, the Government will continue to investigate and implement means for encouraging mass transit and ride sharing.

High-Speed Rail/Magnetic Levitation

The Department of Transportation, the Department of Energy, and the Army Corps of Engineers have begun the National Maglev Initiative to examine the potential and economic viability of magnetic levitation technology, specifically designed for U.S. demographics and travel conditions. Transportation by magnetic levitation, a technology initially examined in the United States during the 1960's and 1970's, offers the potential for providing efficient, high-speed (cruise speed of more than 300 miles per hour) travel, particularly for trips of between 100 and 600 miles. Magnetic levitation travel could be three to four times as efficient as air travel. Integrated into airport and airline operations, magnetic levitation could help the short-haul airline market, which represents the most energy-inefficient portion of the air travel sector. By substituting for a portion of intercity air and highway travel, magnetic levitation could improve the efficiency of intercity travel. In addition, it could provide a reduction in petroleum demand because it is electrically powered. European and Japanese high-speed rail technologies with operating speeds of up to 200 miles per hour are also being considered by a number of States for implementation. High-speed rail could also improve the energy efficiency of intercity travel.

Intelligent Vehicle-Highway Systems

The Department of Transportation, a number of States, and the auto industry are working cooperatively to advance intelligent vehicle-highway system technology in the United States. Major multiyear research and development programs on intelligent vehicle-highway systems have been under way in Japan and Europe since the mid-1980's. For the foreseeable future, automobiles and light trucks will remain the dominant modes of personal travel. In urban areas, a major contributor to wasted energy is congestion. On urban freeways alone, an estimated 2 billion gallons of fuel is wasted annually. Intelligent vehicle-highway systems incorporate advanced communication and computer technologies, electronic displays and warning devices, and vehicle and traffic control systems to allow two-way communication between the road and the vehicle. In concert with urban transportation policies, such systems could significantly increase transportation efficiency. In the long term, an advanced intelligent vehicle-highway system could incorporate automated vehicle control systems that would also provide power to vehicles.

Telecommuting

It is estimated that about 35 percent of passenger vehicle miles traveled is work related. Telecommuting is an attractive alternative for workers in the information and service sectors who can work via computers. In the United States in 1981, there were already 300,000 "flex-place" workers; today there are estimated to be 3.6 million, with a much larger future potential. Research and development on faster, easier-to-use networks and software could make telecommuting more widespread. Telecommuting not only saves fuel but also reduces congestion.

Air Traffic Control Systems

In aviation, continued improvement in technologies to automate the Federal Aviation Administration's air traffic control system could enhance the system's efficiency and performance and thus have a major impact on fuel use. In 1989, airport congestion and delays cost the airlines and airports an estimated $4 billion. A significant portion of this loss represents fuel burned by aircraft delayed either in landing or takeoff because of congestion. Continued programs to improve the technology and system efficiency of air traffic control systems could increase energy efficiency by 5 to 10 percent.

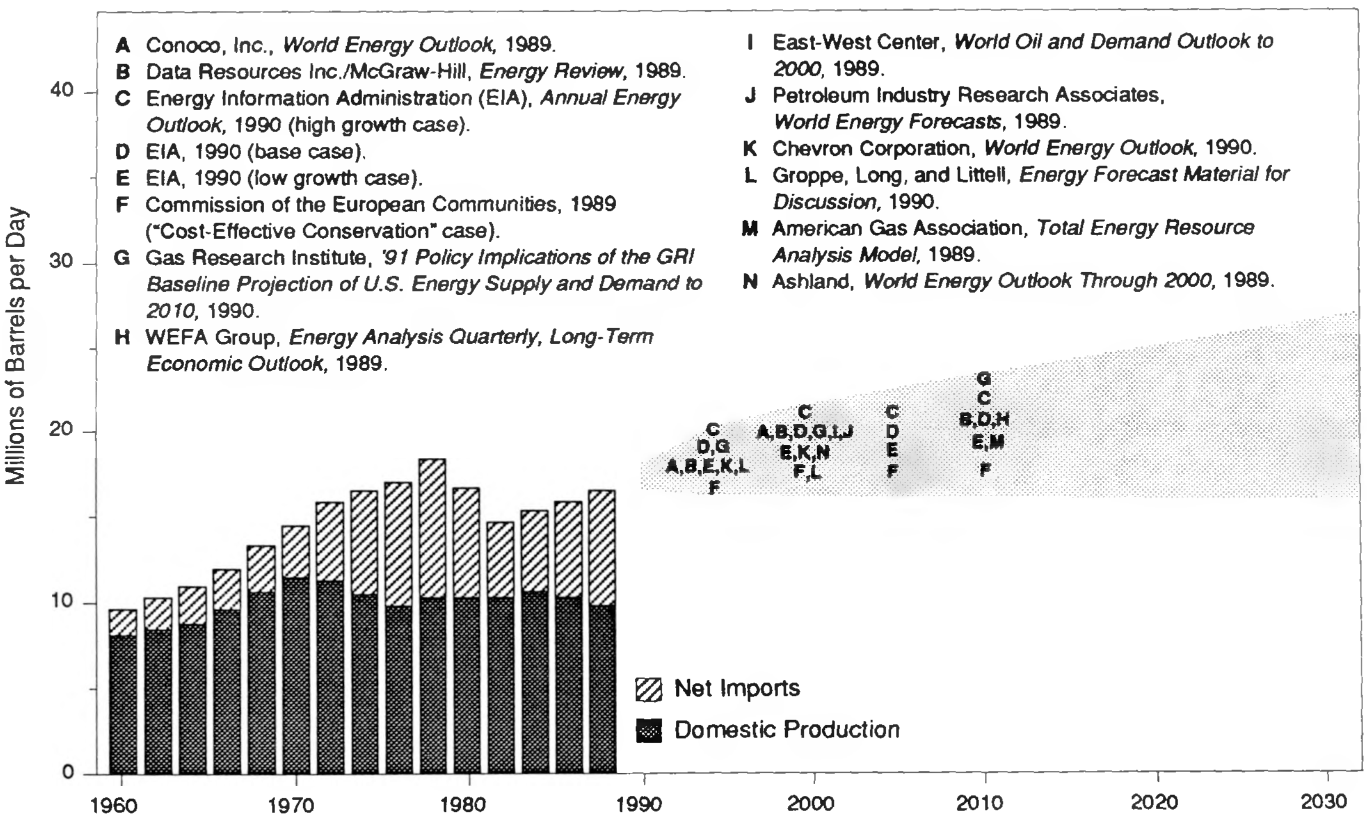
SECURING FUTURE ENERGY SUPPLIES

Oil

Oil is one of the Nation's vital commodities. It currently provides more than 40 percent of the country's primary energy needs and supplies almost 97 percent of the energy used for U.S. transportation. During 1990, the United States consumed almost 17 million barrels per day (MMBD) of oil, about 25 percent of total world consumption. Estimates of future oil demand are uncertain. Figure 22 presents a range of forecasts of future U.S. oil consumption, drawn from a number of independent sources.

Since the mid-1980's, the amount of oil consumed in the United States has increased while domestic oil production has declined steadily. In 1990, U.S. crude oil production fell to 7.3 MMBD, compared with almost 9 MMBD in 1985. Domestic production decreased during the 1980's because of a number of factors, including a drop in drilling activity, the depletion over time of many large domestic oil fields, the abandonment of uneconomic wells, and a decline in exploration and development activity in environmentally sensitive areas. Future additions to U.S. oil reserves are not

Figure 22. Projections of U.S. Petroleum Use



Note: Differences in projections are caused, in part, by varying assumptions concerning energy prices, economic growth, consumer and producer behavior, and rates of technological change, including replacement of capital stock. The shaded area represents an envelope bracketing these differences.

Goals and Approaches—Oil

Goal	Approach
Reduce U.S. vulnerability to supply disruptions by expanding U.S. and worldwide oil and gas production capacity and strategic stocks	• Aggressively develop and use advanced oil recovery technology to provide access to the 300 billion barrels of domestic oil that is unrecoverable using conventional methods • Allow access to the coastal plain of ANWR and to selected areas of the OCS under strict environmental safeguards • Stimulate oil and gas development and excess production capacity outside the Persian Gulf • Expand the strategic oil reserves of the United States and encourage similar action by U.S. allies
Ensure a proper balance between energy security and environmental protection	• Assess the combined impact of the Clean Air Act Amendments of 1990 and other environmental regulations on the production, refining, and distribution of crude oil and petroleum products

likely to fully offset the projected decline in U.S. domestic production, but the rate of decline can be substantially reduced by undertaking the measures proposed in the National Energy Strategy.

The widening gap between U.S. oil demand and domestic supply has made the Nation increasingly reliant on imports. In 1990, imported oil accounted for 42 percent of domestic oil use, the highest percentage since 1979. During 1990, payments for net oil imports totalled approximately $55 billion. In the absence of new energy policy initiatives, U.S. oil imports are projected to rise to 57 percent of domestic oil consumption by the year 2000 and to 65 percent in 2010. The net U.S. oil import bill would double by 2000 and increase to more than $200 billion by 2010 (in 1990 dollars).

For the foreseeable future, oil will remain a critical fuel for the United States and all other industrialized nations. Its availability and price will be influenced substantially by a limited number of oil-producing countries, each with large reserves and "excess" production capacity (that is, the difference between actual and maximum production). About 65 percent of the world's known oil reserves lie in the historically volatile Persian Gulf region, which supplies one-quarter of the oil that the world now consumes. Dependence on oil supplies from this region is likely to grow in the decades ahead, as will the concern of the international community about energy supply and economic security.

The Arab oil embargo of 1973 and the Iranian Revolution of 1978 showed that significant disruptions to world oil markets, and ensuing oil-price shocks, have serious adverse effects on the U.S. economy and on economic stability throughout the world. This economic vulnerability was again underscored by Iraq's invasion of Kuwait. The economic sanctions instituted by the United Nations in August 1990 removed 4.3 MMBD of oil from the world market. Prices rose sharply as a consequence and contributed to inflationary pressures and slower economic activity. Between August 1 and December 1, 1990, U.S. consumers spent $21 billion more for crude oil and petroleum products than would have been spent absent the Middle East crisis. Of that amount, $8 billion was paid to foreign producers.

Although the recent oil-price increases have had adverse short-term effects on economic performance, their impacts are not likely to be as severe or long-lasting as those experienced in the aftermath of the oil-price shocks of the 1970's. The market-oriented energy policies adopted by the United States during the 1980's have substantially improved the ability of our economy to withstand disruptions in world oil markets. Because the United States has dismantled its inefficient energy regulatory apparatus, the sudden constriction of global supplies during 1990 occurred without the market dislocations typical of the 1970's. Moreover, the "energy intensity" of the U.S. economy, defined as the ratio of primary energy use to national output, has decreased by more than 28 percent since 1973, and the cost of oil imports has declined from 2.8 percent of gross national product in 1980 to 1.0 percent in 1989. These improvements have placed the Nation in a better position to weather oil-price shocks.

The National Energy Strategy review confirmed the validity of measures undertaken since the 1970's by the international community to better manage oil crises. The accomplishments of the last two decades include formation of the International Energy Agency, expansion of strategic oil stocks and reserves around the world, greater fuel competition, and increased displacement of oil by other fuels. In addition, the recent Western efforts to assist the nations of Eastern Europe and the Soviet Union in their transition to market-based economies should help to improve those countries' energy efficiency and overall energy supply.

For 17 years, U.S. Administrations have sought to balance the economic benefits of reliance on imported oil against the foreign policy and military costs of maintaining the free flow of oil, particularly from the Persian Gulf. It is tempting to imagine the United States free of all dependence on external sources of oil. Energy independence was for a short time a national goal, but its pursuit proved costly and elusive.

The National Energy Strategy review confirmed that no feasible combination of domestic or foreign energy policy options can fully relieve for the United States the risks inherent in our dependence on domestic and imported oil over the next two decades. Indeed, the evidence is clear that U.S. and worldwide reliance on this critical fuel and on the Middle East as a source of supply will grow.

Moreover, the evolution experienced in the last decade in the trade of oil on world commodity markets makes it infeasible to insulate the United States from the economic forces that drive global supply and demand patterns. An increase in the world price of oil, brought about by events anywhere, would raise the price of U.S. oil, and the price of oil to our allies and trading partners, regardless of the degree of import dependence.

The energy security policy goal of the United States is to manage and reduce our vulnerability to disruptions in the oil market while concurrently reducing the importance of oil use in the U.S. economy. Improvement of U.S. energy security requires efforts on several fronts, and our policy responses must be multifaceted.

The National Energy Strategy charts a course toward increased and diversified worldwide sources of oil; greater fuel flexibility and competition in all sectors of the economy, but particularly in transportation; improved contingency mechanisms, including larger international strategic stocks and "excess" production capacity outside the Persian Gulf; and a higher degree of integration of energy, trade, and foreign policy.

The growth of production capacity, both at home and abroad, has been stymied by a number of obstacles. For example, U.S. producers of oil and natural gas lack reasonable access to certain Federal lands that potentially contain the most important domestic oil resources since Prudhoe Bay. This discovery in Alaska brought about a surge in domestic production beginning in the early 1970's. Another obstacle is the cost of current advanced technologies for recovering additional petroleum from existing fields. Moreover, a number of countries outside the Persian Gulf maintain institutional barriers to external investment and continue to rely on outdated oil production technology. This has virtually guaranteed that the only available excess production capacity (a key measure of market influence) remains almost entirely with a few Persian Gulf producers.

Goals and Approaches

The National Energy Strategy will enhance energy security by pursuing two fundamental objectives: (1) expand U.S. and worldwide oil production capacity and strategic stocks; and (2) reduce U.S. oil use through a combination of measures aimed at increased efficiency, large-scale introduction of alternative transportation fuels, and aggressive research and development of new energy and oil saving technology.

The first of these objectives is the primary subject of this section. The second objective is discussed in the end-use and research and development sections of this report.

Expected Results

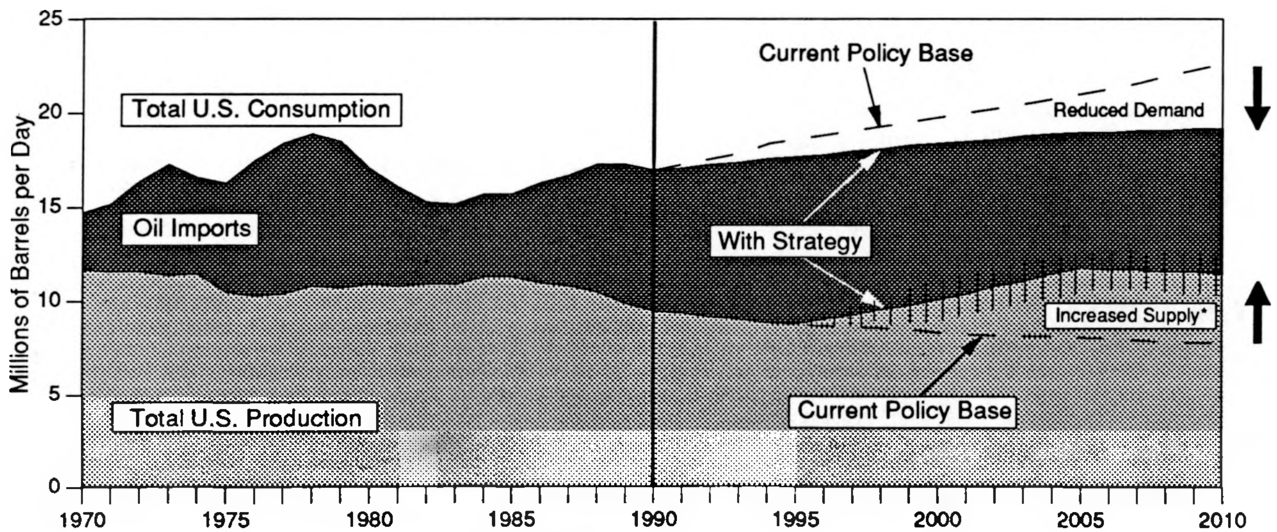
As Figures 23 and 24 show, the Strategy's petroleum supply-and-demand measures will substantially reduce U.S. dependence on insecure supplies of energy, keeping oil import levels at less than 50 percent of U.S. consumption after the year 2000. These projections, like any other, are uncertain and should be regarded as illustrative rather than predictive. Nevertheless, the Department of Energy estimates that domestic oil production would increase by 1.8 million barrels per day above the levels projected for the year 2000, and by 3.8 million barrels per day above 2010 projected levels. These increases are largely due to the use of advanced oil recovery technology made possible by new investments in Federal and private-sector research and development, the environmentally responsible development of the coastal plain of the Arctic National Wildlife Refuge (ANWR), and the implementation of the Administration's Outer Continental Shelf (OCS) leasing program, after the current restrictions expire, and subject to Presidential leasing guidelines.

Recent studies indicate that if economically recoverable oil exists in the ANWR, there is a 5-percent chance of finding 8.8 billion barrels of oil, with a mean estimate of 3.6 billion barrels. For OCS areas, there is a 5-percent chance of finding 7.5 billion barrels of economically recoverable oil, with a mean estimate of 3.1 billion barrels. The estimated reserve additions associated with advanced oil recovery research and development equal 20 to 65 billion barrels.

On the demand side, U.S. oil consumption in the year 2005 is expected to be 2 million barrels per day less than it would be in the absence of National Energy Strategy initiatives—largely because of displacement of oil by alternative fuels in vehicles and electric utilities. As alternative fuels (compressed natural gas, electricity, and alcohol from natural gas, biomass, and coal) and the technologies to use them become more cost competitive, they will become available across the country to a large and growing fleet of fuel-flexible and dedicated alternative-fuel vehicles and gradually erode petroleum's dominant role in the transportation sector.

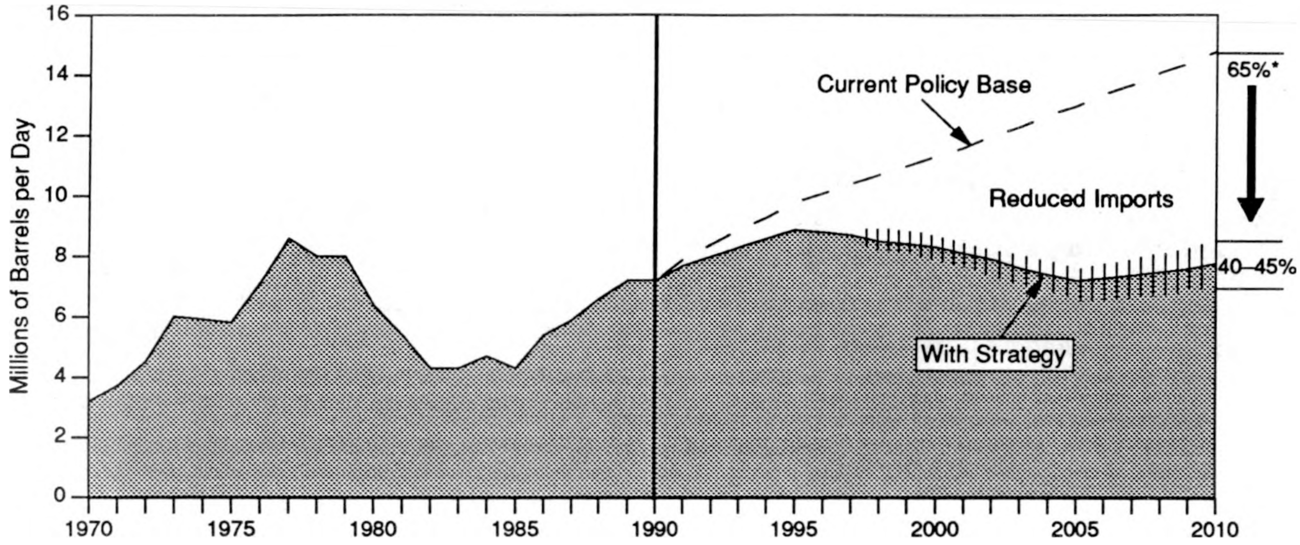
By reducing the volume of imports and our share of world oil demand, National Energy Strategy measures would reduce the projected *cost* of oil imports in 2000 by as much as $36 billion (in 1989

Figure 23. Oil Consumption and Production



*Production range represents uncertainty associated with R&D.

Figure 24. Reduced Oil Imports



*Imports as percent of total oil consumption.

dollars). In 2010, the projected cost of oil imports would be reduced by as much as $115 billion (again, in 1989 dollars).

Additionally, the National Energy Strategy will encourage the development of additional world oil production in countries outside the Persian Gulf. The total oil resources in non-Persian Gulf countries are estimated to range from 562 billion to 1.1 trillion barrels, almost twice the estimated oil resources in the Persian Gulf. Total proved reserves (only a portion of estimated total resources) consist of 50 billion barrels in Asia and the Pacific, 14.5 billion barrels in Western Europe, 59 billion barrels in the Soviet Union and Eastern Europe, 60 billion barrels in Africa, and approximately 120 billion barrels in the Western Hemisphere (outside the United States and Canada).

Reduced Vulnerability to Oil Supply Disruptions

Advanced Oil Recovery Technology

Because the United States is a mature oil-producing region, innovative advanced oil recovery technology is needed to recover the substantial amount of oil that remains in the ground after conventional recovery is completed. Two-thirds, or more than 300 billion barrels, of domestic oil is bypassed using the recovery methods that are available today. Also, without advanced recovery technology, wells with operating costs that exceed the value of the produced oil are being plugged and abandoned. This often results in the loss of the remaining oil reserves because of the costs involved in reopening an abandoned well, drilling a new well, or reacquiring the right to drill. The limited application of advanced geoscientific knowledge, the lack of advanced technology, and the high costs of obtaining this knowledge and technology prevent the development and use of needed advanced oil recovery methods.

Under the National Energy Strategy, the Administration will use research and development funding to promote the development of the advanced oil recovery technologies necessary to maximize the amount of U.S. oil resources that can be economically produced. This will be accomplished by implementing the Department of Energy's *Oil Research Program Implementation Plan*, published in April 1990. This plan will be adapted to the R&D "model" used throughout the Strategy for applied R&D initiatives, using industry R&D consortia, whenever feasible, as funding vehicles in cost-shared cooperative ventures.

The overall approach of the research and development program is first to identify those types of oil deposits that have both the greatest potential for improved oil recovery and the greatest risk of abandonment within the next 5 to 10 years.

The goal is to preserve access to these identified deposits while developing and testing technologies designed to overcome the specific problems that prevent increased oil recovery. These technologies are called advanced secondary recovery and enhanced oil recovery. The first generally involves drilling and improved production methods based on sophisticated geological and geophysical interpretation. Enhanced oil recovery includes the injection of chemicals, gases, or heat to overcome physical barriers in the reservoir.

The proposed near-term research and development measures would result in additional oil production that would peak at 1.4 MMBD by 2005. They would add total oil reserves of 5 billion barrels (at oil prices of $20 per barrel) to more than 25 billion barrels (at $50 per barrel). Application of the near-term and longer term measures to 80 to 90 percent of the known remaining U.S. oil deposits would result in additional oil production of more than 3 MMBD by 2010. The research and development program would, if fully successful, increase the amount of economically recoverable reserves by between 20 billion barrels (at $20 per barrel) and 65 billion barrels (at $50 per barrel).

Access to Resources on Federal Lands

Arctic National Wildlife Refuge

The coastal plain of the Arctic National Wildlife Refuge has the potential to produce the most significant future oil discoveries in the United States. According to a recent study by the Interior Department, there is a 46-percent chance of finding economically recoverable oil in this area. Congress has the authority to allow leasing in this part of the refuge, but has not yet done so.

The National Energy Strategy recommends and the Administration will request that Congress permit oil and gas leasing in a portion of the coastal plain of the ANWR. The Strategy suggests using the traditional leasing process, under which the parties with the highest bids are granted the opportunity to explore for and produce oil and gas. Appropriate stipulations would be included in the leasing agreements to reduce the inherent environmental risks and to protect the North Slope environment to the greatest practical extent. The coastal plain comprises only 8 percent of the refuge and includes no congressionally designated wilderness areas.

The President's fiscal year 1992 budget proposes that all receipts received from the leasing of oil and gas resources within ANWR should be retained in the U.S. Treasury. ANWR is a national resource, and the revenues from oil and gas development should be used to benefit all Americans, not just those residing in one State.

Successful development of this area would substantially increase domestic reserves and offset declines in existing North Slope production. Based on conservative estimates, additional production could amount to an additional 870,000 barrels per day of oil by 2005. Oil production from the coastal plain would prolong the economic life of the Alaska oil pipeline and, therefore, the Prudhoe Bay field. It would also facilitate the development of other North Slope and Beaufort Sea discoveries, increase economic activity, and provide billions of dollars of indirect revenue to the State of Alaska and to the Federal Treasury.

Outer Continental Shelf

The Outer Continental Shelf is a major source of domestic oil and gas. It may contain as much as 26 percent of undiscovered economically recoverable U.S. oil resources.

In June 1990, the President deferred leasing in several OCS areas, including the coasts of Washington, Oregon, and north, central, and southern California, as well as the North Atlantic area and a portion of the eastern Gulf of Mexico. With the exception of about 1 percent of the tracts off the coast of southern California where deferrals expire in 1996, these deferrals expire in 2000. The President requested additional assessments of the extent of the oil and gas resource base and the environmental effects of development in these areas. The President's decision demonstrates the Administration's commitment to prohibit offshore drilling in areas where environmental risks outweigh the potential energy benefits to the Nation.

A congressional leasing moratorium, which will expire on October 1, 1991, denies access to all areas placed under Presidential restriction and to Outer Continental Shelf areas in the Alaskan North Aleutian Basin, the mid-Atlantic, and in some parts of the eastern Gulf of Mexico. Congress has also imposed a 1-year moratorium on leasing and drilling off the coast of North Carolina.

The National Energy Strategy recognizes that production of the economically recoverable oil and gas resources of the OCS is important for meeting national energy needs. The National Energy Strategy recommends that the OCS areas currently under congressional moratoria, along with those now available for leasing, be considered by the Secretary of the Interior in formulating the new 5-Year OCS Program for 1992-1997. All areas that can be developed in an environmentally sound manner should be included in the new program. The Administration will request that Congress not enact leasing moratoria on areas included in the new OCS Program. The Minerals Management Service will continue to study the oil and gas resource potential and the environmental effects of oil and gas activities in the areas under Presidential restriction so that environmentally sound decisions can be made on whether and in what manner to make these areas available for leasing when the Presidential restrictions expire.

Opening these areas would result in the discovery of new, economically recoverable oil and gas resources that can be developed in ways that safeguard the environment. The average estimate of recoverable resources from these areas is about 3.1 billion barrels of oil and 9.4 trillion cubic feet of natural gas. There is a 5-percent chance of finding 7.5 billion barrels of oil. Increased production from the OCS would increase economic activity, provide specific regions with additional energy resources, reduce the rising level of oil imports, and provide billions of dollars to the Federal Treasury through bonuses, royalties, and rental payments.

Last June, the Administration announced that it would develop a legislative initiative that will provide coastal communities directly affected by OCS development with a greater share of the financial benefits of new development and with a larger voice in decisionmaking. Currently, coastal States receive 100 percent of revenues from leases within 3 miles of shore, except for Texas and Florida, whose State waters extend to about 10 miles. Revenues from leases between 3 and no more than 6 miles beyond State waters are divided 73 percent to the Federal Government and 27 percent to the States. Revenues from leases 6 miles or further beyond State waters go 100 percent to the Federal Government. Coastal communities directly affected by development are not presently guaranteed any of these revenues.

Alaskan North Slope Development

Five major discovered fields on the Alaska North Slope remain undeveloped, including West Sak (discovered in 1969), Point Thompson (1977), Seal Island/North Star (1984), Gwydyr Bay (1969), and Sandpiper Island (1986). Significant technical and regulatory barriers block development of these fields.

The National Energy Strategy calls for accelerated development of these discovered North Slope fields. To this end, the Department of Energy will establish a Government-industry task force that will identify specific technical and regulatory barriers and make recommendations for their resolution. The Department of Energy, in conjunction with environmental agencies, will also work with other Federal and State authorities to identify and resolve regulatory barriers relating to the development of the discovered fields. Successful development of these North Slope fields could increase domestic oil reserves by as much as 1 billion barrels of oil and condensate.

Economic Efficiency of Domestic Oil Production

The Nation's oil vulnerability can also be reduced by a number of initiatives, described below, that rely on market forces and existing resources to improve economic efficiency in the oil supply sector.

Elk Hills Reserve

The Federal Government currently produces and sells oil and gas from the Elk Hills Naval Petroleum Reserve in California. As owner and operator of this field, the Government directly competes with private-sector oil and gas producers.

The National Energy Strategy recommends and the Administration will request that Congress authorize the leasing of the Elk Hills reserve in order to increase its operating efficiency. Market-driven private companies will produce oil more aggressively, accelerate gas sales, and lower overhead costs. The proceeds from leasing could be used to create a Defense Petroleum Inventory and to reduce the Federal budget deficit.

Leasing the property would generate lease bonus payments, royalties, and Federal income tax receipts and would reduce federally appropriated operating costs and administrative overhead. Lease revenues would be shared with the State of California. However, leasing would eliminate the sales revenue currently being collected by the Federal Government. Leasing is expected to increase operating efficiency enough to maintain the current value of the property to the Government.

Oil Pipeline Deregulation

Current oil pipeline regulation results from legislation enacted in 1906. That legislation imposed rate and service regulation to ensure that no more than a "just and reasonable" rate of return would be earned by pipelines and that nondiscriminatory access would be available to shippers. However, even without regulation the competitive forces in today's market would achieve the same result in most areas.

The National Energy Strategy calls for legislation to eliminate oil pipeline regulation except for those pipelines operating in markets where sufficient competition from other oil pipelines, trucks, barges, or railroads does not exist. Deregulation would eliminate approximately $10 million of unnecessary government and industry administrative costs and would result in improved pipeline efficiency.

Production and Export of California Heavy Oil

Heavy-oil production in California is well below capacity. Many wells are shut in, due in part to air-quality restrictions that prevent the use of oil to generate the steam used to produce heavy oil. The Administration's policy is to facilitate an increase in this production. Federal agencies are working to resolve regulatory barriers blocking the addition of new natural gas pipeline capacity that would serve heavy-oil production areas. By using natural gas as the fuel for steam generation, producers would comply with the air-quality standards. The resulting increase in heavy-oil production could be as much as 100,000 barrels per day.

In 1989, the Department of Commerce, with other agencies, analyzed the California heavy-oil market and recommended that existing export restrictions be lifted to allow the export of up to 25,000 barrels per day. The study found that lifting these restrictions would provide incentives for new production that would exceed the amount of heavy oil being exported.

Based on this analysis, the National Energy Strategy will promote and encourage the export of heavy crude oil produced in California. Additional revenue from exports would enable producers to reduce well abandonments and therefore would prevent the loss of existing domestic oil reserves. The proposed exports would have a negligible impact on refiner acquisition costs, refiners' access to heavy crude, and the price of lighter products such as gasoline.

Horizontal Well Drilling

Horizontal drilling drains oil from the ground using a well that is vertical at the surface but horizontal at the level of the reservoir. More of the reservoir can be drained using this technique because more of the reservoir is exposed to the wellbore. Though this technology is successful only in certain types of formations, it can increase recoverable reserves, reduce environmental damage, and increase producers' economic efficiency. Horizontal drilling could become one of the most important technological developments of this decade.

However, in some cases State regulations impose barriers that inhibit horizontal drilling. Producers often cannot undertake otherwise economical projects in States where oil and gas regulations do not take account of horizontal drilling technology. Accordingly, the National Energy Strategy recommends that those States modify their regulations, particularly the traditional rules governing minimum well spacing, drilling unit size, and allowable production.

In accordance with the Strategy, the Department of Energy is evaluating industry and State actions relating to horizontal drilling. The Department intends to work with industry and producing States to help remove regulatory barriers. The Department also will promote the transfer of horizontal drilling technology and information among producers.

Also, horizontal drilling will be part of the Strategy's program of research and development for advanced oil recovery. The program will study areas where horizontal drilling has been successful and, within the deposits targeted by the program, will identify additional reservoirs suitable for horizontal drilling. Further, the Department of Energy will share the program's data base with operators and drilling companies. The data on past successes will show how horizontal drilling can be used successfully in new reservoirs.

Financial Incentives

Investments in domestic exploration and development are generally less attractive than similar investments in other countries primarily because of geologic factors. Exploratory drilling in the United States generally involves greater risk and results in smaller discoveries. The competitiveness of domestic investments is marginally reduced by the combined burden of Federal and State income taxes, severance taxes, and private and public sector royalties.

The President, in 1989 and again in 1990, proposed several tax incentives for oil and gas production. The President's proposals, in large part, were adopted by Congress in the 1990 budget reconciliation legislation. The new tax incentive provisions promote enhanced energy security by encouraging additional domestic exploration and development and greater recovery of oil and gas from existing fields. The package includes—

- A 2-year extension of the tax credit for nonconventional production, including a reinstatement of the credit for tight sands gas.
- A 15-percent credit for tertiary enhanced oil recovery.
- Modifications of the percentage depletion rules that will primarily benefit marginal production.
- A special energy alternative minimum tax deduction for independent producers.

A fixed or variable oil import fee is not recommended in the National Energy Strategy because it would produce net losses to the U.S. economy that would far outweigh its energy supply benefits. By raising the cost of oil and oil substitutes in the United States, such a fee would impose increased costs on a broad segment of the economy that relies heavily on petroleum products for transportation fuels, heating fuels, and raw materials for petrochemical products. This would reduce the Nation's economic growth, increase inflation, increase consumer costs, and reduce the competitiveness of U.S. companies in foreign and domestic markets. For example, if a variable oil import fee were used to maintain a $25 floor, the National Energy Strategy analysis indicates that the present value of the associated gross national product losses would be approximately $150 billion.

An oil import fee would also have adverse regional effects, transferring wealth from oil consuming to oil producing regions. It would result in a "drain America first" policy, using up domestic resources while cheaper foreign resources were available. Furthermore, oil import fees may violate provisions of the General Agreement on Tariffs and Trade. The agreement prevents the United States from imposing a higher rate of duty on imports from members than on imports from any other country. Such a differential would occur in the likely event that certain U.S. allies were exempted from the fee.

Finally, the Administration recognizes that changing conditions in the oil and gas markets may justify further initiatives by the Federal Government in support of the National Energy Strategy's goals.

Production in Countries Outside the Persian Gulf

Without new oil production initiatives, worldwide dependence on oil imported from the Persian Gulf is expected to increase, with the Persian Gulf's share of worldwide production reaching 41 percent by the year 2010. Inescapable political and economic uncertainties exist for a world heavily dependent on oil imported from that region.

Large reserves of oil are available in many parts of the world outside the Persian Gulf. However, many of the countries in these areas limit the role of foreign investment by imposing protectionist policies, relying on their own oil field equipment and well services, and subsidizing their domestic oil consumption.

As a result, although non-Organization of Petroleum Exporting Countries producers have increased their share of total oil supply from 40 to 60 percent since 1979, oil production in these countries is still limited relative to its potential. While non-Persian Gulf reserves are large, they do not adequately reflect the vast potential of the total oil resources in these countries. This potential includes both identified reserves and recoverable resources, as well as undiscovered resources—oil that is thought to exist in favorable geologic settings.

Currently, non-Persian Gulf oil reserves total 337 billion barrels, 50 percent less than the 654 billion barrels estimated for the Persian Gulf area. However, as indicated in Figure 25, total oil resources in the non-Persian Gulf countries are estimated to be in the range of 562 billion to 1.1 trillion barrels, significantly more than the 483 to 620 billion barrels of oil resources estimated for the Persian Gulf countries. The wide range of estimated total resources for non-Persian Gulf countries creates the potential for large increases in their production capacity. The amount of such capacity will depend on the price of oil, the availability of advanced technologies and oil field services, and the extent of investment limitations and other restrictions imposed by government policies.

Production capacity from proved reserves can be expanded by drilling more producing wells and managing the existing fields more efficiently. Undiscovered recoverable resources could translate into production capacity if the financial and technological resources are available to these oil-producing countries. The availability of investment capital will determine the speed of development and the success of efforts to construct oil distribution systems.

In trade negotiations and in bilateral and multilateral consultations with leaders of oil-producing countries outside the Persian Gulf, the United States will focus attention on the desirability and benefits of open investment policies that expand worldwide production capacity and diversity of oil suppliers. The Government will sponsor more energy-related investment programs, encourage other countries to remove barriers to external investment, and work with allies in the International Energy Agency to expand oil and gas development and trade outside the Middle East.

Western Hemisphere cooperation on energy issues will be an important focus of the National Energy Strategy. A recently completed Department of Energy study concluded that all countries in the region would benefit from removal of government controls on energy production and pricing, reduction of barriers to trade and investment in energy, and generally closer hemispheric collaboration on energy production and use.

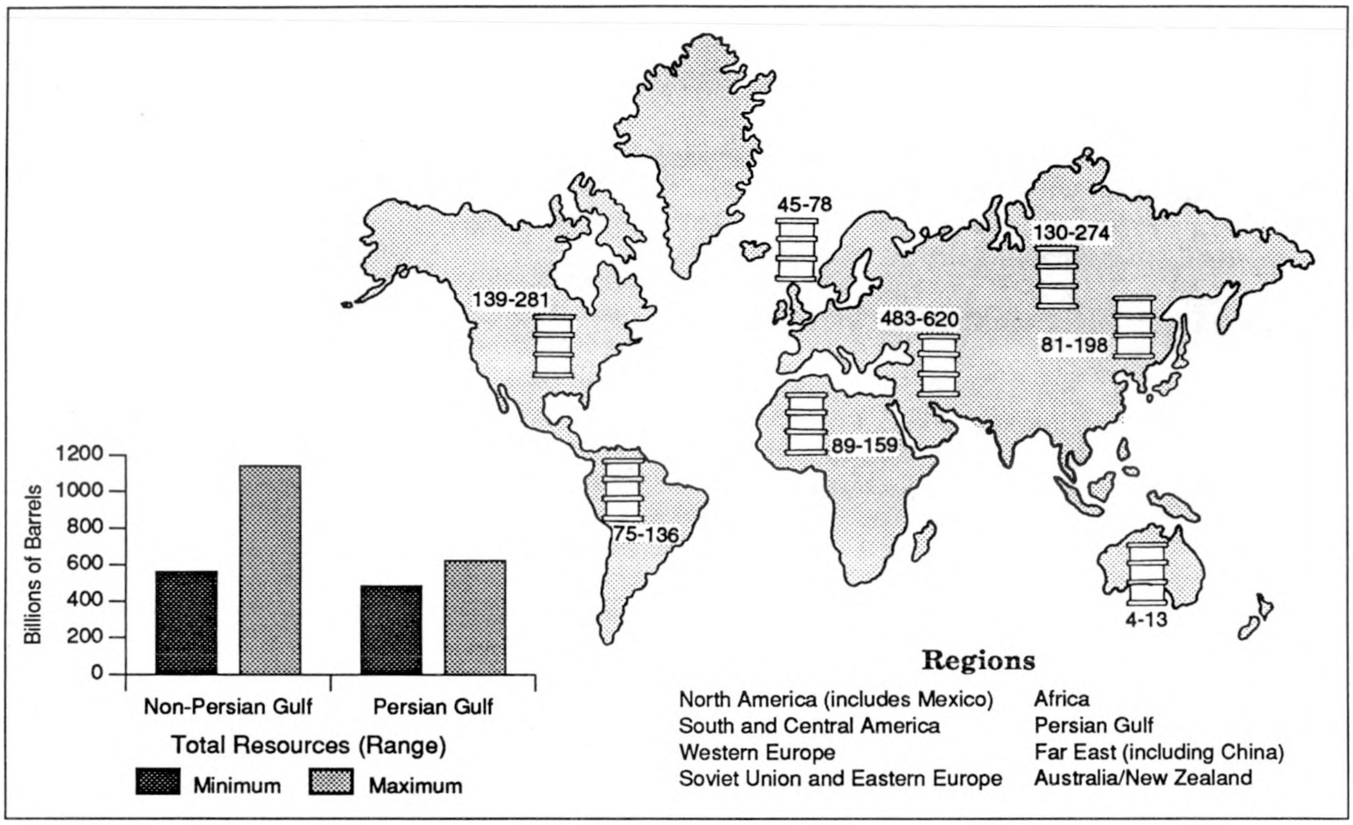
More specifically, within the framework of the National Energy Strategy, the Administration is assessing or undertaking the following international energy policy actions:

- Encouraging initiatives in Eastern Europe, the Western Hemisphere, and other developing nations that promote efficient energy development and use, a prerequisite to sound economic development.

- Highlighting energy investment opportunities as part of broader steps to expand international trade.

- Reviewing the costs and benefits of U.S. laws that discourage U.S. investment in oil exploration and development abroad.

Figure 25. World Crude Oil Resources



- Removing restrictions on exports of technology that unnecessarily handicap U.S. firms seeking to supply goods and services to the energy sectors of some nations.
- Promoting the energy-related aspects of Export-Import Bank programs.
- Developing data and analytical tools that facilitate and encourage private sector energy development in non-Persian Gulf countries.
- Expanding the energy agenda in regional initiatives such as the Organization for Economic Cooperation and Development, the East-West Center for Emerging Democracies, and the Asia-Pacific Economic Cooperation Forum.

Strategic Petroleum Stocks

It is the Administration's policy to encourage a substantial increase in worldwide strategic reserves. The Administration is conducting a review of the conditions under which these reserves can be most effectively used to mitigate the economic impact of disruptions and to maximize their deterrent value.

In 1975, Congress authorized the establishment of the Strategic Petroleum Reserve in response to the oil supply disruption of 1973. By the end of 1990, the reserve contained 585.7 million barrels of crude oil, stored in underground salt caverns at five sites along the coast of Texas and Louisiana. In 1990, Congress directed the development of a plan to expand the Strategic Petroleum Reserve to 1 billion barrels.

The Administration has examined ways to reduce the cost of the reserve or to fill it at a higher rate within current budgetary guidelines. In early 1990, following an interagency review, the Department of Energy advised Congress that a properly negotiated agreement to "lease" oil from a major exporting country was the most promising alternative. In September 1990, the Department was granted statutory authority to enter into contracts to store oil owned by others in the reserve. As soon as practicable, the Department intends to conduct negotiations with a number of prospective suppliers.

Finally, as directed by legislation enacted in 1990, the Department of Energy is designing a 3-year pilot test to examine refined petroleum product storage and to assess its relative costs and benefits. The fiscal year 1992 budget provides that the test will be conducted on the Gulf Coast area. The Department will collect data on the costs, benefits, and efficiencies of this type of storage.

Domestic Refining Capacity

During the past decade, the number of U.S. refineries fell from 319 to 205, a drop of 36 percent. Most of the reduction, however, consisted of smaller and less efficient refineries. Total U.S. distillation capacity declined only 13 percent over the 10-year period. During this period, environmental restrictions on the refining industry increased while oil markets changed dramatically. Responding to these factors, refiners greatly improved domestic refining efficiency. The change allowed refiners to produce more light products per barrel of throughput, and to refine heavier, higher sulfur oil, while meeting more stringent environmental requirements for products.

The Clean Air Act Amendments of 1990 require the introduction of substantial volumes of nonpetroleum fuel additives into the supply system. Additionally, vehicle emission requirements, a variety of State programs, and Federal alternative transportation fuels initiatives—including those recommended in the National Energy Strategy—will foster increased demand for cleaner burning transportation fuels requiring nonpetroleum feedstocks.

The Clean Air Act Amendments will reduce the use of several components that refiners use to meet gasoline octane requirements. In the longer term, new equipment and units will be needed, and this new capacity will be tailored to use heavier feedstocks and produce lighter reformulated products. Emissions of various substances at refineries themselves also are to be reduced under Clean Air Act Amendment provisions.

The requirements that the refining industry will face in the next 10 to 20 years are not fully known because implementation of the Clean Air Act Amendments is barely under way. Recognizing this uncertainty, the Department of Energy has commissioned the National Petroleum Council to conduct a two-phase study. The first phase will produce a report by June 1991 that will address the capabilities of the U.S. refining industry to meet consumer needs, considering especially the requirements of the Clean Air Act Amendments of 1990. The second phase, to be completed in 1992, will provide analysis of the time and investments necessary to meet new environmental regulations, and their effects on petroleum product supply and prices. These studies will provide important information useful in managing the potentially profound changes engendered by the Clean Air Act Amendments in the transportation fuels market.

Harmonizing Oil Supply and Environmental Objectives

Economic prosperity and environmental quality are two of the Nation's most important objectives; increasingly, a consensus is emerging that these objectives must be made compatible. Ensuring a proper balance between them will depend in large part on the careful design of regulatory programs.

The oil and gas industry, including the exploration, production, transportation, and refining sectors, is regulated under numerous Federal and State environmental statutes. As discussed under "Energy and the Quality of Air, Land, and Water," the effect of environmental regulation on oil supply is one element of a much broader National Energy Strategy initiative to assess the energy supply and demand impacts associated with all Federal regulations.

Natural Gas

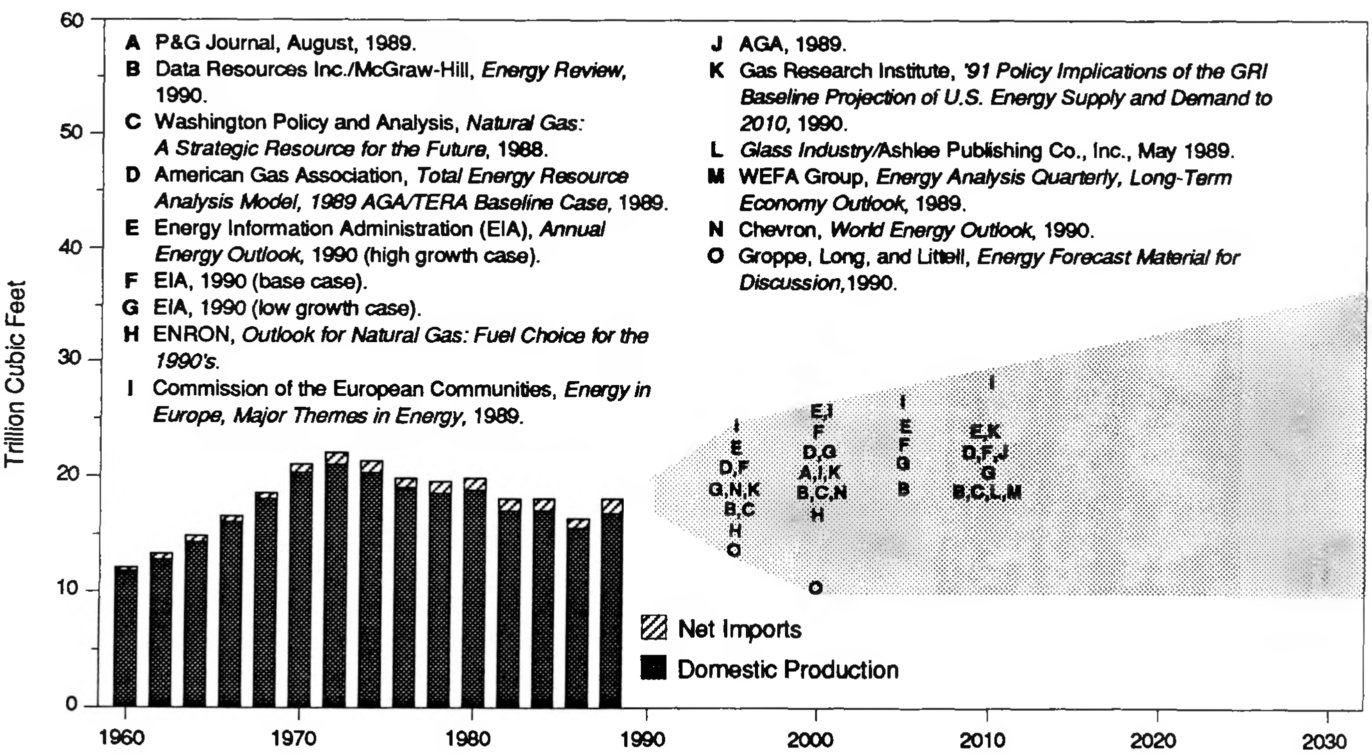
Natural gas provides more than one-fifth of all the primary energy used in the United States. It is especially important in the residential sector, where it supplies nearly half of all the energy consumed in U.S. homes.

As natural gas is consumed, it produces virtually no sulfur oxides or particulate matter, and it emits far less nitrogen oxide, carbon monoxide, and reactive hydrocarbons than other fossil fuels. Additionally, because natural gas emits less carbon dioxide than other fossil fuels, its increased use furthers U.S. policy objectives with respect to global climate change—a matter discussed more fully under "Energy and Global Environmental Issues."

Despite these environmental advantages, ample supplies, and low wellhead prices, natural gas consumption has lagged. Gas consumption in the industrial and electric-generation sectors has fallen significantly over the past two decades. The result is that total domestic use of natural gas today is more than 10 percent *less* than in 1970. Figure 26 shows historical and projected use of natural gas.

There are a number of reasons for this situation, but a primary obstruction to increased utilization of gas is a regulatory morass that, through delays, distortions, and uncertainties, creates an atmosphere that is not conducive to the investment

Figure 26. Projections of U.S. Natural Gas Use



Note: Differences in projections are caused, in part, by varying assumptions concerning energy prices, economic growth, consumer and producer behavior, and rates of technological change, including replacement of capital stock. The shaded area represents an envelope bracketing these differences.

Goals and Approaches—Natural Gas

Goal	Approach
Encourage the efficient production of natural gas in an environmentally sound manner	• Support research and development on better technologies for natural gas production and use; increase understanding of gas resource base; and support production from currently restricted areas
Establish a more efficient, accessible natural gas transportation and distribution system	• Reform Federal statutes and regulations to: – Allow timely construction of new pipeline capacity, liquefied natural gas facilities, and storage capacity – Encourage more efficient pricing of pipeline service and allow unregulated arrangements under certain circumstances – Ensure that third-party shippers have both nondiscriminatory access to pipeline facilities and services and the opportunity to obtain arrangements that are not unduly discriminatory – Eliminate unnecessary regulation of natural gas imports and exports

decisions necessary for producers, transporters, and consumers of natural gas to expand the market. Indeed, our analysis suggests that current statutory and regulatory impediments may be decreasing natural gas use by about 1 trillion cubic feet (tcf) each year.

If these impediments are removed, natural gas use can grow substantially. Industrial gas use has increased over the last 4 years and is expected to remain strong. Given recent technological advancements and the desirable environmental qualities of natural gas, it will supply a greater portion of the Nation's electricity needs. Gas use in the residential and commercial sectors will also remain strong, not only in its traditional space-heating role, but also as a direct substitute for electricity in various end-use applications, especially heating and cooling.

Natural gas can be substituted for oil in many applications, including the generation of steam for enhanced oil recovery. Because domestic natural gas is abundant and significantly less expensive than oil on an energy-equivalent basis, its increased use could boost the gross national product, reduce oil imports, and improve the Nation's trade balance. According to Government and private-sector projections, greater use of natural gas could displace up to 600,000 barrels per day of oil by 1995, and 1.7 million barrels per day by 2000 if unnecessary impediments are removed.

Goals and Approaches

The principal barriers to a more efficient natural gas market include the following:

- Regulatory uncertainty and delay in building new pipeline capacity because of outmoded economic regulation and cumbersome environmental review proceedings.

- Continued regulation of natural gas transactions, including arrangements between consenting buyers and sellers, that is not required to protect against the abuse of market power.

- Pricing schemes that discourage natural gas pipelines and consumers from using existing capacity most efficiently.

- Failure to ensure access to pipeline services on a nondiscriminatory basis for third-party shippers (shippers other than the pipeline and its affiliates).

- Unnecessary regulation of natural gas imports and exports.

- Restrictions on exploration for and development of natural gas in certain areas of the Outer Continental Shelf.

The Strategy will recommend that actions be taken in each of these areas to remove unwarranted regulation and place greater reliance on market forces, while protecting the interests of shippers and consumers.

Legislation to provide new options for the construction of new pipelines will be proposed. Changes in policy to promote more efficient use of pipeline capacity are also necessary, along with further efforts to ensure that third-party shippers have nondiscriminatory access to pipeline transportation and other services. The implementation of these proposals will remove many of the barriers and uncertainties afflicting today's natural gas market.

The table on page 87 lists the National Energy Strategy goals and approaches for natural gas.

Expected Results

The National Energy Strategy regulatory reform actions are projected to increase natural gas consumption by about 0.9 tcf in 1995 and about 1.1 tcf in 2010. These actions would result in natural gas displacing 300,000 to 400,000 barrels per day of oil after 1995 (Figure 27). Increasing the use of natural gas would lead to wellhead prices higher than those prevailing during the depressed market of recent years. More efficient use of the transmission and distribution system, however, would spread fixed costs over greater volumes, thus reducing the transportation costs to customers for each unit of gas delivered. Accordingly, residential consumers are projected to save about $140 million in the year 2000 and about $1 billion in 2010, when compared to the current regime.

Moreover, revenue for domestic producers will increase by about $8 billion in 2000 and $7.5 billion in 2010 because both prices and volumes will increase. Transportation revenue for pipelines and distribution companies is also projected to increase by about $2 billion as a result of the greater natural gas consumption, and the more efficient utilization of the transportation and distribution system, made possible by these regulatory reform actions.

In addition to the economic and energy security benefits, the National Energy Strategy natural gas regulatory reform actions would also benefit the environment. In the year 2000, an annual decrease of 670,000 tons of sulfur dioxide emissions, 200,000 tons of nitrogen oxide emissions, and 11 million metric tons of carbon dioxide emissions will be achieved, compared to estimated projections without regulatory reforms.

Efficient Production of Natural Gas

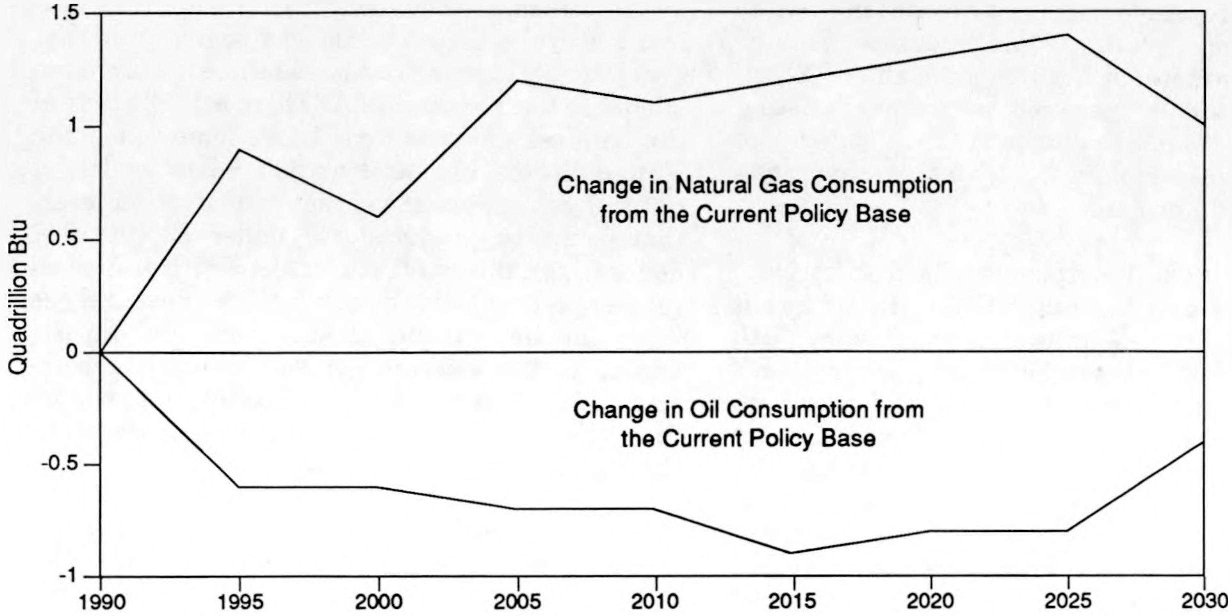
By the mid-1970's, Federal wellhead price controls had led to chronic natural gas supply shortages in the interstate market, although supplies remained abundant in the unregulated intrastate market. These shortages were so serious that some States issued moratoriums on new residential and commercial uses of natural gas, and the Federal Government banned the use of natural gas in most new electric-generation and industrial applications. To remedy these conditions, the Federal Government has taken the following actions over the past decade:

- Enacted the Wellhead Decontrol Act of 1989, which will eliminate all wellhead price controls by January 1, 1993.

- Recommended a proposed rule to FERC to bring the regulated prices of certain natural gas more in line with market prices. FERC's order implementing the Department of Energy's proposal was recently upheld by the Supreme Court.[1]

1. *Mobil Oil Exploration and Producing Southeast, Inc.*, v. *United Distribution Companies*, No. 89–452 (January 18, 1991).

Figure 27. Natural Gas Actions Would Increase Gas Consumption and Help Displace Oil Use



Note: Strategy actions that do not pertain directly to natural gas regulatory reform are not accounted for.

- Conducted analyses of the North American natural gas resource base, which indicated that ample supplies exist to meet projected demand at cost-competitive prices for at least 35 years.

- Demonstrated technological advancements, such as horizontal drilling, that continue to add to the natural gas resource base and the ability to recover it.

- Signed the U.S.-Canada Free Trade Agreement, which will promote an integrated North American natural gas market.

- Removed arbitrary restrictions on the use of natural gas that had been imposed by the Fuel Use Act and the incremental pricing provisions of the Natural Gas Policy Act.

- Approved the establishment of a natural gas futures market, which provides better information on price and helps the industry manage price risk.

- Provided tax incentives to encourage further development of natural gas resources, particularly unconventional resources, in the Omnibus Budget Reconciliation Act of 1990.

These actions contribute substantially to ensuring that the Nation's natural gas supply is one of the strong foundations upon which a National Energy Strategy can be built. The fundamental thrust of the National Energy Strategy natural gas initiatives is to build on the progress that has been made by reducing remaining regulatory barriers and allowing market forces to better ensure the adequate supply and efficient delivery of natural gas.

Research and Development on Improved Gas Exploration and Production Technologies

Last year, the Department of Energy restructured its plan for natural gas production research and development (R&D). This plan will be implemented in accordance with the National Energy Strategy R&D framework, which emphasizes the use of joint government-industry R&D consortia, with an expectation of 50 percent cost sharing. The plan focuses Department efforts on (1) developing better recovery technologies for the conventional natural gas resource base and broadening efforts to recover unconventional gas resources, such as tight-sand formations and Devonian shale; (2) improving secondary gas recovery from existing fields; and (3) more economic development of speculative gas resources, such as gas hydrates, deep gas, and abiogenic gas.

These programs will complement R&D activities of the Gas Research Institute (GRI), the nonprofit research arm of the natural gas industry. GRI, which is funded by a surcharge imposed by FERC on pipeline throughput, also conducts research on producing more gas out of a given field and doing so less expensively. In 1991, GRI will spend more than $60 million on wellhead-related research, such as coalbed methane, tight-sand resources, Devonian shale, deep gas recovery (below 15,000 feet), horizontal drilling technologies, fracturing technologies (forcing a fluid into the formation to crack it and allow the gas to flow more freely), new and advanced seismic methods, borehole gravimetry, and expert drilling systems.

Recently Enacted Tax Incentives

In 1989, and again in 1990, President Bush proposed several tax incentives for oil and gas production, including a measure that provided relief from the alternative minimum tax. The Omnibus Budget Reconciliation Act of 1990 contained several energy tax incentives that will directly benefit gas producers. The unconventional fuels credit under section 29 of the Internal Revenue Code was extended 2 years and will be available for production sold before the year 2003 from wells drilled before 1993. The unconventional fuels credit applies to gas produced from tight formations, coal seams, and Devonian shale. Independent gas producers will also benefit from the act's modifications of the percentage depletion rules and from the energy deduction for alternative minimum tax purposes. This legislation will encourage additional domestic exploration and development and help achieve greater recovery of oil and natural gas from existing fields.

Natural Gas Resource Base and Wellhead Deliverability

Despite strong consensus among geological experts to the contrary, some concern remains that low-cost natural gas resources are scarce and that dramatically higher prices will be needed to ensure adequate future supplies. DOE, in a 1988 study of the natural gas resource base, found that the United States has at least 35 years' worth of natural gas supply at current consumption levels that could be produced for under $3 (in 1987 dollars) per thousand cubic feet. With improved recovery technology, the availability of natural gas from Canada, and liquefied natural gas imports adding to the existing domestic natural gas resource base, gas resource availability will be more than adequate over the 40-year span covered by the National Energy Strategy.

These and other analyses are gradually overcoming the lack of confidence in the natural gas resource base caused by the price-control-induced shortages of the 1970's. Three additional initiatives are under way to assess continuing gas resource base and deliverability issues: First, the Department of Energy and FERC are jointly conducting a study of interstate natural gas pipeline deliverability. This study, due to be completed this year, will provide better information on the capabilities of the current interstate pipeline network. As part of this effort, the Energy Information Administration recently issued a report assessing the adequacy of natural gas wellhead deliverability. Second, the Department will conduct a second resource-base study, to be completed in 1992, that will focus on longer term resources and more aggressive technological assumptions. Third, the Secretary of Energy has requested that the National Petroleum Council conduct a comprehensive study of the constraints on natural gas playing a larger role in meeting the Nation's energy and environmental needs. This study is due to be completed in 1992.

Production From Currently Restricted Areas

The Outer Continental Shelf (OCS) is a major source of natural gas supplies, providing about one-fourth of U.S. production today. Total economically recoverable, undiscovered gas resources on the OCS are estimated to be between 44 and 114 tcf (the mean value is 74 tcf).

As discussed under "Oil," access to many parts of the OCS is restricted. These restricted areas may hold between 3 and 20 tcf (the mean value is 9 tcf) of economically recoverable, undiscovered gas resources. About half of the resources in these restricted areas are in the northeastern Gulf of Mexico and in the Atlantic Ocean offshore from States ranging from North Carolina to New Jersey. These two prospective areas could be available for additional leasing and exploration in the near future if the congressional moratoria imposed on these areas were terminated.

More Efficient and Accessible Natural Gas Transportation and Distribution Network

Natural gas cannot achieve its full potential in the Nation's energy future unless it is efficiently transported and distributed to consumers. Gas is transported to markets by intrastate and interstate pipelines, and by local distribution companies. Although it is technically possible to transport natural gas in a liquefied state by truck and by tanker, these modes are much more expensive.

As the Administration and Congress recognized in 1989, there is no longer any justification for regulation of wellhead prices. The wellhead market is highly competitive and involves thousands of producers. By contrast, competition to existing pipelines may be limited by high barriers to new entrants. When shippers and consumers do not have adequate alternatives to the utilization of existing facilities, some form of regulation is necessary to protect shippers and consumers from undue discrimination or other abuses that could be imposed by the exercise of market power.

The goal of regulation should be to protect consumers and shippers without promoting rigidity that prevents efficient adjustment by all parties to changing economic circumstances. There is no justification for regulating transactions when the only discernible interest being protected is that of competitors. Where regulation is necessary, it should simulate the incentives to efficiency and innovation that competitive markets provide.

In many instances, current regulatory policies and statutory requirements unnecessarily discourage the use of natural gas and actually inhibit competition. For example, the regulatory process for approving proposals to construct new pipeline capacity can result in delays of several years, sometimes prompting consumers to utilize more expensive, but more readily available, fuels. Additionally, natural gas pipeline rate design policies may deter construction of new pipelines and may not provide sufficient economic incentive to pipelines that are built to offer capacity at prices that would encourage maximum efficient use of natural gas. Finally, by substituting the judgment of the regulatory process for that of the marketplace, current rate regulation may inhibit negotiation of competitive commercial arrangements. Significant reforms related to building new pipeline capacity, pricing of pipeline services, third-party access to pipeline services, and imports and exports are needed.

The National Energy Strategy's regulatory reform agenda builds on the substantial progress made by FERC in recent years. FERC has made substantial progress in reforming an extraordinarily complex regulatory structure that has evolved over the past half century for a multibillion-dollar industry. Statutory changes are now necessary to ensure that appropriate further steps to a more efficient, competitive industry can be taken.

Impediments to Constructing Natural Gas Facilities

Interstate pipeline companies can only construct new pipeline capacity, liquefied natural gas facilities, and storage facilities if such construction is authorized by Federal law. Currently, there are three main approaches to authorizing such construction.

First, under section 7(c) of the Natural Gas Act of 1938, pipelines are required to obtain certificates of "public convenience and necessity" from FERC before they can serve new customers or build additional facilities. Pipelines that obtain these certificates are granted the right of eminent domain in Federal courts.

These certification requirements are frequently complex, costly, and time-consuming, and can delay, or even deter, construction of additional capacity to meet new demand or serve new producing areas. Potential competitors of proposed new pipeline facilities frequently intervene in these proceedings with the intent to delay construction or to attach terms and conditions of service to the certificate.

Second, in Order No. 436 in 1985, FERC adopted a new, more streamlined alternative to its traditional certification process called "Optional Expedited Certificates" (OEC). Under that program, if the firm proposing to construct a new pipeline is willing to accept the financial risks of building that line, FERC will expedite its certification process. Because the pipeline accepts the financial risk of the project, FERC does not review whether there is sufficient supply or customers for the project to be profitable. However, the environmental review process triggered by FERC's issuance of a certificate and FERC-imposed conditions relating to recovery of costs limit the value of this procedure. Even applications filed under OEC procedures can take years to obtain FERC approval.

Third, under section 311 of the Natural Gas Policy Act of 1978 (NGPA), interstate pipelines may transport gas in an expedited fashion. FERC interpreted this authority to allow pipelines significant flexibility in constructing new facilities that would be used for section 311 transactions. One of the benefits of this section 311 approach is that pipelines are not required to obtain FERC's approval prior to building new capacity if certain conditions are met. Recent court action, however, has narrowed the application of section 311 and has created uncertainty as to when section 311 can be used for construction.

In addition to these approaches to building capacity, FERC has established expedited procedures for minor facilities such as replacement facilities and facilities that are under certain cost thresholds.

In 1938, when Federal certification was made a prerequisite to the construction of interstate pipeline facilities, the natural gas industry was in its infancy. Federal certification of pipelines was necessary, Congress believed, to prevent wasteful duplication of pipeline facilities, to better ensure security of supply for consumers, and to provide financial assurances for investors who might be reluctant to invest in a new industry. Pipelines were required to demonstrate that they had sufficient reserves (20 years or more) to serve consumers before construction could commence. This was necessary to protect consumers, who bear the costs of constructing the pipeline under this approach.

The natural gas industry of 1990 has matured into a comprehensive nationwide pipeline network that serves about two-thirds of all U.S. counties. Indeed, 85 percent of all gas sales by pipelines are to local distribution companies served by two or more pipelines. Given the development of the industry and the growth in supply options available to consumers, new capacity certification requirements frequently pose unnecessary barriers to potential new suppliers, thwart competition, and increase consumer prices. Moreover, many of the protections provided by certification proceedings, though costly, may not be valuable to today's consumers.

The National Energy Strategy, therefore, calls for legislation to provide new options for the construction of new interstate facilities. First, the ability to construct without a certificate facilities for transportation to any person under section 311 of the NGPA, thrown in question by judicial interpretation, would be clarified.

Second, although a pipeline could continue to pursue certification pursuant to section 7(c), under defined circumstances it would also be allowed to build new pipeline capacity without FERC certification. Pipelines constructed under this approach would still have to comply with State and Federal environmental laws that apply to similar facilities, such as oil pipelines, for which no Federal certificate is necessary. If the pipeline elects to proceed without FERC certification, it would not receive Federal eminent domain rights, and would not be allowed traditional cost-of-service rate recovery.

Third, the Administration will propose legislation that will enable FERC to expedite approval of applications for new pipeline construction, in part by sharply reducing the ability of competitors to delay the construction of new facilities.

The Strategy also calls for reducing impediments to private-sector development of liquefied natural gas (LNG) facilities. The Administration is proposing as part of the Strategy an expedited environmental procedure for the siting of major energy facilities, including LNG plants. This procedure is discussed under "Energy and the Quality of Air, Land, and Water."

In addition to removing economic regulatory barriers, the Administration recommends a more efficient environmental review process for proposals to build new pipeline facilities. Under the National Environmental Policy Act (NEPA), FERC and other Federal agencies must prepare an environmental impact statement (EIS) if they authorize pipeline construction that will have a significant environmental impact. Because some proposals to build additional pipeline capacity may involve "major Federal actions" by several agencies, the potential exists for each agency to undertake its own NEPA review, which can significantly delay the construction of a pipeline project without any additional environmental benefits. (Indeed, in some instances, the delay in constructing new facilities may require consumers to continue using other, less environmentally desirable fuels.)

The Administration supports legislation making FERC the sole agency responsible for preparing an EIS for natural gas pipeline construction. FERC would continue to be required to consult with other agencies and consider their views, but the possibility of multiple agencies doing independent NEPA documents would be eliminated.

The Administration also supports legislation allowing FERC to charge the applicant directly for an EIS and other environmental documents prepared by a private-sector firm, without the reimbursed cost counting against FERC's budget appropriation. This will enable FERC to leverage its staff resources and process new facility applications more quickly, without jeopardizing environmental protection.

While wellhead supplies of natural gas are plentiful, there is not enough pipeline capacity to satisfy demand in a number of regions. Expansion of pipeline capacity would allow natural gas to displace oil in many areas and would benefit consumers by creating more competition among fuels. Additionally, if pipeline capacity could be built in a timely manner, it could also facilitate imports from Mexico and Canada, as well as exports from the United States, where these transactions make economic sense.

Comparable Third-Party Transportation Service

Unlike railroads and oil pipelines, natural gas pipelines are not common carriers. A natural gas pipeline has no statutory obligation either to transport natural gas for third parties on a nondiscriminatory basis or to expand or prorate capacity when a customer's request exceeds the pipeline's capacity. Regulation of pipeline and distribution companies is necessary to protect consumers without alternative suppliers, as well as some producers and other shippers who lack alternate means of transporting their gas to market. Otherwise, a pipeline with market power could dictate lower purchase prices to producers and higher sales prices to customers by restricting access to transportation and other pipeline services.

Although FERC has succeeded in securing the commitment of most pipelines to provide nondiscriminatory transportation service, issues remain with respect to whether the nondiscriminatory transportation services being offered by participating pipelines are truly comparable to the transportation services offered by the pipelines to their sales customers. For this reason, the Administration supports full utilization of FERC authorities to ensure that pipelines with monopoly power over transportation services offer transportation and other services for third parties on a nondiscriminatory basis.

This does not mean prohibiting all price discrimination in transportation and other services. Rather, it means that a pipeline may not use its control over transportation services to block transactions between willing buyers and sellers of gas.

The Administration also supports requiring that pipelines unbundle and sell separately the various services they provide—transportation, balancing, marketing, gas purchasing and storage—so that customers can choose and pay for only those services they desire.

Deregulation and Efficient Pricing of Pipeline Services

The Natural Gas Act of 1938 requires that FERC regulate the prices interstate pipelines charge for their services, specifically transportation and gas sales for resale. The National Energy Strategy calls for reforming this regulation by allowing more flexible and market-responsive arrangements between pipelines and their customers, more competitive pricing of pipeline services, and more efficient utilization of the existing pipeline system. The Strategy recommends reform in two areas—the prices a pipeline charges for natural gas and the prices it charges for natural gas transportation and other services.

Reform Natural Gas Pricing

Historically, FERC has required that pipelines reflect their actual cost of gas purchased in their sales rates. The rationale for cost-based rates was concern that a pipeline could extract monopoly profits on its natural gas sales because its customers had no other alternative.

If consumers do have access to alternative suppliers of natural gas, there is no basis for sales rate regulation. Accordingly, the National Energy Strategy calls for deregulating the price a pipeline charges for natural gas, *if* it offers comparable transportation and other services to all on a nondiscriminatory basis. Customers unhappy with the price offered by the pipeline will be able to purchase gas not only from the pipeline, but also from many other suppliers—most of whom are unregulated.

Reform Pricing of Pipeline Services

The Strategy also calls for reforming pipeline rate design. Traditional cost-of-service regulation does not encourage the most efficient use of natural gas pipeline and storage facilities. For example:

- Because fixed costs are spread over historical and projected transportation and sales volumes, cost-based rates traditionally increase when demand falls and decrease when demand rises, contrary to the reaction of unregulated competitive markets.
- Current capacity use is inefficient on some systems because pipeline prices are too low during peak periods, leading to excess demand, and too high during off-peak periods, leading to unused capacity and insufficient incentives to develop storage that would enable better utilization of pipeline capacity year-round.
- Customers on certain pipeline systems cannot easily resell, or broker, to other parties the pipeline capacity they have reserved.
- Under the filed rate doctrine, as interpreted by the courts, pipelines generally have to charge the prices they have on file with FERC, and cannot negotiate individual rates with customers (although limited discounts from the filed rates may be permitted).
- Significant business risk may be shifted from pipelines to their customers in a way that diminishes a pipeline's incentives to obtain new business, fully utilize its facilities, and engage in cost-saving innovations.

FERC issued a policy statement on rate design in 1989 that encouraged the incorporation of several components of economically efficient rate design into pipeline rates and practices, including seasonal rates designed to ration scarce capacity and capacity-brokering options. The Administration supports these FERC efforts, as well as the following rate policies, to promote more efficient pricing of pipeline services.

Safe Harbors. "Safe harbors" define where regulation is unnecessary. For example, in those markets and services in which pipelines do not possess market power, they should be exempt from rate regulation entirely. Similarly, exemptions might also apply to contracts between pipelines and customers where customers have recourse to protection by regulatory authority when commercial arrangements cannot be negotiated.

Incentive Regulation. For markets in which a pipeline has market power, a maximum price that the pipeline may charge would be determined. To create incentives for efficiency, this ceiling price ideally would be independent of actual costs and actual revenues, possibly through price caps imposed on particular services.

Reselling of Capacity Rights. Unless a pipeline's customers have monopoly power in the market for rights to firm pipeline capacity, customers should be allowed to resell firm capacity to others at unregulated prices. Since most pipeline firm capacity customers are local distribution companies, reselling this capacity at market prices could substantially benefit consumers, especially residential and commercial customers.

Deregulate Rates of New Pipelines. A new pipeline's rates and services would not be regulated if the new pipeline does not have monopoly or monopsony power over customers or producers, and customers of *existing* facilities do not bear any of the financial risk of the new facilities. While these pipelines would be free to negotiate arrangements with customers and shippers who consent, protection would be provided for those without competitive alternatives who are unable to reach contractual agreement with the pipeline. Thus, new pipelines would be given far greater pricing and contracting flexibility than would be permitted under traditional regulation.

Unnecessary Regulation of Natural Gas Imports and Exports

The United States imports about 8 percent of the natural gas it consumes (virtually all from Canada) and exports a relatively small quantity of natural gas, mostly Alaskan liquefied natural gas, to Japan. Imports of natural gas have doubled over the past 4 years and are expected to increase both in absolute terms and as a percentage of future consumption. In the year 2000, the Department of Energy estimates that imports will be about 12 percent of consumption; and in 2010, about 14 percent.

Imports and exports were originally regulated on the assumption that market forces would not ensure that imports and exports of natural gas would be reasonably priced and consistent with reliable service for U.S. consumers. With today's well-developed, competitive wellhead natural gas market, there is no reason to substitute the Federal Government's judgment for that of contracting parties as to what is a competitive price, and what level of supply security is appropriate.

When all regulation of domestic producers ends on January 1, 1993, both the price and the producer's need to obtain a certificate to sell its gas will be completely deregulated. However, there will be no comparable deregulation of transactions involving the import or export of natural gas. There is no reason to treat these two kinds of transactions differently. Indeed, eliminating this differential treatment will contribute to a more competitive, integrated North American natural gas market.

The National Energy Strategy, therefore, calls for legislation that eliminates the Department of Energy's authority over import and export transactions where those transactions are treated differently from similar transactions involving domestic natural gas.

State Regulation

Though States do not regulate the wellhead price of natural gas, they do regulate wellhead activities, such as the spacing of wells on acreage, correlative rights, and the prorating of production from wells and fields. Such regulation of wellhead activities may significantly affect the production of natural gas.

State public utility commissions also comprehensively regulate local distribution companies (LDC's). Because natural gas regulatory reform has given LDC's new natural gas supply options, it also has caused LDC's to be responsible for the proper exercise of those options. This, in turn, has increased the role of State public utility commissions.

For example, prior to open access transportation, virtually all gas bought by LDC's was sold by the pipeline under close regulation by FERC. FERC open access reforms allow LDC's to buy gas from producers and marketers directly, without FERC regulation. Many States, therefore, are now giving closer scrutiny to LDC purchasing practices.

In addition, the role of State integrated resource planning for natural gas utilities is becoming increasingly important, as is the issue of whether LDC's should be required to provide third-party access to LDC facilities for delivery of natural gas.

The advent of competition and greater reliance on market forces within the natural gas industry suggests that State policies that affect the efficient production and use of natural gas will take on greater importance in the future. Because insufficient information exists on how a wide variety of State regulatory practices may affect the natural gas market, the Department of Energy could not definitively reach conclusions on many important State issues. Accordingly, the Department will conduct a study on the impact of State wellhead and public utility regulation on the efficient production and use of natural gas.

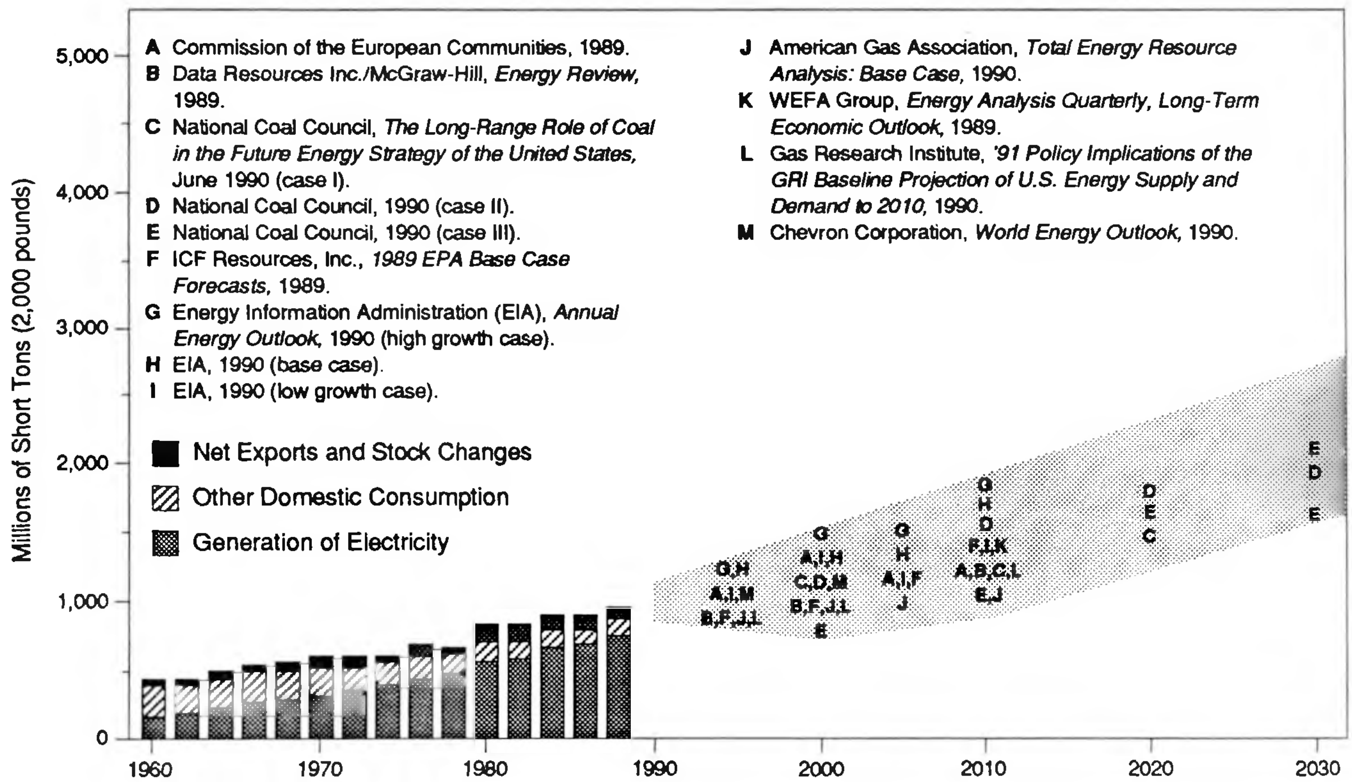
Coal

Coal is this country's most abundant fossil fuel. Over the past decade, its contribution to the Nation's energy supply has increased significantly—so that 23 percent of total U.S. requirements for primary energy in 1989 were met by coal, very largely through its use as a fuel to generate electricity. U.S. coal is also a valuable export, helping to supply energy in Europe, South America, and the Far East.

More than one-fourth of the world's known coal reserves lie within U.S. borders. Coal deposits are located beneath 38 of our 50 States, and they represent 90 percent of all known U.S. fossil energy resources. The magnitude of this resource, coupled with the multiple uses for coal and coal-derived products (including the manufacture of synthetic fuels), ensures that coal is likely to be a major contributor to the Nation's energy supply-mix for the foreseeable future.

The linkage between coal and electricity supply is especially strong, though the burning of coal to provide heat directly also provides a critical input to much U.S. industrial activity. In 1989, 86 percent of U.S. coal consumption went into

Figure 28. Projections of U.S. Coal Production



Note: Differences in projections are caused, in part, by varying assumptions concerning energy prices, economic growth, consumer and producer behavior, and rates of technological change, including replacement of capital stock. The shaded area represents an envelope bracketing these differences.

Goals and Approaches—Coal

Goal	Approach
Maintain coal's competitiveness while meeting environmental, health, and safety requirements	• Promote development and demonstration of new coal-related technologies • Develop performance-based safety regulations that allow use of new mining technologies • Clarify environmental requirements for refurbished generating units
Create favorable export climate for U.S. coal and coal technology	• Accelerate international transfer of new coal-related technologies • Enhance visibility of potential exports • Improve coordination among U.S. agencies to support coal-related exports • Facilitate financing for the export of U.S. coal and coal technology

generating electricity. About 55 percent of the Nation's electricity is now produced from coal, and this figure could go much higher in the decades ahead. New ways of producing, transporting, and using coal that are both environmentally acceptable and economical can benefit the Nation considerably.

The international dimension of coal use and coal technology is also important. In 1990, the first year in U.S. history during which more than a *billion* tons of coal were mined in this country, more than 100 million tons were exported. Electricity demand and the use of coal for generation and industrial processes are growing rapidly worldwide. However, environmental quality is also a worldwide concern; and this has produced some apprehensions about an expanded role for coal. U.S. leadership in developing and demonstrating technologies that use coal in more economical and environmentally acceptable ways is expected to develop large new markets for U.S. coal, equipment, products, and services. This could improve the quality of life significantly in many countries, including some in the Third World as well as those in Eastern Europe where economic and political reforms are under way.

As shown in Figure 28, the Energy Information Administration's midrange projection in its *Annual Energy Outlook 1990* was that the total amount of coal produced in this country could increase by more than 65 percent between 1989 and 2010—rising to almost 1.6 billion tons annually. However, the same figure shows that projections of future U.S. coal use vary widely. The differences reflect uncertainties about future environmental constraints, the rate of economic growth, and the effects of new coal and noncoal technologies on coal's share of the overall energy market.

Goals and Approaches

The National Energy Strategy goals for the coal sector and the approaches for achieving them are summarized in the above table. Many of the programs needed to achieve these goals are already in place.

The National Energy Strategy's major effort in the coal sector is to continue implementing the Clean Coal Technology Program. This is an important program that will help to achieve the emission requirements established in the Clean Air Act Amendments of 1990, at minimal cost and with minimal disruption in regional coal markets.

Expected Results

As shown in Figure 29, compliance with the Clean Air Act requirements using today's technologies with added environmental controls (for example, "scrubbers"), would increase electricity prices over the long term. By comparison, use of the new technologies will help to stabilize electricity prices. Accelerating the deployment of the new technologies through regulatory reforms and incentives would provide additional benefits. The savings are achieved through lower capital costs per kilowatt of generating capacity, use of lower cost fuels, and more efficient use of fuels.

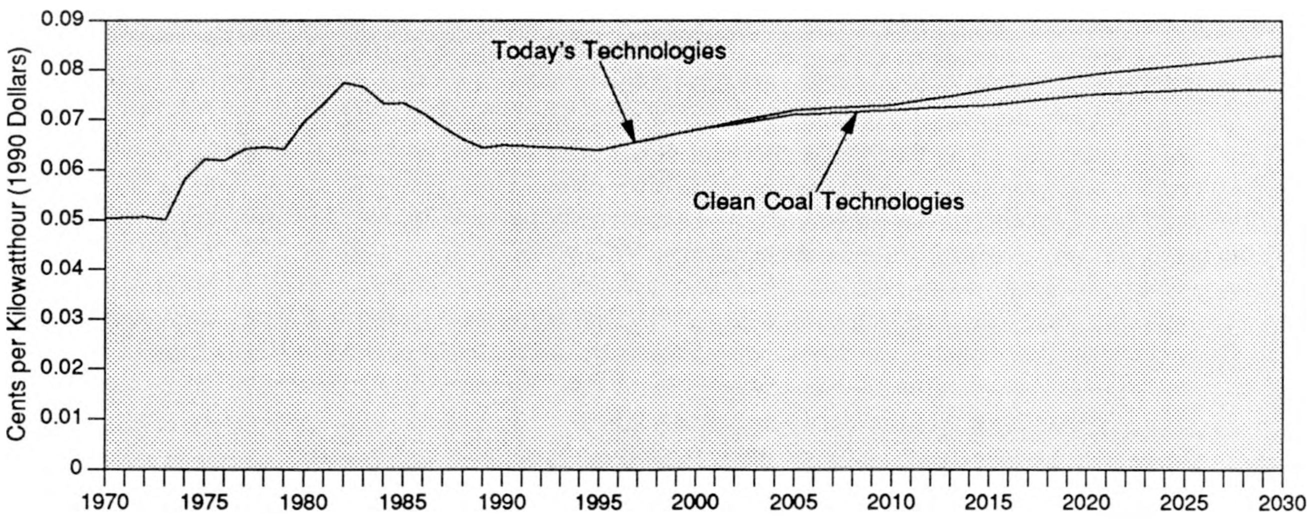
Clean, Competitive Coal

If coal is to remain acceptable as a major energy source, it must be produced, transported, and used in ways that fully protect the environment, the miners producing the coal, and the residents of areas affected by coal use. At the same time, the cost of complying with environmental, health, and safety requirements must not increase the overall cost of using coal to the point that coal becomes noncompetitive in the marketplace. If coal were to become noncompetitive, many coal users would shift to alternative sources of energy that are not as available as and more expensive than coal. Because of coal's importance in the economy as a primary energy resource, the cost of such a shift would be very large.

The Strategy's approach to achieving this goal is to implement the existing program for the development and demonstration of new technologies that will comply with environmental, health, and safety requirements at costs that will keep coal competitive in the marketplace. In some cases, as discussed below, this approach will require changes in regulations that hinder the use of new technologies. These actions are intended to speed up the commercial testing of the new technologies to ensure that coal can compete with other fuels in the marketplace and to increase the diversity of the fuels and technologies that generate electricity.

Over the past two decades, Federal and State governments have established a body of stringent regulations for coal production and use. With the continued use of coal by electric utilities and the industrial sector, these regulations have made the U.S. coal industry a world leader in protecting the environment and ensuring miner safety during coal production. The Clean Air Act Amendments of 1990 will require further advances to reduce the impact of coal use on air quality.

Figure 29. Projected U.S. Average Electricity Prices, With and Without Clean Coal Technologies



Source: Argus Model Runs for National Energy Strategy, January 1991.

Specific actions that will help to achieve this goal are discussed below in a sequence that corresponds to the overall process of leasing, mining, transporting, and consuming coal.

Federal Coal Leases

To avoid limiting the availability of low-sulfur coal at competitive prices, the Department of the Interior's Federal Coal Leasing Program must anticipate market trends and lease Federal coal resources in adequate quantities. To avert such difficulties, the program anticipates future needs for Federal coal and will facilitate the prudent and timely development of Federal reserves as they are needed. This process determines if and when Federal coal-bearing lands should be made available for leasing and ensures that the Government receives a fair market value for its coal.

Coal Production

The most important environmental concerns in coal production (such as surface subsidence caused by the collapse of underground mines, dust resulting from surface mining, acid water runoff, and land reclamation) are subject to regulations established over the past two decades. These regulations will continue to be administered effectively. In addition, the U.S. Bureau of Mines will continue its research and development on new technologies that protect the environment during mining (for example, acid mine runoff can be treated with a biological bog-like "filter" to purify the water, as an alternative to the conventional holding pond).

Methane emissions from underground coal mines also have become a concern, because methane is potentially significant as a "greenhouse gas." To respond to this concern, the Environmental Protection Agency (EPA) will conduct a study on the effect of methane emissions on possible global climate change. This study will fulfill a statutory requirement established in the Clean Air Act Amendments of 1990. The Federal Government also is providing tax credits for extracting coal-bed methane as a marketable product instead of simply venting it to the atmosphere during mining.

Surface Mining Regulations

It is necessary to reduce uncertainty about potential new environmental constraints under the Surface Mining Control and Reclamation Act that would affect coal production, so that this uncertainty does not hinder the flow of investment capital to the industry. The Administration's policy goal is to protect the environment, but also ensure that regulations are effective, timely, and economical. Reducing uncertainty over the content of new regulations is a critical element of this policy. The Department of the Interior has primary responsibility for implementing the Surface Mining Control and Reclamation Act, and it is working to achieve this objective.

Mine Safety

The safety record of the U.S. coal industry has improved steadily since the Federal Coal Mine Health and Safety Act of 1969 was passed. However, as coal use continues to grow, mine worker safety must remain a paramount concern. One area for improvement is in the regulations that govern safe mining practices, which are administered by the Mining Safety and Health Administration in the Department of Labor.

Present regulations hinder the use of new mining techniques that would further enhance both safety and economic efficiency. To further achieve these goals, performance-based safety standards will be developed to allow advances in mining technology. Examples of pertinent new technologies or approaches include using computers to help design mine roof pillars and linking mine ventilation requirements to actual air quality rather than to prescribed volumes of air movement. In addition, the U.S. Bureau of Mines will continue its research and development program in mine health and safety. Examples of current research and development topics include self-contained self-rescue equipment, automated mining, and the effects of the velocity of air for mine ventilation on the movement of fires in underground mines.

Slurry Pipelines

A coal slurry pipeline can be an efficient means of transporting coal to a distant market. However, coal slurry projects increase water use and raise environmental issues in areas where water is a scarce resource. The Administration supports proposed Federal legislation to grant the power of eminent domain to qualified pipeline proposals, but only if these proposals have satisfied all regional and State concerns about water rights. This legislation would allow slurry pipelines to be constructed only where regional and State authorities consent to the use of water resources for this purpose.

Railroad Work Rules

Archaic work rules and Federal regulations now permit strikes against both the principal railroad in a given dispute and connecting railroads. The Taft-Hartley Act banned the latter practice, called secondary boycotting, in most other industries. Similarly, current regulations place the coverage of railroad injuries under the Federal Employees Liability Act, rather than under State workmens' compensation programs as in other industries. As part of its policy on transportation, the Administration has determined that these rules need to be updated and that the Railway Labor Act should be reformed to eliminate outdated, counterproductive regulations and permit railroads to operate more efficiently. These issues are addressed in the Department of Transportation's *Statement of National Transportation Policy: Strategies for Action* (February 1990).

Clean Air Act Amendments of 1990

The 1990 Clean Air Act Amendments establish as a goal for the year 2000 a reduction in total national sulfur dioxide (SO_2) emissions of at least 10 million tons below the 1980 level. The statute also establishes a permanent cap on SO_2 emissions at the level reached in the year 2000. Moreover, the legislation requires the installation of devices for controlling emissions of nitrogen oxides (NO_x) from existing coal-fired electric utility powerplants. Compliance with these stringent requirements on SO_2 and NO_x emissions may have regional impacts on the production of coal. As a compliance strategy, switching to low-sulfur coal would disrupt local economies and create unemployment in some regions that produce high-sulfur coal. Reducing the use of coal would hurt coal-producing regions in general. New technologies can help minimize adverse effects on both the economy and the environment through improved performance and combustion efficiency, using most types of coal.

The Administration supports the commercial use of advanced coal technologies in electric generation and other applications (for example, in the transportation and industrial sectors) through a wide range of research, development, and demonstration programs. These efforts include the following:

- An extensive technological research program to continue improving the performance of coal-fired systems.

- A multibillion dollar, multiyear Clean Coal Technology (CCT) Demonstration Program, through which the Federal Government pays up to 50 percent of the costs of selected projects that test emerging technologies on a commercial scale. Participating private-sector firms pay the remainder of the project costs. In this program, the most promising advanced coal-based technologies are being moved to the marketplace through demonstration. The demonstration program is scaled large enough to generate the data needed for the private sector and regulators to judge the commercial potential of the processes being developed.

These advanced technologies will greatly reduce SO_2 and NO_x emissions, ease waste disposal requirements, and increase the energy efficiency of coal use. The program includes technologies for advanced coal cleaning and for combustion, conversion, and postcombustion cleaning. Some of the most promising advanced processes include integrated gasification–combined-cycle and atmospheric and pressurized-fluidized combustion, and gasification fuel cells.

Electric utilities want to reduce uncertainties about the specific environmental requirements they will have to meet under the Clean Air Act Amendments of 1990. They also want a degree of flexibility that will allow them to comply with those requirements in the most cost-effective manner. The Department of Energy will work closely with EPA to develop timely, clearly written, and effective regulations.

Powerplant Refurbishment

When Congress passed the Clean Air Act in 1970, most existing generating units were subject only to State regulations needed to attain Federal health and welfare standards, and they were not required to comply with the strict standards imposed on new units. Today, the high costs of siting and constructing new generating capacity have caused utilities to seriously consider refurbishing existing units as an alternative to constructing new units. The prospect of widespread "life extension" programs for existing units has increased the importance of determining the extent to which refurbished units should comply with EPA's "New Source Performance Standards" and "Prevention of Significant Deterioration" regulations. Comparatively little new coal generating capacity was added in the 1980's. Accordingly, the fraction of the Nation's coal-fired generating capacity that might be refurbished will grow rapidly over the next two decades.

The issue of environmental requirements for refurbished electric powerplants became prominent after a decision by EPA in October 1988 (now widely known as "the WEPCO decision") involving a plant refurbished by the Wisconsin Electric Power Company (WEPCO). In this case, EPA held that when a utility makes "nonroutine" changes in the operation, repair, or maintenance of a unit, it may become subject to "New Source Performance Standards" or "Prevention of Significant Deterioration" requirements. To meet them, the utility may have to make large capital expenditures on such equipment as flue-gas "scrubbers," which eliminate almost all sulfur oxides from the stack emissions. EPA will determine what constitutes a "nonroutine" change on a case-by-case basis. As a result, utilities interested in refurbishing older units are uncertain about what standards they will have to meet and what the capital costs are likely to be.

The cost of the steps taken by the Wisconsin Electric Power Company to comply with EPA's decision shows that the WEPCO decision may have significant impacts. The refurbishment project's capital cost increased by 50 percent—from $80 million to $120 million. At the same time, the size of the project dropped from 400 megawatts (MW) to 320 MW when an 80-MW unit had to be retired because it would have been uneconomic to refurbish it and install the required pollution controls. Overall, refurbishment cost $375 per kilowatt (kW) instead of $200 per kW. Economically, cost increases of this size make refurbishment less suitable as a means of meeting electricity supply requirements.

Except for some CCT demonstration projects, the Clean Air Act Amendments of 1990 do not address the question of emission standards for refurbished plants. However, the congressional conferees directed EPA to resolve the question promptly by administrative means. A quick solution is needed to reduce uncertainty in utility supply planning. It is important to recognize that, because of the SO_2 emissions cap and the market for emission allowances established in the new legislation, imposing additional pollution control requirements on older coal units will have little effect on aggregate SO_2 emissions. That is, aggregate emissions will stabilize at or near the cap in any case; strict requirements for refurbished plants would provide greater latitude for other emission sources and increase the total costs of meeting the requirements set by law.

Some of the technologies in the CCT Program may be used to refurbish existing units and therefore help to reduce emissions from the Nation's growing inventory of aging coal-fired units. Clean coal technologies are also being scaled down for industrial and commercial applications. Because these technologies emit extremely low levels of SO_2 and NO_x, they can be used effectively to hold total emissions within the cap imposed by the 1990 Clean Air Act Amendments. Further, many of these advanced technologies can burn a wide variety of coals and other solid fuels to comply with environmental requirements. Thus, they will allow utilities more flexibility in adjusting to changes in the availability and prices of fuels.

The Department will identify those parts of current EPA regulations where revisions are critically needed to eliminate uncertainties regarding standards for refurbished powerplants. It will also work with EPA to develop new regulations.

Public Perceptions

Many people are not aware that major progress has been made in the development of coal-based technologies to generate electricity. Recent efforts in Massachusetts, Rhode Island, and elsewhere to site new coal-fired facilities using new technologies have shown that it is difficult for prospective developers of such projects to have their proposals examined solely on merit. For example, there are new and highly efficient advanced-design coal units that emit less SO_2 than most of the coal- or oil-fired capacity they would displace; they also emit less NO_x than today's plants fired by natural gas.

To improve public understanding of the status and implications of clean coal technologies, the Department of Energy will augment its existing outreach program to provide up-to-date information to regulators, industry, and the general public. This effort will include publication of annual updates on the CCT Program, attention to clean coal technologies in various educational materials developed by the Department, indepth reports on specific projects, sponsorship and participation in conferences and workshops, and meetings with State legislative leaders and utility commissioners.

Global Climate Change

Concern over possible climate changes on a global scale because of increased emission of "greenhouse gases" has risen sharply in recent years. (See "Energy and Global Environmental Issues" for additional discussion on this subject.) One of the most significant greenhouse gases is carbon dioxide (CO_2). The use of coal with current technology results in more CO_2 per unit of energy consumed than does any other fuel. Coal use is rising worldwide, and increased concern over global climatic change has led to calls for agreements to limit or reduce coal use. Such restrictions could adversely affect the economies of the United States and many other nations.

The following actions are planned in response to this concern:

- The Federal Government will continue to pursue the world's most extensive scientific program to monitor and analyze the impacts of all greenhouse gas emissions, including manmade CO_2, on global climate change.
- The Department of Energy will implement its existing program to develop and demonstrate high-efficiency coal-based technologies that will reduce CO_2 emissions per unit of energy produced, in addition to reducing SO_2 and NO_x emissions. The Department also is encouraging cogeneration applications that use the waste heat from coal-based combustors, thereby increasing the thermal efficiency of such units and reducing CO_2 emissions.
- The criteria for selecting additional projects for Federal cofunding in the CCT Demonstration Program will stress achieving high energy efficiency, which will help to develop systems for coal use that are consistent with the Administration's policy on matters related to possible global climate change. (See "Energy and Global Environmental Issues.")
- The Department will conduct research and development on the feasibility of cost-effective methods for the capture, disposal, and use of CO_2. Specific topics for research and development include CO_2 scrubbers, injection of CO_2 into oil wells for enhanced oil recovery, disposal of CO_2 by injection into abandoned oil and gas wells, and recycling of CO_2 through biomass production.
- The Department will continue to participate in a program on CO_2-related research and development organized by the International Energy Agency. A task force with representatives from 14 industrialized countries will exchange information on the results of current research and development programs and perform economic studies on the impacts of possible measures to control CO_2.

Sharing Financial Risks

The use of generation technologies that are not yet fully tested on a commercial scale entails additional financial risks that utilities are not likely to assume unless they can expect to recover costs. The Department of Energy will coordinate efforts with State regulatory authorities to support the States' use of regulatory incentives to offset these additional risks, in return for Federal support for the technologies through the Department's research and development and CCT demonstration programs.

Synthetic Liquid Fuels From Coal

Coal can be used to produce synthetic liquid feedstocks for making gasoline, diesel fuel, heating oil, jet fuel, and methanol, as alternatives to petroleum-derived products. Using today's technologies, the cost of producing such liquids in small test plants is currently estimated to be equivalent to $35 to $40 per barrel of oil. These results would not be competitive with oil prices forecast for the near term. In addition, the significance of such cost estimates is uncertain, because problems frequently arise in replicating the performance achieved at the test-plant level in a plant one thousand times larger. Moreover, these technologies require large capital investments that would determine 50 to 60 percent of the cost of the final product, creating a business risk because oil prices might fall.

In its research and development program, the Department of Energy is developing advanced coal liquefaction technologies. The Department's goal is to demonstrate further cost improvements at its test facilities over the next 5 years. The National Research Council identified $30 per barrel (at the test-facility level) as a reasonable cost goal for the next 5 to 10 years. If this objective is met, additional efforts may be needed to resolve scaleup issues.

Whether coal-derived synthetic fuels are commercialized will depend not only on achieving economically competitive prices, but perhaps also on whether total fuel-cycle CO_2 emissions can be reduced. Currently, production and use of coal-derived synthetic fuels would release more CO_2 per unit of end-use energy consumed into the atmosphere than the production and use of petroleum fuels, or the direct combustion of coal.

Exports of U.S. Coal and Coal Technology

The United States has traditionally been a world leader in coal exports and is well positioned to become a major exporter of coal technologies. U.S. firms produce and market virtually every type of equipment and service related to coal production, preparation, and use. In many cases, U.S. firms are marketing some of the most advanced equipment in the world.

Competition from foreign vendors, however, is strong. Other countries offer comprehensive financial assistance—including subsidies, in some cases—to exporters and have extensive programs to develop coal technologies. To improve the climate for the export of U.S. coal and coal technology, the National Energy Strategy will build upon our current and increasing technological advantages and take both generic and coal-specific actions to assist technology transfer on an international scale.

The international demand for coal and coal combustion technologies is expected to grow rapidly in the next 10 years. The capacity for coal-fired electric generation in Pacific Rim nations alone is expected to increase by 60 gigawatts (equivalent to more than 60 of today's largest coal-fired units) by the year 2000. There are large potential benefits to expanding the U.S. share of this emerging multi-billion dollar market. Capturing even small percentage gains in market share will have significant benefits for U.S. industry and the Nation's balance of trade. The global environment will benefit if state-of-the-art U.S. technologies are shared with the many nations planning to increase their use of coal.

Some obstacles to increased export of coal technologies, such as concerns over antitrust law as it affects joint sponsorship of research and development, and the protection of intellectual property rights in international markets, are not specific to the coal sector. Rather, they affect many industries and thus lend themselves to generic solutions.

Other obstacles, such as limited visibility of U.S. firms and technologies in international markets, are specific to coal-related industries but have counterparts in other industries. These obstacles can be addressed by using generic measures as well as efforts focusing on specific industries. Generic solutions are discussed in more detail under "Technology Transfer."

Visibility of Potential Exports

Greater efforts are needed to make U.S. firms and technologies more visible to buyers of coal-related equipment and services in other countries, and to demonstrate the suitability of U.S. technologies to their needs.

The Department of Energy plans three initiatives along these lines:

- Create a clearinghouse for the export of coal technology, which will provide U.S. companies with information on specific markets and act as an interagency and international advocate for U.S. coal equipment, product, and service firms. It also will provide information to foreign buyers on economic, environmental, and technical advantages offered by U.S. clean coal technologies.

- Establish a closer liaison with representatives in U.S. embassies abroad and develop a program to inform these individuals about the advantages of U.S. coal and coal technologies.

- Increase the emphasis on clean coal technologies with potential for export markets.

Interagency Coordination

In the Clean Air Act Amendments of 1990, Congress directed the Department of Energy to prepare a report (in consultation with the Department of Commerce) assessing various Federal programs related to the export of clean coal technologies. The purpose of this report, which must be submitted to Congress late in 1991, is to study export programs that could relate to clean coal technology within U.S. Government agencies, including the Departments of State, Commerce, and Energy, the Export-Import Bank, and the Overseas Private investment Corporation. The study will address interagency efforts to promote the export and use of clean coal technologies.

Financing

Greater efforts are needed to increase financing for projects using U.S. coal and clean coal technologies in other countries. As part of the congressionally mandated study cited above, the Department of Energy also will review existing programs and polices of U.S. and U.S.-assisted international financing agencies and institutions and propose new initiatives to foster widespread use of U.S. clean coal technologies abroad. More specifically, the Department will review programs administered by the Agency for International Development, the Overseas Private Investment Corporation, the Export-Import Bank, the World Bank, and regional development banks.

Export Trading Companies

Export trading companies can offer significant advantages to U.S. firms competing in international markets by providing services to help exports pass through all the legal, regulatory, and operational steps that are needed to sell in these markets. These services include coordinating the unloading and reloading of the product at the U.S. point of export, arranging the transport of the product to its destination, and providing legal counsel on customs laws and regulations in the United States and abroad. Thus, export trading companies can provide critical services that producing firms otherwise would have to develop in-house. The services of export trading companies are likely to attract smaller firms who sell primarily in domestic markets and for whom developing an export trading capacity in-house would not be economical. The Department of Energy will work to inform U.S. industry of the existence and potential advantages of export trading companies.

Nuclear Power

About 20 percent of the Nation's electricity is generated by nuclear powerplants, making nuclear fission second only to coal as a source of U.S. electricity. Nuclear power is a proven electricity-generating technology that emits no sulfur dioxide, nitrogen oxides, or greenhouse gases. Virtually every nuclear powerplant in the free-market countries has operated safely. Nuclear power is a plus for "energy security" because it does not rely on fuel whose supply is threatened by depletion or cutoff.

Despite these features, our Nation—which was a pioneer in using nuclear power for generating electricity—is in danger of losing its ability to apply this technology. Since the early 1970's, plans for more than 100 nuclear power units in this country have been either canceled or deferred indefinitely. Only three nuclear powerplants remain in the construction "pipeline"—all scheduled for completion within the next few years. No *new* commercial U.S. power reactor has been ordered since 1978. Unless license renewal is permitted, existing nuclear plants must shut down when their licenses expire, but the term of these licenses is not necessarily related to the useful life of the facilities.

To sustain U.S. economic growth, electric utilities must be able to provide reliable and competitively priced electricity. Based on projections made during the formulation of this National Energy Strategy, a substantial amount of new generating capacity—from 190 gigawatts to more than 275 gigawatts, depending on the effects of the Strategy's conservation actions—must be added between 1991 and 2010 to serve the Nation's growing requirements for electricity. Approximately 85 percent of the additional capacity needs over this 20-year period will be for "base-load" capacity—the type of generating installation that can operate continuously to provide amounts of power that are always needed, year-round and around the clock. Primary sources for base-load capacity that are feasible today include coal, natural gas, oil, some renewables, and nuclear power.

How the Nation meets this requirement for future base-load capacity is a critical matter from the standpoints of environmental protection, economic health, and energy security. The market, rather than government, should determine which fuels and technologies can best supply it. Utility companies are unwilling at present to risk the potential escalation of capital costs associated with long construction delays. Further, issues relating to the disposal of high-level nuclear waste, which are as much institutional as technical, must be resolved.

Goals and Approaches

The National Energy Strategy includes four key goals for nuclear policy, summarized in the table on the next page. An overriding theme behind these goals is to remove undue regulatory and institutional barriers to the use of nuclear power for generating electricity in the United States. These include some barriers to constructing new nuclear powerplants, to extending the life of existing generating units, and to disposing of powerplant radioactive waste. Attaining these goals will require changes in law and in regulatory practices. It also will require funding of research and development that can lead to advanced reactors that are safer, more economical, and easier to license.

Public concern about the safety of nuclear power was heightened in the aftermath of the accidents at Three Mile Island and Chernobyl. While U.S. powerplants have a demonstrated record of safety, research and development by the Federal Government and industry can play a key role in increasing safety margins even more through advanced nuclear powerplant designs.

Improving the life-cycle economics of nuclear power requires a coordinated approach on several fronts. Stepped-up regulation and other factors

Goals and Approaches—Nuclear Power

Goal	Approach
Maintain exacting safety and design standards	• Accelerate introduction of advanced design nuclear powerplants
Reduce economic risk	• Accelerate introduction of standard powerplant designs
Reduce regulatory risk	• Reform the NRC licensing process
Establish an effective high-level nuclear waste program	• Site and license a permanent waste repository and a monitored retrievable storage facility

contributed to long construction delays affecting all nuclear plants completed after the Three Mile Island accident and resulted in substantially higher construction and financing costs. This has helped to push the cost of nuclear power slightly above that of coal-fired power, the primary alternative for base-load generation of electricity. However, the cost of U.S. plants completed in the last several years is not representative of what could be achieved in the United States with successful reform of plant licensing procedures and successful implementation of Government-industry initiatives to modernize and standardize plant designs.

Reform of the U.S. Nuclear Regulatory Commission (NRC) licensing process is an important step in revitalizing nuclear power. It will reduce the lead time and financial risk associated with building nuclear powerplants. The uncertainty of the outcome in the licensing process for nuclear powerplants and the potential for long delays, particularly in the postconstruction hearing process, create large risks for utility investors and utility customers. Utilities, the financial community, State regulators, and consumer advocates have been reluctant to invest in nuclear powerplants because they have little confidence that the regulatory process will permit any given plant to be built on schedule and operated without undue added delay. To compound these problems, uncertainty about the NRC's limited ability to change procedures under current law suggests the need for statutory reform.

For nuclear power to remain a major energy contributor, it is imperative that the United States maintain an effective nuclear waste management program. There is broad public consensus on the need to solve the nuclear waste problem and strong scientific agreement on the technical approach to be used in solving it. Nevertheless, any action that pertains to siting high-level waste encounters public and local political opposition. The approach to achieving this goal is to coordinate a vigorous effort to implement the waste disposal program as currently legislated and at the same time to seek legislative remedies that can overcome barriers to siting and developing a licensed permanent geologic waste repository and a licensed monitored retrievable storage facility under this program.

Expected Results

The National Energy Strategy actions are designed to ensure that the nuclear power option is available to utilities. A calculation of the combined benefits envisioned from achieving commercial standardization, simplified and modular design, improved construction management, and licensing reform indicates that the cost of using nuclear fission to generate electricity could be reduced from the current average of 9.9 cents per kilowatthour for powerplants brought into service since 1980 to 6.6 cents per kilowatthour—comparable to other sources.

If these cost reductions are realized, National Energy Strategy projections show that nuclear power can provide utilities an economically competitive source of base-load generation. As shown in Figure 30, a projected 195 gigawatts (and as much as 290 gigawatts) of nuclear capacity could be on line by 2030 if the Nation can overcome the barriers to investing in new nuclear powerplants, extending the lifetime of existing plants, and disposing of nuclear waste.

Figure 31 illustrates two roles that nuclear power could play in meeting the need for future generating capacity. Reducing uncertainties and promoting stability in the licensing process can lead to more predictable construction times and costs. These changes can alter investor perceptions of the financial risks associated with a billion-dollar nuclear plant construction project. With these actions, nuclear power could flourish, as indicated by the upper line in Figure 31. (For clarity, the range of uncertainty about this trend line is not shown.) Without these actions, nuclear power would all but disappear by 2030, as shown by the lower line in Figure 31. This will force the Nation to rely on less environmentally sound or potentially more costly alternatives. This would happen because of continued regulatory and licensing uncertainties, financial risk, and public opposition.

National Energy Strategy actions will result in nuclear power production being about 0.5 quad higher in 2010 than it otherwise would be; and by 2030, it is projected to be about 12 quads higher than it otherwise would be.

Safer, Standardized Designs

A 1990 national public opinion poll showed that 78 percent of the U.S. public thought that nuclear power should play a very important or somewhat important role in future national energy strategy. However, there is concern about the possibility of a nuclear accident. Even though the overall safety record of the nuclear power industry has been very good, past incidents have caused some to question the competence of those who operate nuclear facilities, be they electric utilities or the Federal Government.

The electric utility industry has a major role to play in reducing public concerns about the safety of nuclear power by operating existing nuclear powerplants in a safe and reliable manner. For its part, the Administration will continue to support funding to develop both evolutionary and advanced reactor designs that are even safer than current technologies.

Figure 30. Projected Nuclear Component of U.S. Electric Generating Capacity Under the Strategy

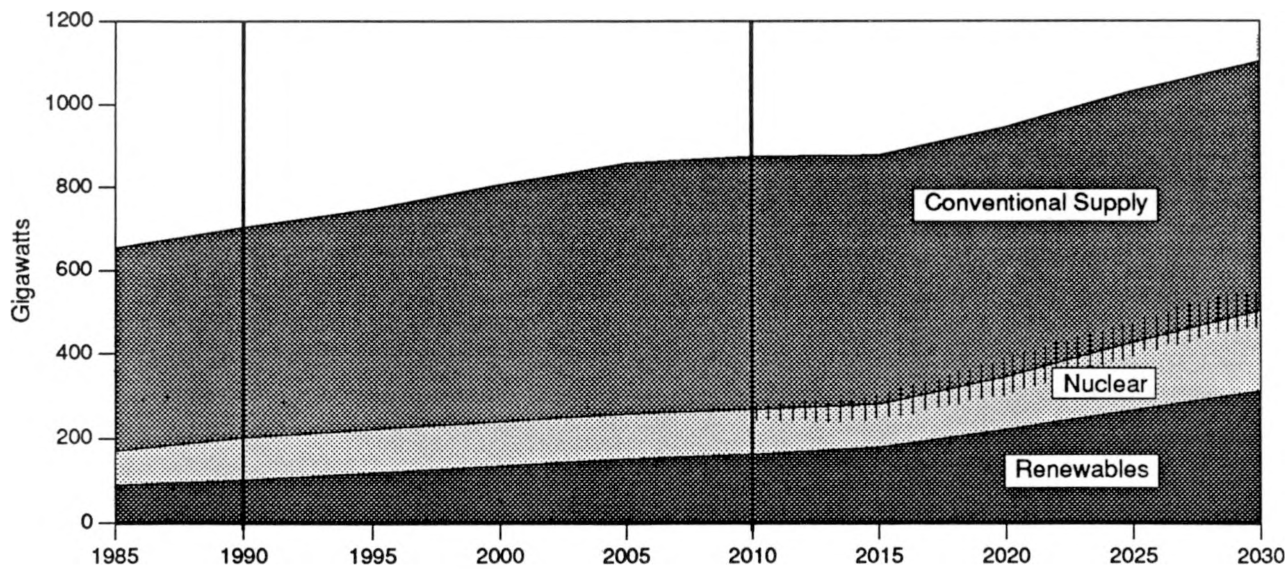
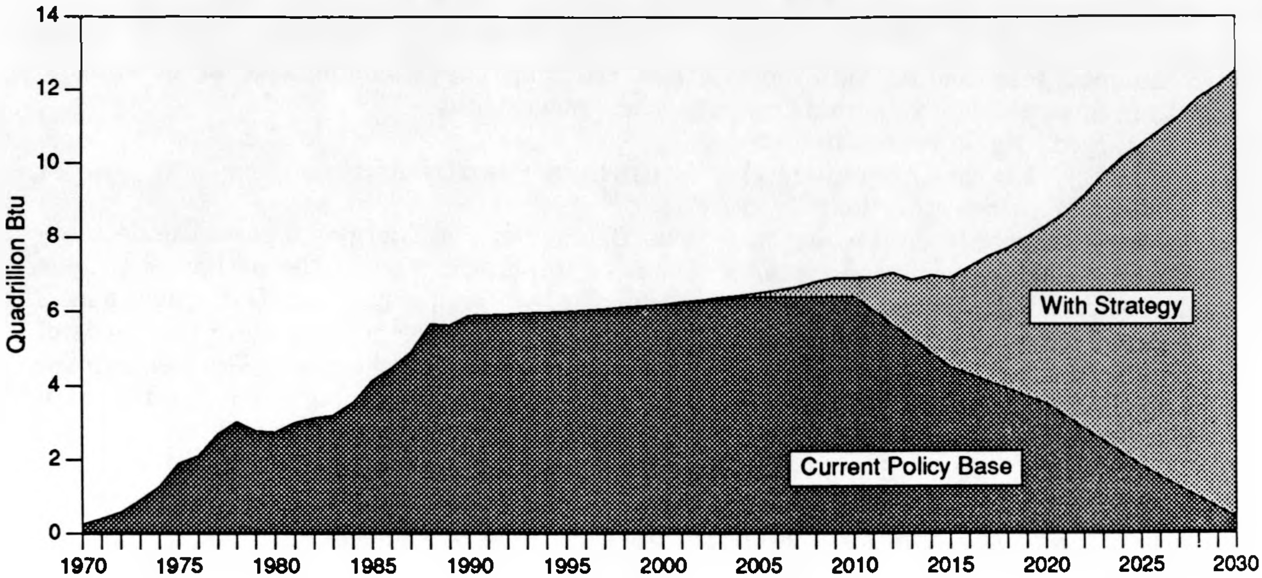


Figure 31. National Energy Strategy Actions Result in Extended Production of Nuclear Power



Advanced Light-Water Reactors

Most of the nuclear powerplants operating in the United States today use ordinary water (so-called "light water") to remove heat from the reactor. Designs for advanced light-water reactors (ALWR's), which will benefit from the lessons learned in operating today's nuclear powerplants, are currently under development. ALWR designs will be simpler, and they will improve safety with better engineered safety systems and advanced control systems. Besides reducing further the possibility of accidents, these features will simplify nuclear powerplant operations and maintenance.

Even more advanced reactor designs are on the drawing board. These designs feature passive safety systems, which will minimize the need for an operator to intervene in the event of an accident or breakdown. Passive safety systems will use certain physical properties of materials, along with gravity, to remove heat automatically in an emergency, thus cooling the reactor and maintaining its temperature at safe levels. This will reduce the likelihood of operator error and further ensure a sound emergency response. Should the reactor temperatures approach safe operating limits, passive safety features would shut the reactor down to prevent damage; reliance on external power supplies or operator action would be minimized. Passive safety designs will eliminate many "active" safety components, reduce the total number of components and systems, and generally reduce the size of the powerplant. This will lead to simplified engineering designs, lower construction costs, and improved powerplant operations and maintenance.

In cooperation with reactor manufacturers, the Department of Energy is supporting the development of two evolutionary ALWR designs and two ALWR designs that include passive safety features. The Department intends to work with the NRC to demonstrate that these designs can be certified. The certified designs are targeted to be available to meet the needs of the Nation's power producers by 1995, with the objective of having a first new plant operational by the year 2000.

Other Advanced Technologies

The Department of Energy will continue to fund research and development on more advanced nuclear systems that show promise of possible breakthroughs in economics, safety, licensing, and waste management. Continuation of the research and development for two advanced reactors (the advanced liquid-metal reactor and the modular high-temperature gas reactor) can lead to a demonstration of the commercial potential of these reactors by 2010.

The advanced liquid-metal reactor (ALMR) is a sodium-cooled reactor that may provide favorable safety and environmental features. Its high temperature results in greater efficiency, so that less waste heat is discharged. Its low pressure enhances operating safety. Further, liquid-metal reactors can be designed to consume long-lived radioactive elements (such as plutonium, neptunium, and americium) that are produced in current commercial reactors. Potentially, then, this type of reactor could make a contribution to reducing the future burden of radioactive waste. In 1991, the National Academy of Sciences will evaluate the technical and economic feasibility of ALMR technology. By 1995, this National Academy of Sciences study, studies sponsored by the Department of Energy, and continuing research and development will provide a sound technical basis for evaluating ALMR technology's possible contribution to the long-term radioactive waste management system.

The modular high-temperature gas reactor is another advanced technology that is capable of high-temperature operation, making it, too, highly efficient. This reactor uses helium gas as a coolant. Helium, an inert gas, does not react with other materials in the reactor and does not become radioactive in the reactor core. The reactor structure is composed of graphite, a material with certain inherent safety features. Other attractive features include direct use of the hot helium gas to drive a turbine with very high system efficiency, a feature that increases the economic attractiveness of this design. Potentially, this type of reactor could have cogeneration and direct process heat applications.

Reduced Economic Risk

The economic competitiveness of nuclear power, as compared with other ways of generating electricity, depends on the cost and financial risk of investing in nuclear powerplants. Cost and risk can be lowered through improvements in the technology and reductions in fuel cost.

Under the National Energy Strategy, the Administration will continue to fund research and development intended to accelerate the introduction of standard designs for nuclear powerplants. The capital costs associated with standard plant designs will be lower than those of current plants, thus reducing the economic risk of building a nuclear powerplant.

Standard Plant Designs

The Department of Energy supports the development of standardization in the design of nuclear powerplants. Previously, most U.S. powerplants have been custom-designed to meet the needs of the utility purchasing the plant. The Department is cofunding activities leading to NRC certification of four standard designs, and it intends to cofund the first-of-a-kind engineering needed to produce standard commercial designs for selected advanced light-water reactor systems.

Certification of standard designs is an important step in lowering the cost of nuclear powerplants. Use of standard designs will result in faster procurement after a plant is ordered. There will be greater certainty as to the quality of equipment and materials delivered to the construction site. Furthermore, simplified modular design will permit greater use of prefabrication techniques that will require less field labor and reduce the complexity of construction management. These factors all contribute to lower costs.

If the proposed institutional and technical solutions are implemented successfully, constructing a nuclear powerplant would likely become a shorter and more predictable process with dramatically reduced uncertainties and risks. In addition, utilities would be able to establish a more realistic cost estimate for each plant at the start of the project. In short, certified standard designs for nuclear powerplants can build confidence about the cost and safety of nuclear power among utilities, regulators, and the public.

Midsize Plant Designs

The Department of Energy is supporting the design of midsize nuclear powerplants, as well as large ones. Certification of midsize (600-megawatt) nuclear powerplant designs will reduce economic risk, because smaller powerplants require a lesser financial commitment and may better match incremental supply with growth in demand. Regulators have the authority to disallow full-cost recovery for new investment if a utility has excess electricity-generating capacity. The overly optimistic sales forecasts of the 1970's caused many utilities to build powerplants that were at least partially unneeded upon their completion. As a result, some utilities failed to recover their full investment in electricity-generating plants during the 1980's. This makes some utilities reluctant today to build a single large plant. Smaller plants, phased in over time, allow the utility more flexibility in responding to changes in the demand for electricity. To compete in this environment, the nuclear power industry must provide economical powerplants of the size the market requires.

Uranium Enrichment

An economical supply of nuclear fuels must be assured. This can best be achieved by converting the U.S. uranium enrichment enterprise into a more competitive business entity. The Administration supports legislation creating a temporary Government enrichment corporation as an interim step to the ultimate goal of privatizing this enterprise.

The Administration also supports a research, development, and demonstration program on the Uranium-Atomic Vapor Laser Isotope Separation process. The principal objective of this program is to develop an advanced technology that can enrich uranium at a cost significantly below that of the current technology. This would also help the domestic industry compete in the international market.

Reduced Regulatory Risk

All U.S. nuclear powerplants have been licensed in a licensing process in which several important decisions were made only after construction was complete. Such a licensing process creates great financial risk and uncertainty for utilities wishing to build nuclear powerplants. After billions of dollars have been invested in construction, an operating license can be denied. Further, the unnecessarily high cost of the nuclear licensing and regulatory processes places nuclear power at a relative economic disadvantage in comparison to other base-load technologies. Without compromising steadfast adherence to public safety, decisions relating to approval of the site, the ability to evacuate the area in case of an emergency, and the safety of the plant design could be made before construction begins.

The NRC has acted to significantly improve the licensing process. In 1989, it approved a new rule (10 CFR 52) governing the licensing of new nuclear powerplants. Part of the rule sets a new standard for determining the subject of a postconstruction hearing. However, it did not completely eliminate the possibility of a long adjudicatory hearing and possible procedural delays after the plant is completed and ready for operation. Further, in November 1990, the United States Court of Appeals for the District of Columbia vacated the provisions of 10 CFR 52 that relate to the postconstruction hearing, observing that "such reforms lie not with the NRC, but with Congress." This court decision, though on appeal, emphasizes the need for a clear statutory basis for a fully reformed licensing process for new nuclear powerplants.

No statutory change in the regulatory process is required to extend the operating lives of existing nuclear generating units. The Department of Energy will continue its current efforts to encourage accomplishment of this goal through appropriate regulatory measures.

Another concern is the potential for dual regulation of radioactive materials released by nuclear powerplants. Some State governments have asserted that they have authority under the Clean Air Act Amendments of 1990 to promulgate their own radionuclide standards. The issue of the States' rights to set standards was not resolved in the bill, and nothing in the Amendment's provisions restricts or denies the right of States to establish stricter standards.

NRC Licensing Procedures

The Administration is preparing legislation containing provisions of the 1989 NRC rule addressing emergency planning procedures *before* construction, thus avoiding the procedural delays allowed in the current postconstruction hearing process. Such legislation would provide a clear statement of public policy on nuclear plant licensing. It would encourage public participation in and final resolution of safety issues before construction begins. Under the reformed process, all design work essential to safety evaluation, siting, and emergency planning decisions would have to be completed before construction.

In the past, public input was provided at the construction permit stage, when the design was not completely defined. The first time the public had an opportunity to comment on a design that was sufficiently complete to allow all safety questions to be answered with finality was *after* construction. With licensing reform, the public will have an opportunity to participate in design certification proceedings, as well as in the adjudicatory hearings required in connection with site selection and the approval of a combined construction and operating license.

The Department of Energy also is sharing costs with industry in a demonstration of the early site permit process. Under the new NRC regulation, 10 CFR 52, powerplant sites can be approved well before construction begins or any significant financial investment is made. Completion of this program by 1995, together with the program to demonstrate the certification of two evolutionary and two advanced midsize light-water reactor designs, will be a major step toward providing investor confidence that the United States has a rational and predictable process for licensing nuclear generating units. Utilities will be able to build powerplants with pre-approved designs at pre-approved sites.

These improvements in licensing processes will reduce the risk and uncertainty associated with investing in nuclear powerplants. They also will reduce the capital costs of new nuclear powerplants, thereby improving the competitiveness of nuclear power in relation to other base-load technologies.

License Renewal for Existing Plants

The Department of Energy is cooperating with industry and the NRC in developing the information needed to establish the regulatory process by which the licenses of safe nuclear powerplants can be renewed. Between the years 2000 and 2010, more than 30 nuclear powerplant licenses will expire. Studies indicate that the cost of safely extending the operating life of an existing plant can be much lower than the cost of a new plant. The Department is demonstrating the process through its plant life extension program, and is helping to prepare a plant license renewal application for two older nuclear generating units and submit it to the NRC for approval. Extending the licenses of existing nuclear powerplants—in a safe and economical manner—can replace the need for about 66 gigawatts of new capacity by 2030.

Dual Regulation of Radionuclides

The Administration supports legislation that would make State radionuclide standards that are more stringent than Federal standards contingent upon a showing that additional regulations are necessary to provide for the public health and safety. The legislation would prevent States from adopting standards that discriminate among radiation sources and types.

Managing High-Level Nuclear Waste

The nuclear power industry has safely stored and managed spent (that is, used) nuclear fuel since the outset of commercial nuclear power. It continues to do that. However, several utilities are rapidly reaching storage capacity limits at their reactor sites. Solving the problem of permanent disposal of nuclear waste to eliminate potential long-term risks to public health and safety and the environment is needed to increase public and utility confidence in the nuclear option. Progress in the management and disposal of nuclear waste remains an important element in removing an institutional barrier to the further development of nuclear power.

Years of effort by interested and concerned citizens led to the passage, in 1982, of Federal legislation for the management of high-level nuclear waste. The Nuclear Waste Policy Act of 1982, as amended, directs, among other things, the Department of Energy to site, design, construct, and operate the Nation's first geologic repository for the permanent isolation of spent nuclear fuel and high-level radioactive waste. The waste management program now being implemented by the Department includes the following objectives:

- Placement of commercial spent fuel in a permanent repository, licensed by the NRC and beginning in 2010, should the current candidate site be found suitable. Placement of defense-generated, solidified, high-level waste in a geologic repository is scheduled to begin in 2015 in the same repository.
- Identification by the Nuclear Waste Negotiator, a position created by the Nuclear Waste Policy Amendments Act of 1987, of a State or tribe willing to host a monitored retrievable storage (MRS) facility or a repository at a qualified site. The MRS facility is an integral part of the waste management system and, after NRC licensing, should begin to receive spent fuel from utilities at a licensed facility beginning in 1998.

The major components of the plan—an MRS facility and operation of a high-level waste repository—are needed under all energy scenarios for the future, whether or not new nuclear plants are ordered. A negotiated agreement with a volunteer host State or tribe for an MRS site could be presented to Congress by 1992 for review and approval. Site selection for the MRS facility would demonstrate progress in solving the waste management problem and could be a basis for the start of new nuclear powerplant orders.

The future need for long-term waste disposal is driven by the current and projected buildup of spent fuel now stored at reactor sites around the country. The buildup will occur with or without new nuclear plant orders. Even in a scenario with no new nuclear orders, with only 6 gigawatts of nuclear capacity left in 2030, the total spent fuel accumulated by 2030 would be substantial.

This spent fuel is to be disposed of in a repository. The Department is legally required to assess the need and timing for a second repository within the 2007 to 2010 timeframe, and decisions about a second repository will await that assessment. After 1988, operation of an MRS facility would begin to relieve the burden of additional spent fuel buildup at onsite storage facilities at plants, assuming that the current linkages between the MRS facility and the repository are modified.

Administrative Actions

At the direction of the President, the Secretary of Energy will chair an interagency coordinating committee to:

- Ensure that all Federal agencies carry out their activities consistent with the initial operation of an MRS facility to accept spent fuel by 1998.
- Allow the timely characterization of the candidate repository site at Yucca Mountain, Nevada.
- Achieve the licensing and operation of a repository at a suitable site as expeditiously as possible (and by 2010, should Yucca Mountain be suitable).
- Develop options to ensure the availability of a transportation system consistent with the above objectives.

The Department of Energy also will undertake to:

- Intensify efforts to provide meaningful participation by affected parties.
- Develop contingency plans that could lead to development of the MRS facility and geologic repository if siting efforts undertaken by the Nuclear Waste Negotiator or the Department should prove to be unsuccessful.
- Evaluate the desirability, timing, and conditions of providing Federal interim storage for utilities that may require such service.

The Department of Energy also will develop processes that ensure focused, productive dialogs with all interested parties, and it will strive to see that all program managers are aware of and responsive to issues that concern the public. For example, upon gaining access to the Yucca Mountain site, the Department will establish and pursue a prioritized site-evaluation program, reviewed by independent experts, that assures the early investigation of site features that could potentially disqualify the site. It is critical to determine, as soon as possible, whether Yucca Mountain is suitable as a site for a geologic repository.

The Nuclear Waste Negotiator will present the opportunity to host a repository or an MRS facility to State or tribal officials and discuss openly with them the conditions under which they may volunteer to host a nuclear waste facility. With the full support of Federal agencies, the Negotiator will conduct activities with all due speed, identifying potential facility hosts and reaching proposed agreements. The Negotiator also will develop a model framework to facilitate both intergovernmental relationships and continuing input from the general public.

The Department of Energy will evaluate the suitability of alternate ways to carry out the high-level nuclear waste management program. An independent, federally chartered corporation or another distinct management structure may provide the following features:

- The ability to go outside the Federal personnel system to recruit staff with the skills and expertise necessary to design and implement programs that are both technically complex and institutionally sensitive.

- Insulation from year-to-year budgetary pressures.

- Flexibility to ensure early and frequent involvement of those who hold a stake in safe management of high-level nuclear waste.

- The ability to implement a program that extends over decades.

Legislative Actions

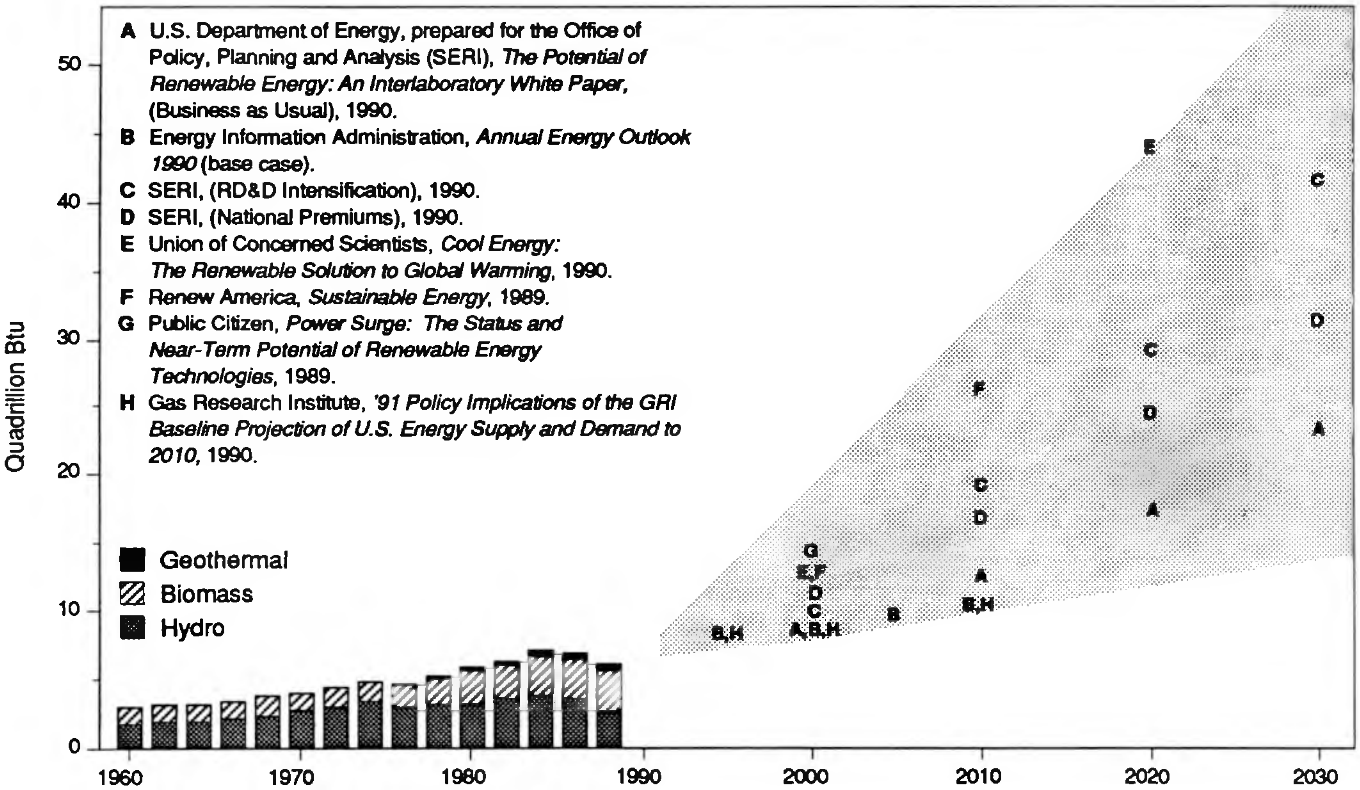
Congress will be requested to enact legislation to ensure that, while preserving regulatory requirements to protect the public's health and safety and the environment, the Nation's need for facilities to isolate high-level waste permanently is met in a timely and participatory manner.

Proposed legislation must address the two conditions that are critical to the successful implementation of the Federal nuclear waste disposal program. One is the timely determination of the suitability of the Yucca Mountain candidate repository site. Should the site prove to be suitable, a facility for permanent waste disposal could open by 2010. The second condition is the siting and operation of the MRS facility, which is needed to begin Federal acceptance of spent nuclear fuel by 1998. Progress on the siting and licensing of the MRS facility should be independent of the schedule for siting and licensing the repository.

Renewable Energy

Renewable energy technologies use resources that generally are not depleted, such as heat and light from the Sun, the force of winds, falling water, plant matter, and geothermal heat from inside the Earth. These very large stores of natural energy can be converted in various ways into usable energy. The technologies available for conversion are at various stages of development: some are relatively mature (such as hydropower, the use of dry steam from geothermal wells, and the simple burning of biomass and waste); others are emerging but already well developed (including wind turbines; the concentration of solar heat; photovoltaics, which convert the Sun's rays directly into electricity; the use of hot water from geothermal wells; and the conversion of biomass into gaseous or liquid fuels); and still others are advanced concepts in the research phase. The applications of renewable technologies are varied and include direct solar heating, daylighting, geothermal heating and cooling, biomass fuels production, and a substantial amount of electricity generation.

Figure 32. Projections of U.S. Renewable Energy Use



Notes: Historical use of other renewable resources is too small to be represented here.
Differences in projections are caused, in part, by varying assumptions concerning energy prices, economic growth, consumer and producer behavior, and rates of technological change, including replacement of capital stock. The shaded area represents an envelope bracketing these differences.

Goals and Approaches—Renewable Energy

Goal	Approach
Encourage environmentally acceptable hydroelectric power	• Eliminate excessive regulatory barriers that add costs and risks to hydropower development • Require a continuing review of existing hydropower projects to improve operation and maintenance and identify improvements in efficiency that can be made economically • Conduct research on environmental studies and mitigation
Reduce the costs of, and increase industry confidence in, selecting solar, wind, biomass, and geothermal technologies to generate electric power	• Increase funding for research and development (R&D) related to renewable energy • Extend the 10-percent investment tax credit for solar and geothermal and expand it to wind and certain biomass technologies • Eliminate regulatory barriers to the development of renewable resources for electricity generation
Support the conversion of municipal solid waste to energy	• Increase R&D on waste-to-energy systems as part of a comprehensive waste management program • Provide better information on waste-to-energy systems
Develop economical liquid fuels from biomass as alternatives to petroleum-based fuels	• Increase R&D on new biomass feedstocks and conversion technologies • Renew the ethanol tax credit
Use renewable energy for direct heating, cooling, and lighting in buildings	• Increase R&D on innovative building materials and designs

The use of renewable resources in this country has been growing since 1970, and it will continue to grow. Figure 32 shows historical U.S. use of renewable energy resources—almost exclusively hydropower, biomass, and geothermal. It also shows several projections by various groups, using a variety of assumptions, of how the level of U.S. renewable energy use could change over the next 40 years.

In 1990, renewable energy resources supplied approximately 8 percent of the Nation's energy needs, compared to 6 percent in 1970. Whereas in 1970 essentially all renewable energy came from hydroelectric power and wood burning, the 6.8 quads provided by renewable energy in 1990 included increasing contributions from geothermal powerplants, municipal waste-to-energy powerplants, wind farms, solar energy systems, and alcohol fuels plants.

The renewable energy industry has made significant technical progress in the last 10 years. The efficiency of single-crystal silicon photovoltaic cells has increased by more than 50 percent, to 23 percent, while costs have declined by a factor of 2 or more. The cost of wind turbines has decreased from the range of $2,500 to $3,000 per kilowatt (kW) in 1980 to about $1,100 per kW today, while system availabilities have increased from 80 percent to more than 95 percent during the same period. By comparison, a typical range of current costs for conventional power generators is from $600 to $1,500 per kW. Other renewable electric technologies have made similar advances. Further cost reductions and performance improvements require no scientific breakthroughs, but rather a succession of research, engineering, and manufacturing improvements that are well within reach of U.S. industry.

The use of renewable energy resources generally benefits the environment. Renewable energy technologies contribute little or nothing to air pollution or to the potential for global climate change. Using renewables also reduces demand for fossil fuels and the consequences of their use. Burning municipal waste to generate electricity reduces the need for, and the problems associated with, landfill space.

Adding cost-effective renewable technologies to the menu of available energy choices can contribute to a strong, growing economy—domestically, by spurring competition and innovation within U.S. markets; and in the balance of trade, by displacing imported energy and by providing new products and technologies for export.

The price of energy from renewable technologies is dropping. As environmental and regulatory barriers to the more mature renewable technologies are removed, and as emerging renewable technologies *become* mature, renewables should penetrate the Nation's energy markets more broadly. The National Energy Strategy recognizes that the respective costs of energy from conventional and renewable resources are converging. By hastening that convergence and thus encouraging competition, the actions identified in this section can speed up benefits to the Nation from the energy resources that consumers deem best in combining environmental soundness, economy, and domestic availability. Using the market to promote growth in the use of renewable energy resources will avoid the unrealistic expectations and consequent setbacks of some earlier renewables programs.

Investment in renewable power systems is currently hampered in several ways. First of all, there is a much larger experience base for fossil-fueled power systems than for renewable power systems, so investors view renewables as having less of a "track record." Energy planners are reluctant to use new technologies when reliability, operating lifetimes, maintenance requirements, and availability are not well known. Closely associated with this is the large existing infrastructure for building and operating more conventional power technologies. The infrastructure for renewables is only beginning to develop. Finally, some renewable energy facilities may be comparable to other energy sources in long-term cost, but involve large capital outlays. Although these outlays are offset over time by low or no fuel costs, financial markets prefer the lower risks associated with low-capital-cost facilities.

Some mature renewable energy technologies are constrained by excessive regulatory requirements and environmental concerns. Hydropower projects are subjected to overlapping and sometimes contradicting regulatory requirements. Obtaining all regulatory approvals for non-Federal hydropower projects may take 5 to 10 years or more. Benefits provided to renewables under the Public Utility Regulatory Policies Act (PURPA) are limited to projects with a generating capacity of 80 megawatts (MW) or less for renewable technologies. Environmental concerns include water-use impacts for hydropower and toxic atmospheric emissions from burning waste.

Hydroelectricity has been the mainstay of U.S. renewable energy, but many hydropower facilities are getting old; some of these continue to operate with outdated, inefficient equipment. Many Federal projects are not being maintained optimally either, which leads to further inefficiencies. In many cases, improved operations, better maintenance, and new equipment are economically feasible. For Federal hydropower projects, many steps to improve efficiency are not being taken because of a lack of coordination between those entities responsible for operating them and those that market the power they produce. As for *non*-Federal hydropower projects, the Federal Energy Regulatory Commission (FERC)—which issues 50-year licenses for them—has had no mandate to encourage efficiency improvements until a particular project is due for relicensing.

Goals and Approaches

The National Energy Strategy goals that apply specifically to renewable energy, and the approaches being taken to achieve those goals, are summarized in the table on page 119.

The Strategy calls for greater cooperation among Federal and State agencies that construct, operate, and regulate hydropower projects to remove excessive regulatory requirements. Permanently removing the 80-MW size limit for all renewable energy technologies under PURPA and allowing facilities that benefit from this act to use as little as 50 percent renewable energy will permit development of larger and more efficient electricity generating facilities that use renewable energy. Efforts to improve cooperation and remove regulatory barriers will allow hydropower and other renewable technologies to compete fairly.

The Strategy calls for a continuing increase in research and development (R&D) to reduce costs and improve the performance and efficiency of emerging technologies. Where appropriate, the Government will seek to pursue R&D in partnership with industry. The Strategy will also identify appropriate methods for reducing and mitigating the environmental impacts of mature technologies. The environmental concerns of burning municipal solid waste (MSW) will also be addressed by a research and information program. Reducing costs and environmental uncertainties will improve the energy market by providing a greater variety of fuel choices.

Because economical improvements are not being made at existing hydropower projects, the Strategy calls for improving coordination among the Federal agencies responsible for Federal projects and for establishing a program at FERC to encourage efficiency improvements *before* project relicensing, which will permit the development of economical electricity-generating capacity.

Expected Results

Figure 33 shows projected renewable energy production for both the Current Policy Base case and the Strategy's entire package of actions, including the National Energy Strategy actions in this section. The Strategy's actions are projected to increase renewable energy production to about 11.8 quads in 2010, which is 16 percent higher than it would be without these actions; and during the following two decades, the Strategy is projected to increase renewable energy production to about 30 percent higher than it would be without the Strategy's actions. The total impact of all Strategy actions will be a greater diversification of fuel choices, reduced costs for emerging renewable energy technologies, greater incentives for investing in certain electric-generating renewable technologies, and increased generating capacity and energy efficiency at existing projects.

Hydroelectric Power

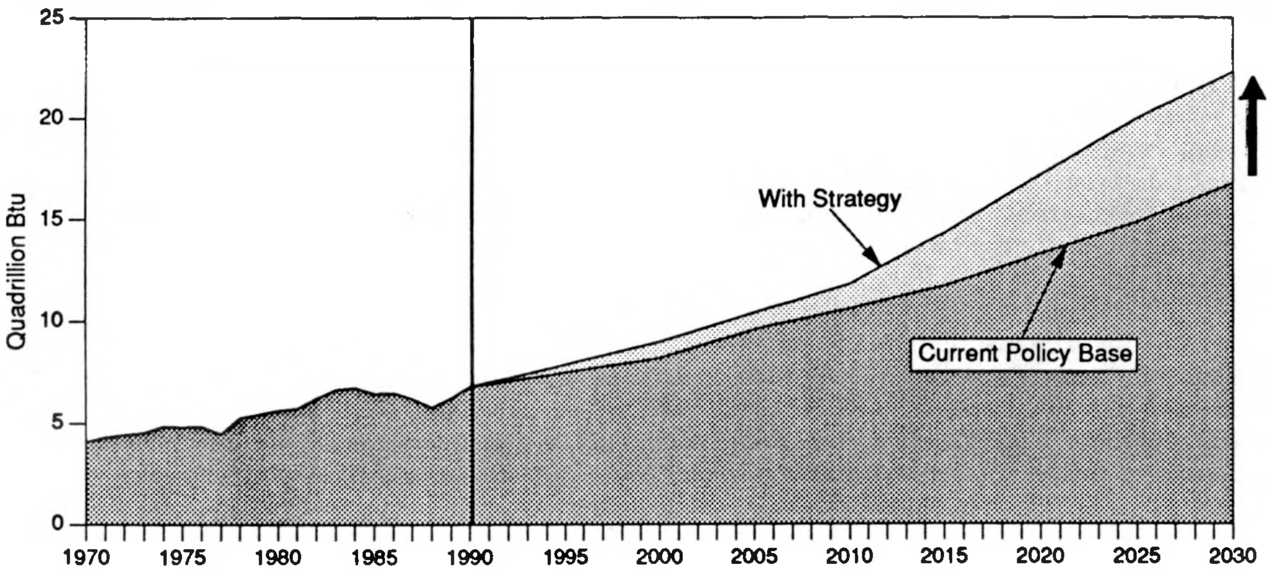
In 1990, conventional hydropower provided an estimated 74 gigawatts (GW) of electric-generation capacity. In addition, pumped-storage hydropower provided about 17 GW (pumped storage involves pumping water to a higher elevation, where it can be released to spin turbines during periods of peak demand). This capacity was projected to generate about 260,000 gigawatthours (GWh) of electricity in 1990—representing a displacement of almost 3.2 quads of primary fuel consumption, or 9.2 percent of total U.S. utility industry electric generation.

The National Energy Strategy actions to improve the hydro regulatory environment and encourage efficiency improvements are expected to increase hydroelectric capacity by about 16 GW by the year 2030. In addition, improvements to the regulatory environment and R&D advances in mitigation strategies will also help retain the 22 GW of capacity due for Federal relicensing by 2010.

Hydropower Projects

Most Federal hydropower projects are constructed and operated by either the U.S. Army Corps of Engineers or the Department of the Interior's Bureau of Reclamation. Electric power from Federal hydropower projects is marketed by the Federal power marketing administrations (Bonne-ville, Southwestern, Southeastern, Western Area, and Alaska). Most non-Federal hydropower projects are regulated and licensed by the Federal Energy Regulatory Commission. This section addresses both Federal and non-Federal hydropower projects.

Figure 33. National Energy Strategy Actions Are Expected To Increase Production of Energy From Renewable Resources



Conflicting and overlapping regulatory and environmental regulations prevent hydropower from competing effectively as an electricity resource. As a result of recent new legislation, court decisions, and FERC regulations, the licensing process for non-Federal hydropower projects has become complex and decentralized. Although FERC remains the primary regulator of non-Federal hydropower projects, many other Federal and State agencies can mandate license conditions or issue separate permits that may encumber or even void FERC licensing decisions. These agencies conduct multiple environmental reviews. There are overlapping regulatory processes, conflicting license and permitting requirements, and disagreements over environmental study and mitigation requirements.

When reviewing license applications, FERC must balance power and nonpower uses of the waterway used by the hydropower project. The presence of many other agencies that set license conditions or issue separate permits unduly constrains FERC. FERC itself contributes to licensing delays by not routinely identifying the studies necessary to evaluate a project until after the application is filed.

The result of these inefficiencies is a lengthy and expensive regulatory process that takes 5 to 10 years or more to complete. Even small projects, which generally have less significant impacts, are subject to virtually the same level of review and delay as large projects. Prospective hydropower developers are discouraged by the costs and the length of time necessary to acquire regulatory approvals, and by the risks of lost investments if any of the many required permits are denied. Of those who initiate the regulatory process, fewer than 5 percent are able to complete regulatory review successfully and build a hydropower project.

The National Energy Strategy proposes to streamline this regulatory process to increase hydroelectric capacity and generation when it is economically feasible and when its environmental effects are limited.

The funding process for operation and maintenance and equipment and efficiency improvements at existing Federal hydropower projects is overly complex and inefficient. These funds currently are collected by the Federal power marketing administrations and deposited into the Federal Treasury.

The Corps of Engineers and the Bureau of Reclamation must then ask Congress to appropriate these funds. These requests must then compete with other agency budget requests. Additionally, once appropriated, these funds may be diverted to nonhydropower activities.

During the next 20 years, 22 GW of existing hydro capacity will be subject to FERC relicensing. Because FERC does not encourage improvements or additions to facilities prior to relicensing, many economical improvements and capacity additions to existing projects are delayed until that time.

For non-Federal hydropower projects, the Strategy calls for FERC to ask all licensees of older hydropower projects to evaluate their potential for efficiency improvements. For Federal hydropower projects, the Strategy calls for greater cooperation among the power marketing administrations and the Federal operating agencies to identify and fund operation and maintenance activities and efficiency improvements.

Combined Regulatory Review

For non-Federal hydro projects, the Administration will submit legislation authorizing FERC to coordinate a single, comprehensive, combined State and Federal agency review of hydro projects. Interested agencies would participate with FERC in identifying needed studies before filing applications and in the preparation of comprehensive environmental, economic, and engineering analysis documents. FERC and other interested agencies would use this single, joint review process to make the licensing decision, set license conditions, and act on any other required approvals. The law would establish FERC as the sole decisionmaker for hydro projects at existing dams, including those requiring relicensing.

Reduced Regulation of Small Projects

The National Energy Strategy also calls for exempting from FERC regulation non-Federal hydropower projects with a capacity of 5 MW or less. This could be accomplished most efficiently through legislation. As an alternative, FERC could make greater use of its existing waiver and exemption authorities. This is appropriate because the issues raised by small hydropower projects are local and ought not to require a FERC decision; and small projects have little or no impact on navigation or interstate commerce, the motivation for FERC jurisdiction over many projects. The States—and Federal land management agencies when projects are located on Federal lands—would retain the authority to review small projects.

Efficiency Improvements

The Strategy calls for FERC to establish procedures to solicit and expeditiously approve applications from licensees of older, non-Federal projects to replace inefficient equipment and make efficiency improvements that increase electricity-generating capacity and energy output without changing water flows. Such project changes have little or no environmental impacts and should be routinely approved by FERC.

The Strategy envisions the power marketing administrations and the operating agencies for Federal hydropower projects as entering into a formal memorandum of understanding. This memorandum of understanding would establish a planning and budget process to identify opportunities for increased hydroelectric generation at existing projects and ensure that sufficient funds are requested for, and remain dedicated to, Federal hydroelectric operation and maintenance and efficiency improvements. The memorandums of understanding will also require that the power marketing administrations and the operating agencies jointly provide timely project operation and maintenance and that they identify and implement economical efficiency improvements. Coordination and planning among the power marketing administrations and the Federal operating agencies will allow resources to be allocated to the highest priority operation and maintenance and replacement of inefficient equipment.

Environmental Research

The Department of Energy will conduct research and analysis to address environmental issues associated with hydropower and to develop uniform evaluation criteria and procedures that can be used by FERC and other agencies to establish an authoritative technical basis for decisionmaking in the evaluation and approval of hydropower projects. The costs and effectiveness of various environmental mitigation requirements will be assessed. The Department of Energy will also develop guidelines for generic mitigation strategies, avoiding site-specific studies where possible to reduce processing time and costs.

Electric Power From Nonhydro Renewables

The contribution of nonhydro renewables to the Nation's electricity supply will continue to grow. Biomass and waste-to-energy plants currently provide about 6 GW of electricity-generating capacity. Present installed geothermal capacity is about 3 GW; the largest of these hydrothermal power sources, The Geysers dry steam field in northern California, has been steadily developed since 1960. Of the intermittent technologies (those using intermittent power sources, such as wind and sunlight), wind power is currently the largest contributor, with an installed power-generating base of about 1.5 GW, primarily in California. Currently, 354 MW (0.354 GW) of privately funded, grid-connected, parabolic-trough solar-thermal generating capacity is operating in southern California; and there are firm plans for another 300 MW to be built by 1994. Photovoltaic (PV) systems currently provide about 20 MW of electrical capacity in the United States. The U.S. PV industry, the world leader, had worldwide deliveries of 17 MW of PV systems in 1990, representing 35 percent of the world's total and a 25-percent increase from 1989.

However, photovoltaics, wind, solar thermal, and some biomass and geothermal technologies have not yet reached a level of performance and cost that permit their diverse, widespread use. Because these technologies are still developing, they are not yet cost competitive with conventional energy sources, except in certain markets.

To improve their cost effectiveness and reduce risks to developers and investors, the National Energy Strategy calls for increased R&D funding for renewable technologies, extension of the investment tax credit for renewables, and reforming the Public Utility Regulatory Policies Act. These technologies have established a base of operational experience in the last 10 years—suggesting that, if projected cost and performance improvements are realized as a result of these actions, they can penetrate markets in most regions of the country.

Research and Development

The Department of Energy will increase its R&D program for renewable energy technologies, in collaboration with industry, utilities, and States, to improve performance, lower costs, and address environmental concerns. The Department will also work with State and local governments, industry groups, and other stakeholders to identify performance requirements for renewable applications and to transfer cost and performance information to these groups to help with local renewable systems planning and development. In addition, as discussed under "Electricity Generation and Use," the Department of Energy and the Federal power marketing administrations will enhance their integrated resource planning programs. Using cost and performance information, these IRP programs will appropriately evaluate the benefits of renewable electricity generation. This process is expected to contribute to increased market acceptance of renewable technologies.

The Committee on Renewable Energy Commerce and Trade (CORECT) will accelerate development of the renewable energy infrastructure by supporting exports of renewable technologies. CORECT was established by the Department of Energy to help the U.S. renewable industry compete in the international marketplace.

Cost-shared collaborative ventures and industry consortia will reduce technical risks and help bring renewable technologies to the marketplace. These ventures will promote opportunities to demonstrate and evaluate emerging renewable technologies by identifying potential manufacturers and users for technologies with no established technical and economic operating records. Such ventures will validate cost projections, production estimates, and economies of scale and will help determine future research and development needs. In addition, collaborative ventures will open channels of communication and encourage customer-supplier interaction on design criteria, standards, specifications, and documentation. Specific R&D approaches to improving the cost and performance of renewables developed according to industry recommendations are as follows:

- **Geothermal.** A major problem for the geothermal industry is identifying, characterizing, and managing hydrothermal resources (resources that consist largely of hot water, rather than steam that can be released by drilling). R&D will emphasize improving technology for identifying and developing hydrothermal resources, including advanced drilling technology to reduce the cost of field development; reduced fluid-collection costs through modular energy conversion systems; and improved performance of geothermal heat pumps.

- **Photovoltaics.** Although photovoltaic systems are an established technology for a variety of remote applications, such as water pumping, communications systems, and off-grid residences, their costs are too high for basic utility electricity generation. The major technology issue is making photovoltaic systems more cost competitive through R&D on advanced cell materials and modules and through the development of advanced integrated manufacturing technology. Collaborative efforts will focus on integrating photovoltaic technology into the utility system.

- **Solar Thermal.** Existing parabolic trough technology is currently cost competitive in certain markets; expanding the market requires improved technology, higher efficiency, and lower cost. In addition to parabolic trough technology, other approaches, such as dish-Stirling and central receiver technologies, appear promising. R&D will focus on lower cost collectors, advanced receivers that convert solar energy into heat energy, advanced heat engines, and advanced materials and components for all technologies.

- **Wind Energy.** Cost reductions and performance improvements are needed before wind energy can expand beyond current markets. The major challenges to producing turbines that are cost-competitive in more parts of the country are to improve turbine designs so they last for 20 to 30 years, to develop advanced components such as airfoils, and to integrate these advances into cost-effective systems. The Department of Energy will continue both its Advanced Wind Turbine Program, to help U.S. industry develop systems for the mid-1990's and beyond, and its core research program on aerodynamics and structural dynamics for improved design tools. the Department of Energy will also help prospective users (both utilities and independent power producers) evaluate wind energy options.

- **Biomass.** The contribution from biomass technology can be significantly expanded through the development of advanced feedstock supply systems and conversion technologies. Consequently, research will pursue short-rotation, nonfood feedstock crops. Another research thrust will be to develop advanced biomass generating technologies that are significantly more efficient than existing technologies.

Reform of the Public Utility Regulatory Policies Act

The National Energy Strategy calls for modifying the Public Utility Regulatory Policies Act of 1978 to help develop larger powerplants that use renewable and waste energy resources. Expanded use of these resources would help developers to diversify their energy sources and to reduce adverse environmental impacts.

Until recently, PURPA required utilities to purchase power from electric-generating plants that use renewable energy resources and generate less than 80 MW of power. The law helped users of renewable resources but occasionally caused problems as well. Generating costs were higher for some operators because they were not allowed to build plants large enough to be fully efficient or to use fossil fuels for more than 25 percent of their total fuel. Recognizing these problems, Congress recently lifted the size cap temporarily for most renewable energy resource technologies.

Under the Strategy, the Administration will submit legislation that will remove the size cap permanently and will reduce the act's fuel-use restrictions to a 50–50 ratio for all renewable technologies. The new law will apply to generating plants that are selected under a State-approved competitive bidding procedure. Thus, companies that have developed competitive renewable energy technologies will have greater flexibility in supplying electricity markets.

Investment Tax Credits

The National Energy Strategy calls for extending business energy tax credits for solar and geothermal properties for 1 year beyond their current expiration date of December 31, 1991. Extension of these credits through 1992 will encourage investments in these emerging renewable energy facilities. Such investment credits, together with increased R&D, will enhance opportunities to build these facilities and evaluate their performance characteristics. As experience is gained in operating these facilities, performance records will be established that allow these renewable resources to become proven options in the electric power business.

Energy From Municipal Solid Waste

Combustible wastes can be burned to provide heat energy for industrial processes, electricity, and municipal district heating. An estimated 250 million tons of residential, commercial, institutional, and industrial wastes flow to municipal landfills each year. These wastes consist primarily of paper, paperboard, and yard wastes. Currently, there are about 160 waste-to-energy (WTE) plants converting about 11 percent of the Nation's waste to 0.3 quad of energy annually.

With the National Energy Strategy actions to encourage the conversion of municipal solid waste (MSW) to energy, WTE plants are expected to provide up to 2.1 quads of energy for electricity generation by the year 2010. Additional benefits include reduced landfill requirements and use of an economic, domestic energy resource.

Current use of WTE technologies is restricted by concerns regarding the toxicity of air emissions and ash byproducts. The effectiveness of controls to prevent or minimize air emissions is disputed, and the lack of good information in these areas has resulted in widely differing State requirements. A related difficulty is the high capital cost of a WTE facility, combined with the lack of attention to life-cycle economy and costs of disposal alternatives. Many see the fuel requirements of WTE facilities as competition for recycling programs—when in fact, WTE and recycling can be very compatible components of a comprehensive waste management program.

Research and Development on Waste-to-Energy

To accelerate the environmentally acceptable conversion of MSW to energy, the Federal Government will analyze a number of technical options, including methods for removing heavy metals and other contaminants from combustion products, ash disposal, improved combustion and gasification technologies, and biological techniques for combined treatment of MSW and municipal sewage. This collaborative research will address public concern about environmental impacts. The potential for MSW as an energy supply option for rural areas also will be evaluated. Federal installations that have unique conditions conducive to technology demonstration will be made available to industry where appropriate.

New technology, such as improved fluidized bed combustion technology for WTE and gasification of MSW, will be assessed as part of the National Energy Strategy. These could provide less capital-intensive, more efficient, environmentally acceptable systems.

Better Information on Waste-to-Energy

Waste-to-energy systems will be more widely used if institutional and environmental concerns are adequately addressed through information collection and dissemination: Potential users must have current, accurate information about these technologies. Toward this end, the Department of Energy will collect and disseminate economic, engineering, and environmental data in collaboration with the Environmental Protection Agency, States, local jurisdictions, industry, and public interest groups. The information will cover both MSW projects and related technologies such as recycling, landfilling, and displaced energy sources.

Liquid Fuels From Biomass

Liquid fuels from biomass (biofuels) contribute to energy security by providing an alternative to petroleum fuels. Additionally, technologies for the renewable, domestic production of these fuels can

Liquid Fuels From Biomass

Liquid (and alternative transportable) fuels from biomass include the following: (1) methanol fuels produced by gasifying biomass; (2) ethanol fuels derived from corn, grains, or other crops, or from wood and wood wastes or municipal wastes; (3) hydrogen fuels derived from biomass by gasification, from water by electrolysis (using electricity), from water-splitting bacteria, or by chemical-membrane reactions; (4) gasoline derived from biomass—including wood, agricultural crops, or biomass wastes—through the use of high-temperature refining technologies currently under development; and (5) diesel fuel produced from such biomass oil crops as vegetable oils and microalgae oils.

strengthen rural economies (where the feedstocks are generally grown). Biofuels potentially provide environmental benefits through reduced emissions of pollutants and greenhouse gases—both because these fuels generally burn more cleanly than petroleum-based fuels and because the plants grown as feedstocks for these fuels absorb carbon dioxide.

Currently, only ethanol fermented from corn is produced in commercial quantities; 850 million gallons of ethanol is produced annually for blending with gasoline. Although this represents only 0.8 percent of the gasoline market, when blended with gasoline in concentrations of 10 percent, the resulting "gasohol" makes up 8 percent of the gasoline consumed in the United States.

To develop biofuels that are cost competitive without the need for subsidies, the Administration supports accelerating R&D on new feedstocks and conversion technologies. With successful research, liquid fuels from biomass could possibly provide 3 to 4 quads of energy per year by 2030.

Research and Development on Feedstocks and Conversion to Liquid Fuels

The Administration will accelerate R&D on renewable feedstocks and liquid-fuel conversion technologies through cooperative Department of Energy–Department of Agriculture–industry research programs. Improving the economic competitiveness of liquid fuels from biomass will help introduce these fuels into the transportation sector. The Department of Energy and the Department of Agriculture, with industry cooperation, are currently conducting research on technologies for producing ethanol from biomass feedstocks such as wood, grasses, and municipal waste. Alternative liquid fuels are discussed in greater detail under "Transportation Energy Use."

Ethanol Tax Credit

The renewal of the ethanol tax credit in 1990 will help ethanol remain price competitive through the short term, as discussed under "Transportation Energy Use," until advanced technologies and feedstocks become available.

Direct-Thermal and Lighting Applications

Direct-thermal and lighting applications use the Sun and the heat of the Earth to heat and light buildings. Improving the cost competitiveness of direct-thermal (geothermal and solar thermal) and natural lighting (daylighting) technologies through improved building designs and materials will reduce the demand for oil and electricity and the attendant environmental impacts associated with producing this displaced energy.

The more than 1 million active solar space- and water-heating systems installed in the United States today displace approximately 0.04 quad of primary fuel. These systems chiefly use low-temperature collectors for pool and water heating. An estimated 300,000 to 350,000 U.S. homes employ some type of passive solar design features (for example, orienting a building toward the Sun), displacing about 0.01 quad of primary energy; and more than 100,000 homes and businesses use geothermal heat pumps for primary heating and air-conditioning.

The development and introduction of direct-thermal and daylighting technologies has been slow. The more than 100,000 firms that build housing nationwide are regulated by more than 10,000 local jurisdictions. Despite its importance to the economy, the U.S. building industry invests less than one-third of 1 percent of its revenues in research, the lowest of any industrial sector. The decentralized and cyclical nature of the buildings sector, low profit margins due to intense competition within the industry, and lack of uniform building codes have discouraged firms from supporting direct-thermal and daylighting research and development.

Research and Development on Materials and Building Designs

To lower the cost of direct-thermal and daylighting applications, the Administration will continue R&D on innovative building materials and designs and on incorporating photovoltaics and geothermal heat pumps into building designs. The Department of Energy will conduct an expanded program of R&D on new building energy technologies, including direct-thermal and daylighting applications. Expanded R&D would validate innovative concepts in a variety of climates, advance the commercial availability of technologies, and make them cost competitive with other heating, space conditioning, and lighting technologies energy use.

The Federal Government will help commercialize these technologies through cost-shared collaborative ventures, including field tests of solar building technologies. Collaborative ventures will validate cost projections, identify future R&D needs, and encourage customer-supplier interaction on design criteria, standards, and specifications. Additional discussion on direct-thermal and daylighting applications can be found under "Residential Energy Use" and "Commercial Energy Use."

Fusion Energy

The process of nuclear fusion—evident in stars, including the Sun—releases enormous amounts of energy. It occurs when the nuclei of lighter elements (such as hydrogen) are fused together at extremely high temperatures and pressures to form heavier elements (such as helium). For almost 40 years—with intensive work started in the late 1970's—scientists have been working to develop practical methods for harnessing fusion reactions, with the hope of realizing the potential of this energy source. Achieving the benefits of power from fusion, however, has proved to be a difficult, long-term challenge.

Fusion energy is an important, albeit long-range element of the National Energy Strategy because of its many potential advantages as an energy resource. The successful application of practical fusion energy technologies at some point in the 21st century could help to enhance the Nation's energy security, provide an environmentally acceptable alternative to fossil-fuel combustion, and help ensure continued economic growth through reliable electricity supply. Advanced research and development in fusion energy also could provide high-technology spinoffs in such areas as superconducting magnets; high-speed computing; high-power lasers; electronic diagnostic equipment; and high-power, high-frequency radio sources. Further, fusion technology developed within the United States could help enhance the Nation's position as a major supplier of energy and energy technologies in the world market.

The fuel for a fusion reactor consists of the less common isotopes of hydrogen, which are readily available domestically and are essentially inexhaustible. The potential use of deuterium fuel (one heavy isotope of hydrogen) together with lithium to breed tritium could provide enough energy for thousands of years at current levels of world power demand.

The successful commercialization of fusion energy (which could be realized by the middle of the next century) could ultimately change the overall pattern of electricity generation—as fusion powerplants replace those now fueled by nuclear fission power and fossil fuels. Because fusion powerplants would not produce air pollutants that contribute to acid rain and that may contribute to global climate change, they could minimize the environmental risks associated with the burning of fossil fuels and could substantially decrease demand for premium hydrocarbon fuels. Further, because fusion reactors would contain only small quantities of fuel at any time, they could eliminate the potential for runaway reactions that might lead to accidents. The development of low-activation materials or advanced fuel cycles for fusion reactors could make the amounts of high-level radioactive waste that result from fusion-produced energy far smaller than those produced by fission reactors—thus simplifying waste disposal problems.

Goals and Approaches

A thorough review of the Nation's fusion program by the Department of Energy's Fusion Policy Advisory Committee, published in September 1990, has led to a redefinition of the program's goals, which are summarized in the table on the next page. The overall strategy for fusion energy development is directed toward providing a sound scientific and technical base from which future source-secure, environmentally safe, and long-lasting sources of fusion energy can be derived.

The technical complexity associated with fusion development is such that substantial investments are required for new experiments, design facilities, and test facilities. This implies the need for long-term growth in research and development funding. The Strategy considers the necessity for cost-effectiveness in all parts of the program.

Goals and Approaches—Fusion Energy

Goal	Approach
Prove fusion energy to be a technically and economically credible energy source, with an operating demonstration plant by about 2025 and an operating commercial plant by about 2040	• Develop both magnetic and inertial confinement approaches to fusion separately until sufficient R&D exists to permit a choice • Achieve early industrial involvement
Ensure a cost-effective research and development program	• Continue international collaboration and cost-sharing in the magnetic fusion program • Incorporate results of this collaboration to the fullest practical extent into the inertial fusion program
Develop fusion as a safe, environmentally sound energy source	• Develop materials that minimize radioactive wastes and design features that optimize safety and environmental advantages

Expected Results

In spite of its potential, the production of net electrical energy from controlled fusion has yet to be demonstrated. Consequently, the economics of electrical power produced from fusion energy are still unknown. Steady progress has been made, but the practical use of fusion to produce usable energy has taken longer to demonstrate than scientists envisioned in the 1950's. The size and complexity of fusion experiments have grown to the point where both near- and long-term program objectives must be considered carefully to ensure the successful development of fusion technologies in light of budget realities.

Demonstration of the technical soundness of fusion energy through operation of a practical powerplant by about 2025—especially if it is followed by proof of economic feasibility—could help ensure fusion's introduction as a major energy source. The environmentally attractive nature of fusion energy and its safety features could help reduce public objections to expanding its use. In the long term, the expanded use of fusion energy could provide a low-cost, continuing supply of base-load electrical energy for the United States and could do much to reduce dependence on imported energy of any sort.

Credible Energy Source

The National Energy Strategy recognizes that fusion energy offers the potential to provide an inexhaustible supply of electricity with little, if any, environmental impacts; and it is setting long-term goals for developing fusion as a technically credible energy resource.

Programs that pursue both magnetic confinement fusion energy systems and inertial confinement fusion energy systems will continue under the National Energy Strategy. These two approaches to fusion, which are described below, compete technically. This helps to ensure that the necessary—and the best—technology will become available. However, resource limitations eventually will require a decision to determine which course to pursue. Each program involves the National Laboratories, universities, and increasing participation by the private sector as an integral part of the fusion research effort. U.S. participation in international fusion energy activities also plays an important role, particularly in the magnetic fusion energy program.

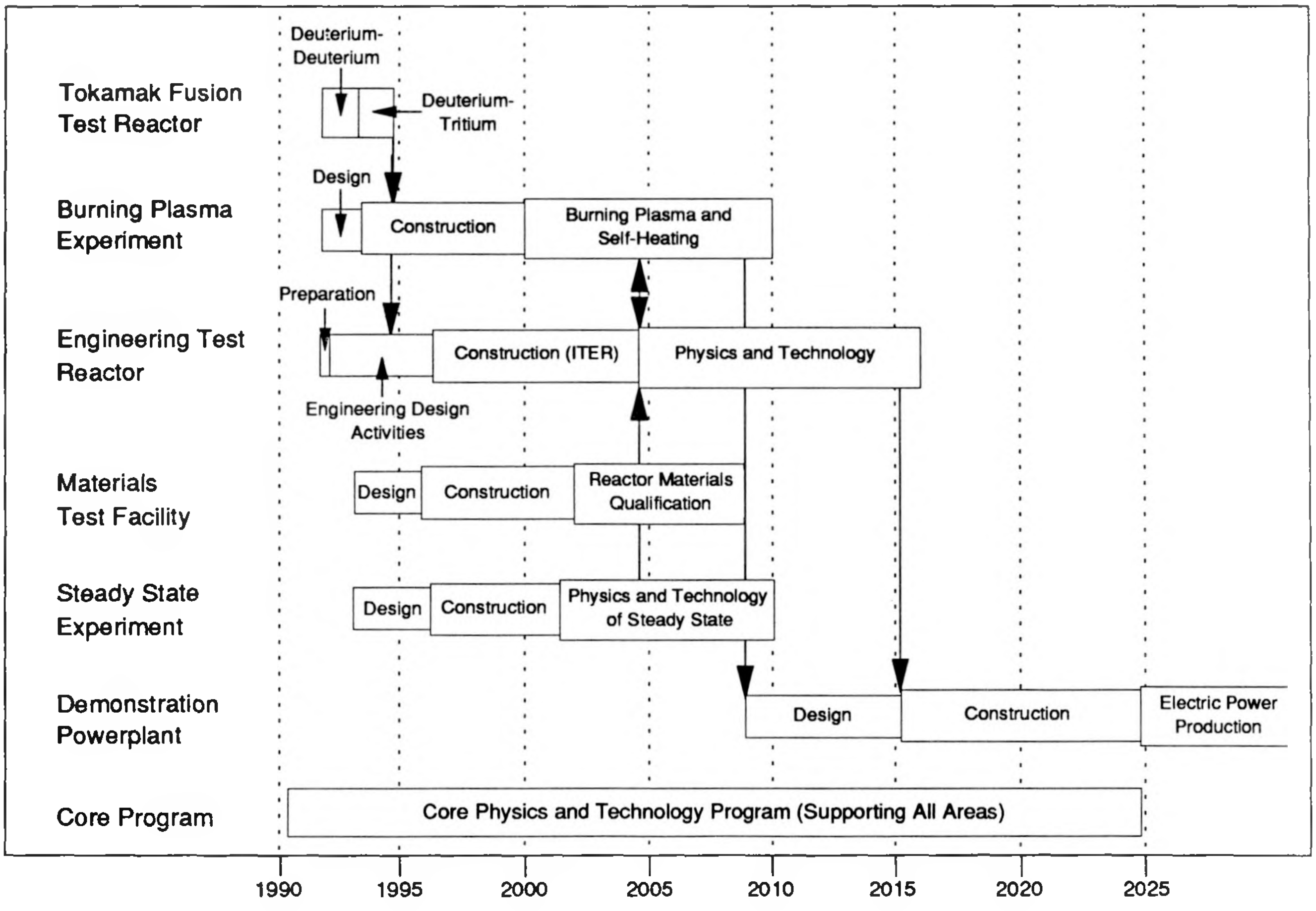
The Administration's fiscal year 1992 budget request to Congress for fusion energy research and development is consistent with the recommendations of the Fusion Policy Advisory Committee, as shown in Figures 34 and 35. For the fusion energy programs, both magnetic confinement and inertial confinement, a 23-percent increase (from $275 million to $337 million) is proposed in fiscal year 1992 to help move fusion energy from a scientific endeavor to the engineering stage. The Defense Inertial Fusion Program is funded separately. Decisions regarding outyear funding for the entire program, as well as the choice of magnetic confinement or inertial confinement technologies, will be addressed in the future in view of ongoing progress and technology developments.

Magnetic Confinement Fusion—Tokamak Reactor

In magnetic confinement fusion, a hot, ionized gas (plasma) is confined by an intense magnetic field and heated by external sources until the fusion reaction thus induced can become self-sustaining. Confinement within the magnetic field prevents particles in the plasma from bouncing off the walls of the containment vessel and prematurely stopping the fusion reaction. A continuous source of energy can be maintained as small amounts of fresh fuel are added.

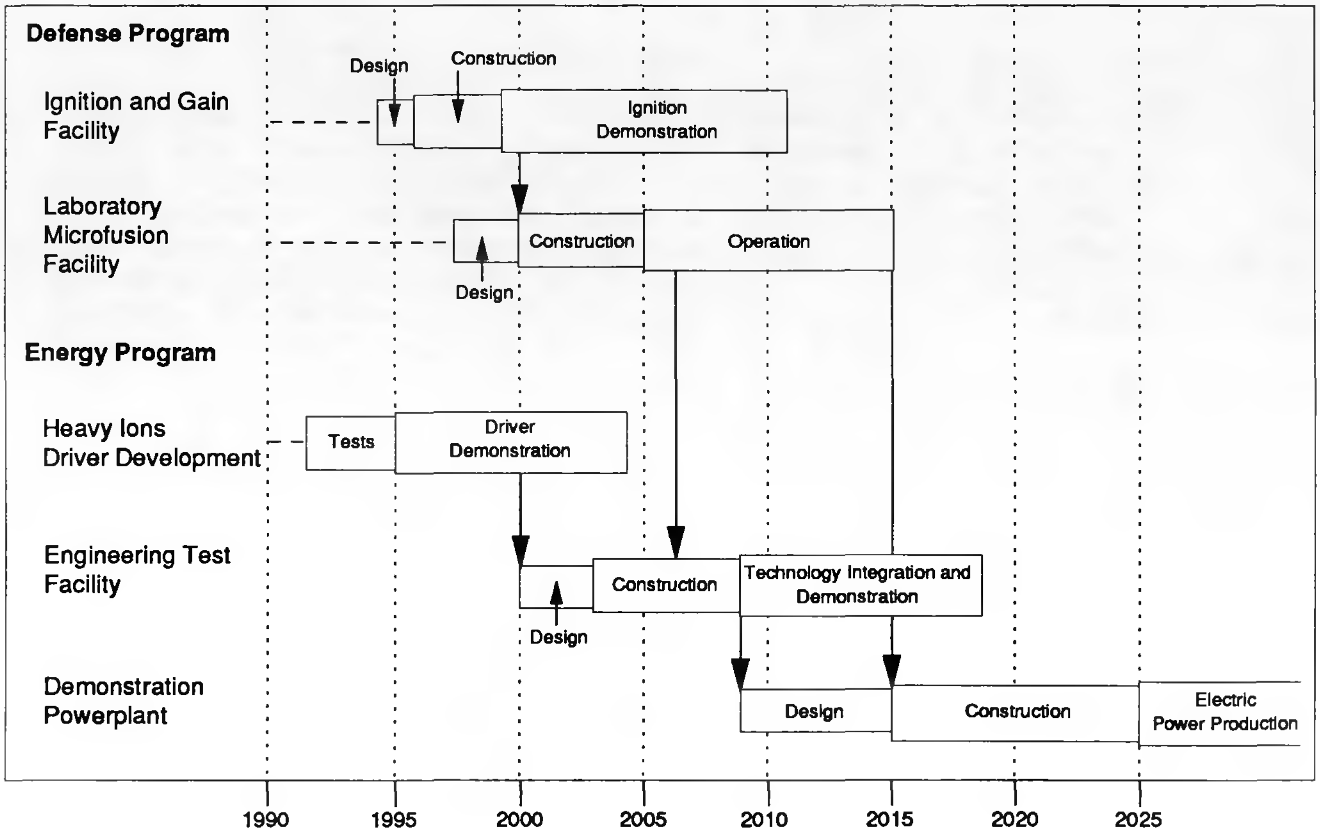
The U.S. Magnetic Fusion Energy (MFE) program will pursue a magnetic fusion energy development concept that seeks to confine burning plasma within a doughnut-shaped magnetic container called a tokamak. The near-term focus in this regard is on the International Thermonuclear Experimental Reactor (ITER) program, which will

Figure 34. Magnetic Fusion Energy Development Strategy



Note: Elements are drawn from recommendations of the Fusion Policy Advisory Committee, U.S. Department of Energy (September 1990). Schedule estimates are subject to uncertainty and will depend upon technical readiness, availability of funding, and international agreements.

Figure 35. Inertial Fusion Energy Development Strategy



Note: Elements are drawn from recommendations of the Fusion Policy Advisory Committee, U.S. Department of Energy (September 1990). Schedule estimates are subject to uncertainty and will depend upon technical readiness, availability of funding, and international agreements.

move from the conceptual design phase to engineering design activities. ITER involves scientists from the United States, the European Community, Japan, and the Soviet Union. In addition, research and development as well as design studies are being initiated on a new tokamak device called the Burning Plasma Experiment, which will help scientists determine the physical behavior of burning plasma and also demonstrate the production of substantial amounts of fusion power.

Collaborative U.S. and international efforts are expected to provide the necessary engineering tests that will allow the MFE program to proceed with design of a full-scale demonstration plant. Construction of the international test reactor is expected to be completed by about 2005. Operation of a full-scale demonstration powerplant for net electricity production is planned for about 2025.

Inertial Confinement Fusion

In the inertial confinement fusion process, small fuel pellets are bombarded by high-intensity laser or particle beams to produce a very small quantity of plasma, which is confined for a very short time by its own inertia. This process produces short, sequential "pulses" of high-intensity energy. The U.S. Inertial Fusion Energy (IFE) program will include the development of a system that uses inherently efficient heavy ions to drive the reaction, as well as reactor studies and the technology development needed to apply inertial fusion to energy production. Although much of the existing data related to inertial fusion are classified, an ongoing classification review could allow international collaboration in inertial fusion. The U.S. IFE program will continue to benefit from the results of the Department of Energy Defense

Program's Inertial Confinement Fusion Target Physics Development program.

An overview of the IFE program is shown in Figure 35. Complementary programs will work toward the design and construction of both laboratory fusion demonstration and energy engineering test facilities for inertial fusion energy, targeted for completion by about 2015. Successful operation of these facilities will provide the impetus to build a demonstration powerplant.

Industry Involvement

The ultimate goal of the fusion program is a new source of commercial electrical energy. In the interest of achieving this goal, actions will be undertaken to encourage substantial involvement of U.S. industry in fusion energy development. This participation will be sought not only for the hardware phases of the program, but also in the planning, research and development, and analytical phases.

Actions to be pursued include the exchange or loan of scientists and other personnel from the private sector; professional-service contracts; purchases of equipment and systems; and industrial construction, maintenance, and operating contracts. This interchange with industry will benefit the program by providing broadened technical support; heightened quality control; expanded cost-sharing opportunities; and enhanced capability to fabricate equipment, construct facilities, and operate and maintain powerplants.

Cost-Effective Program

The magnitude of the fusion development task, the approximate equality of effort in collaborating countries, and the need to exchange information among the limited number of scientists engaged in fusion research make international collaboration a natural extension of most efforts in this area. The advantages of international collaboration include sharing of knowledge and experience; increased potential for cost-sharing; optimization of special facilities and capabilities; increased opportunity for technology spinoffs; and the spreading of technical and economic risks across a broader base. The U.S. fusion program will encourage scientific collaboration and international cost-sharing wherever and as often as possible to ensure that fusion development is cost-effective at every stage.

International Collaboration

The U.S. Magnetic Fusion Energy program has been a model of successful international cooperation. The free exchange of ideas, data, concepts, personnel, and equipment has resulted in an expanded technology base for magnetic fusion concepts, and progress toward development of the fusion option has been cost-effective. Actions taken under the National Energy Strategy will promote and extend continuing cooperative activities on an international scale. The expected result will be considerable cost-sharing of major design and facility expenses among participating nations.

Design activities for the ITER program represent a major collaboration among the European Community, Japan, the Soviet Union, and the United States. This activity, which began in 1988, included joint efforts at a site in Germany where representatives of the participating nations worked together directly. The tokamak magnetic confinement fusion program currently under way in the United States will allow the United States to operate as a full partner in the ITER program and thus take full advantage of collaborative progress. Opportunities for international collaboration on the Burning Plasma Experiment also are being explored. A strong domestic fusion program will continue to make the United States a desirable and effective international partner.

Incorporation of Results Into the Inertial Fusion Energy Program

The results of the collaborative process will produce information that could be used to advance the development of both inertial fusion and magnetic fusion technologies. Magnetic fusion concepts under development in the United States, Japan, and Germany (such as advanced breeding blankets for the in-reactor production of tritium) also may prove attractive for inertial fusion. Complementary research and design activities that will lead to heavy ion beam drivers appropriate to energy applications have been initiated in the United States, Europe, and Japan. Expanded international cooperation could reduce the costs and time involved in early development of drivers and reactor technology for inertial fusion energy. Both programs will take steps to guarantee ample interchange of relevant data and experimental concepts, ensuring that these data and concepts also are fully utilized in this country.

A Safe, Environmentally Sound Energy Source

The motivation for pursuing controlled fusion is not based solely on technological and economic factors. Widespread introduction of fusion energy reactors could substantially reduce the environmental impacts of increasing demands for electricity in the United States. A reliable and secure electricity supply could ensure that the energy needs associated with continued economic growth are satisfied. The safety of fusion reactors would provide additional ecological benefits that should help to promote public interest in the goal of a substantial production capacity for fusion energy in the future. However, a number of issues associated with fusion power must be considered before controlled fusion can reach its potential as an environmentally benign source of energy.

Although the reaction products and most of the radioactivity induced in a fusion reactor vessel would be short-lived, the use of fusion to generate power would still produce high-energy neutrons. Powerplant designs must incorporate materials that minimize the radioactivity induced by these neutrons. Such materials are being developed, but will require substantial testing with neutrons simulating a fusion environment before they can be used in a fusion device. Special methods also will be needed for the efficient generation and recovery of tritium fuels, for the extraction of heat for electricity generation, and for refueling. While radioactive byproducts generated by a fusion power reactor should be considerably less than those from a conventional fission power reactor, the issues of radioactive waste and decommissioning associated with fusion still will need to be addressed.

Low-Activation Materials

As part of the fusion program's research into ways to reduce high-level nuclear waste, materials that are less susceptible to becoming radioactive by neutron capture in reactors will be studied and developed. Use of these materials in reactor structures would greatly reduce the amount and types of radioactive wastes generated in the production of energy from fusion. Success in this effort would obviate the need for geologic repositories and greatly simplify waste disposal.

Advanced Fuel Cycles

Other possible actions that could be undertaken by the fusion program to minimize high-level nuclear waste will emphasize research and development on advanced fuel cycles. Advanced fuel cycles could entirely eliminate the use of radioactive tritium as an input fuel for the fusion process. Successful development of some such fuel cycles also would reduce neutron flux. This could further reduce the radioactivation of reactor structural materials, potentially eliminating the waste disposal problems associated with these materials.

Breeding Blankets

The fusion program will address critical environmental and safety issues associated with the transport of radioactive fuels through research in "breeding blanket" technologies. Breeding blankets provide a lining, within the fusion reactor, that contains lithium. The lithium is to be transformed into tritium fuel by neutron capture within the reactor, generating all of the tritium fuel needed to produce energy. By enabling fusion reactors to generate their own tritium fuel, breeding blankets would eliminate the need to transport this radioactive gas from one installation to another, obviating the associated environmental and safety hazards.

Passive Barriers

In conjunction with efforts to reduce inventories of radioactive fuel, the fusion program will emphasize the use of passive barriers to radioactive releases. Passive safety systems should be less subject to human error than active safety systems and possibly more reliable than containment buildings. With such systems, the increased public protection from accidental releases of radioactive materials should be demonstrable.

Enhanced Research and Development for Energy Security

One of the keys to ensuring future energy security is reducing U.S. oil vulnerability. Technological advancements are one of the best ways to achieve this, and the National Energy Strategy calls for increasing investments for technology research and development (R&D) in areas with the greatest potential for reducing oil vulnerability. Specifically, R&D is essential for—

- Reducing the transportation sector's near-total reliance on oil—by making oil use more efficient, by introducing alternative fuels and technology, and by diversifying travel modes.
- Increasing the environmentally protective production of domestic energy resources.
- Improving energy efficiency and increasing the range of economical, clean technology choices.

Goal and Approaches

The National Energy Strategy proposes an aggressive program to fund multiagency R&D that will facilitate the development and introduction of advanced technology in critical oil-producing and -consuming sectors of the economy. A range of higher performance and lower cost technologies can decrease oil use by making more efficient use of the resource, by improving the recoverability of oil resources, and by providing substitute sources of energy to replace oil.

The National Energy Strategy will strengthen existing R&D programs in selected areas to accelerate the development of new technology. It will also use innovative approaches to accelerating technological development by encouraging joint Government-industry-university cost-shared efforts and by offering prizes and awards for inventive technical approaches. Because most of the specific National Energy Strategy R&D initiatives are applied, the Strategy emphasizes the need for a new approach to supplement or even replace much of the "business as usual" applied R&D research contracting of the past two decades. This new approach will use, where feasible, industry R&D consortia and cooperative R&D ventures. Because the Strategy research initiatives are largely applied and focused, it is reasonable to seek 50 percent industry cost-sharing; the newly formed industry cooperative R&D venture for electric vehicle batteries is a good example. The table on page 137 lists the approaches for achieving this goal.

Expected Results

By the year 2030, this initiative is expected to save between 5 million and 8 million barrels per day of oil, depending on the success of the proposed R&D programs. About half of these savings will be from reduced oil demand, and about half from increased oil supplies and the production of alternative fuels. In addition to saving oil and improving U.S. energy security, significant environmental and economic benefits are expected. Lower oil demand and clean alternative fuels from biomass will reduce pollutants. Increased domestic production of oil and alternative fuels should improve U.S. competitiveness in world markets and provide additional jobs, thereby boosting the U.S. economy.

Advanced Energy Technology

Increased investment in advanced energy technology R&D is a major element of the National Energy Strategy. The fiscal year 1992 budget includes $903 million—an increase of $227 million, or 34 percent—for increased investments in R&D in support of Strategy R&D initiatives Governmentwide. The budget proposes $653 million for Department of Energy Strategy-related R&D, an increase of $134 million, or 26 percent. Over the 5-year period from 1992 through 1996, the Department of Energy would invest $3.5 billion in the National Energy Strategy R&D initiatives discussed in this section.

Goals and Approaches—Enhanced Research and Development for Energy Security

Goal	Approach
Expand the role of advanced energy technology in reducing U.S. oil vulnerability	• Enhance Federal support for potentially high-payoff R&D aimed at reducing oil demand, increasing oil supplies, and developing oil substitutes • Encourage cost-shared programs with universities and industry • Establish prizes and awards to stimulate innovation in oil-reducing and -saving technologies

Table 1 shows the fiscal year 1992 funding requests for specific technology areas that are included in the enhanced R&D initiative. The following is a brief description of the major technology areas:

- **Advanced Oil Recovery Technologies.** Advanced oil recovery technologies will permit production of portions of the two-thirds of known U.S. oil that are normally not recovered using present techniques. Research success in this area is expected to increase significantly U.S. proved reserves and daily production.

- **Advanced Energy Technologies.** Advanced energy technologies depend critically on breakthroughs in advanced materials (including superconductors), chemical sciences (including catalysis research), and geosciences and biosciences. Increased support for these areas will accelerate the rate of developing new technology, increase the probability of its success, and provide new tools and methods for the private sector to use in technological applications.

- **Industrial Technologies.** Increased funding for improving industrial processes and equipment and for alternative fuels and feedstocks will also reduce petroleum demand. Areas covered by increased funding will include biotechnologies, high-temperature materials, and cogeneration.

- **Vehicle Propulsion.** Enhanced R&D on advanced propulsion technologies such as automotive gas turbines, fuel cells, and high-efficiency internal combustion engines (both gasoline and diesel fueled) will increase their commercial viability and accelerate their entry into the market. These turbines will be more efficient than internal combustion engines and will be capable of operating on alternative fuels. Fuel cells, which would also use alternative fuels, will also be more efficient. The development of advanced ceramic engine components is the critical technical step in turbine development, as turbines derive their higher efficiency from operating at higher temperatures. High-efficiency internal combustion engines incorporating advanced ceramics and other new materials can operate at higher temperatures without the need for cooling systems, and they also will be more capable of operating on alternative fuels.

- **Electric Vehicles.** A consortium of vehicle manufacturers, battery companies, and utilities, with Government support, will be formed to accelerate R&D on improved batteries with increased range and power at an acceptable cost. The current range is under 100 miles, which limits potential use to urban fleets. Development of hybrid vehicles, which would use a smaller engine to overcome the limitations of battery power, will also be considered.

- **Advanced Transportation Fuels From Biomass.** Ethanol is produced commercially from starch and sugar crops such as corn and sugarcane; however, lignocellulosic feedstocks (biomass) such as trees and grasses have not yet been converted to ethanol on a commercial

Table 1. Enhanced Research and Development for Energy Security

Initiative	Budget Authority (millions of dollars) 1991 Enacted	1992 Proposed	Dollar change	Percentage change
Displacing oil in the transportation sector	302	432	+130	+43
Surface transportation efficiency	162	260	+98	+60
Improved vehicle propulsion technology	39	42	+3	+8
Electric/hybrid vehicles	30	42	+12	+40
Intelligent vehicle-highway systems	23	60	+37	+161
High-speed rail and magnetic levitation	12	24	+12	+100
Telecommuting	58	92	+34	+59
Air transportation efficiency	51	59	+8	+16
Energy-efficient aeronautics	16	17	+1	+6
Efficient air traffic control	35	42	+7	+20
New transportation fuels	89	113	+24	+27
Fuels from biomass	33	44	+11	+33
Alternative fuel utilization	14	17	+3	+21
Advanced oil recovery	42	52	+10	+24
Increased energy efficiency in buildings and industry	129	157	+28	+22
Targeted industrial energy efficiency	84	102	+18	+21
Targeted buildings energy efficiency	45	55	+10	+22
Advanced electricity technology	245	314	+69	+28
Photovoltaics	47	51	+4	+9
Superconductivity	19	22	+3	+16
Advanced light-water reactors	29	63	+34	+117
Advanced reactor concepts	150	178	+28	+19
Total, all activities	676	903	+227	+34
Total, Department of Energy	519	653	+134	+26

scale. Successful research here will provide a major alternative to gasoline that is domestic, renewable, and competitively priced—and one that could reduce the United States' dependence on oil. Research will be conducted on both feedstock improvements and on scaleup of conversion processes.

- **Aeronautical and Air Systems.** In 1989, U.S. air carriers logged 446 billion passenger revenue-miles, consuming about 1 million barrels per day of jet fuel and aviation gasoline. World air travel is projected to double in the next 10 years and to continue to grow by more than 5 percent annually thereafter. Promising areas of energy-efficiency research to reduce consumption include composite airframe materials for weight reduction; propulsion materials and components for high-efficiency engines; increased aircraft efficiency through drag reduction; and automation aids for the air traffic control system to optimize aircraft scheduling and control.

- **Telecommuting.** An estimated 35 to 40 percent of passenger vehicle-miles traveled is work-related. Telecommuting—working at home via a computer modem—is an attractive alternative for workers in the information sector, which now constitutes the majority of the work force. R&D and other investments to improve the interconnection of networks and enhance the capabilities for digital data will do much to build and improve the broadband transmission networks, powerful and inexpensive desktop workstations, easy-to-use software, and extensive remotely accessible data bases necessary for telecommuting.

- **High-Speed Rail and Maglev.** High-speed rail and magnetic levitation (Maglev) can provide efficient, high-speed travel and reduce petroleum demand. These technologies appear best suited for trips of 200 to 600 miles, making them credible alternatives for both long-distance automobile travel and short-haul air travel. The Federal Maglev initiative will focus on safety issues related to the German Transrapid system and the R&D needs of a Maglev technology.

- **Intelligent Vehicle-Highway Systems.** Traffic congestion greatly reduces highway fuel efficiency. Intelligent vehicle-highway systems (IVHS) will use state-of-the-art electronics, communications, and computer technology to improve traffic control systems, warn drivers of dangerous and congested situations, and to help use the existing road system more efficiently. IVHS can also help reduce congestion by reducing fares to encourage transit use or by increasing the cost of parking or freeway tolls to discourage highway use. Public transit systems will also benefit from IVHS developments.

- **Advanced Light-Water Nuclear Reactors.** Advanced light-water nuclear reactors will incorporate major design advances, including passive safety features. This will reduce the time needed to license and construct new plants. The Department of Energy is currently supporting first-of-a-kind engineering work that will assist companies in their efforts to have the Nuclear Regulatory Commission certify the new standardized designs.

- **Advanced Reactor Concepts.** Advanced reactor concepts will have safety features that go beyond even the standardized designs currently before the Nuclear Regulatory Commission. High-temperature gas-cooled reactors use specially coated fuel elements that will not fail even under the high temperatures that could occur during an accident; liquid-metal reactors use liquid sodium as the heat exchange medium. Researchers have demonstrated that both reactor types can shut themselves down safely under conditions that would be extremely serious for present-day reactors. The Department of Energy continues R&D support for both of these advanced concepts.

In addition to increased funding, the Strategy calls for a number of unique actions to help improve research productivity and accelerate community and industry participation in the overall effort. Two actions in particular will be pursued: cost-shared R&D and prizes and awards.

Cost-Shared Research and Development

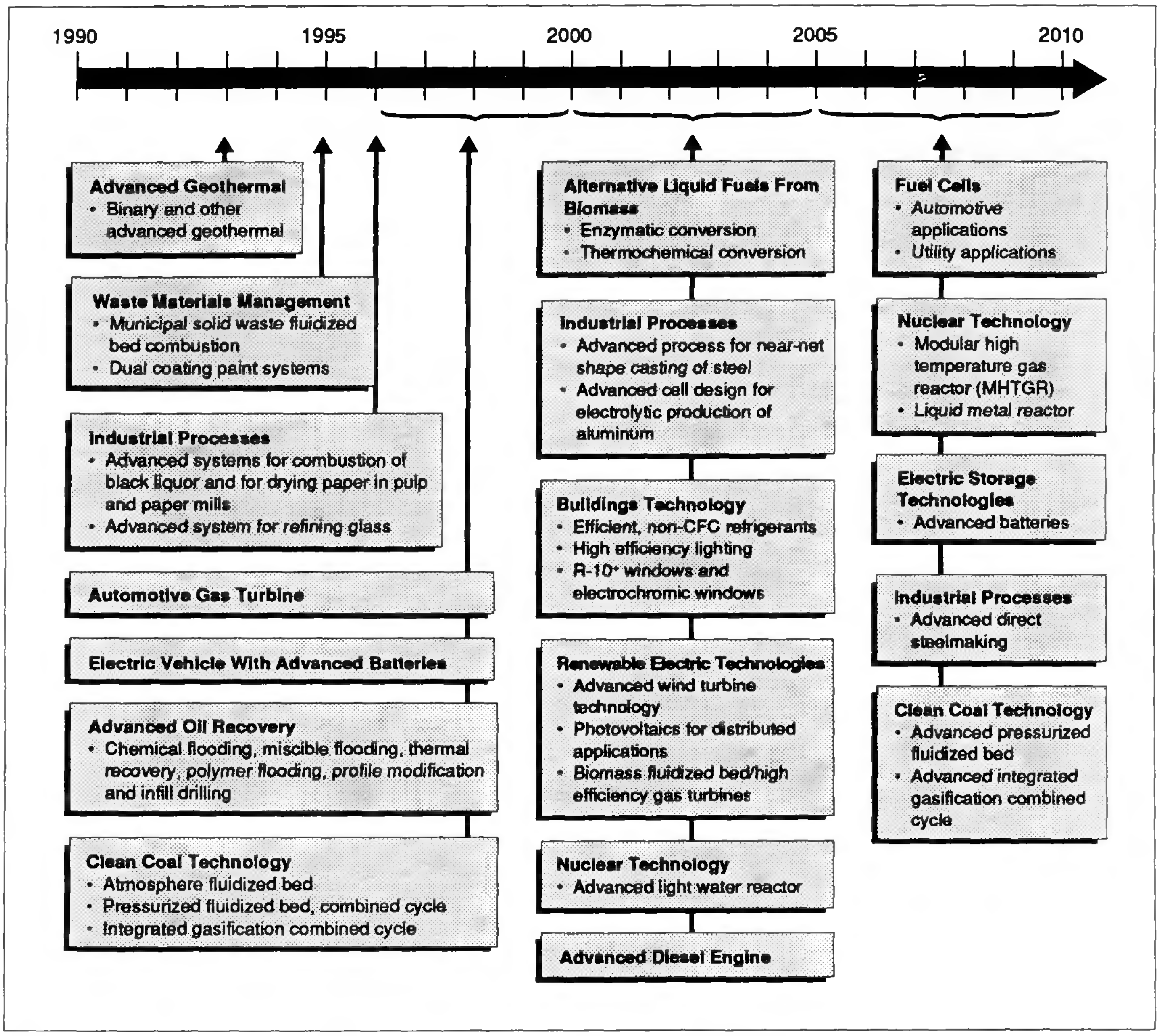
The Strategy calls for increased involvement in industry-led, joint Government-industry-university R&D planning and management; costs will be shared to some degree. The formation of industry R&D consortia will be encouraged where feasible, for example, in the precompetitive R&D stages. Intellectual property rights will be assigned to the appropriate participants consistent with current laws and policies. Universities will play a major role in fundamental science and engineering research initiatives. This action will maximize the involvement of the ultimate technology users, enhance the technology-transfer process, and minimize Government overhead.

Beginning in 1991, the Department will participate in the new joint auto-industry–Government consortium to develop battery technology for electric vehicles. Improved batteries that could extend vehicle range to 120 to 200 miles could enable electric vehicles to capture as much as 20 percent of the market by 2030.

Prizes and Awards

A national award program will be initiated, with large cash grants for major innovations in energy technologies that can reduce U.S. oil vulnerability. The program would also set forth specific energy-related technological challenges and award grants for achieving those breakthroughs. Prizes of this nature often stimulate inventive new approaches

Figure 36. Timeline for Commercial Introduction of Selected Energy Technologies

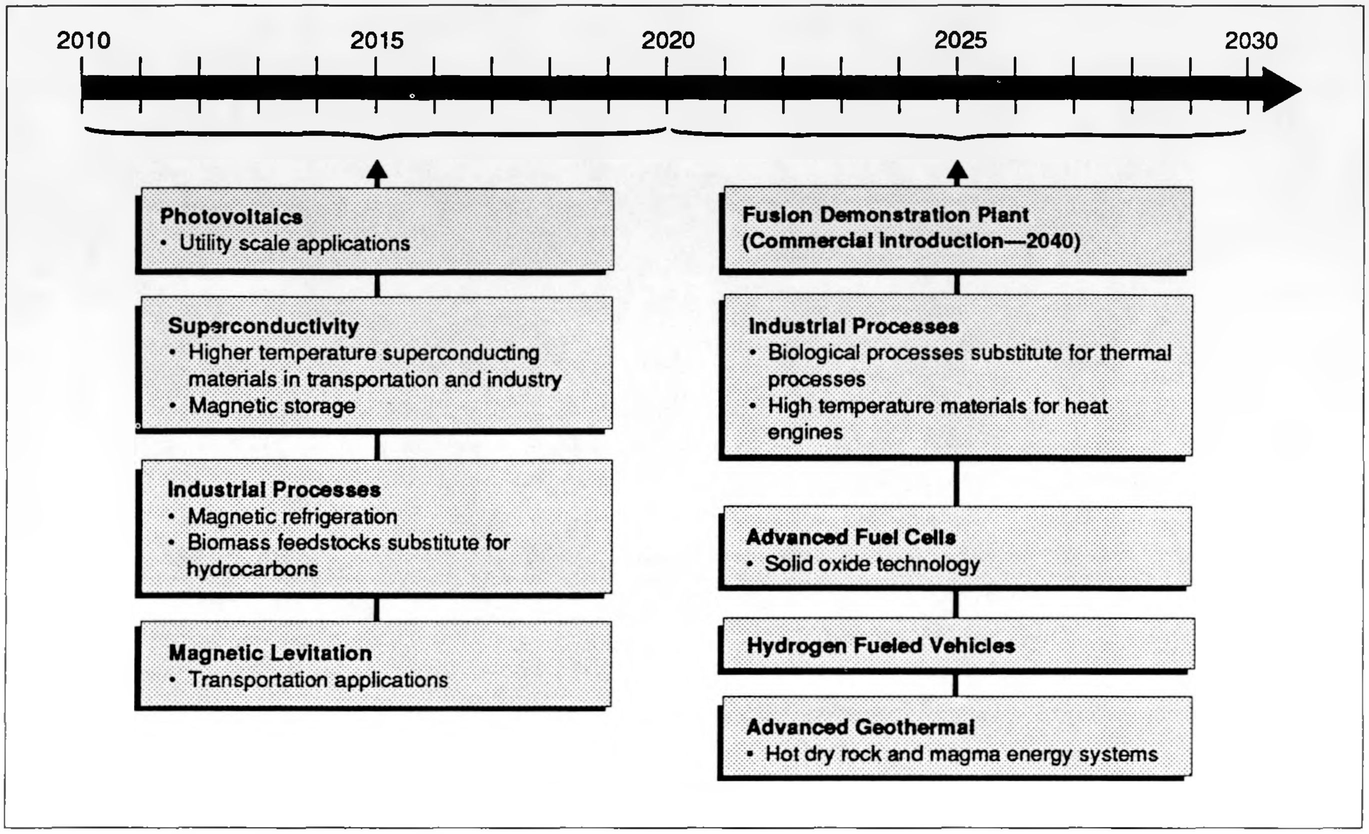


and scientific breakthroughs that significantly accelerate technology development.

Commercial Introduction

In summary, the National Energy Strategy calls for enhanced efforts in research and development across a broad front of energy security-related advanced technologies. Many Federal agencies will be involved. These efforts will include significant increases in R&D funding for key technologies, strengthening of existing R&D programs, and greater involvement in technology development by industry and the research community outside the Federal Government.

Figure 36. (continued) Timeline for Commercial Introduction of Selected Energy Technologies



The combination of these efforts is expected to accelerate the commercial introduction of such technologies. Figure 36 illustrates current estimates of when these technologies are expected to begin to penetrate commercial markets in significant ways.

Enhancing Environmental Quality

Energy and the Quality of Air, Land, and Water

Energy and Global Environmental Issues

Energy and the Quality of Air, Land, and Water

Energy policies that do not protect the environment and public health will not be supported. Environmentally sensitive energy policies can substantially reduce the impacts on air, land, and water quality that come from energy extraction, production, and use. The keys are advanced technology, improved energy production, distribution and use practices, and use of market mechanisms that can help us maintain adequate supplies of affordable energy while enhancing the quality of our environment.

A large portion of the Nation's air pollution originates from producing and using energy, especially the burning of fuels. Coal-fired powerplants generate the majority of the Nation's sulfur dioxide and a substantial fraction of nitrogen oxides—the pollutants most closely linked to acidic deposition (acid rain). Motor vehicles use about one-fourth of the primary energy consumed in the United States, and they create much of the pollution that leads to urban "smog" and related air-quality problems caused by ground-level ozone and carbon monoxide. In addition, energy production and use contribute to toxic air pollution and radionuclide emissions.

Water is widely used in the production of energy. Drilling for oil and gas, coal mining, cooling energy facilities, and underground storage of petroleum are a few of the energy-related activities that can affect water resources and water quality.

The transport, storage, and handling of petroleum and petroleum products can involve accidental releases to water bodies. The 1989 oil spill near Valdez, Alaska, demonstrated the potential damage to natural ecosystems posed by transporting petroleum on ocean waters. Furthermore, although the environmental impacts on marine and coastal ecosystems from major oil spills receive more public attention, minor spills and chronic oil discharges also are an environmental hazard to inland, coastal, and groundwater resources.

Managing the wastes that come from energy production is another significant environmental and economic issue. Coal-fired electric utilities generate large volumes of solid combustion wastes that must be disposed of properly. (Issues related to nuclear waste disposal are discussed under "Nuclear Power.")

We must rely on our vast domestic energy resources to maintain our economic growth. Yet, tapping some of these resources may appear to conflict with environmental goals and be inhibited by land-use policies. Many of these resources are now excluded from development, even though the comparative analysis of the benefits and potential risks is incomplete.

Our economic growth also requires that sites be found for hundreds of new powerplants. Numerous other energy facilities will also be needed over the next 40 years to ensure that the United States will have enough energy for its growing population and economic development. However, coal-burning electrical generating plants, hydroelectric facilities, petroleum refineries, and other energy-related facilities are faced with lengthy, overlapping, and highly restrictive Federal, State, and local licensing and siting procedures for new construction. These procedures often unnecessarily delay, add to the overall cost of, and sometimes prevent the construction of needed energy production facilities that are environmentally acceptable. Unless considerable simplification or standardization of such permitting programs takes place within the next 5 to 10 years, there may be significant supply limitations as we attempt to meet near- and long-term demand for electricity, refined petroleum, and alternative fuel products.

Energy needs are not adequately considered in general regulatory decisions. The result is that regulations often unnecessarily restrict innovative or less costly approaches to *protecting* the environment. A significant portion of the more than $100 billion annual cost to the Nation for environmental regulation is related to energy. The magnitude of these costs requires that every effort be made to use efficient, market-based approaches in meeting environmental goals.

Environmental problems arise in market economies when private individuals and businesses lack the incentive to take responsibility for the environmental consequences of their own actions. The public interest is best served when environmental statutes and regulations create incentives for the private sector to seek out the most cost-effective means of meeting regulatory requirements.

Innovative techniques, cleaner fuels and technologies, and efficient processes are all needed. The challenge is to satisfy the need for additional energy supplies while enhancing environmental quality.

Goals and Approaches

Many of the National Energy Strategy goals and actions related to energy security or economic efficiency are also effective in reducing air, water, or waste concerns. These goals and approaches, along with some that address environmental issues exclusively, are summarized in the table that begins on this page.

The first goal is to improve environmental quality by carrying out those Strategy actions that will provide health and environmental gains. These actions are discussed in the other parts of the Strategy ("Increasing Energy and Economic Efficiency," "Securing Future Energy Supplies," and "Fortifying Foundations"). Although done primarily for policy reasons other than protecting human health and the environment, these actions improve efficiency, promote conservation, provide alternative energy fuels and sources with lower emissions, and stimulate the early use of modernized technologies.

The second goal is to provide greater flexibility and to lower costs to meet environmental requirements. Flexibility can be achieved in several ways. As new environmental laws and regulations are developed, the Strategy requires improved analysis of their effects on the supply and cost of energy. Analysis is needed to account for the full costs and benefits of energy production and fuel consumption, especially taking into consideration environmental, public health, and safety concerns.

Goals and Approaches—Energy and the Quality of Air, Land, and Water

Goal	Approach
Improve environmental quality by National Energy Strategy actions	• Increase energy efficiency and reduce energy demand to lower future emissions • Stimulate use of natural gas, renewable energy, nuclear power, alternative transportation, and clean coal technology to reduce air-, land-, and water-quality impacts
Increase flexibility in meeting environmental requirements	• Improve analysis of energy impacts as a part of rulemaking • Expand flexibility and use of market mechanisms, such as emissions trading, to reduce compliance costs • Amend legislation and administrative programs to allow more flexibility in control practices while maintaining environmental protection • Provide more complete analysis of the environmental impacts of competing technologies (total fuel-cycle analysis); ensure that environmental concerns with emerging energy technologies are addressed in advance

(continued)

Goals and Approaches—Energy and the Quality of Air, Land, and Water (continued)

Goal	Approach
Maintain environmental concerns in energy facility siting and licensing decisions while reducing process delays and overlaps	• Identify elements of unnecessary delay and restriction; propose model programs to guide regulators • Analyze both the energy resource potential and the environmental impacts that may result from exploration and development on public lands
Achieve and maintain the National Ambient Air Quality Standards for carbon monoxide and ozone	• Implement the Clean Air Act to reduce tailpipe emissions to meet air-quality standards • Reduce oil use in transportation by encouraging cleaner fuels, greater vehicle efficiency, and use of alternative vehicles
Reduce threat of "acid rain" through cost-effective control strategies	• Reduce emissions of sulfur dioxide and nitrogen oxides through implementing the Clean Air Act Amendments of 1990 • Increase energy efficiency and develop new, lower polluting technologies to further reduce emissions at lower costs
Address other air-quality issues	• Study toxic air emissions from utilities; regulate emissions from transportation and industries • Assess radionuclide regulatory practices by States • Modify "new source review" policy for existing powerplants
Protect and improve water quality	• Improve tanker safety, make better preparation for potential accidents, and provide stronger incentives for transporters to prevent accidents • Expand the use of market approaches and energy concerns in reauthorizing the Clean Water Act
Protect human health and the environment and reduce costs through effective waste management	• Propose amendments to the Resource Conservation and Recovery Act to increase land-use and groundwater protection and reduce compliance costs by expanding the use of market mechanisms
Reduce energy-related waste generation	• Remove regulatory disincentives to waste minimization; promote research and outreach activities

Another approach is to continue the success of market and economic mechanisms to achieve environmental quality requirements. In several air-quality programs, these initiatives are saving substantial costs at no net increase in overall emissions. Tradable allowances, emissions offsets, "banking" early reductions, and "bubbling" are new approaches that provide more cost-effective environmental compliance.

A third Strategy goal (common to all environmental media) concerns the siting and licensing of new facilities and the upgrading of older plants. Duplication of requirements, overlapping authorities, and inefficient requirements have halted some proposed developments and delayed others for decades. The Strategy will identify instances where overlapping programs add costs and delays *without* enhancing the protection of health or the environment. The Strategy also will address possible administrative and legislative improvements, such as analyzing the resource and environmental tradeoffs in developing energy resources on public lands.

The National Energy Strategy has three goals related more specifically to energy and air quality. These goals will be achieved primarily in two ways: implementing the Clean Air Act Amendments of 1990 and pursuing energy research and initiatives to reduce energy use and provide cleaner energy and transportation technologies.

Air pollution control is costly. The Nation already spends more than $30 billion annually on air pollution controls and improved technologies required by Federal programs. These costs will increase by more than $20 billion annually as the Clean Air Act Amendments are implemented. The amended act promotes greater use of market mechanisms to lower the costs of compliance through emissions trading and banking. The National Energy Strategy initiatives that promote energy conservation also reduce air pollution compliance costs by decreasing emissions. In addition, developing and deploying low-emission energy processes (such as clean coal, natural gas, solar, nuclear, and hydroelectric technologies) offer the prospect that the lower emissions technologies may have lower overall costs than conventional technologies.

The National Energy Strategy also recognizes the goal of ensuring that energy production and use facilities protect water quality. The Oil Pollution Act of 1990 (which establishes a comprehensive oil-spill prevention, response, and liability program) will improve tanker safety, increase liabilities for oil-spill cleanup costs and damages, and require better contingency planning and preparedness at Federal, State, and local levels.

Congress is now considering the Clean Water Act for reauthorization and possible amendment. The Administration will work with Congress to foster increased flexibility and the use of cost-effective choices to meet regulatory requirements.

Finally, the National Energy Strategy has two goals related to energy and waste management: to protect human health and the environment while reducing costs by managing waste effectively, and to reduce energy-related waste.

The principal waste management act, the Resource Conservation and Recovery Act, is expected to be reauthorized and amended in the early 1990's, possibly by 1992. The Administration will work with Congress to foster waste minimization as well as determine opportunities to reduce risks from wastes and to provide lower cost, more flexible alternatives to meet regulatory requirements.

The projected growth of nonnuclear energy wastes from 1990 to 2030 can be reduced by modernizing energy facilities, improving energy efficiency, and switching (in part) to fuel cycles that generate less waste (such as renewables and natural gas). Waste reduction will be promoted by removing regulatory disincentives and encouraging investment in innovative technologies that minimize waste and pollution. An outreach program to communicate research results to the public will hasten the use of technologies that reduce waste.

Expected Results

The National Energy Strategy will improve environmental quality and reduce risks to human health. Throughout this discussion on air, land, and water, national trends in emissions and waste loads between now and the year 2030 are compared for two sets of assumptions: The projections show (1) what would happen if current policies—with no subsequent change—were used for this 40-year period and (2) what would happen if the Strategy supplements those policies. For air quality and water quality, the results are dramatic. If the recent Clean Air Act Amendments of 1990 (the 1990 Amendments) had not occurred, the annual national level of nearly every pollutant would have increased. The 1990 Amendments set limits on national emissions for some pollutants and initiated new programs that will result in substantial reductions in others. The National Energy Strategy goes even further for air quality, and reverses the trends in energy effluents to water as well. Even for the tightly regulated "acid rain" and ozone-related emissions, long-term projections show that the Strategy brings levels below even the requirements of the 1990 Amendments.

National Energy Strategy actions will reduce the water-quality impacts of several pollutants, including total suspended solids (primarily from powerplants, coal mines, and petroleum refineries) and oil and grease (primarily from petroleum refineries). If only the current policies were continued through 2030, these water effluents would increase steadily—reaching levels that are 20 to 50 percent higher than present-day levels. Instead, the National Energy Strategy actions will decrease these pollutants by 2030 to approximately the same levels as today. The relative improvement will be greatest after 2010, when the trend shows continual decline.

Wastes, on the other hand, grow under all projections. For newer technologies and fuel sources that substitute for fossil fuels, however, the growth in new wastes is less than would otherwise occur. Early identification of these wastes allows us to develop adequate controls and practices at lower cost. The ability to identify emerging potential environmental concerns early will be strengthened because of improved total fuel-cycle analysis of impacts and costs. As a result of the National Energy Strategy actions, less waste will be generated by both new and existing facilities than if these actions were not taken. For instance, the National Energy Strategy, over time, will dramatically reduce the growth of coal wastes, with reductions by the year 2030 of 30 to 60 percent of the volume that could be expected otherwise.

Additionally, National Energy Strategy actions, while improving environmental quality, provide increased opportunity to cut regulatory costs—in some programs by up to 50 percent—and to eliminate restrictions on useful compliance technologies and practices. Other constraints (such as delays and conflicting requirements in licensing processes) will be reduced. These actions collectively will help modernize technologies and facilities and speed commercial acceptability of alternative fuels and energy sources.

Total Fuel-Cycle Analysis

Present environmental analyses are often criticized because they are incomplete, failing to identify and quantify *all* impacts to health, the environment, and society. For instance, an initiative promoting development of a new coal combustion technology may not be analyzed in regard to the environmental impacts of the added coal mining, coal cleaning, coal transportation, coal ash transportation and disposal, or disposal of sulfur pollution control wastes that are involved. When all of these components are considered, the analysis is said to address the total fuel cycle.

In addition to the environmental impacts normally described in physical terms (such as tons of sludge produced and increase in the temperature of receiving water), such analyses should also include the costs of complying with regulations and licensing conditions and costs to repair associated environmental damage. Still other factors—such as operating costs or environmental impacts associated with the construction of a facility and the manufacture of its capital equipment—could be included to broaden the analysis even further. For example, the price consumers pay for electricity does not always fully reflect the costs or benefits to the Nation of building and operating generating facilities. The indirect costs associated with electricity use, including the cost of some environmental and human health impacts, impose a burden on society that is not included in the price of electricity. Doing these analyses involves complexities, but it allows the comparable analysis of impacts across such disparate technologies as dispersed solar heating and centralized electric generation that employs fossil fuels.

Improving Environmental Quality

The National Energy Strategy provides an array of actions that improve energy efficiency and promote conservation, stimulate greater diversity of available energy sources and fuels, and modernize technologies for electric utilities, industry, transportation, and space heating and cooling. In nearly every case, implementing these actions has the added benefits of lowering the rates of emissions into air and water and reducing the hazard posed by wastes generated. These Strategy actions are discussed in detail in the previous two parts of this report: "Increasing Energy and Economic Efficiency" and "Securing Future Energy Supplies." These actions include:

- Increasing energy efficiency of appliances, vehicles, buildings, and industrial processes.
- Removing barriers to availability of lower emission fuels and energy sources, such as natural gas, biomass fuels, hydropower, and geothermal energy.
- Developing alternative fuel vehicles.
- Enhancing research on technologies that use renewable energy sources.
- Encouraging new nuclear powerplants by streamlining the permitting process for facilities and developing advanced reactors and the capacity to store and dispose of wastes.
- Advancing such fossil fuel technologies as clean coal, and shifting among the fossil fuels generally to lower emission fuels and technologies.
- Ensuring that advanced technology design incorporates systems to reduce pollutants at lower cost than traditional pollution control technologies that are simply add-ons to the waste stream.

Figures 37 to 47 (pages 150 and 151) show how emissions levels for various pollutants will be affected by implementing the National Energy Strategy, as compared with the Current Policy Base case. Results from the National Energy Strategy scenario include assumptions (for example, economic growth rates and fuel assumption prices) that are less certain as the forecast period increases. We have represented these uncertainties by providing ranges of potential results for specific years over the long term (2010–2030). Clearly, the Strategy reduces air and water pollution from energy activity overall, as well as minimizing the growth in energy-related waste streams.

Air Quality

Sulfur dioxide (SO_2) and nitrogen oxides (NO_x) are associated with the threat of acid rain. The Clean Air Act and National Energy Strategy actions will reduce SO_2 and NO_x well into the next century.

For example, Figure 37 provides comparisons of SO_2 projections prior to the Clean Air Act and the additional improvements from the act and the Strategy actions. By the year 2000, as a result of the act's enactment and National Energy Strategy actions, annual SO_2 emissions are expected to be 40 percent lower. By 2030, the reductions will be 35 to 45 percent below the projections prior to these actions. In Figure 37, additional SO_2 reductions as a result of the Strategy assume that new cost-effective technologies will be available and result in lowering SO_2 emissions below the required level (8 to 9 million tons annually), as specified in the Clean Air Act.

For NO_x emissions (Figure 38), the Clean Air Act will reduce annual levels until the year 2000, but these would grow steadily thereafter. However, the National Energy Strategy actions will appreciably reduce the *rate* of increase between 2000 and 2030. The set of actions can reduce NO_x annual emissions in 2030 by as much as 25 to 30 percent.

For other pollutants associated with urban air quality concerns—volatile organic compounds (VOC's) and carbon monoxide—similar results occur. For VOC's in both the current policies and the Strategy cases, steady growth in annual emissions is seen after the year 2000, but the maximum emission value reached in the Strategy case (in the year 2030) is 25 to 35 percent less than for the current policies (Figure 39). The carbon monoxide value in 2030 for the Strategy case is 35 to 45 percent less than for current policies (Figure 40).

Water Effluents

The effects of the National Energy Strategy are projected for two water effluent suspended solids, which are associated with coal mines, powerplants, and oil refineries (Figure 41), and oil and grease, associated with oil refineries (Figure 42). In both cases, significant reductions can be foreseen as a result of the Strategy.

Figure 37. Projected Emissions of Sulfur Dioxide

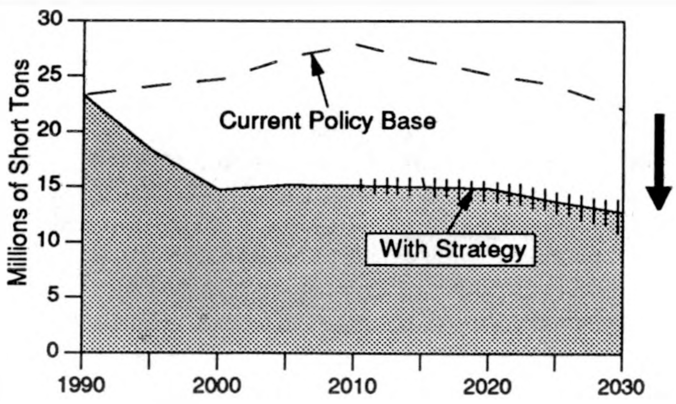


Figure 38. Projected Emissions of Nitrogen Oxides

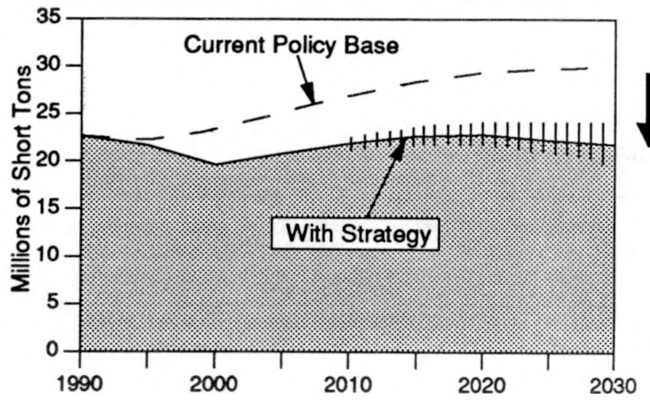


Figure 39. Projected Volatile Organic Compound Emissions

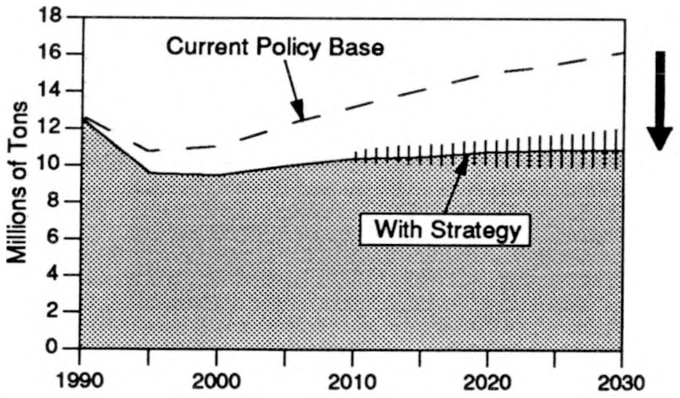


Figure 40. Projected Emissions for Carbon Monoxide

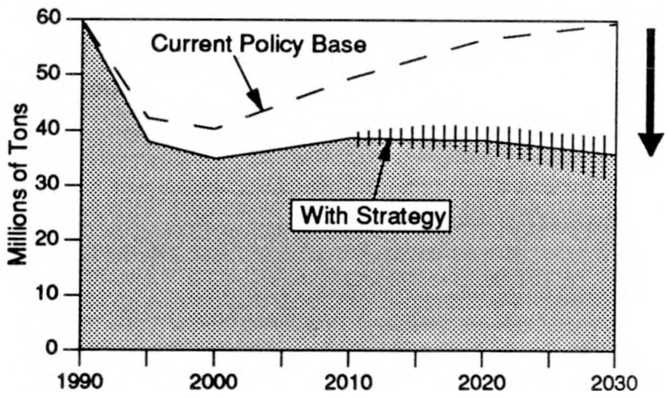


Figure 41. Projected Total Suspended Solid Effluents

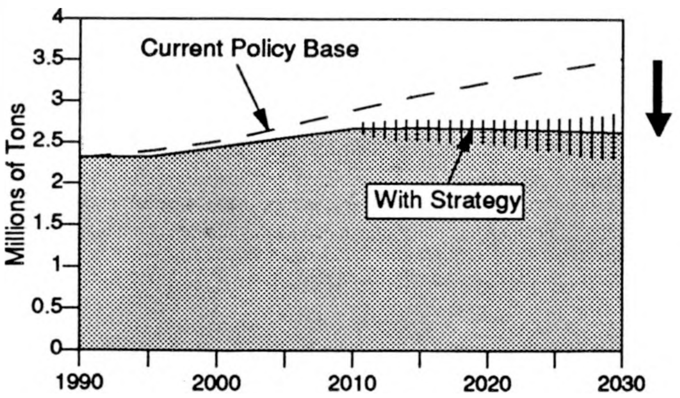


Figure 42. Projected Oil and Grease Effluents

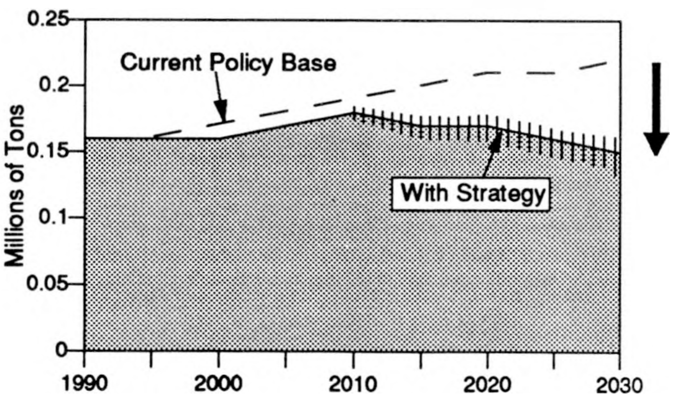


Figure 43. Projected Sulfur-Based Solid Wastes From Coal Combustion

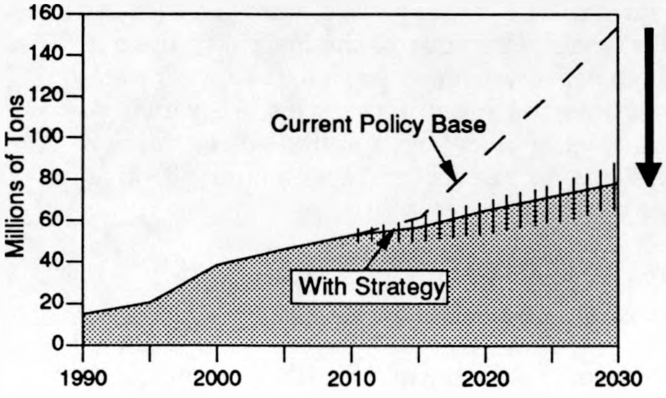


Figure 44. Projected Coal Ash

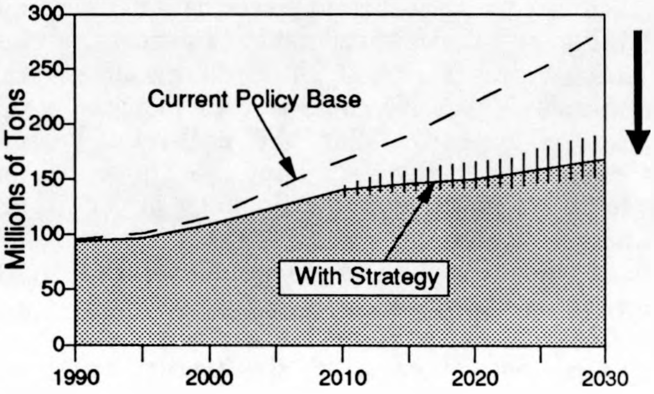


Figure 45. Projected Coal-Cleaning Wastes

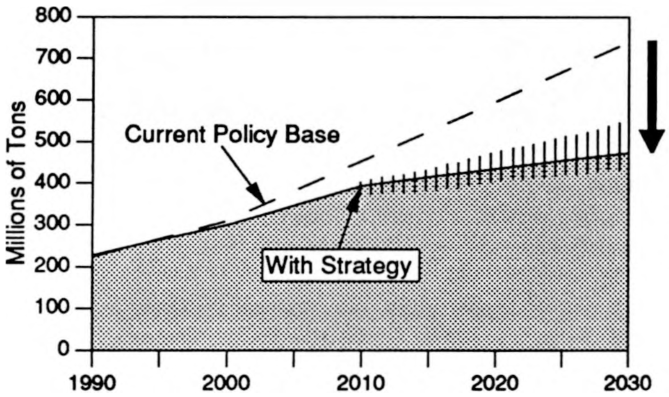


Figure 46. Projected Hazardous Waste Emissions From Petroleum Refining

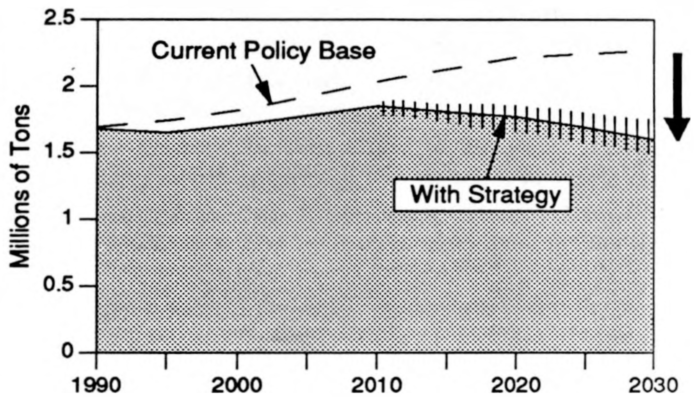
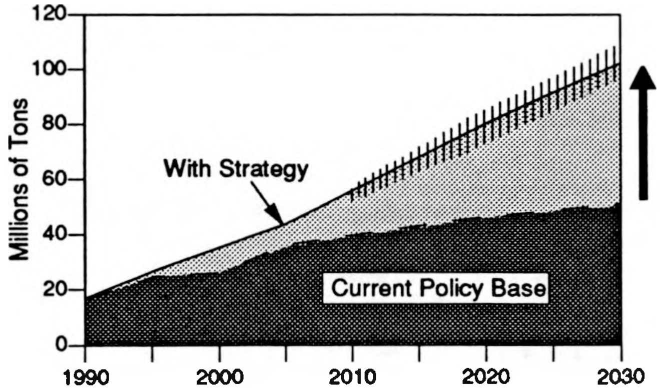


Figure 47. Projected Biomass Combustion Ash Wastes



Waste Volumes

The projected effects for the Strategy for waste volumes are provided for five categories: sulfur solids (associated with coal-fired powerplants' SO_2 controls) (Figure 43), coal-fired ashes (Figure 44), coal cleaning wastes (Figure 45), hazardous wastes from refineries (Figure 46), and ash from biomass combustion (Figure 47). For the coal-related wastes, there is growth throughout the 40-year period. Reduced coal use in the Strategy projections (along with improved technology) cut these anticipated rates of growth by at least 50 percent. For the refinery wastes, a 30-percent growth rate over the 40 years may be cut so there is no growth at all in the wastes because of the Strategy options.

The biomass ash waste projections in Figure 47 point out another element of the Strategy. Waste generation in the form of biomass ash will be considerably higher in the Strategy case than is expected under current policies—because the Strategy promotes alternative fuel sources. The Strategy recognizes that increased use of new technologies may cause higher levels of pollution. Therefore, the Strategy provides for identifying such potential environmental concerns early, and it includes research to minimize the volumes and risk of wastes and air and water pollutants.

Table 2 provides the National Energy Strategy actions, including the 1990 Amendments, that provide the greatest contributions to the reductions discussed above. These actions are discussed in detail in the previous two parts of this report: "Increasing Energy and Economic Efficiency" and "Securing Future Energy Supplies."

Flexibility in Meeting Environmental Requirements

Currently, compliance with environmental regulations is estimated to cost more than $100 billion per year and are growing. The Clean Air Act Amendments of 1990 are projected to cost more than $20 billion by 2000. The costs of the other laws are expected to increase as well; in particular, water and wastes laws are expected to be amended soon, adding new programs and thus new costs. The Strategy actions will reduce these costs while ensuring that the Nation benefits from enhanced environmental quality.

The water-quality laws and related waste management laws will be reviewed and amended over the next few years. Drawing on the insights gained in the Clean Air Act reauthorization, the Administration will work to strengthen existing programs and maintain water and land quality—using market mechanisms to reduce costs and add effective, flexible controls.

Analyses of Regulatory Impacts on Energy Facilities

A number of legislative and regulatory initiatives being considered to protect the environment could affect the economics of U.S. oil and gas exploration and production. Not all statutes require the U.S. Environmental Protection Agency (EPA) or other regulatory agencies to consider costs or energy impacts. For example, even when energy impact analyses are performed, they are often limited in scope because they generally only consider the impacts associated with a specific regulation and may not clearly show impacts from regulations in other areas. The cumulative costs of multiple future regulatory initiatives could affect U.S. crude oil production significantly.

The National Energy Strategy requires that the costs and other impacts or energy supply options be considered in all major rulemaking and legislative proposals as part of the analyses required under Executive Order 12291. An interagency group, led by the Department of Energy, will develop guidelines for preparing energy impact analyses. The Office of Management and Budget will review regulations to ensure that guidelines are being applied consistently. For example, regulations on petroleum refineries and municipal waste-to-energy plants would be models for developing energy impact analyses to assess compliance costs that could shut down domestic supplies and increase imports of foreign oil.

Emissions Trading

Emissions trading is a market-based incentive approach for reducing the cost of environmental compliance. Instead of relying on traditional or command-and-control policies that dictate how to

Table 2. Major National Energy Strategy Actions That Improve Environmental Quality (percent reduction from current policies)

	Air Pollutants						Water		Wastes			
	SO_2		NO_x		VOC		Suspended Solids		Coal Ash		Petroleum Hazardous Wastes	
Strategy Action	2000	2030	2000	2030	2000	2030	2000	2030	2000	2030	2000	2030
Clean Air Act, including clean coal	39	37	15	14	11	16	1	1	2	5	2	1
Alternative vehicles and fuels	*	1	0	1	1	2	1	3	0	0	3	8
Transportation technology R&D	0	0	3	9	10	27	0	8	0	0	1	20
Industrial energy-efficiency R&D	0	5	0	3	0	1	0	6	0	5	0	1
Integrated resource planning	1	5	1	3	0	0	1	3	1	10	1	0
Expanded nuclear energy	0	11	0	6	0	0	0	6	0	24	0	1
Natural gas reform	3	1	1	0	0	0	1	1	1	1	2	1

Note: Value is percent reduction below current policy resulting from the National Energy Strategy action. The combined effect of these actions will be less than the sum of the individual expected benefits.

*Less than 0.5 percent.

reduce pollution, emissions trading relies on the marketplace to reduce pollution from sources where reductions are least expensive. By relying on the marketplace rather than administrative fiat, the costs of environmental compliance can be reduced substantially.

Additionally, incentive-based policies promote innovation and efficient use of resources, both routes to better environmental performance; technology standards often stagnate technologies and provide disincentives for conservation of resources (such as fuel inputs). For example, the requirements to install scrubbers discouraged the innovation of better emissions-control techniques and gave no reward to utilities that used less fuel or less polluting fuel. In contrast, the new acid rain program, using a performance standard and tradable allowances, will encourage innovation and resource efficiency.

Under an emissions trading system, the Government sets the quantity of allowed emissions (or other resource use) and then issues allowances to emitters. The emitters can trade allowances among themselves but may generate only as much emissions as the number of allowances they hold for an applicable period. Emitters where costs of compliance are higher may decide to buy allowances, while those with a lower cost of compliance can invest added emissions reductions—freeing up allowances for selling. Each emitter has the flexibility to decide how to implement its own emissions reduction effort, including use of new control technology, use of new processes or materials, greater conservation, or the holding of allowances.

Emissions trading has been used in limited situations, such as the Clean Air Act's "bubble" and lead-phasedown programs. Environmental compliance costs in each program were reduced by many millions to billions of dollars, or about one-half of

General Provisions of the Clean Air Act Amendments

The Clean Air Act provides for the principal Federal authorities to control impacts on human health and the environment resulting from air emissions from industry, transportation, and space heating. The programs of the act were initially established in 1970 and had major amendments in 1977 and 1990. The primary programs are:

Setting National Ambient Air Quality Standards (NAAQS)

In the original 1970 programs, the atmospheric concentration of the six most universal pollutants must meet a set air-quality standard that protects human health and welfare and includes a margin of safety (the NAAQS). Nearly all regions meet the standards for SO_2, NO_x, and lead. However, because the standards for ozone, carbon monoxide, and particulate matter are not met as often, very specific new programs to bring the noncomplying areas into conformance with the NAAQS were included in the 1990 Amendments. Even though they take stringent steps, this will take some locales 20 years.

Setting New Source Performance Standards (NSPS)

For major new facilities that are projected to emit any pollutant in significant amounts, a national rate-of-control standard is established by the Environmental Protection Agency (EPA). It must be met or exceeded for the new unit to receive an operating permit.

New Source Review Permits

In the 1977 Amendments, some requirements were added beyond NSPS if a new plant is to be licensed. These permits require control levels that are at least as stringent as NSPS but that also reflect the best available control technologies. The precise level of control is set for each case in detailed reviews by the States.

Hazardous Air Pollutants

After a 1970 air-quality-based program to control emissions of hazardous (or toxic) air pollutants proved too complex to implement generally, the 1990 Amendments set up a new program to control 189 pollutants—using technology-based standards as a first step. This program will be fully implemented for both old and new plants by the year 2000. Then EPA will assess the residual risk level to determine whether additional controls are needed.

Mobile Sources

In each major legislative action, the level of emissions allowed from vehicles has been set for future model years. Additionally, controls on the fuel and its additives are specified. The 1990 Amendments will foster development of new fuels and of vehicles with lower emissions rates than those of gasoline and diesel engines.

Acid Rain Emissions From Electric Utilities

Because of the concern that the existing NAAQS and NSPS do not adequately reduce acid rain levels resulting from SO_2 and NO_x emissions, the 1990 Amendments set up a new two-stage program to control SO_2 and NO_x emissions. By the year 2000, SO_2 utility emissions will be held below 9 million tons per year, and NO_x national emissions will be reduced 2 million tons from their 1980 level.

Protecting Stratospheric Ozone (see "Energy and Global Environmental Issues")

The act also established programs to phase out the long-lived chemicals that affect the stratospheric ozone layer.

the estimated costs of a command-and-control program. The emissions trading system is an important component of the environmental compliance of the 1990 Amendments. It is the centerpiece of the compliance mechanism for acid rain (Title V). It is being used, along with an emissions fee, to phase out chlorofluorocarbons (CFC's) under the CFC's title, as well as under the Montreal Protocol.

Use of Market Mechanisms in the 1990 Amendments

Currently, EPA is writing rules to implement the emissions trading system in the acid rain title of the Clean Air Act Amendments of 1990 and has formed the Acid Rain Advisory Committee (ARAC) to involve other agencies in its rulemaking activities.

Use of Market Mechanisms To Reduce Costs in Water-Quality Regulation

The water-quality laws and related waste management laws will be reviewed and amended over the next few years. Drawing on the insights gained in the Clean Air Act reauthorization, the Administration will work to strengthen existing programs and maintain water quality using market mechanisms to reduce costs and add effective, flexible controls.

National Energy Strategy actions promoting energy conservation and improvements in technology efficiency will reduce total energy-related water pollutant emissions nationwide by reducing energy consumption. Strategy actions to minimize waste will also benefit the environment.

Use of Market Mechanisms in Other Environmental Laws and Regulations

As part of the National Energy Strategy, the Administration will identify other environmental programs to deploy market-based approaches to environmental compliance. For example, the emissions trading system could provide substantial cost reductions in environmental compliance under the Resource Conservation and Recovery Act (RCRA). An interagency group will be formed to identify opportunities for including market-based mechanisms (such as emissions trading and fees) in new legislation and in rules, regulations, and policies following from the new law, and to develop strategies for their effective implementation. The interagency group will give special consideration to multimedia approaches to emissions, fees applied to municipal solid wastes, fees or trading applied to hazardous wastes, and deposit-refund systems for selected hazardous wastes such as lead-acid batteries and solvents.

Total Fuel-Cycle Cost Analysis

In addressing energy-related environmental problems, the National Energy Strategy recognizes how much can be gained through improved methods of assessing the costs and benefits of energy production and use on a total fuel-cycle basis. Comparative analysis of this type helps to identify the environmental and economic tradeoffs associated with various energy technologies and alternatives under consideration. It also serves to identify potential problems early—as in the case of biomass wastes as noted earlier. This makes it more likely that technology development programs will assess the risks fully and move toward lower cost solutions in protecting environmental goals.

An increasing number of State regulatory authorities are requiring utility companies to include assessments of environmental, public health, and safety costs as part of the utilities' planning process. By improving its capabilities for such analysis, the Department of Energy will be able to help integrate environmental considerations into programs of energy technology development and transfer. It will also be in a position to provide critical environmental data that may be needed for energy policy and planning. In addition to State governments, the Department will be working with other countries to ensure that total fuel-cycle analysis is developed and considered in energy-related decisions.

Facility Siting and Land Use

Regional, State, and national needs to site new energy facilities must be balanced against local quality-of-life concerns. The environmental impacts of energy development are felt primarily at local levels, while benefits are spread more broadly. There has been a perception that public institutions have not been considerate of local views and protective of the public health, along with a general public mistrust of those institutions. These factors have resulted in local opposition to new energy-related facilities, some of which have few alternative sites because of the location of energy resources, transportation and transmission corridors, and space requirements.

Land-use decisions for energy facilities are controlled by a host of local, State, and Federal regulations. Many Federal laws affect land use and therefore energy development—for example, the Clean Air Act, the Federal Water Pollution Control Act, RCRA, the Coastal Zone Management Act, and the Wild and Scenic Rivers Act. Energy projects must typically obtain permits and licenses at the Federal, State, *and* local levels—permits that are frequently duplicative or overlapping. The absence of coordination among permitting or approving agencies may result in conflicting or contradictory terms and conditions for the developer. As a result, permitting and construction for some facilities have taken 10 to 20 years.

Federal lands contain about 33 percent of the Nation's coal reserves, 50 percent of the country's oil and gas fields, 40 percent of its uranium deposits, and 60 percent of its geothermal fields. There are substantial oil and gas reserves in areas of the Outer Continental Shelf and the coastal plain of the Arctic National Wildlife Refuge, and accelerated development of discovered resources on the Alaskan North Slope could significantly increase domestic production. When deciding whether to recover these resources, the environmental risks associated with exploration and development need to be weighed against the likely value of the resource. Public support for using these resources will depend on the quality of this information.

Environmental protection has increased substantially because of new technologies and alternative fuel resources. However, land-use and siting constraints are slowing some new technologies and facilities, thus reducing opportunities for even faster environmental improvement.

Energy Facility Siting Improvement

The National Energy Strategy calls for streamlining Federal and State licensing of new energy by developing model programs for siting facilities, identifying and implementing activities to expedite energy projects, and initiating other appropriate cooperative efforts. Better Federal-State coordination of siting and permitting activities will help protect environmental quality while reducing the construction time for new energy facilities. An interagency task force, chaired by the Council on Environmental Quality, will determine the role of the Federal Government in improving licensing procedures so energy projects can be expedited while protecting the environment. An example would be identifying areas in the existing laws (for example, the National Environmental Policy Act) where the permitting process can be improved. Also, the study will review existing State programs and will develop models (see the box on the Florida and Colorado programs) for consideration. If other actions are deemed necessary, the task force will recommend appropriate legislative solutions. Issues to be addressed include:

Model State Siting Programs

Two States—Florida and Colorado—have developed *consolidated* processes for facility siting and environmental permitting.

The Florida process is new, based on amendments to the State's Power Plant Siting Act and associated procedural rules that govern siting and environmental issues specific to powerplants (both coal-fired and nuclear-powered). The goal is to put in place a "one-stop" process, making it possible to resolve siting and environmental concerns more expeditiously.

The Colorado program is referred to as the "Joint Review Process." It closely follows the basic management principles contained in the Council on Environmental Quality regulations. Under this system, an *interagency* management team studies all pertinent siting and environmental permitting decisions. By consolidating all Federal, State, and local siting and environmental issues, this team approach streamlines the overall process. Furthermore, public participation and all necessary administrative elements are included.

- *Permitting and licensing processes for new energy-related activities should be streamlined.* Federal and State permitting and licensing of new energy-related activities can be complicated and time consuming. The process could be streamlined by satisfying, at a minimum, three primary goals: (1) set clear deadlines for all steps of the licensing process; (2) ensure early participation by all interested parties; and (3) ensure early identification and consideration of all environmental issues associated with a proposed action. Pertinent examples of permitting and licensing procedures that could be streamlined include those applicable to the siting and construction of waste-to-energy, hydropower, and nuclear power facilities.

- *Regulations governing nonhazardous wastes need to be established.* Under RCRA, EPA must promulgate regulations governing the management of nonhazardous wastes. Because the energy industry generates large volumes of nonhazardous wastes, growth—particularly within oil and gas development, mining and ore processing, and coal-fired power generation—is directly linked to regulations governing the management of these waste materials. Siting decisions regarding waste management facilities depend on EPA's regulations; at a minimum, the agency will establish consistent baseline guidance that would serve as a foundation for State programs.

- *Processes associated with the management of government lands need to be improved.* As noted above, the Federal Government owns and administers a significant amount of land. This land is rich in energy resources, and the recovery of these resources depends on Federal land management policies and procedures. We must determine the resource areas that will yield the most revenues and what are the potential risks. Past inadequacies in procedures have led to delayed or suspended minerals development activities and the subsequent delay or loss of Federal revenues.

- *Jurisdictional issues affecting energy industries need to be resolved.* The split between Federal and State jurisdiction concerning energy-related activities is incoherent. Jurisdiction over local matters should be vested in the States, while multistate matters should be vested in the Federal Government. As examples, two particular issues are of concern to the electric power industry. The first is the siting of multistate transmission lines. Currently, a State has the ability to impede or regulate interstate commerce in electricity, regardless of the actions of other States. A strong Federal role in the siting of multistate transmission lines should be considered. The second issue is intrastate wholesale sales. Consideration should be given to returning jurisdiction over intrastate wholesale transactions to the States, except in instances where there is a clear demonstration of a significant multistate impact.

- *Federal environmental laws and policies can result in conflicts between energy and land use.* While the Federal Government has been very active in promulgating environmental laws, comprehensive national land-use legislation has never been passed, and land-use laws primarily have been enacted by States. This results in a situation where Federal laws designed to provide environmental protection affect land-use decisions associated with energy-related activities, but without a set pattern. Federal and State environmental programs must be coordinated to achieve a level of environmental protection while allowing development of natural resources.

Assessment of Risks to Sensitive Lands

The estimated value of the gas and oil resources on the restricted Outer Continental Shelf and the Arctic National Wildlife Refuge does not include any values associated with environmental benefits or costs. The potential for each area may not be sufficient to justify the environmental risks of recovering and transporting these resources.

To make wise choices, the restricted areas will be analyzed and ranked according to the expected magnitude and value of the resource as well as the likely environmental consequences of exploration and development. Environmental impacts will be assessed on both an individual site basis and a cumulative basis. The environmental sensitivity of some areas, combined with the variable resource potential of individual areas, requires such a ranking to be used that incorporates both criteria.

Siting and Land-Use Issues

A wide range of Federal, State, and local laws and regulations constrain the siting of energy-related activities on environmental grounds. In general, four primary types of constraint are dominant:

- *Land availability.* Most energy-related operations require considerable land, but the problem here goes beyond merely finding operating sites. Among the prime examples are coal-fired steam-electric powerplants, which already generate large volumes of coal ash. Future requirements for controlling air pollution will contribute further to the generation of solid wastes (for example, flue-gas desulfurization sludge). The costs of transporting solid wastes to available disposal sites have been rising, and land for disposal sites near facilities tends to be difficult to find. Yet, the current emphasis on coal use suggests widespread conversion from oil and gas to coal in the future.

- *Environmental laws and regulations.* Comprehensive national land-use legislation has never been passed. Thus, assorted laws and their associated regulations affect the siting of energy-related operations. The Clean Air Act, the Clean Water Act, and RCRA are major examples. Many Federal environmental laws have created conflicts in relation to land-use decisions—in which State environmental and land-use programs also play a very important role.

- *Federal lands.* The Federal Government owns and administers roughly one-third of the land area of the United States, with most such holdings being concentrated in the Western States and Alaska. Much of this land is rich in energy resources, but their recovery depends on Federal land management policies.

- *Public opposition.* As public participation becomes a larger factor in the regulatory process, facility siting becomes more controversial. This is particularly true for the siting of powerplants, transmission systems, waste disposal facilities, and Outer Continental Shelf facilities.

Any or all of these factors can pose formidable barriers to energy-related activities across the United States—even in the case of replacement facilities, which may offer substantial improvement in environmental protection as compared with the continued operation of existing facilities.

Siting Process Improvements in Other Strategy Actions

Specific National Energy Strategy actions detailed in other parts of this report will also help improve licensing procedures. For example, the licensing of future nuclear powerplants will include improved emergency planning and postconstruction hearing provisions.

To facilitate construction of new natural gas pipeline capacity, the National Energy Strategy calls for the following (see "Natural Gas" for a detailed discussion):

- Allow interstate natural gas pipelines the alternative of building certain new capacity without a certificate from the Federal Energy Regulatory Commission (FERC) and clarifying the scope of section 311 of the Natural Gas Policy Act.

- Streamline the certification process by amending the Natural Gas Policy Act to make FERC the sole agency responsible for administering the National Environmental Policy Act environmental reviews in pipeline certification proceedings (although FERC could still be required to consult and solicit comments from other agencies).

- Establish deadlines for completing FERC reviews.

To reduce siting requirements for new hydroelectric facilities, the Strategy calls for improving the licensing procedure for expanding capacity at existing Federal and private dams, including:

- Require a single, multiagency review of projects, coordinated by FERC.
- Require agencies to recommend licensing conditions as part of the joint review.
- Designate FERC as the sole decisionmaking agency, if a consensus cannot be reached.
- Remove FERC jurisdiction over small projects if FERC cannot deregulate them with waivers and exemptions (see "Renewable Energy").

Urban Air Quality

EPA established the National Ambient Air Quality Standards (NAAQS) (under the auspices of the Clean Air Act of 1970) for six "criteria" air pollutants—SO_2, NO_x, particulate matter, ozone, lead, and carbon monoxide—to protect health and the environment. As a result, ambient concentrations of all of these regulated pollutants have decreased (some are shown in Figure 48). Despite these accomplishments, many major cities fail to meet the NAAQS for carbon monoxide and ozone (nonattainment areas for ozone are shown in Figure 49). However, urban air-quality problems will increase as the number of vehicles, miles traveled, and traffic congestion all grow, and as industrial and commercial activities expand, unless further emissions reduction opportunities exist.

Clean Air Act Amendments of 1990

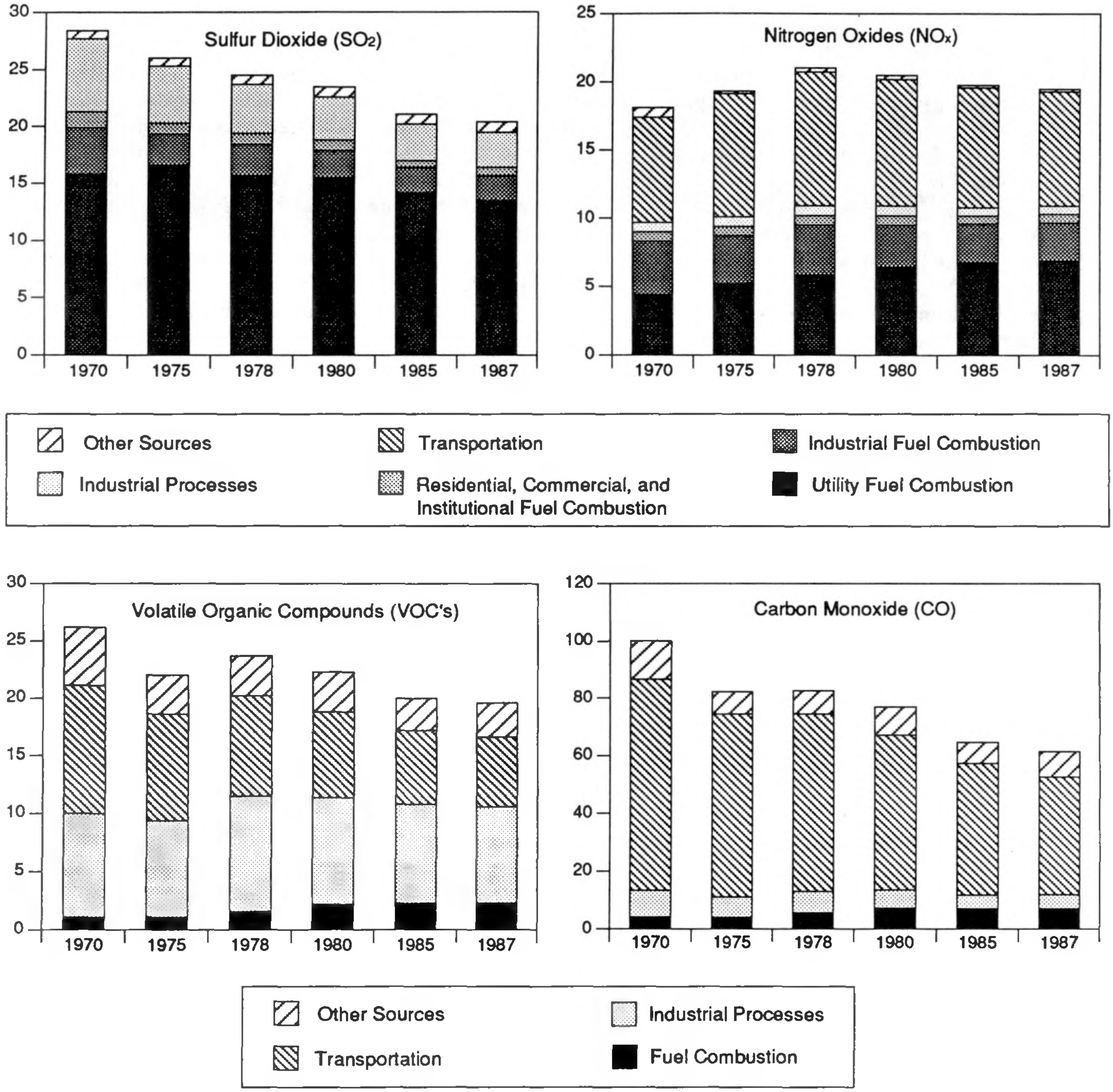
Despite an incomplete understanding of the atmospheric chemistry involved in ozone formation, it is generally accepted that large reductions in man-made volatile organic compound emissions will be required to achieve the NAAQS for ozone. Natural VOC emissions are substantial and peak during the summer months, the time when ozone nonattainment is most likely to occur. The passage of the Clean Air Act Amendments of 1990 will result in a tightening of control requirements in cities not attaining the NAAQS, including adding controls on small polluters (such as autobody shops, bakeries, and gas stations) and altering the composition of some products (such as paint and solvents). The amended act also requires tighter auto emissions standards, mandates cleaner gasoline and some clean-fueled vehicles in the Nation's most polluted cities, and may require additional or improved inspection and maintenance programs in some areas. Increasing the number of vehicles in fleets that use alternative fuels will lower reactive VOC emissions, because the emissions rates for such vehicles are lower than for similar gasoline-fueled vehicles. Implementing the 1990 Amendments will result in resuming reductions of national emissions levels, with the greatest reductions in present nonattainment areas. The reductions in national emissions levels projected from the 1990 Amendments for NO_x and VOC's are illustrated in Figures 37 and 38 on page 150.

Reduced Oil Use in Transportation

Achieving the emissions reductions required under the 1990 Amendments will be accelerated by initiatives in the National Energy Strategy. Several transportation-related initiatives, aimed at lowering oil use, would have the added benefit of lowering air pollution levels. For instance, accelerated scrappage of older cars, which have higher emissions rates, would hasten emissions reductions, especially in urban areas. Stimulating mass transit and ride sharing would lower automobile use and thus reduce NO_x, VOC's, carbon monoxide, and other emissions. Development of new and improved technologies that reduce energy use and emissions will be facilitated through increased research and development directed at developing advanced engines such as electric vehicles; high-speed rail and Magnetic Levitation; new, more energy-efficient aircraft designs; and advanced transportation fuels from biomass. (See "Enhanced Research and Development for Energy Security.")

In addition, a proposal jointly developed by the Department of Transportation and the Department of Energy to study corporate average fuel economy

Figure 48. Estimates of National Air Pollutant Emissions for Selected Years (million metric tons)



Note: Totals do not add because of rounding.

Sources: U.S. Environmental Protection Agency, *National Air Pollution Emission Estimates, 1940–1987,* 1989. (EPA–450/4–89–018)

(CAFE) legislation will provide initiatives to eliminate inequities in the current law and provide more flexibility (and hence lower costs) to car manufacturers to meet higher fuel-efficiency standards. The study could consider the technical feasibility and economic and safety impacts of higher fuel-economy standards. If total vehicle traffic stays the same, increased efficiency results in the lowering of all transportation-related emissions, especially evaporative VOC's and carbon dioxide.

The National Energy Strategy will reduce several air pollutants beyond the expected achievements of the 1990 Amendments. As Figures 37 and 38 illustrate, the combination of the National Energy Strategy actions described here and the Clean Air Act Amendments will reduce NO_x and VOC emissions 25 to 35 percent by 2030 from what is projected without these actions.

Acidic Deposition

Several air pollutants related to energy production and use—SO_2, NO_x, and VOC's—react in the atmosphere to form acidic compounds that are deposited on the Earth's surface in dry form or in rain, snow, or fog (phenomena collectively known as acidic deposition) (Figure 50). Acidic deposition affects aquatic systems, possibly some species of trees located at high elevations, building materials, human health, and visibility.

Clean Air Act Amendments of 1990

Containing emissions levels to below the required "cap" on SO_2 emissions will require careful planning and using technologies and fuels that have very low emissions rates. To meet near-term reductions required under the amended Clean Air Act's provisions, switching from high- to low-sulfur coal may prove to be the least-cost option. Other options for control, such as use of flue-gas desulfurization (FGD) devices, would result in reduced energy efficiency (lower electricity production per unit coal consumed) and would produce high-volume wastes that must be disposed of on land.

To achieve the emissions reductions called for in the recently amended Clean Air Act, powerplants are free to employ any continuously used method, including fuel switching and conservation. Not only must the emissions reduction targets be met by the existing units, but any emissions from new sources are required to be offset by emissions reductions from existing sources by the year 2000. A new system of "marketable permits" will be created to allow utility owners to trade permits, cost-effectively achieving emissions reduction goals (for example, a high-emissions plant would either reduce its emissions or pay for lower cost emissions reductions at other plants). (See also the earlier discussion on market mechanisms.)

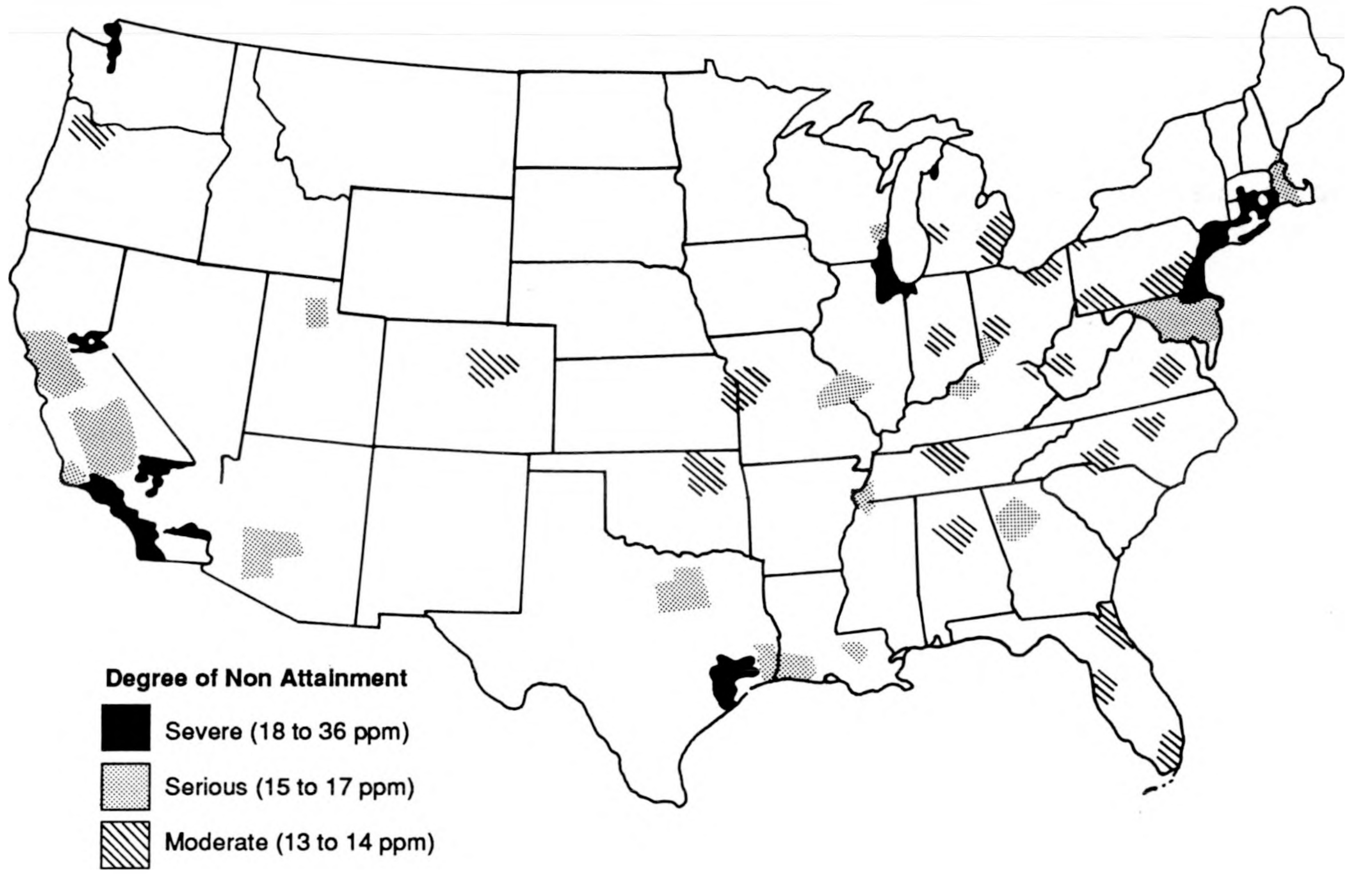
Increasing Energy Efficiency and Technology Development

Although the 1990 Amendments provide flexibility to utilities to map out their own strategies for compliance, the National Energy Strategy reduces market barriers and provides economic incentives to expand the potential of low-cost alternatives. These include:

- Increasing the availability of natural gas.
- Providing incentives and other means of promoting energy conservation.
- Increasing research and development and promoting the greater use of renewable energy technologies.
- Improving the licensing process for nuclear plants.
- Providing incentives and removing constraints associated with using clean coal technologies.

Compared to fuels such as residual oil and coal (which have higher sulfur contents and hence higher SO_2 emissions), natural gas achieves lower emissions of NO_x and virtually no SO_2. The National Energy Strategy reforms the natural gas pipeline certification process, deregulates gas pipeline sales rates, reforms gas pipeline rate design, improves gas pipeline transportation, and eliminates the Department of Energy's gas import/export regulation. (See "Natural Gas" for details of these actions.) All of these elements increase the availability of natural gas, increasing its ability to substitute for oil and coal.

Figure 49. Areas in Which Ozone Criteria Were Not Met, 1983–1985



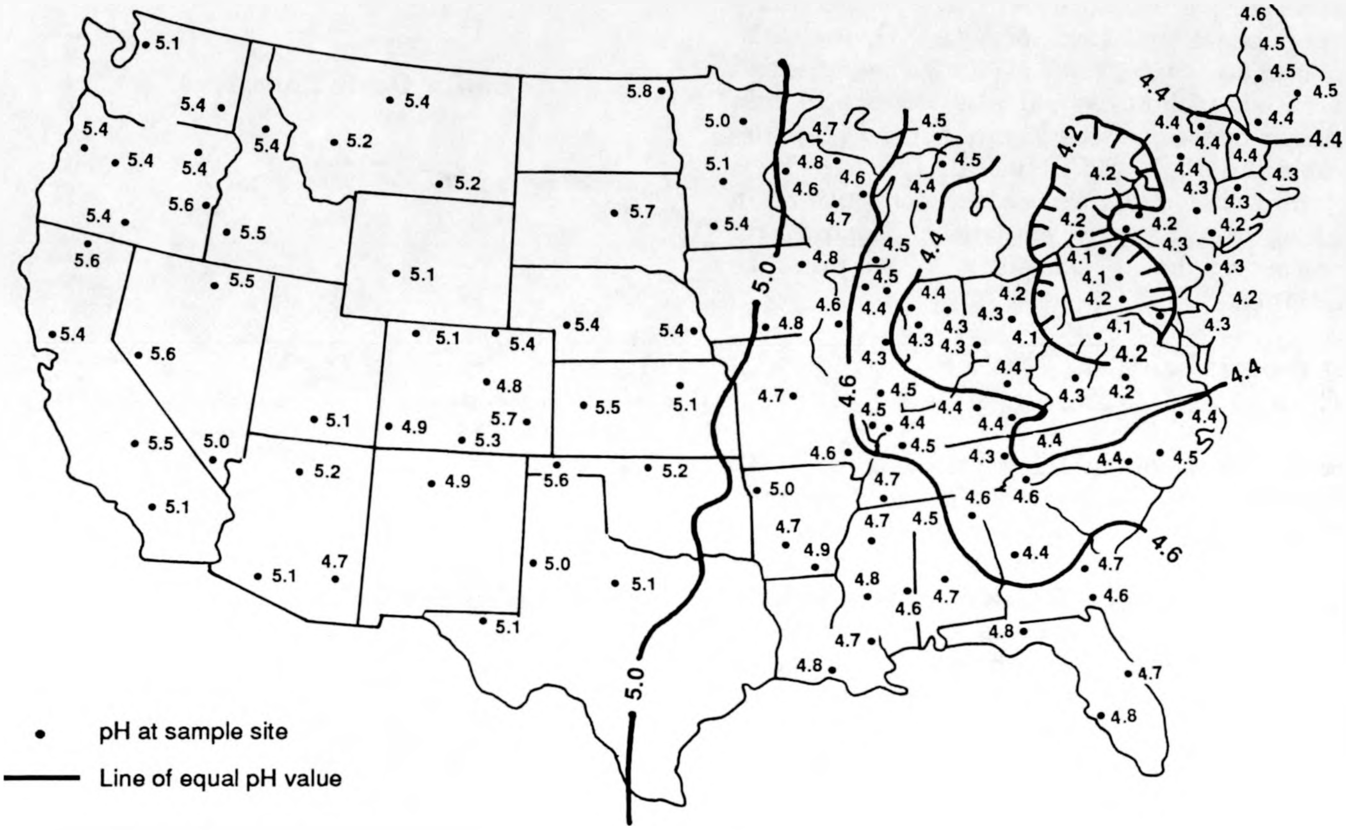
Source: Office of Technology Assessment, "Urban Ozone and the Clean Air Act: Problems and Proposals for Change," Staff Paper, April 1988.

NAAQS for Ozone

Ozone is produced through chemical reactions of NO_x and VOC's in the presence of sunlight. Nitrogen oxides are a combustion product of all fossil fuels. VOC's are a broad class of organic compounds found in solvents, gasoline, and other hydrocarbon products. A large portion of both pollutants come from small dispersed sources, making control programs difficult to implement.

EPA estimates that 23 urban areas can meet ozone standards by reducing VOC emissions by 25 percent or less; 25 areas need a 25- to 50-percent reduction; and 16 areas must cut them more than 50 percent. Some of the more serious nonattainment areas may also need controls on NO_x. In the past, emphasis has been placed on control of NO_x and VOC emissions from motor vehicles, but this has produced only partial success, so more sources are now targeted and control levels are tightened. However, each additional reduction may cost much more than those already achieved.

Figure 50. Acidity (pH) of Wet Deposition
1986 Annual Average



Note: The lower the number, the more acidic.
Source: National Acid Precipitation Assessment Program, *Annual Report*, 1986.

Acidic Deposition

Rainfall in much of the northeastern United States and southeastern Canada is more acidic than normal (with a pH of less than 5). The most acidic rainfall on an annual average basis falls in western Pennsylvania, eastern Ohio, and southwestern New York at pH levels in the range of 4.1–4.2 (see figure above). The greatest rate of recent increase of acidic deposition has occurred in the Southeast.

Acidic deposition from U.S. sources is generally associated with coal- and oil-fired powerplant emissions, primarily SO_2, from electric utilities in the Ohio River Valley. Electric powerplants (mostly coal-fired) produce about two-thirds of total national SO_2 emissions and are the second largest source of NO_x. The transportation sector is the largest single source of NO_x and VOC's. To date, VOC's have been targeted in efforts to reduce urban ozone; and SO_2 and NO_x emissions are the prime targets of acidic deposition control initiatives.

Various current Department of Energy program and National Energy Strategy energy-efficiency initiatives (discussed in the chapters covering the end-use sectors) would lower fuel and electricity use and hence emissions of both NO_x and SO_2. Increased use of renewable utility technologies and nuclear powerplants would also lower acid rain precursor emissions (see Figure 51 and also "Renewable Energy" and "Nuclear Power"). It is important that emissions reductions continue in the long run because electricity demand will increase, yet lower emissions levels must be maintained.

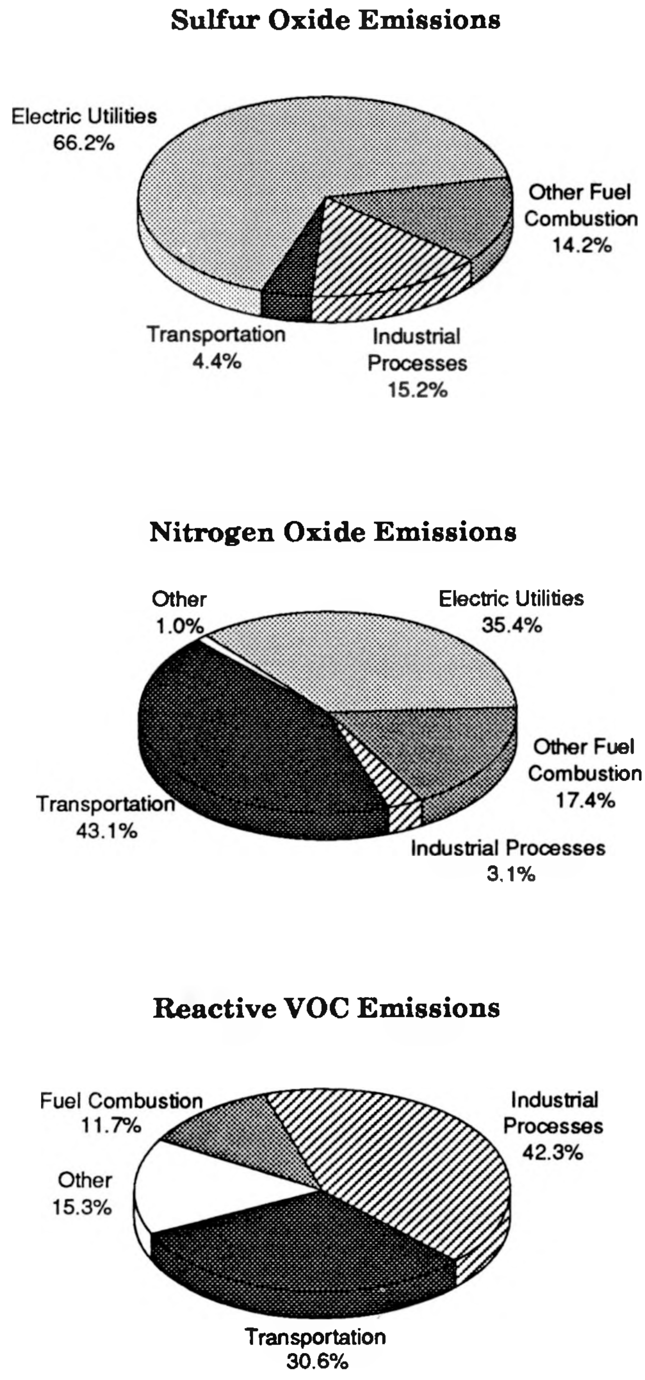
Commercialization of Clean Coal Technology

Another means of reducing both NO_x and SO_2 emissions, while increasing the range of commercially available electricity generation technologies, is to promote regulatory reforms and incentives for clean coal technology (CCT) development projects. CCT's have very low SO_2 emissions rates and have the extra advantage of significantly decreasing NO_x emissions compared to conventional coal-combustion technologies with today's FGD devices. In addition, many of the CCT's do not generate the high-volume solid wastes produced by conventional technologies with FGD, and they are highly energy efficient. Replacement or retrofitting of current high-emission powerplants with CCT and dependence on CCT for a significant portion of the Nation's new electricity demand will result in significant decreases in SO_2 and NO_x emissions and solid wastes, as well as higher energy efficiency.

The 1990 Amendments provide a 4-year extension for units that comply by using clean-coal repowering technologies. The National Energy Strategy will provide extra incentives for CCT's. By providing incentives and exemption of CCT's from new source review, simplifying siting and project approval procedures, reducing regulatory lag, and providing incentive rates of return, the National Energy Strategy will increase the use of CCT's. Of particular importance is the review by the Administration of its policies regarding new source review conditions.

Decreasing acid rain and its effects involves implementing the 1990 Amendments, together with the

Figure 51. Sources of Precursors of Ozone and Acid Deposition, 1987



Source: U.S. Environmental Protection Agency, *National Air Pollutant Emission Estimates, 1940-1987,* 1989. (EPA-450/4-89-018)

Strategy initiatives to develop innovative technologies that will further reduce emissions rates. National Energy Strategy initiatives increase the technological alternatives available to utilities for reducing their emissions, often lowering costs. Figure 37 (page 150) provides projections of annual SO_2 emissions as a result of implementation of the 1990 Amendments and implementation of the National Energy Strategy. Figure 38 (also on page 150) includes similar projections for NO_x. Dramatic early reductions result from the 1990 Amendments; continuation of these trends are provided by the lower cost measures of the National Energy Strategy.

Modification of New Source Review for Existing Powerplants

All *new* powerplants must meet the new source requirements of the Clean Air Act. In addition, *existing* powerplants also may be required to comply with the same new source requirements if they are "modified." The EPA policy of applying new source requirements to "modified" existing plants is often referred to as "WEPCO," named after a 1988 EPA decision involving a plant refurbished by the Wisconsin Electric Power Company.

Although the WEPCO policy has been applied in only one major instance so far, there is concern that it may be applied to many more powerplants in the future. For example, the installation of pollution control equipment could be determined to be a modification, causing a powerplant to undergo new source review, with its attendant costs and delay. This is especially important because of the need to control emissions of SO_2, NO_x, and other pollutants that is required by the 1990 Amendments.

In addition to pollution control measures, the repair or replacement of worn out or damaged plant equipment also can cause an existing plant to undergo new source review. This is expected to become a critical issue as the larger powerplants built in the 1960's and later undertake maintenance, repair, and replacement programs to maintain their reliability and safety and to make efficiency improvements.

The 1990 Amendments addressed only those circumstances where the installation of certain CCT demonstration projects might subject a plant to new source requirements. Other potential problems associated with WEPCO were not addressed, leaving EPA to resolve those problems.

EPA will issue a WEPCO interpretative ruling to implement (to the extent possible) the policy changes that were proposed by the Administration as part of the clean air debate last year. If all provisions of the Administration proposal cannot be implemented by EPA, a new legislative proposal will be developed for those provisions that require changes to the Clean Air Act.

Air Toxics

A large amount of toxic air pollutants—approximately 1.3 million tons—is released each year by chemical and manufacturing facilities. EPA estimates that facilities in 37 States release toxic air pollutants that increase cancer risk. Furthermore, toxic pollutants can migrate to surface- and groundwater, where they may pose added risk to the environment and human health. Such pollutants may also be taken up by crops and distributed throughout the food chain. Although many of the control technologies for conventional pollutants also remove air toxics, additional controls are required.

Energy-related sources of air toxics include oil- and coal-fired utility boilers, petroleum refineries, oil and gas exploration and production operations, and waste-to-energy plants. In addition, benzene and diesel particulate emissions from motor vehicles may present a significant cancer risk in urban areas. Hence, added costs to maintain air quality will be borne by units in the energy sector.

Regulation of Air Toxics

By law, electric utility hazardous air pollution emissions will be studied in a 3-year program to determine the need to add additional control technologies on steam-generating units. A special study of mercury emissions over 4 years will also be carried out. If the EPA Administrator deems that added controls for toxic pollutants are necessary and effective, regulations will be promulgated.

The Hazardous Air Pollutant Title (Title III) of the 1990 Amendments establishes a list of 189 hazardous pollutants to be regulated and requires that maximum achievable control technology (MACT) be applied on plants that are major sources of these air toxics. After MACT controls are installed, EPA is to assess remaining health risks and issue more stringent "residual risk" standards if needed. A list of all categories of major sources (such as oil refineries, chemical plants, and steel plants) is to be established by EPA. Timetables to issue MACT standards (ranging from 2 to 10 years after enactment) are specified in the 1990 Amendments.

The Amendments also call for a study of the hazardous air pollutants from motor vehicles and motor vehicle fuels; and depending on the results, EPA must regulate these pollutants. At a minimum, regulations must be issued for benzene and formaldehyde. In addition, the act requires greater use of oxygen-containing additives, such as ethanol and MTBE (a natural gas additive), which may lower emissions of air toxics and other pollutants.

Radionuclides

Radionuclide emissions are a byproduct of nuclear power generation, medical uses, nuclear material, pharmaceuticals, and many research applications. Radionuclide emissions are currently regulated under three authorities: the Atomic Energy Act gives authority to the Nuclear Regulatory Commission (NRC); the Clean Air Act provides authority to EPA; and State governments can impose additional standards on radionuclide sources. In the past, there were two Federal agencies regulating the nuclear power industry and other users of nuclear material. The States could impose standards to prevent the siting of certain energy facilities. Multiple standards for nuclear powerplants reduce the potential for successful development of new standardized plants.

Rulemaking Changes of the 1990 Amendments

The 1990 Amendments state that EPA can choose not to issue radionuclide emissions standards for sources licensed by NRC if EPA determines that NRC regulations provide an ample margin of safety. In the past, EPA has found that the NRC regulations provide ample margins of safety, reducing the need for further regulation.

Consistent Regulation by States

As part of the National Energy Strategy, an interagency group will examine State regulatory practices. The group will study State practices in applying standards and permitting requirements among various radionuclide sources. Based on the results of its analyses, the group may propose legislation to ensure that State regulations reflecting health and safety needs do not discriminate among *sources* of radionuclides.

Water Quality

About 20 percent of all "point sources" of water pollution in the United States are energy-related. Electric powerplants, petroleum refineries, coal and uranium mines, and some oil wells discharge a wide range of contaminants directly into surface waters. For example, Figure 52 shows principal coal deposits and streams affected by acid mine drainage. The Clean Water Act, which regulates direct discharges, has generally improved surface-water quality.

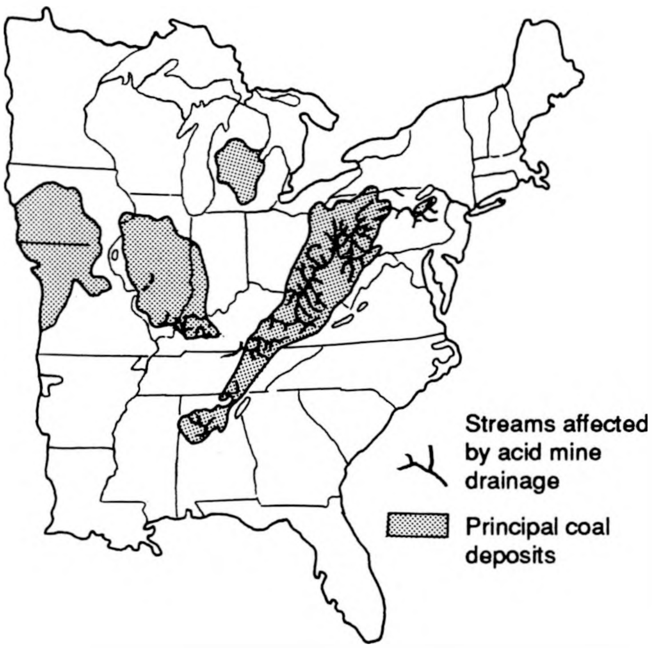
Under the Oil Pollution Act of 1990, most oil tankers and barges will be required to have double hulls by 2015. Additional provisions would increase navigational safety and expand research on the environmental impacts of (and cleanup methods for) oil spills. The laws preserve States' rights to have stricter liability laws than Federal authorities and to have their own oil-spill compensation funds.

Alternative energy technologies and fuels developed to respond to air-quality or other "energy security" concerns may have unanticipated impacts on water quality. For example, if methanol spills during its transportation and use or leaks from methanol storage tanks, it may potentially contaminate surface water and groundwater. Runoff from agricultural activities can increase the levels of suspended solids, nutrients, and pesticides in water bodies. This is a potential concern for biomass grown for energy applications, although the effluent rate from such "energy crops" is likely to be lower than from many common food crops.

A number of Federal regulatory authorities address groundwater-quality concerns. For example, the 1984 amendments to the Resource Conservation and Recovery Act impose stringent design and technological requirements—such as bottom liners and leachate collection systems—on hazardous waste disposal sites. (A bottom liner is an impermeable barrier to prevent leachate—a liquid resulting from water trickling through waste—from leaking out of a landfill.) RCRA will reduce both the quantity and toxicity of wastes. In addition, RCRA regulations require owners of underground storage tanks containing petroleum to prevent, detect, and correct any leaks—and to have the financial resources to do so.

Protecting the Nation's groundwater has become a growing environmental concern. Although the current extent of groundwater contamination is estimated to be small—probably around 1 to 2 percent—only a fraction of the total groundwater resource has actually been tested. Groundwater supplies drinking water for more than half of the U.S. population (including about 97 percent of rural residents) and provides 40 percent of the Nation's irrigation needs. While controls on potential sources of groundwater contamination are required by various environmental statutes, there is no comprehensive approach to protecting groundwater—partly because of the issues involved in State versus Federal jurisdiction over groundwater. The problem is compounded because of the numerous and diverse sources of contamination and the fact that aquifers, once contaminated, can be extremely difficult, costly, and in many cases, impossible, to clean up.

Figure 52. Principal Coal Deposits and Streams Affected by Acid Mine Drainage



Source: The Water Conservation Foundation, *Ground-Water Protection*, Washington, DC, 1987.

The primary public health concern over contaminated groundwater relates to its use as drinking water. As it arrives at the tap, groundwater may contain volatile and synthetic organic contaminants, such as pesticides, several organic chemicals falling under the group known as trihalomethanes, and several natural and manmade radionuclides, including radon. These contaminants are produced by both industry and agriculture.

Energy industries are significant *potential* sources of groundwater contamination. Transporting, storing, and handling petroleum and petroleum products can result in accidental releases, which can reach groundwater. Coal storage areas and waste disposal sites are also potential sources of contamination. The extraction of energy resources (for example, coal and uranium mining and oil and gas production) can also contaminate aquifers.

The Superfund program identifies and cleans up the country's worst toxic waste dumps and thus addresses groundwater contamination from past energy-related waste disposal activities. Additionally, the Safe Drinking Water Act, which requires permits for all injection wells (wells into which fluids are injected), controls the underground injection of wastes and the reinjection of water produced during oil and gas extraction. Injection well permits consider the well's location, the material injected, and the distance from underground drinking water supplies; they also ensure that energy-related injection is environmentally acceptable.

Clean-Water Legislation Improvement

As the Clean Water Act is reauthorized in the early 1990's, the Administration will endeavor to improve controls and regulatory programs as needed, to allow greater flexibility and lower cost methods for regulated industries to achieve the regulations, and to reduce conflicting and overlapping programs. Early actions on the Clean Water Act and in RCRA will begin this spring.

Oil Spill Reduction

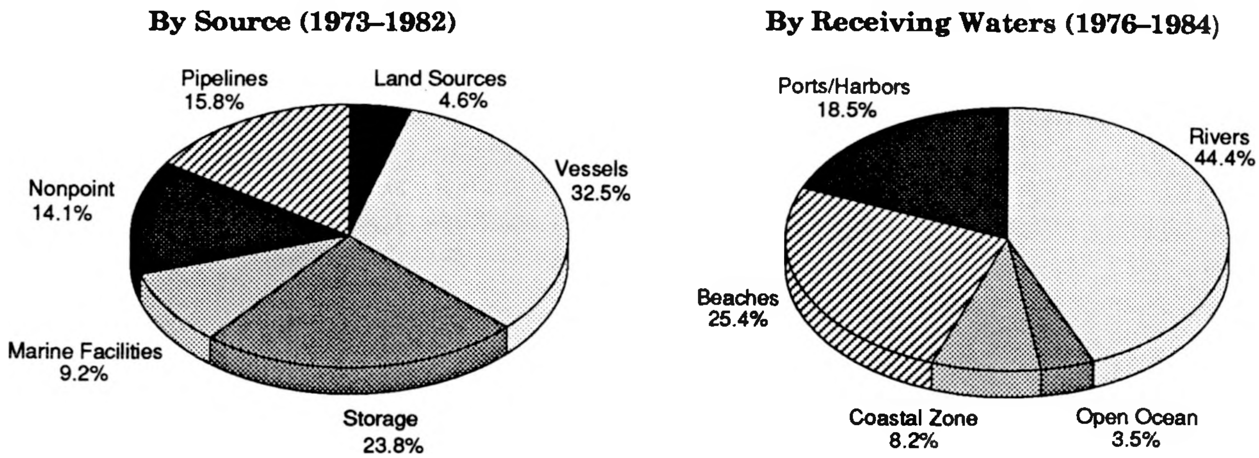
Compliance with the Oil Pollution Act of 1990 will improve tanker safety, help reduce risks from potential accidents, and provide storage incentives for transporters to prevent accidents. Figure 53 provides data on oil spills.

Effective Waste Management

Managing the wastes from nonnuclear energy production is a significant environmental and economic issue. Coal-fired electric utilities generate large volumes of solid combustion wastes that must be disposed of properly. Disposal of wastes from both the coal and the petroleum fuel cycles is becoming a significant component of total production costs, as environmental regulations become more stringent. In fact, the costs of complying with environmental requirements in waste management are becoming a larger portion of overall spending across all industries. As costs rise, greater emphasis will be placed on pollution prevention rather than treatment of wastes that are produced.

Human exposure to the contaminants contained in wastes can occur through a variety of means. However, the impacts of hazardous wastes to

Figure 53. Percent Volume of Oil Spilled by Source and by Receiving Waters



Source: Council on Environmental Quality, Executive Office of the President, *Environmental Trends,* 1989.

Oil spills can have significant adverse impacts on water quality. In 1990, the U.S. Coast Guard reported 5,000 to 6,000 spills involving either oil or other toxic substances in U.S. waters. According to a recent petroleum industry task force report, roughly 90 percent of reported oil spills for the 10-year period ending in 1986 involved less than 1 ton (7.2 barrels, or 302 gallons) of oil; an average of only two spills per year involved more than 3,500 tons (25,200 barrels).

Oil spills occur in both marine and freshwater environments. The large majority is spilled in river channels, ports, and harbors, or within 3 miles of shore; less than 5 percent is typically spilled outside of this 3-mile zone. The largest spills are from tank ships and tank barges, with the primary causes being ruptures in hulls and tanks.

public health are often difficult to assess. There is considerable controversy about the risks posed by hazardous wastes, with the public ranking this as an issue of high priority while some scientists believe that these risks are less than risks associated with other environmental concerns. A key factor in reducing these risks is the containment of wastes to reduce the likelihood of exposure via air, water, or soil.

The quantity and toxicity of nonnuclear energy production wastes that require disposal are a function of the levels of domestic energy production and use; the mix of energy sources; the types and level of treatment applied (including waste reduction and recycling); and the degree to which other environmental controls are applied to energy sources (for example, particulate and SO_2 emissions controls on coal- and oil-fired electric utilities and industrial boilers). Implementing more stringent air pollution controls under the Clean Air Act Amendments of 1990 is expected to result in dramatic increases in the already large volumes of coal-processing and coal-combustion wastes generated by electric utilities.

The large majority of energy-related wastes are stored and disposed of on land—either in surface enclosures, reserve pits, or landfills, or by soil application. Largely because of concerns about potential groundwater contamination, there has been a trend toward better containment for those wastes that continue to be stored and deposited on land. EPA estimates that the total private-sector spending on land-based waste management will increase by $10.3 billion from 1987 to 2000. Efforts to improve the economic efficiency and cost-effectiveness of these expenditures can be constrained by:

- Existing legislative mandates that do not provide acceptable rulemaking flexibility.
- Regulatory frameworks that discourage advanced control technologies, efficiencies, and cost-saving approaches.
- Regulatory and siting issues that delay the introduction of less polluting facilities and processes.

These concerns are addressed by the National Energy Strategy for all environmental media, as discussed under the general goals earlier.

A major opportunity to introduce more flexible and less costly management programs will be the reauthorization and the amendment of RCRA, expected to be taken up with the current Congress.

Legislative and Regulatory Program Improvement

RCRA is likely to be amended by Congress in the early 1990's, perhaps as early as 1992. The Administration will develop proposals for effective, flexible, and cost-effective legislative and regulatory programs, as was done in the jointly developed Clean Air Act Amendments of 1990.

Experience with market-based incentives, such as the emissions trading systems used in the Clean Air Act's air-quality attainment and lead-phasedown programs, indicates that they can achieve similar or better health and environmental protection results while substantially cutting the costs of compliance—often in half.

Waste Reduction

As waste management costs and liabilities increase, industry is focusing on waste reduction as a cost-effective control technique. Waste reduction focuses on in-plant practices that minimize, avoid, or eliminate the generation of waste. Waste reduction techniques can include in-process recycling of wastes or their components, changes to process technology or equipment, improved plant maintenance and operations, and changes in raw materials to those with lower levels of contaminants.

Waste reduction provides an alternative to many existing pollution control methods that do little more than move waste from one medium to another. For example, the control of air pollutants from coal-fired electric utilities results in large volumes of coal-combustion wastes, which require proper landfill disposal. Because of the existing environmental regulatory structure, more than 99 percent of Federal and State environmental spending has been devoted to controlling pollution *after it is generated*. The present "command and control" regulatory approach tends to stifle innovation and the development of waste-reduction approaches.

Although many industries support the concept and viability of waste reduction, the immediate requirements of current environmental regulations and timetables may limit the amount of time, thought, and money that industry can devote to waste reduction. Although progress in research and development will eventually allow many wastes to be converted into resources, restructured regulations can provide incentives for minimizing waste in the nearer term.

Capturing the full potential of waste reduction requires a speeding up in innovation—through carefully selected industry-government research consortia and a regulatory environment that encourages investments that reduce emissions, effluents, and wastes at the lowest cost instead of concentrating on end-of-pipe regulation. The Pollution Prevention Act of 1990 places a high priority on reducing or eliminating wastes at their source and recycling or treating any waste that is generated. The *disposal* of waste is a last resort.

The reauthorization of RCRA will provide opportunities to include incentives for pursuing waste reduction in flexible, cost-effective ways—and as an integral part of facility and technology modernization. Additionally, the Strategy includes the following actions.

Removal of Regulatory Constraints. The Department of Energy and EPA will determine the extent to which existing regulatory programs discourage investment in innovative waste and pollutant minimization technologies. They will propose legislation or regulatory changes to encourage such investment.

Outreach Programs and Improved Information. The Department of Energy will develop an active outreach program to communicate waste-reduction results to the academic community, engineering community, commercial sector, industrial production and manufacturing community, and the public. Workshops and energy audits will help industry identify opportunities and barriers to implementing waste minimization technology. This effort should be coordinated with EPA's outreach mechanisms and activities.

To better understand the significance of waste minimization for energy and the environment, a strategy of data collection and analysis activities is essential. Energy-related data will be developed through cooperation with the Department's Energy Information Administration, EPA, the Bureau of the Census, and other Federal data collection agencies. Cooperation with industry and industrial associations will be used to further strengthen the Department's and others' knowledge of waste-reduction opportunities.

Waste Minimization Research and Development. As technical barriers are identified, the expertise available in Federal laboratories will be used to address specific industry problems, using cooperative research and development agreements and other creative mechanisms to identify, research, demonstrate, and transfer new minimization systems.

Energy and Global Environmental Issues

Despite large uncertainties regarding potential global climate change, there is sufficient scientific concern to have persuaded the world community to start acting to curb the buildup of the so-called "greenhouse gases"—a number of which are related to the production or use of energy. Some of these gases also have been depleting the stratospheric ozone layer, which absorbs potentially harmful ultraviolet radiation from the Sun.

Rising global temperatures could result from increasing greenhouse gas emissions, and this could change regional climates in ways that are not fully understood. Based on a recent United Nations scientific assessment, continued growth in the releases of greenhouse gases as currently projected could lead to a worldwide increase of 1°C (1.8°F) by the year 2025 and a 3°C (5.5°F) increase by the end of the next century. Such a degree of warming could raise the sea level by 8 inches in 2030 and by more than 2 feet by the end of the next century. Temperatures and sea-level impacts are both highly uncertain. Growth in concentrations of carbon dioxide (CO_2), a greenhouse gas, will improve the efficiency of photosynthesis and increase growth of some species. It also could affect agriculture by changing soil moisture and the availability of water.

The U.S. strategy for addressing global climate change is to take a comprehensive approach that incorporates all of the sources and the sinks of all greenhouse gases. The major gases from manmade sources include CO_2, methane (CH_4), nitrous oxide (N_2O), tropospheric ozone, carbon monoxide (CO), and chlorofluorocarbons (CFC's). CFC's deplete the stratospheric ozone layer as well as add to the potential for warming. Sources of these gases include energy, agriculture, industry, and deforestation. Recognized sinks of greenhouse gases are the oceans, added trees, and other vegetation. The U.S. strategy not only will consider steps to reduce the emission sources, but also will increase the planting of trees (which absorb carbon dioxide) and will conduct research on how to increase other sinks.

The National Energy Strategy provides a series of actions that will reduce greenhouse gases from future energy production and use. The Strategy includes actions to provide cost-effective alternatives to burning fossil fuels during generation of electricity and to encourage greater use of alternative fuels and vehicle fuel efficiency (thereby reducing the amount of gases produced from exhausts). These actions—when added to the actions already under way, such as the recently passed Clean Air Act Amendments of 1990, the phaseout of CFC's, and the Presidential initiative to plant more trees—should, based on the National Energy Strategy scenario, hold the U.S. contribution to potential global warming at or below the 1990 level into the foreseeable future. While there is greater uncertainty regarding projected results in the future years, the Strategy will significantly lower energy-related greenhouse gas emissions relative to any current policy.

Actions by the United States and other industrialized nations alone will not reduce the buildup of greenhouse gases in the atmosphere. For example, while the U.S. share of world CO_2 emissions is declining, the contribution from countries of the developing world continues to increase. By 2025, the developing countries' share of CO_2 output is projected to be about 48 percent of the world total. By contrast, the U.S. share will be 14 percent of the total.

International cooperation on control of CFC's has been effective. All major CFC-producing countries and more than 50 other countries have begun to implement internationally coordinated control programs. Recently, these countries agreed not only to phase out CFC's and related gases but also to accelerate the phaseout process.

Goals and Approaches

The National Energy Strategy includes four key goals for addressing global climate change. The overriding theme behind these goals is to reduce

Goals and Approaches—Energy and Global Environmental Issues

Goal	Approach
Improve understanding of the emissions and processes that could potentially change global climate, as well as the associated impacts and the possible control and mitigation measures	• Carry out current U.S. research programs • Continue to evaluate and focus U.S. research programs to reflect current national and international assessments
Improve energy efficiency and shift to energy sources and technologies that emit fewer greenhouse gases. Emphasize responses that are justified for reasons other than potential climate change	• Support a wide range of energy-efficiency initiatives • Increase market acceptance of lower emitting technologies and energy sources
Cooperate with other countries to improve understanding of potential global climate change and its impact, and to develop a consensus on appropriate responses	• Support technical efforts of the Intergovernmental Panel on Climate Change (IPCC) • Participate in the Intergovernmental Negotiating Committee convened by the United Nations General Assembly to negotiate a framework convention on climate change
Protect the stratospheric ozone layer through strengthening the current international agreement	• Implement the stratospheric ozone protection provisions contained in the Clean Air Act Amendments of 1990 and achieve added reductions due to a tax on ozone-depleting chemicals used in the United States

the scientific uncertainty associated with climate change and to develop cost-effective, long-term strategies that will balance energy and environmental needs.

The approach taken in the Strategy will be not only to improve our capability to determine if climate change is occurring, but also to estimate the potential impacts of this change. The National Energy Strategy will expand the number of initiatives taken primarily for other energy and environmental reasons that will also reduce the growth in U.S. greenhouse gas emissions. In addition, the Strategy will provide a series of actions to support U.S. efforts to develop an international consensus on the appropriate worldwide response strategies.

The above table summarizes these goals and approaches.

Expected Results

With National Energy Strategy actions, the United States' annual CO_2 and CH_4 emissions would be held to slow increases until 2015, reaching a level of 25 percent above today's level, and then decline steadily. (This is based on the National Energy Strategy scenario as described in Appendix C.) The improvement that Administration policies will make in reducing U.S. use of CFC's is even more dramatic. The major long-term contributors to stratospheric ozone depletion and potential warming will be phased out of use by 2002; the short-term contributors, by 2030. If other countries take similar actions, the present small deterioration of the ozone layer will be fully reversed by about 2060. Further, the total U.S. greenhouse gas emissions as measured by "global warming potential" (GWP) would, in the National Energy Strategy scenario, remain at or below present levels for the foreseeable future (Figure 54).

Uncertainties of Potential Climate Change

Worldwide concern about global climate change has resulted in a major assessment of the scientific research on climate change. Under the United Nations Environment Program (UNEP) and the World Meteorological Organization (WMO), an *ad hoc* study group—the Intergovernmental Panel on Climate Change (IPCC)—was formed in November 1988. Scientists, economists, and policymakers from many countries participated in the 2-year assessment, released in August 1990.

The IPCC scientific assessment points out that uncertainties about some of the most basic issues will require a substantial investment, and many years, to resolve. For example, the report estimates that it may take a decade or more to unequivocally detect by observation that man-induced climate change has occurred. Key areas of uncertainty within the earth sciences are how clouds respond to the buildup of greenhouse gases and temperature changes, how heat is exchanged between the ocean and the atmosphere, how heat is transported among the ocean layers and regions, how the atmosphere takes up and releases greenhouse gases, and how polar ice sheets may change (which affects predictions of sea-level rise and albedo). The IPCC report of potential impacts on natural and socioeconomic systems notes that the confidence in regional estimates of critical climatic factors is particularly low, especially for precipitation and soil moisture.

The United States as early as the late 1970's recognized the need to increase understanding of climate change and its major components, such as the carbon cycle. We are the country with the largest research budget. U.S. research programs continue to expand, with efforts coordinated by the Committee on Earth and Environmental Sciences (CEES). The earth sciences portion of the budget for fiscal year 1992 will be $1.2 billion, and budgets for the impacts and economic analysis areas are rapidly expanding.

In virtually all these issues, the salient feature is the significant scientific uncertainty associated with predicting the behavior of the coupled ocean-atmosphere-land Earth system. To reduce this uncertainty, the U.S. Global Change Research Program (USGCRP) has been developed as a central component of the U.S. Government's approach to global environmental change and its contribution to worldwide efforts.

The overarching and long-term goal of the USGCRP is to establish the scientific basis for national and international policymaking relating to natural and human-induced changes in the global Earth system.

Focus of Scientific Research

In October 1990, the CEES published an initial research plan for the USGCRP. In response to the IPCC report, the CEES is revising and updating this plan to ensure that the U.S. climate change program remains focused on efforts to resolve critical scientific uncertainties identified by the IPCC. Special consideration will be given to supporting a new National Energy Strategy-related research initiative that increases the use of a series of specialized climate-monitoring satellites to provide more near-term verification of climate change. This will be reviewed in the context of the planned engineering review of the NASA Earth Observing System program. The National Energy

The Contributions of Greenhouse Gases to Global Warming

The largest single gas contribution to potential climate change comes from the increase in atmospheric CO_2, but other gases also are important. Since the industrial era began (about 1850), CO_2 has increased about 25 percent (Table 3). At present, CO_2 represents about half of the potential for warming (called radiative forcing) attributed to the increased concentrations of trace gases in the atmosphere. Greenhouse gases vary in their atmospheric lifetimes and ability to absorb and reradiate heat. Figure 55 shows contributions by various gases and economic sectors to increased radiative forcing in the 1980's. These estimates are based on an index of contributions of greenhouse gases called the Global Warming Potential (GWP). The GWP for various gases is given in Table 4.

Strategy process also identified additional research needs to deploy a new system of ocean monitors, improve understanding of the role of the biosphere in the carbon cycle, and increase the utilization of advances in computer designs to assist global climate change research and related educational activities. These ideas will be further reviewed and developed in the USGCRP.

Economic Methods Development

As part of the National Energy Strategy, funding will be increased for studying the cost impacts of climate change and the costs of response strategies. Also included will be studies of the international trade aspects, modeling of the market penetration of new technologies, and improved macroeconomic analyses. These efforts will support the U.S. position in international negotiations and assist ongoing analysis of global climate response strategies.

Energy Efficiency and Energy Sources

Despite the large scientific uncertainties associated with climate change, the IPCC report called on governments to consider taking actions that are:

- Beneficial for reasons other than climate change and justifiable in their own right—for example, increased energy efficiency and lower greenhouse-gas emission technologies; better management of forests and other natural resources; and reductions in emissions of CFC's and other ozone-depleting substances that are also radiatively important gases.
- Economically efficient and cost-effective, in particular those that use market-based mechanisms.
- Able to serve multiple social, economic, and environmental purposes.

Circulation of Greenhouse Gases

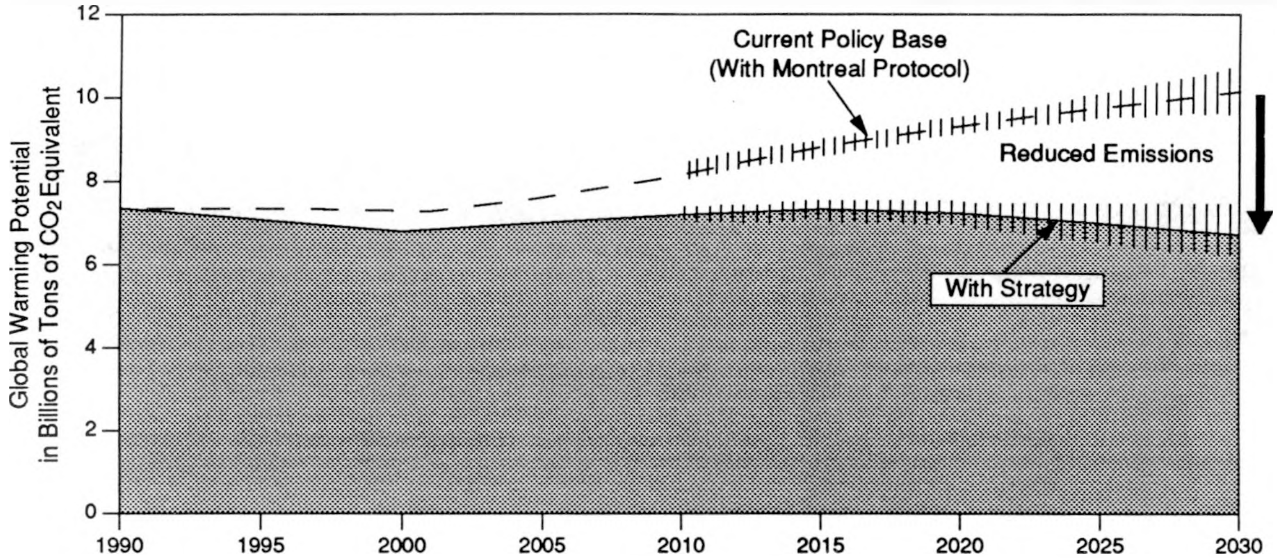
Carbon circulates continually through the atmosphere, the oceans, and the biosphere (Figure 56). Manmade emissions of CO_2 are a very small part of the global carbon cycle, with annual emissions being about 1 percent of the CO_2 in the atmosphere. Yet, the atmospheric concentration of CO_2 has increased by about 25 percent since 1850, as human emissions have increased. It is not adequately understood how the carbon cycle or the various flows within it have reacted to this change in atmospheric CO_2 concentration.

The pathways and fates of other greenhouse gases to and within the atmosphere are understood even less. CFC emissions and transport to the stratosphere are relatively well known; but, with this exception, the atmospheric changes that may be caused by continuing greenhouse gas releases or by reducing their emissions cannot be predicted accurately.

Observations clearly indicate that the composition of the atmosphere is changing. The key questions are: (1) whether the increasing atmospheric concentrations of greenhouse gases will necessarily result in a significant change in the climate at the Earth's surface; (2) if so, by how much; (3) how any such climate change would be distributed over the Earth's surface; and (4) how any climate change would affect regional ecologies and economies.

The uncertainties evident in estimating trends for global temperature change and in regional distribution of climate change become more pronounced when impacts on local natural ecosystems and regional socioeconomics are examined. The various model results do not agree on where precipitation would increase or decrease, or how changes would be distributed seasonally. Uncertainties about the magnitude and the timing of potential impacts on regional climate, in turn, cause uncertainty about what regional responses might be appropriate, how effective they might be, and how much the costs associated with them are likely to be.

Figure 54. Reduced Potential for Global Warming



Note: Global Warming Potential (GWP)—Unit of 100-year global warming potential measured in billion metric tons of CO_2 equivalents. Greenhouse gases vary in their atmospheric lifetimes and in their ability to absorb and reradiate heat. This chart is based on converting the projected volumes of greenhouse gases to one common measure, Global Warming Potential. If indirect gases that form tropospheric ozone (nitrogen oxides and volatile organic compounds) were to be included, a slightly lower GWP for the National Energy Strategy scenario would result.

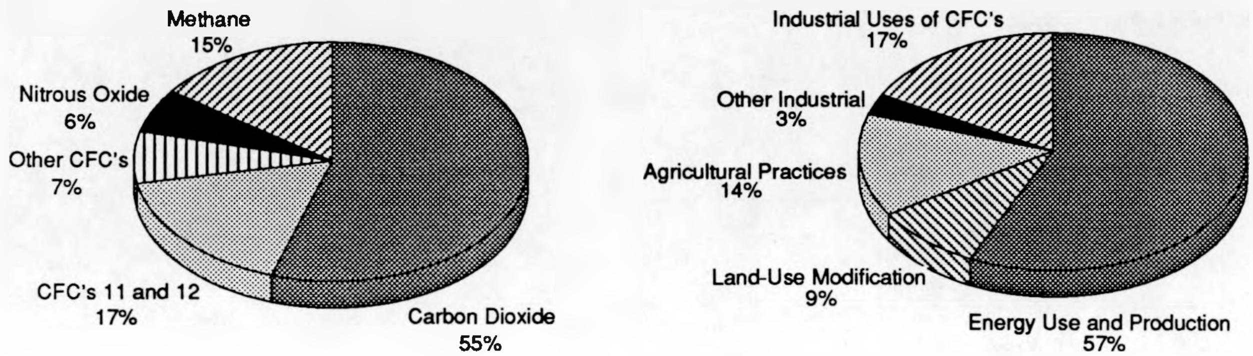
Table 3. Greenhouse Gases: Atmospheric Concentrations and Trends

	Atmospheric Concentrations	
Gases	Pre-1850	1985
Carbon dioxide	275 ppmv	345 ppmv
Methane	0.7 ppmv	1.7 ppmv
Nitrous oxide	0.285 ppmv	0.304 ppmv
CFC-11	0	0.22 ppbv
CFC-12	0	0.38 ppbv

ppmv = parts per million by volume
ppbv = parts per billion by volume

Source: V. Ramanathan, "The Greenhouse Theory of Climate Change," *Science*, 240:293–299, 1988.

Figure 55. Relative Contributions of Greenhouse Gases and Economic Sectors to Radiative Forcing in 1980's



Sources: Gases: IPCC Scientific Assessment; sectors: U.S. Environmental Protection Agency, *Policy Options for Stabilizing Global Climate,* draft report to Congress, 1989.

Note: The contribution from tropospheric ozone may also be significant, but cannot be quantified at present.

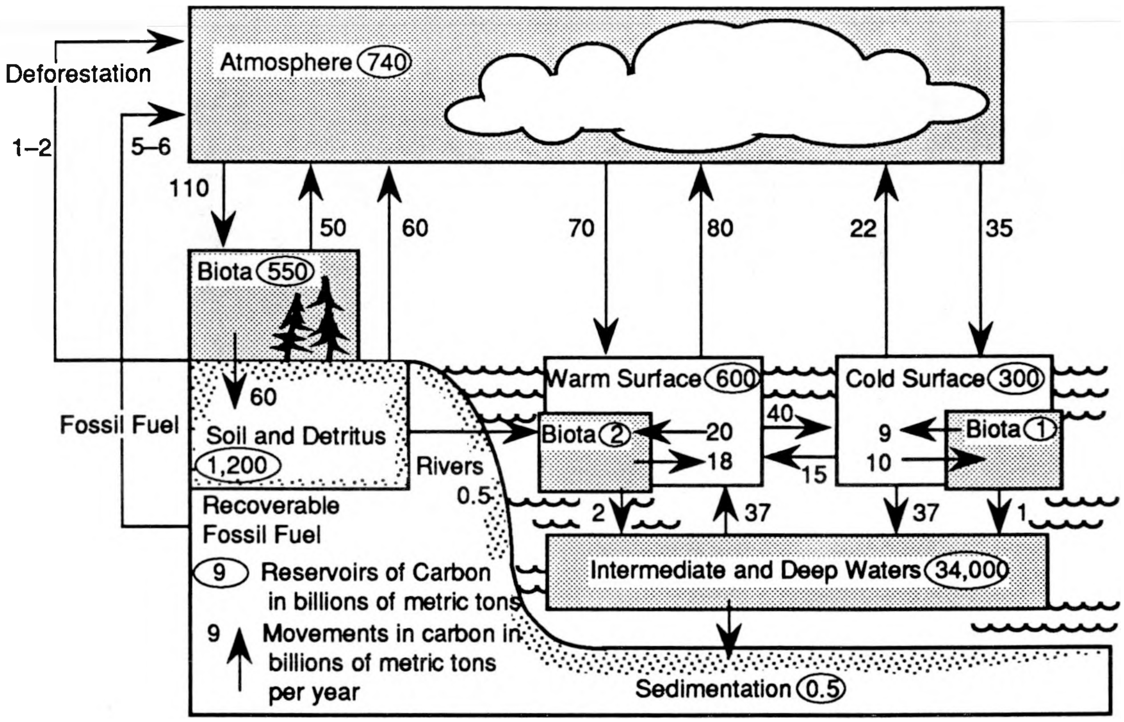
Table 4. Global Warming Potentials (GWP's) Normalized to Carbon Dioxide

	Time Horizon of Impacts (years)		
	20	100	500
Carbon dioxide	1	1	1
Methane (including indirect)	63	21	9
Nitrous oxide	270	290	190
CFC-11	4,500	3,500	1,500
CFC-12	7,100	7,300	4,500
HCFC-22	4,100	1,500	510

Source: *IPCC Scientific Assessment*, August 1990

Note: Value is the potential impact on global warming caused by 1 kilogram of the gas for the time period noted compared to 1 kilogram of carbon dioxide. For example, in the 100-year time horizon a kilogram of methane will have a global warming potential equal to 21 kilograms of carbon dioxide.

Figure 56. Global Carbon Cycle



Source: Moore, B., and B. Bolin, "The Oceans, Carbon Dioxide and Climate Change," *Oceanus* 29(4), 1988.

- Flexible and phased, so that they can be easily modified to respond to increased understanding of scientific, technological, and economic aspects of climate change.

- Compatible with economic growth and the concept of sustainable development.

- Administratively practical and effective in terms of application, monitoring, and enforcement.

- Mindful of the obligations of both industrialized and developing countries in addressing this issue, while aware of the special needs of developing countries, in particular in the areas of financing and technology.

If no actions were taken, use of fossil fuels to meet U.S. energy demand would result in an 80-percent increase of energy-related CO_2 emissions by the year 2030 over present levels. The United States has already taken a number of actions that meet the criteria proposed by the IPCC. These are described in the box titled "Current Administration Actions That Reduce Greenhouse Gases" (page 181).

The actions described here are justified for other energy and environmental reasons in addition to climate change. These benefits are not subject to the very great scientific and economic uncertainty of climate change.

Improving energy efficiency and switching to lower-emission energy sources will both reduce air emissions, including CO_2, and help achieve the Nation's energy security and domestic energy supply objectives. Alternatives to current fossil fuel technology include natural gas, hydropower, biomass, wind, solar energy, nuclear power, and clean coal technology. Nuclear, hydropower, wind, solar, and geothermal energy do not emit *any* greenhouse gases, and, if fuels are made from biomass and the biomass is regrown, net CO_2 emissions from this source would be minimal. In transportation, alternatives include expanding use of nonpetroleum fuels and introducing more fuel-efficient vehicles and electric vehicles.

Consistent with the approach proposed by the IPCC, the National Energy Strategy will stimulate the introduction of cost-effective energy efficiency alternatives and accelerate the adoption of new energy supply technologies that are low emitters or nonemitters of greenhouse gases. Market acceptance of these initiatives can lead to significant reductions in the projected growth of CO_2 emissions. The Strategy's measures as reflected in the National Energy Strategy scenario would result in U.S. CO_2 levels increasing by approximately 25 percent through 2015 and then maintaining annual CO_2 emissions at or below that level through 2030.[1] The Strategy will reduce the rate of increase of other energy-related greenhouse gases, such as carbon monoxide and methane, through 2015. Similar to CO_2, after 2015 the annual emissions of these gases will decline. A "comprehensive approach" allows for the measurement of the potential harm of all greenhouse gases in common units called "global warming potential," or GWP. When added to existing Administration actions, the National Energy Strategy will hold GWP emissions at or below the 1990 level through at least 2030.

The National Energy Strategy considered alternative ways to encourage reductions in carbon emissions that come from burning fossil fuels. One method is to tax resulting carbon emissions. This approach was considered and rejected. Analyses showed that a tax of $135 per ton, combined with implementation of the National Energy Strategy, would reduce CO_2 emissions by nearly 10 percent in the year 2000. However, a tax of this size could significantly harm the Nation's economy if the United States is the only nation to enact such a tax. A tax at this level also would lead to reductions in the GNP of 1.2 percent in the year 2000.

Burning Fossil Fuels Results in Greenhouse Gases and Other Air Emissions

Burning fossil fuels releases oxides of carbon, nitrogen, sulfur, and various hydrocarbons that contribute to ozone formation. These substances all contribute, in one way or another, to various air quality problems, including the buildup of greenhouse gases in the atmosphere, acidic deposition (also called acid rain), and urban air pollution.

Previous attempts to address air quality problems have involved piecemeal technology to control emissions or fuel substitutions targeted at specific emissions from specific sources. Efforts to reduce one kind of emissions may increase other types. For example, equipment to remove oxides of sulfur uses more fossil fuel; this in itself increases CO_2 emissions. Regulating the quality of automobile fuel to reduce volatility can increase emissions of CO_2 and other pollutants from petroleum refineries. Regulating stationary emission sources makes it more attractive for some businesses to switch from burning fossil fuels onsite to buying electricity that is generated offsite—which could increase emissions caused by generating electricity.

The total cost, expressed in terms of present value, would be more than half a trillion dollars. The cost would rise from about $50 billion to $70 billion per year over the course of the decade. By 2005, even a 1-percent decline in GNP would mean extra costs of about $300 per person per year. If a carbon tax were imposed without implementation of the National Energy Strategy, the tax might need to be as high as $270 per ton in 2010 just to stabilize CO_2 emissions. As a consequence, the general economic effects would be even more severe.

In addition to these macroeconomic effects, a carbon tax would significantly hurt specific energy industries and the Nation's overall competitiveness. A carbon tax would produce a sharp decline in coal production, exports, and jobs. These

1. Results from the National Energy Strategy scenario include assumptions (for example, economic growth rates and fuel prices) that, as the forecast period increases, become less and less certain. We have represented these uncertainties by providing ranges of potential results for specific years in the long-term period.

> **The Comprehensive Approach**
>
> Traditional management of air pollutants has been on a piecemeal basis, with a regulation for each type of emission. This is primarily because each pollutant causes different health or environmental effects. Greenhouse gases (GHG), on the other hand, each have the same type of impact. Increased concentrations in the atmosphere of each GHG increase the trapping and reflection of radiative heat back to Earth's surface. Therefore, management of this single effect provides special opportunities to reduce costs and to increase the flexibility of effective responses by considering all of the GHG's.
>
> Each GHG comes from different sources, including energy, agriculture, and industry, and is removed by different "sinks" such as forests. The comprehensive approach considers all these GHG's, sources, and sinks together. It ensures a sound scientific approach to predicting future climate, for which information on all the GHG's is needed. Also it provides the best design for any efforts to limit emissions (whether through technology or regulation). It ensures that one GHG is not reduced while another is inadvertently increased, a lesson learned from traditional environmental policy. And it provides nations the flexibility to choose their least costly mix of policies addressing the diverse GHG's, sources, and sinks.

impacts would be especially severe in those regions of the country heavily dependent on the coal industry. More generally, a carbon tax could be expected to affect the competitiveness of all U.S. industries that rely on fossil fuels, especially steel and petrochemicals.

By pursuing a comprehensive approach that considers other energy and environmental objectives, the National Energy Strategy provides a better way to reduce greenhouse gases. The National Energy Strategy will accomplish reductions in emissions comparable to a carbon tax, but by encouraging the development and deployment of new technologies and instituting constructive policies, without resorting to punitive measures or new taxes.

Energy Efficiency

A wide variety of Clean Air Act programs and the National Energy Strategy actions will reduce greenhouse gas emissions by promoting increased energy efficiency. A list of initiatives of the Strategy is provided here; they are discussed in greater detail in the chapter that is cited for each.

- Increased transportation fuel efficiency through accelerated scrappage of older cars, policies to stimulate mass transit and ride sharing, and development of alternative-fuel vehicle fleets ("Transportation Energy Use").

- Improved building efficiency through initiatives addressing low-income housing energy efficiency, public housing energy efficiency, building energy efficiency and equipment standards, mortgage financing incentives for residential energy efficiency, and energy efficiency improvements in Federal facilities; also, enhanced research and development in improving industrial energy efficiency ("Residential Energy Use," "Commercial Energy Use," and "Industrial Energy Use").

- Enhanced transportation research and development, including the development of electric vehicles and high-speed rail systems. The National Energy Strategy also includes enhanced research and development on new aviation technology to improve the fuel economy of aircraft ("Transportation Energy Use").

- Federal support for integrated resource planning in electricity markets through a number of financial, regulatory, and technical assistance mechanisms, such as eliminating Federal taxation of utility efficiency rebates to consumers ("Electricity Generation and Use").

New and Existing Technologies

The National Energy Strategy actions will increase the availability of energy supply technologies associated with low or minimal net greenhouse gas emissions. They will:

- Remove regulatory constraints to natural gas production, transmission, and use ("Natural Gas").

- Reduce constraints to obtaining additional hydroelectric power from existing dams, and extend investment tax incentives for certain renewable electric energy technologies; also, increase research and development as well as promote expanded use of waste-to-energy facilities ("Renewable Energy").

- Facilitate nuclear power development through improved licensing, development of standardized advanced light-water reactor plant designs with improved safety and economic features, public communication programs, and comprehensive solutions to the high-level nuclear waste management problem ("Nuclear Power").

- Develop accelerated research and development on biomass-based alcohol and alternative fuels and renewable energy-based feedstocks ("Renewable Energy").

- Continue research and development efforts to develop photovoltaic, wind, solar thermal, biomass, and geothermal technologies for electric power applications, as well as research to support advanced energy technologies ("Renewable Energy").

- Provide incentives for the deployment of clean coal technology that will be more efficient than current coal-fired powerplants. A more efficient plant will emit less CO_2 ("Coal").

Based on the National Energy Strategy scenario, the set of actions listed above will reduce carbon dioxide and methane emissions from current policy projected levels. For example, in the year 2000, the Strategy actions that are the largest contributors to carbon dioxide reductions would be the following (with the percentage change of the total reduction from each National Energy Strategy action shown in parentheses):

- Integrated resource planning efforts, coupled with energy efficiency actions, that reduce electricity demand (25 percent of the total reduction).

- Greater use of alternative fueled vehicles (23 percent).

- Natural gas reforms (23 percent).

Current Administration Actions That Reduce Greenhouse Gases

Examples of recent U.S. actions to reduce greenhouse gases (GHG) include the following:

- Clean Air Act Amendments for urban air quality and acid rain reduce carbon dioxide and methane as well as the indirect greenhouse gases of nitrogen oxides, volatile organic compounds (VOC's), and carbon monoxide.

- The Montreal Protocol and the Clean Air Act, and the U.S. tax on gas-depleting substances, will phase out chlorofluorocarbons and related gases in the United States by 2000 and phase out hydrochlorofluorocarbons (HCFC's) by 2030.

- DOE appliance efficiency standards and initiatives to accelerate adoption of energy efficiency and renewable energy technology will reduce CO_2 and CH_4.

- The landfill regulations proposed by the Environmental Protection Agency will capture VOC's and methane emissions.

- The U.S. Department of Agriculture and the Department of the Interior will conduct larger scale tree planting programs, capturing CO_2 from the air.

Together, these recent U.S. actions will result in total U.S. GHG emissions in the year 2000 being at or below their present level.

- Expanded use of waste-to-energy technology (15 percent).

In the later years, improved technology plays a greater role. The largest contributors in 2030 would be:

- Increased transportation fuel efficiency and expanded use of alternative fuels and alternative vehicles (25 percent).

- Expanded use of nuclear energy (36 percent).

- Energy efficiency and integrated resource planning efforts (15 percent).

- Industrial energy efficiency improvements (11 percent).

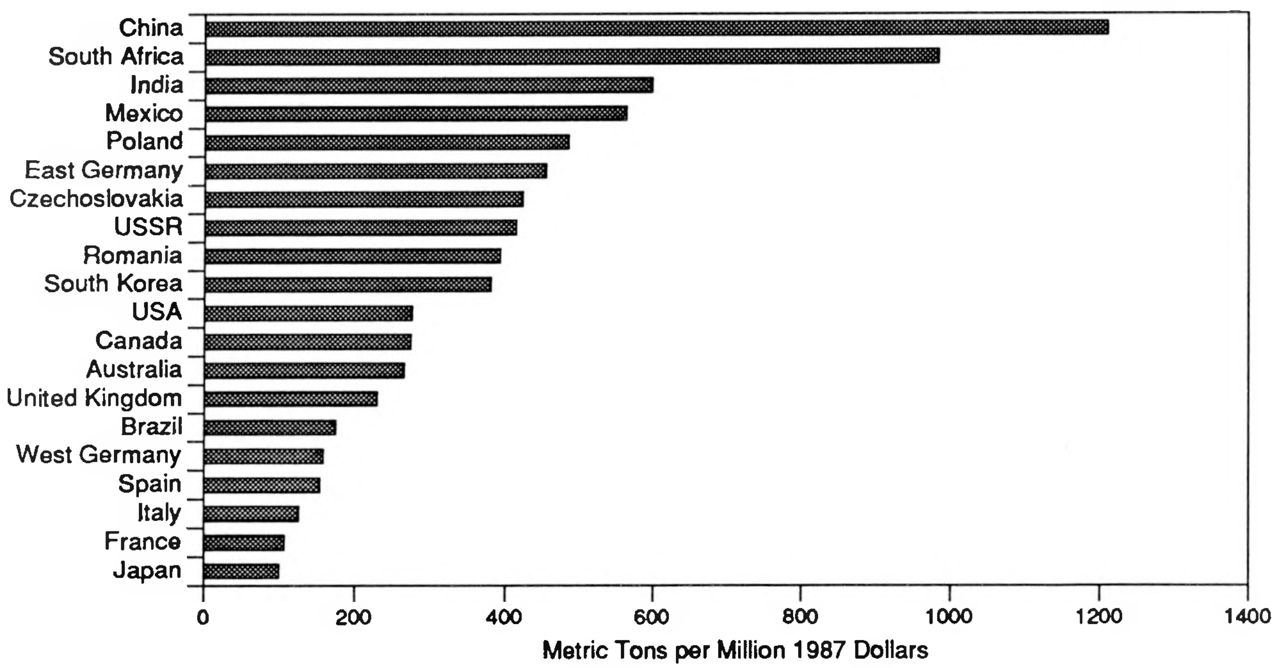
Global Cooperation and Consensus Building

Industrialized countries and developing countries differ greatly in the rate at which they emit greenhouse gases (Figure 57). The level of concern as to the probability of accelerated climate change and its risks to national societies also varies among countries.

The United States has been a leader in both action and research on possible climate change and its implications. Large-scale government-sponsored research programs were begun in the late 1970's, with general assessment of the research results documented in the mid-1980's by the Department of Energy and others. These assessments in turn have led to calls for an international dialog to develop a consensus on the science and the need for potential responses to global climate change.

Crucial decisions will be made in 1991 and during the next few years about responding to global climate change, both within the United States and internationally. The development of the first international agreement laying out principles for global cooperation will be a major focus of international efforts in 1991 and 1992.

Figure 57. 1987 World Fossil Fuel Carbon Emissions
Top Twenty Countries—Emissions/GNP



Source: Carbon Dioxide Information Analysis Center and U.S. Bureau of Census.

International Negotiations

As part of the 1990 Economic Summit, the United States and its major trading partners have agreed to begin negotiations as soon as possible on an international agreement on the protection of forests. A consensus has formed that the IPCC report should be followed by negotiations for an international framework convention that would be ratified by a large number of nations. In its continuing support of the international process for forming an international consensus on climate issues, the United States hosted in February 1991 a first meeting of nations under the auspices of the United Nations to begin development of a climate change convention. A first agreement on what should be done in research, in information exchange, and in developing a basis for any further international action is expected by June 1992.

A Comprehensive Approach

Consideration of possible responses to potential global climate change will include analysis of the merits of different strategies. The United States suggested a comprehensive approach to the Response Strategies Working Group of the IPCC. Under a comprehensive, performance-based strategy, all greenhouse gases (including all their sources and sinks) would be addressed under the single strategy. Each country might agree to take actions that, when evaluated together, can reduce net emissions. An approach of this type would give each country the flexibility to develop innovative, cost-effective measures that best fit its domestic situation while meeting any international obligation to reduce emissions.

The Need for International Cooperation

Most human economic activities emit greenhouse gases, and all countries are likely to be affected by regional impacts of any global change in climate. No one country or group of countries could unilaterally take measures that would significantly affect worldwide greenhouse-gas emissions levels that affect climate processes. Greenhouse gases are produced by nations in all stages of development. Within a few decades, some of the more populous developing countries could increase their greenhouse-gas emissions enough to overwhelm any emission-reduction measures taken by the industrialized countries alone. Even with concerted action, some degree of continued rise in greenhouse-gas emissions and atmospheric concentrations would appear to be inevitable.

Significant strides in global cooperation concerning potential global climate change have occurred over the past 2 years: the number of participating countries grew from 35 at the first IPCC meeting in 1988 to nearly 100 in November 1990 at the Second World Climate Conference. Many of the substantive issues of 2 years ago, however, remain—the scientific and economic uncertainties discussed earlier, issues of what responses should be agreed to now, questions as to how responsibility and action should be distributed among countries, and how developing countries might be supported in their participation.

Stratospheric Ozone

International action has been taken to limit use of fully halogenated CFC's and halons. In the late 1970's, the United States and a few other countries banned most aerosol uses of CFC's. In 1985, the major CFC-producing nations (and many others) agreed to the Vienna Convention, which formed a basis for international research and monitoring. In September 1987, continued negotiations under the Vienna Convention resulted in the Montreal Protocol, which includes specific limits on CFC and halon use and provides trade sanctions to enforce the obligations. By June 1990, more than 60 nations had become parties to these agreements.

By the time the Montreal Protocol entered into force at the beginning of 1989, new data had caused many nations to call for further reductions in the use of CFC's and halons. In March 1989, President Bush called for phasing out all production and use of the controlled chemicals by the year 2000, if safe substitutes existed. Additionally, two other chlorine-containing chemicals, carbon tetrachloride and methyl chloroform, were determined to contribute to the abundance of chlorine in the stratosphere.

In 1990, the nations that developed and agreed to the Montreal Protocol completed a new set of scientific and technical assessments and a new set of negotiations to further cut production of the controlled substances and to add new chemicals to the set of controlled substances. New controls include the full phaseout of all fully halogenated CFC's and halons by the year 2000 (except if a substitute is not available for an essential safety or health application), plus phasing out production of carbon tetrachloride (by 2000) and methyl chloroform (by 2005). Additionally, shorter lived substitutes that include chlorine are to be used only for applications where other adequate substitutes do not exist.

Domestic Implementation of the Agreement

As part of the Clean Air Act Amendments of 1990, Congress provided both the authority for a domestic U.S. program that is somewhat more stringent than the updated Montreal Protocol, and the means for the United States to ratify the new (June 1990) international agreement. The increased controls being implemented by the United States will cut out all new production and imports of CFC's, halons, and carbon tetrachloride by the year 2000, and methyl chloroform by 2002. Further, production of the partially halogenated CFC's that act as transitional substitutes will be frozen in 2015 and will be phased out by 2030. If other countries meet the U.S. commitment, stratospheric ozone should recover to pre-1970 levels by about 2060.

Assistance to Complying Developing Countries

In the June 1990 meeting, a program to assist developing countries in adopting substitute processes and chemicals was set up to ensure that all potential *future* major users will forgo use of these chemicals. While the June 1990 agreements are not yet in force, there seems little likelihood that they will not be accepted by the time the interna-

Ozone-Depleting Chemicals

In the 1930's, a new category of manmade chemicals was formulated—the chlorofluorocarbons and the related compounds, the halons. These chemicals have become very popular in a number of diverse products and uses, many of which are associated with energy-use efficiency (refrigerants, insulation, foams) and with firefighting. They have often been used for convenience products (such as aerosol propellants, fast food containers, and packaging) and for solvent uses.

In the early 1970's, it was postulated that these atmospheric gases would eventually migrate to the stratosphere—that band of the atmosphere 12 to 50 kilometers above sea level—and reside there for decades. During their residence in the stratosphere, the compounds disassociate into their constituent atoms, and the chlorine and bromine atoms could catalytically convert to change ozone (O_3) to oxygen (O_2) molecules.

Ozone in the stratosphere acts to reduce ultraviolet (UV) radiation reaching the Earth's surface. Ozone is particularly effective in reducing the amount of UV-B radiation, which has been associated with incidence of cataracts and skin cancer and has been postulated as having immune system impacts and a range of impacts on terrestrial and aquatic biota.

Continuing monitoring results are strengthening the evidence that average global depletion of stratospheric ozone is occurring. Monitoring has also discovered another, now annually occurring, event—the formation in the Southern Hemisphere springtime of severe stratospheric ozone depletion, lasting for several months, and occurring over a substantial area of the Antarctic. This "Antarctic ozone hole" was discovered in the late 1970's and has increased in severity.

tional programs are expected to be initiated. However, without the acceptance of this agreement by larger developing countries, in a few decades the actions taken by industrialized countries will be overwhelmed by increased uses in expanding developing countries' economies. The Clean Air Act Amendments of 1990 include funding to support U.S. obligations to the assistance programs for developing countries. Thus, the United States continues to show global leadership on this important global environmental issue.

Fortifying Foundations

Fundamental Science and Engineering Research

Technology Transfer

Education: Investing in Human Resources

Fundamental Science and Engineering Research

Technological advances are critical to achieving the energy, economic, and environmental objectives of the National Energy Strategy. Such advances will not only increase energy efficiency; they could possibly alter energy requirements as we know them today. Advanced energy technologies will make energy production safer and more productive and will help reconcile the seemingly competing objectives of fueling a robust economy while enhancing environmental quality.

Scientific advancements also fuel economic growth. In 1987, the Nobel Prize in economics was awarded for work establishing that growth in economic productivity arises principally from the introduction of new technology—the foundation of which is science. The science policies of the United States, Europe, and Japan are based on this conviction; all developed countries invest a significant fraction of their gross national product in research.

The U.S. scientific enterprise is the largest and strongest in the world, and the National Energy Strategy will continue to build on this leadership. The number of U.S. scientists and engineers involved in research and development (R&D) is about 800,000, roughly equal to the total of all scientists and engineers in Japan, Germany, France, and the United Kingdom combined. This scientific leadership, and accompanying technological advances, has helped make the U.S. standard of living one of the highest in the world.

Though the private sector has primary responsibility for developing and commercializing technology, the National Energy Strategy recognizes that the Federal Government plays a critical role in fundamental and applied scientific research—the basis for technological breakthroughs. Through its extensive system of National Laboratories and its support of academic and private research, the Federal Government substantially influences the scope and pace of energy science and technology development.

Goals and Approaches

Accordingly, the National Energy Strategy goals for fundamental science and engineering research are to (1) maintain U.S. preeminence in fundamental science and engineering research; (2) expand the role of energy science and technology in achieving national energy, economic, and environmental objectives; and (3) promote excellence and productivity throughout the U.S. research establishment. These goals, and the approaches for achieving them, are summarized in the table on the next page.

The first two goals focus on the need for both fundamental science and engineering research, driven primarily by scientific curiosity, and strategic research, driven more by a need to support specific National Energy Strategy technical programs. These two categories of research are not mutually exclusive. The third goal focuses on strengthening the U.S. research infrastructure—the collection of trained persons, modern facilities, and policies needed to advance the Nation's overall effort in science and engineering.

Expected Results

The Strategy's actions concerning science, engineering research, and research and development are detailed in the rest of this section and, as appropriate, throughout other parts of this report. Collectively, the successful implementation of these actions will help maintain the Nation's leadership role in fundamental science and engineering research and applied research and development; keep the Nation at the forefront of emerging scientific knowledge and technology development; help balance the Nation's energy, environmental, and economic objectives; and reduce the Nation's vulnerability to future oil supply disruptions.

Goals and Approaches—Fundamental Science and Engineering Research

Goal	Approach
Maintain U.S. preeminence in fundamental science and engineering research	• Maintain a balanced portfolio of Federal investments in fundamental science and engineering research
Expand the role of energy science and technology in achieving energy, economic, and environmental objectives	• Realign Federal energy R&D budget priorities to ensure that funding of relevant technical programs is consistent with and supportive of key National Energy Strategy goals and related technical objectives
Promote excellence and productivity throughout the U.S. research establishment	• Enhance national capabilities for research • Strengthen university and Federal laboratory research capabilities, including instrumentation and facilities • Encourage cost-shared research programs with universities and industry • Maintain state-of-the-art, user-oriented research facilities • Capitalize on international collaboration

U.S. Preeminence

Although the practical fruits of fundamental science and engineering research are not often immediately apparent, the history of science and technology consistently shows that lines of inquiry undertaken for the most esoteric of reasons often lead to results of great practical value. It is reasonable to expect that future discoveries and innovations arising from fundamental science and engineering research will result in entirely new ways of supplying and using energy and of protecting the environment and human health.

The United States now leads the world in support for fundamental science and engineering research. The National Energy Strategy calls for continued and significant investments in fundamental science and engineering research and in the concomitant advanced training of scientists and engineers. These investments are seen as preconditions for reaping the practical benefits of energy sciences and technology in the future.

Balanced Portfolio

The National Energy Strategy calls for a diverse and balanced portfolio of fundamental science and engineering research investments, spread across numerous Federal agencies. While these investments are not solely motivated by the technological requirements of the National Energy Strategy, *all* such efforts fortify the broad, underlying foundation of scientific and engineering knowledge both necessary for and relevant to more focused National Energy Strategy goals and technical objectives.

This portfolio is substantial. In fiscal year 1990, for example, the Federal Government invested more than $11 billion in basic research, as shown in Table 5. This amount represents about two-thirds of the total U.S. investment in basic research, taking into account all U.S. sources of support, including industry, universities, colleges, and nonprofit organizations.

The National Energy Strategy reaffirms the Federal Government's support of such research. Areas of fundamental science and engineering research that are particularly important to the

Table 5. Obligations for Basic Research, by Agency and Field of Science and Engineering, Fiscal Year 1990 (millions of dollars)

Agency	Mathematics and Computational Sciences	Physical Sciences	Biological and Life Sciences	Earth and Environmental Sciences	Economic, Behavioral, and Social Sciences	Engineering Research	Other Sciences NEC[a]	Total[b]
Total, all agencies	369	2,754	5,199	1,048	417	1,107	308	11,201
U.S. Departments								
Agriculture	5	34	439	5	19	11	—	512
Commerce	1	23	—	4	—	4	—	31
Defense	113	180	104	147	43	376	3	964
Energy	45	1,087	109	39	—	112	1	1,394
Health and Human Services	12	117	4,125	—	250	61	188	4,754
Interior	2	9	4	84	—	29	—	129
Veterans' Administration	—	—	15	—	1	—	—	16
Environmental Protection Agency	—	15	28	20	—	13	—	76
National Aeronautics and Space Administration	21	816	40	276	3	297	8	1,462
National Science Foundation	167	454	301	465	55	204	108	1,754
Other agencies	2	19	34	8	44	—	—	106

Source: National Science Foundation.

[a]Not elsewhere classified.
[b]Totals may not add up because of rounding to nearest million.

Strategy are highlighted in the following paragraphs.

Fundamental Sciences

Mathematics and Computational Sciences. Mathematical concepts often find applications to difficult problems in the physical sciences and engineering. For example, much of the recent progress in understanding the most fundamental structure of matter has resulted from complementary work between mathematicians and physicists. In the future, the interaction of the computational sciences with other fields is expected to become much stronger, with particular promise seen for economics and biology.

Physics. The scope of physics research is extremely broad, ranging from investigations of matter and energy at their most fundamental level (for example, high energy physics and the Superconducting Super Collider) to studies of matter in its solid and liquid state that might lead to new, high-performance materials. Atomic, molecular, and optical physics is a particularly rich subfield of physics in terms of applicability to National Energy Strategy concerns. Here, the development of high-precision techniques, research on the motion of electrons and nuclei in condensed matter, and the development of coherent light sources from the infrared to the x-ray region provide valuable tools and concepts applicable to energy-related problems. The physics of fluids and plasmas are also important areas of investigation. Further investigations to study gravitation and cosmology, or to develop new theoretical ideas about matter, space, energy, and time, might provide unexpected new insights important for energy systems.

Chemical Sciences. Chemical sciences have entered an era of exceptional promise as powerful new instruments for probing and understanding the elemental steps of chemical change have been developed. Lasers have greatly expanded experimental horizons; and progress in chemical theory and chemical synthesis has been so rapid that it is now becoming possible to tailor the properties of molecules and materials to exacting specifications. The potential also exists to dissect and completely understand the basic steps in such complicated chemical processes as combustion and the transport and transformation of hazardous wastes in the environment.

Materials Sciences. The field of materials sciences and engineering is entering a period of great intellectual challenge and productivity. Researchers are learning how to calculate properties of materials from basic principles and how to combine atoms and molecules in large aggregations in precisely controlled ways. Enhanced materials, by increasing the heat resistance of materials in engines, will enable those engines to be run at higher temperatures—thus boosting their energy efficiency. Superconducting materials afford great potential for improving technologies across a broad range of energy applications. Materials sciences lies at the very heart of technologies for the generation, transmission, storage, and conversion of energy. An understanding of materials underlies the increasingly important areas of waste management and the environmental impacts associated with energy technologies.

Biological and Life Sciences. Basic research on how the structures of proteins determine their functions in living cells is providing new insights into all the interactions within biological systems. The development of new genetic stocks of plants with improved characteristics for biomass conversion will be powerfully assisted by techniques of molecular biology applied to plants. Molecular biology, along with applied microbiology, will help develop microorganisms tailored to the fermentation, or enzymatic conversion, of biomass to fuels. These same tools and insights are also being used to provide a new appreciation of the structure and functioning of ecological communities and systems. Research on the human genome will open profound new areas for biological research and applications for human health and the environment.

Earth and Environmental Sciences. An enlarged base of scientific knowledge in earth and environmental sciences can help improve our ability to extend our natural resources: water, food, fibers, energy, and minerals. Basic research focuses on the understanding of fluid flow in the Earth, the elucidation of processes in oceans near coastlines that may affect global balances in carbon dioxide and other materials, and a better understanding of the important physical processes that affect weather and climate. Expanded knowledge of global environmental interactions with energy systems is essential for sound energy policies.

Economic, Behavioral, and Social Sciences. The economic, behavioral, and social sciences strive to understand the conduct of human beings and of animals. Basic research in these sciences focuses on such topics as individual and collective decisions and their consequences in market-based systems; the linkages among health, behavior, and social context; the interaction of science, technology, and society; and world trade. Results of such research may have considerable relevance and important implications for energy policy, planning, and management.

Engineering Research

Aeronautical Engineering. Aerodynamics and aeronautical engineering research is crucial to improving the energy efficiency of vehicles, particularly aircraft. The incorporation of novel, lightweight, high-strength materials into airframes of the future promises to further increase fuel-use efficiencies.

Chemical and Process Engineering. Chemical and process engineering is needed to develop better analytical and design tools for advanced industrial processes; to integrate the chemical process steps used in the manufacture of advanced materials; to find new chemical process pathways for the production of liquid fuels from solid and gaseous resources; to provide more efficient separation and purification processes; to understand the generation, movement, and fate of environmental pollutants; and to develop cost-effective methods for managing hazardous materials.

Electrical and Electronics Engineering. The electrical grid of the future, with highly decentralized power sources and substantially higher capacity than today's systems, will not be possible without major breakthroughs in electrical power engineering.

Nuclear Engineering. Research focused on nuclear engineering issues to facilitate simplified and standardized designs would improve safety margins and ease operation and maintenance for nuclear powerplants.

Mechanical Engineering. The development of methanol turbines and gasoline-methanol flexible-fuel engines in the next 20 years will require research efforts in mechanical engineering. Mechanical engineering expertise will also be required to optimize the performance of existing hydroelectric dams. Future gains in energy efficiency for nonchemical manufacturing industries will come from research on robotics and other forms of manufacturing engineering. The design of innovative wind energy systems in the 2010–2030 time period will be facilitated by additional research in mechanical engineering and aerodynamics.

Petroleum Engineering. Advanced oil and gas recovery depends heavily on research in petroleum engineering to achieve needed results in secondary and tertiary oil recovery.

Energy Science and Technology

The National Energy Strategy seeks to expand the role of energy science and technology in achieving energy, economic, and environmental objectives. Enhanced investments in research and development aimed specifically at potentially high-payoff technologies for reducing oil vulnerability are detailed under "Enhanced Research and Development for Energy Security."

Beyond these enhanced research and development investments, and beyond the Federal investments in fundamental science and engineering research, the Strategy outlines a substantial portfolio of investments in research and development aimed at other, more broadly defined strategic objectives.

Altogether, the Strategy calls for a total fiscal year 1992 investment of approximately $1.7 billion for Strategy-related technology development research by the Department of Energy. These investments are organized around three objectives: increasing energy efficiency, securing future energy supplies, and enhancing environmental quality. Each of these, in turn, focuses on the specific needs of their respective technical areas, as detailed throughout this report. The National Energy Strategy, consistent with the Administration's fiscal year 1992 budget request, outlines specific priorities for R&D funding in these areas. The Strategy, in addition, calls for the establishment of a continuing process for reviewing and refining these priorities in subsequent years, as outlined below.

Energy Research and Development Priorities

Setting R&D priorities is an essential element of the National Energy Strategy. In fiscal year 1991, an initial step was taken when the Administration increased its funding request for R&D in the technology areas of conservation and renewable energy. In fiscal year 1992, a significant additional step was taken by increasing the Administration's budget request for R&D on potentially high-payoff technologies capable of reducing U.S. oil vulnerability, as contained elsewhere in this report (see "Enhanced Research and Development for Energy Security"). Further, the National Energy Strategy recognizes a continuing need to assess and refine R&D priorities over the years and to respond to changing situations and emerging developments.

Accordingly, the Strategy establishes a process for periodically reviewing relevant Federal R&D investments, assessing technology potential, articulating top-priority technical objectives consistent with and supportive of National Energy Strategy goals, and ensuring that agency program planning and budget review procedures are followed.

The Department of Energy and other Federal agencies annually support approximately $3 billion worth of energy-related R&D. These other Federal agencies include the Departments of Agriculture and Commerce (including the National Oceanographic and Atmospheric Administration and the National Institute of Standards and Technology), the Department of Transportation, the National Aeronautics and Space Administration, the National Science Foundation, and the Environmental Protection Agency.

The Strategy calls for establishing an interagency working group, led by the Department of Energy and under the auspices of the Federal Coordinating Council on Science, Engineering, and Technology, on R&D related to the National Energy Strategy. This group will review ongoing research activities, assess potential high-payoff technologies, and develop and publish a list of high-priority, Strategy-related technical objectives. The Department and other agencies will then implement program-planning and budget review procedures to ensure that the National Energy Strategy-related portions of their R&D programs support Strategy objectives.

Excellence and Productivity

The pace and extent of scientific undertakings and their findings are increasing; the challenge for the United States is to stay on the cutting edge of scientific research. Maintaining scientific excellence and productivity requires state-of-the-art research facilities and equipment, flexible interactions with partners, shrewd planning to make full use of available resources, and sufficient complementary research in the private sector, where technological contributions must ultimately be brought to fruition.

While the Federal Government provides a substantial portion of the total U.S. investment in basic research, the actual performance of the research lies largely with industry, universities, colleges, and federally funded research and development centers. Combining Federal funding with other sources, total support of basic research in 1989 amounted to approximately $18.6 billion. Of this amount, Figure 58 reveals the importance of the various performers in this effort, constituting the overall U.S. research establishment.

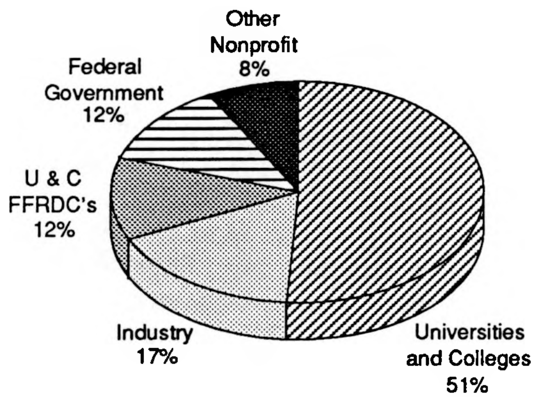
The National Energy Strategy seeks to promote excellence and productivity throughout the U.S. research establishment. Specifically, the Strategy calls for actions in five areas: industrial research, university and laboratory research, cost-shared research, user facilities, and international collaboration.

Industrial Research

Industry is the largest supporter of R&D in the Nation, providing about 50 percent of the total national R&D investment. Industry also performs much of the R&D funded by the Federal Government. In total, more than 70 percent of all R&D is performed by industry.

From the early 1960's through the mid-1980's, total real industrial R&D expenditures increased significantly, mostly in development. Since the mid-1980's, however, the rate of growth in industrial R&D spending has leveled off, dropping from a rate of 7 percent average annual real growth between 1980 and 1985 to 2 percent between 1985 and 1990.

Figure 58. Performers in the U.S. Research Establishment ($18.6 billion total in fiscal year 1989)



Note: U & C FFRDC's = University and college federally funded research and development centers.

As a result, the U.S. industrial capability to apply fundamental science and engineering research results and turn them into new technologies and products is potentially at risk because of industry's limited or declining involvement with basic research.

The National Energy Strategy will encourage industry to increase its research investments in energy science and technology through a number of approaches, including financial incentives for industrial research consortia, permanent tax credits for R&D investments, cost-shared research projects, increased use of personnel exchanges, intellectual property rights for industrial participants that are consistent with current laws and policies, and prizes and awards for specific national energy technology challenges.

University Research

Forefront research today requires sophisticated equipment, laboratory facilities, and computer resources. Individual university investigators, as well as Federal laboratories, often do not have appropriate research tools. Additionally, competition for scarce resources can place individual investigators at a disadvantage relative to larger scientific ventures.

The National Energy Strategy will capitalize on the strengths and creativity of individual investigators by providing reasonably predictable financial support for universities and by continuing to invest in equipment and instrumentation upgrades. In fiscal year 1990, the Department of Energy provided about $50 million in funding for laboratory equipment and instrumentation upgrades. The Strategy will continue this general level of support.

For example, in the key research area of nuclear science and engineering and the related field of radiation protection and health physics, the Department of Energy will support the upgrade and expansion of the capabilities of the Nation's research and test reactors to strengthen university research capabilities and maintain state-of-the-art research facilities. This will allow investigators to accomplish basic and fundamental research and to train scientists and engineers on state-of-the-art research facilities—thereby ensuring the national resource of qualified personnel for nuclear powerplant research, design, construction, operations, and regulation.

Cost-Shared Research and Development

Because Federal R&D funding is under increasing pressure from rising costs and constrained budgets, leveraging scarce resources, increasing research productivity, and, in general, making maximum effective use of available assets are becoming increasingly important.

Cost-shared R&D is a long-established element of certain Department of Energy research programs—for example, the Clean Coal Technology Program, which requires 50 percent cost-sharing. Certain R&D advanced industrial process technology programs routinely seek cost-sharing from private consortia of 20 to 30 percent. Cost-sharing is not unprecedented in fundamental science and engineering research areas, particularly with States and international partners.

Cost-sharing has numerous benefits: not only does it leverage Federal resources; it also is a proven, effective indicator of the merit of a potential technology. Additionally, cost-sharing engages private and other interests in the technology development process at early stages, which facilitates technology transfer.

The National Energy Strategy will formalize and expand cost-sharing to other Department of Energy R&D program areas. Specifically, the Department will develop guidelines for expanding requirements for participation by industry and others; the goal is to achieve a minimum cost-share of at least 25 percent of the Department's applied civilian energy R&D programs. Cost-sharing of fundamental science and engineering research is also expected, but to an unknown degree. Cost-sharing negotiations are expected to help focus on the highest research priorities and increase R&D productivity.

User Facilities

Forefront research facilities are vital to U.S. leadership in both science and industrial research. However, they can be expensive and may require frequent upgrades to address new problems and

Major Department of Energy User Research Facilities

Argonne National Laboratory
  Argonne Tandem/Linear Accelerator Facility
Brookhaven National Laboratory
  National Synchrotron Light Source
  Alternating Gradient Synchrotron
  High Flux Beam Reactor
  Continuous Electron Beam Accelerator
Fermi National Accelerator Laboratory
  Entire laboratory
Hanford Westinghouse Laboratory
  Fast Flux Test Facility
Idaho National Engineering Laboratory
  Idaho National Engineering Laboratory Environmental Research Park
Lawrence Berkeley Laboratory
  Bevalac/SuperHILAC
Lawrence Livermore National Laboratory
  National Magnetic Fusion Energy Computer Center
Los Alamos National Laboratory
  Clinton P. Anderson Meson Physics Facility
  Los Alamos National Environmental Research Park
Oak Ridge National Laboratory
  Oak Ridge National Environmental Research Park
  High Flux Isotope Reactor
  Holifield Heavy Ion Research Facility
Pacific Northwest Laboratory
  Hanford National Environmental Research Park
Sandia National Laboratories
  Combustion Research Facility (Livermore, California)
Savannah River Ecology Laboratory
  National Environmental Research Park
Stanford Linear Accelerator Center
  Positron-Electron Project Storage Ring
  SPEAR Storage Ring
Stanford Synchrotron Radiation Laboratory
  Entire laboratory

Source: Department of Energy.

challenges. They also must be staffed with scientists, engineers, and technicians who have solid training and who are informed about research progressing worldwide.

The first cost of these facilities is often prohibitive for a single firm or academic institution. Accordingly, the Department of Energy supports the construction and operation of a number of state-of-the-art, "user" facilities to aid researchers involved in both federally sponsored and proprietary research. A list of the Department's user facilities is shown in the accompanying box.

The National Energy Strategy calls for making the maintenance and staffing of these facilities a high priority. At the same time, the Strategy will explore alternative means for supporting these facilities, including scientific equipment and instruments, through cost-sharing and by creating regional research centers for world-class facilities or equipment; and it will explore the advantages and disadvantages of joint ownership by the Federal Government and State governments, the private sector, or international groups.

International Collaboration

While some user facilities, such as research reactors, neutron sources, and synchrotron light sources, are heavily subscribed by U.S. private interests involved in proprietary research, others are more experimental in nature, exploring fundamental topics that are years from commercial application.

The National Energy Strategy will pursue increased international collaboration in both the construction and the operation of these high-cost, long-term experimental facilities. Planning, constructing, and operating these facilities on as broad an international basis as possible will increase research productivity. One example of successful international cooperation is the International Thermonuclear Experimental Reactor for fusion energy research and development, which has been conducted as an equal international partnership from the earliest stages of its conceptual design. The Strategy will ensure that future proposals for such facilities be encouraged to involve international participation and cost-sharing from the outset. The Strategy will also increase U.S. benefits from such international collaborations.

Technology Transfer

The success of every technology-related action in the National Energy Strategy depends on transferring the results of scientific and technological research from the laboratory into useful goods and services. The knowledge gained from basic scientific research must be shared so that practical applications for the new knowledge can be found. The results of applied research must be further developed and demonstrated to ensure that a new technology addresses the needs of its users. Whether in the form of patents, information, standards, processes, or physical products, a technology ultimately must be adopted by industry, consumers, and other end-users if it is to contribute to the Nation's energy, environmental, and economic goals.

Most technology transfer efforts conducted by Federal agencies historically have been oriented toward "technology push," where a market application is sought only after development of the technology is well under way or completed. A fundamental goal of the National Energy Strategy is to improve technology transfer by encouraging more "market pull," where the actual efforts to develop technology are more focused on possible technology transfer applications as well.

Goals and Approaches

The National Energy Strategy goals and approaches for technology transfer are summarized in the table on the next page. The approaches include elements of current activities as well as new actions.

The National Energy Strategy for technology transfer centers on a philosophy of increasing reliance on market pull on federally supported research and development (R&D), technology transfer, and export promotion programs by fostering strengthened collaborative relationships between the Government and the U.S. private sector throughout all phases of these programs. Through improved financial incentives, continued

What Is Technology Transfer?

Generally speaking, technology transfer is the process by which technology, knowledge, or information developed in one organization, in one area, or for one purpose is applied and utilized in another organization, in another area, or for another purpose. From the Federal perspective, technology transfer is the process of making federally funded science, technology, and "know-how" more responsive to the needs of the marketplace and users in industry, academia, State and local governments, and the public.

Technology transfer is not a new activity for the Federal Government. Federal technology transfer programs have contributed to the successful commercialization of new products, have helped solve industrial manufacturing problems, and have helped State and local governments influence the rate at which new technologies and practices are accepted by industry and the general public.

Technology transfer covers a wide range of activities. For example, basic science programs within the Department of Energy have actively pursued the transfer of *scientific knowledge* as part of their missions. Applied energy programs have emphasized *direct* transfer of technologies that produce or conserve energy to industry and consumers. *Spinoff* technology transfer, where a technology developed for one purpose or industry is applied in another application or industry, also has occurred, but to a lesser extent. All three types of transfer are recognized as missions of the Department's R&D activities, including defense-related programs.

Goals and Approaches—Technology Transfer

Goal	Approach
Increase the participation of U.S.-based industry in research and development, and the speed and amount of commercialization of new technologies	• Improve financial incentives to encourage industry investment in R&D • Remove regulatory barriers that discourage industry participation • Promote the export of energy and environmental technological goods and services
Increase the participation of the Federal Government in the technology transfer process	• Better utilize existing policy and legislative authorities to support technology transfer
Accelerate the process of transferring federally funded technology to private industry and consumers	• Reform the national technology transfer infrastructure to improve public-private collaboration

removal of regulatory and trade barriers, and more unified export promotion efforts, U.S.-based companies will be encouraged to develop these relationships with universities, with Federal agencies and laboratories, and with each other.

The Strategy also calls for increased participation by federally supported programs and facilities in the transfer process—or increased technology push. A common misconception with regard to Federal research is that numerous technologies are available for private industry to readily "take off the shelf" and commercialize. In fact, promising commercial applications often are difficult to identify and require a detailed knowledge, on the part of both the developer and the potential user of the technology, of each other's needs.

"Market Pull" or "Technology Push"?

"Market pull" and "technology push" are complementary components of increasing innovation. Technology push provides the underlying base of science and technology from which innovations can flow. Market pull provides the market need that is necessary for an invention to find application. Both a strong underlying base in science and technology and attention to market needs are necessary components of successful innovation.

Finally, the National Energy Strategy seeks to reform the Nation's technology transfer infrastructure. Many public and private organizations provide a wide variety of services to enhance technology transfer; market intelligence gathering and technical assistance are two examples. Improving the coordination of these services will make the delivery of such services more efficient and more effective, which will help increase the rate at which new innovations are introduced to the marketplace.

The Strategy's approach to technology transfer builds on a strong base of legislative and policy mandates. The authorizing legislation for many Federal agencies, including the National Aeronautics and Space Administration and the Departments of Commerce, Energy, and Agriculture, contains specific provisions that support technology transfer. In recent years, Congress and the Administration have cooperated on legislation specifically directed toward increasing the transfer of federally developed technology to U.S. industry. The box on the next page contains a brief summary of this legislation.

Recent Technology Transfer Legislation and Policy

- The Stevenson-Wydler Act of 1980 and its subsequent amendments made technology transfer a mission of Federal laboratories and required that all Federal laboratories establish an Office of Research and Technology Applications to coordinate technology transfer efforts.
- The Bayh-Dole Act of 1980 (amended 1984) allowed certain nonprofit and small-business Government contractors to retain title to and royalties from most Government-funded inventions; earlier legislation gave the Department of Energy the authority to waive rights to inventions to large-business contractors for purposes of commercialization.
- The Federal Technology Transfer Act (a 1986 amendment to the Stevenson-Wydler Act) permitted Government-operated laboratories to enter directly into cooperative agreements with industry; allowed them to license patents to cost-sharing partners of such agreements; required that Government inventors share in royalties from patent licenses; and gave preference in technology transfer to companies planning to manufacture a substantial portion of any new product in the United States.
- Executive Order 12591 (1987), Facilitating Access to Science and Technology, required Federal agencies and laboratories to assist universities and the private sector in broadening the Nation's technology base.
- Section 5171 of the Omnibus Trade and Competitiveness Act of 1988 required that federally supported international science and technology agreements be negotiated to ensure that intellectual property rights are properly protected. Super 301, a key provision of the act, created a program to eliminate the major trade barriers of foreign countries.
- The National Competitiveness Technology Transfer Act, or NCTTA (a 1989 amendment to the Stevenson-Wydler Act), required agencies to permit contractor managers of Federal laboratories to enter into Cooperative Research and Development Agreements, provided that commercially valuable information brought into or generated under such an agreement may be withheld from public disclosure for up to 5 years, and required that agencies provide "sufficient funding" for technology transfer activities.

Expected Results

Providing a stable financial environment, through actions such as enacting permanent research and experimentation tax credits, will provide an incentive for investors and entrepreneurs to make investments in R&D. If Federal laboratories and U.S. industrial partners collaborate on and share the cost of R&D, Federal R&D investments will be more rapidly transformed into highly innovative competitive products, and limited public and private funds will be more effectively put to use.

Reducing legal and regulatory barriers will better allow the marketplace to dictate which technologies are to be commercialized and also will provide greater incentives for private firms to work cooperatively with the Federal R&D facilities and among themselves. This, in turn, will reduce the high costs of commercializing innovative yet risky technologies and increase the rate at which innovative technologies are brought into the marketplace. New advanced technologies will reduce energy costs while increasing the supply of energy. Increased innovation will reduce the cost of environmental compliance and increase the overall efficiency and competitiveness of U.S. industry.

Increasing exports of U.S. technological goods and services, particularly as they relate to international energy and environmental needs, will improve the Nation's general economic performance by strengthening its energy and environmental firms, generating new jobs, and decreasing trade deficits. It will help other countries, particularly developing countries, solve their energy, environmental, and economic problems by providing more efficient technologies and practices, and it will enhance energy security for most industrialized and developing countries by reducing pressures on global oil supplies and prices. However, actually achieving these increased exports will be very difficult in today's increasingly competitive global marketplace.

Industry Participation in R&D and Commercialization of New Technologies

In a free-market economy, private industry plays the lead role in commercializing technology. Thus, increasing the private sector's participation in the full spectrum of R&D and the commercialization of new technologies is an essential element of improving technology transfer and meeting the Nation's energy, environmental, and economic goals. The actions incorporated in the National Energy Strategy are designed to encourage increased industry participation while continuing to rely on market forces to drive commercialization decisions.

Many companies lack the financial incentives to undertake long-term investments in R&D and commercialization of new technologies. Furthermore, a number of legal and regulatory barriers affect technology transfer and commercialization; these include intellectual property rights, conflict-of-interest concerns, antitrust barriers, product liability laws, classification policies, and Federal procurement practices. The areas of law affecting technology transfer are complex because they must balance competing governmental objectives. Legislative and regulatory changes made in the last 5 years, such as the National Competitive Technology Transfer Act of 1989, represent a significant step forward and should be given time to take effect.

In addition, U.S. exports are affected by trade policies in the United States and abroad, Federal export assistance programs, U.S. industry practices, and other factors. Development of trade policy is affected by a number of complex issues, such as concessionary financing, subsidies, and tariffs that are part of the General Agreement on Tariffs and Trade. The Federal Government provides a wide array of export assistance; however, many potential U.S. exporters lack the international presence and perspective, the historical export focus, and the long-term planning horizon required to meet the unique needs of other countries. The highly subsidized export promotion programs of many competitor nations also can act as obstacles to greater U.S. industry participation.

Permanent Research and Experimentation Tax Credit

According to numerous studies, there is an empirical link between the total amount of R&D investment in a country and that country's long-term industrial productivity and profitability. Tax credits for research and experimentation are widely used, both in the United States and elsewhere, to stimulate the dollar volume of R&D activities. In 1981, Congress enacted a research and experimentation tax credit to encourage increased R&D spending by the U.S. private sector. This tax credit, which will expire on December 31, 1991, has resulted in some increase in industrial R&D investment. However, its impact has perhaps been limited because of its temporary nature. This National Energy Strategy action, which requires the cooperation of the Administration and Congress, will make the tax credit for industrial R&D permanent, thus providing greater incentive for U.S. industry to invest in long-term, high-risk R&D.

Increased Collaborative, Cost-Shared R&D

Developing many of the technologies described in other sections of this report, such as fusion energy and advanced renewable energy systems, is beyond the means of any one company or industry to support. This is especially true for small, innovative firms that have little capacity for large financial risks. Collaborative, cost-shared R&D projects between government and industry are an effective way to reduce the financial risk of these R&D activities and increase market pull on federally supported R&D programs. Cost-sharing effectively leverages increasingly limited public and private

R&D funds; and, from the standpoint of energy and environmental technologies, it can be used to provide more focus than the general enhancement of R&D tax credits alone.

The Federal Government has sponsored many successful collaborative, cost-shared programs, such as the Clean Coal Technology Program, the High-Temperature Superconductivity Pilot Centers, and the Small Business Innovation Research Program. However, the National Energy Strategy recognizes that collaborative, cost-shared activities will require additional encouragement of U.S. industry from the Government if the perceived risks of long-term investment in R&D are to be reduced. Increased collaboration and cost-sharing of R&D with small and midsize companies, through consortia, joint ventures, and other collaborative and cost-shared arrangements, will be particularly encouraged at all Federal R&D agencies. In support of this action, the Administration will seek to form a diversified portfolio of projects directed at accelerating the transformation of Federal R&D investments into highly innovative and competitive products.

Intellectual Property Protection

The United States has a history of broad and rapid dissemination of the results of its basic scientific research programs. Even the results of unclassified basic research associated with defense missions have been made widely available. It is important that this free flow of basic scientific information be maintained to support technology development. In developmental work, U.S. industry places a premium on protecting information with potential commercial value that can lead to a competitive advantage in the marketplace. Therefore, it is important to be able to adequately protect such information in order to encourage industry to collaborate with the Government.

The protections afforded to intellectual property depend on the kind of property that needs to be protected. Intellectual property important to technology transfer includes inventions that can be patented, commercially valuable information protected under State and Federal law, and works (including computer programs) that can be copyrighted. The National Energy Strategy promotes the increased use of patents and copyrights, for both private and federally funded researchers, to protect commercially valuable property.

Some commercially valuable information generated at private expense is protected under the exemptions of the Freedom of Information Act. However, where there is joint Government-industry funding, Federal statutes requiring dissemination also can apply. The recently enacted National Competitiveness Technology Transfer Act and the Steel and Aluminum Energy Conservation and Technology Competitiveness Act provide a new form of protection from this requirement. These acts allow the Government to protect information from Freedom of Information Act disclosure for up to 5 years under certain agreements. This greater protection of commercially valuable information is expected to make Government-industry collaboration more desirable to industry.

Copyright protection for technical data and computer software also can be important to commercialization. Federal protections will be expanded to include works by Federal contractors under a new

Intellectual Property Protection at the Department of Energy

Before 1974, exclusive rights to inventions funded by the Department of Energy were transferred primarily through licenses to patents held by the Department. Increasingly, these patent rights are "waived" to the institution responsible for the invention. Under the 1980 Bayh-Dole Act, patent rights also can be "elected" by the small business or nonprofit institution responsible for the invention. The Department of Energy and its laboratories are making increased use of the various Freedom of Information Act exemptions that are available. In addition, the Department permits contractors to copyright technical data and computer software for commercial purposes. Coupled with commercialization incentives, such as royalties or license fees, ownership by the contractor of these intellectual property rights is expected to bring about expanded commercial use of federally funded inventions.

rule proposed by several agencies on October 15, 1990 (55 FR 41788). The National Energy Strategy also supports allowing Federal agencies to secure copyrights for computer software developed under certain cooperative research and development agreements.

Intellectual property protection is even more important in the international arena. Many countries do not provide the same level of protection that can be found in the United States. Through further negotiations under the General Agreement on Tariffs and Trade, multilateral and bilateral agreements, and the World Intellectual Property Organization, the Administration will seek to obtain greater protection of intellectual property in international markets.

Conflict of Interest

Conflict-of-interest laws are important because they maintain the credibility of the parties involved and assure the public that access to technology opportunities is open and fair. At the same time, these laws can discourage collaboration between federally supported researchers and industrial researchers. All Federal agencies and laboratories have conflict-of-interest guidelines that cover a variety of activities. The recently passed National Competitiveness Technology Transfer Act more clearly identifies the responsibilities of agencies and contractors to prevent conflicts of interest in technology transfer activities. The Department of Energy has incorporated these provisions into its contract agreements for contractor-operated R&D laboratories. To date, conflict-of-interest laws have been a barrier to public-private collaboration in only a few instances, such as in the field of medical research. As agencies seek to increase the level of collaborative, cost-shared agreements as part of the National Energy Strategy, however, the potential for real or perceived conflicts of interest will grow. Consequently, the Administration will continue to evaluate conflict-of-interest laws and policies to ensure that they provide adequate safeguards without introducing unnecessary barriers to collaboration and innovation.

Antitrust Reform

Cooperative arrangements among companies can either encourage or discourage competition, depending on the circumstances of the market. The National Cooperative Research Act of 1984 (NCRA) identified R&D as an activity that could encourage competition and competitiveness, and clarified antitrust law regarding industry consortia for the purpose of conducting joint R&D. In addition, the NCRA provides for the reduction of penalties for any antitrust violations by these consortia from treble damages to actual damages upon notice to the antitrust agencies.

Although a large number of consortia have been formed in accordance with the NCRA, their effectiveness may be limited because the act's protections do not extend to joint production activities. Under this National Energy Strategy action, joint production activities will be afforded NCRA protection. The proposed changes will reduce the perceived risk of antitrust litigation and claims and consequently promote cooperative arrangements among companies.

Product Liability Reform

Product liability laws govern the payments to victims of defective or dangerous products. These laws can discourage innovation by raising the costs of introducing new products and services, not only through excessive payments to victims and the high costs of the litigation, but also by diverting capital that could have been spent on developing new technologies. The National Energy Strategy supports adoption of more uniform product liability standards based on three principles: first, a victim should be compensated for actual damages; second, liability should be based on responsibility for harm, not on ability to pay; and third, alternatives to costly litigation should be encouraged. In addition to maintaining incentives for producing safe, innovative products, these proposed changes also will reduce inefficiencies and inequities in the current system. Under this action, the Department of Justice will take the lead in the effort to reform product liability laws to restore balance to the tort system.

National Security Classification Policy Review

A significant portion of federally funded R&D activities takes place within the laboratories and facilities of the Nation's defense complex, including those operated by the Department of Energy. Some aspects of these activities, including R&D in advanced materials and advanced manufacturing techniques, may no longer present significant risks to national security should the technology become publicly available. Some of these technologies could have significant Federal application. However, existing security and classification policies may make it difficult for industry to obtain access to technologies and knowledge that might have broad, commercial application. In an action related to the National Energy Strategy, the Department of Energy is conducting a comprehensive policy study that includes a review of the effect of the Department's classification policies and procedures on the transfer of technology from the National Laboratories and other departmental facilities. This study will identify any changes that may be necessary and appropriate to enhance U.S. competitiveness while continuing to protect national security interests.

Federal Procurement Regulation Reform

As a major user of goods and services produced by U.S. private industry, the Federal Government can play a major role by removing obstacles to efficiency and innovation in the production of these goods and services. Under existing procurement regulations concerning technical data and proprietary information, many companies are reluctant to combine their commercial R&D activities with their federally funded R&D activities. On the one hand, these companies are concerned that privately funded research and inventions they provide to the Government for Federal applications will be disclosed to their competitors. On the other hand, there is no incentive for these companies to risk investment in commercial applications for technologies developed under Government contracts because the information and data used in their development may be made available to their competitors.

The National Energy Strategy encourages, to the extent feasible, use of commercial products for defense, space, and other Government applications. This will reduce the development and production costs of those technologies. The Federal R&D agencies, in cooperation with the Office of Federal Procurement Policy, will revise Federal procurement regulations and practices to permit greater integration of Government and commercial production and thus encourage greater innovation and efficiency in development and production.

Unified Federal Export Promotion Effort

The National Energy Strategy encourages increased public and private collaboration with other nations to ensure that exported technologies meet the world's energy, economic, and environmental needs. More than 10 Federal agencies are involved in exports—by providing export financing and insurance, market information, trade negotiations, studies, technical help, and grants. However, these efforts often are viewed by industry as inefficient and ineffective.

Meeting the challenge of global competition calls for a more unified Federal approach to export promotion. A first step already has been taken. The President issued a directive to the Economic Policy Council, instructing it to carry out a Commercial Opportunities Initiative that will assist U.S. exporters in pursuing opportunities in international markets. The Council recently established the Trade Promotion Coordinating Committee, coordinated by the Department of Commerce and including all Federal agencies involved in export promotion, to provide a unifying framework for improving coordination and cooperation. This united effort will help achieve the energy, environmental, and economic goals of the National Energy Strategy. The Department of Energy will provide the Trade Promotion Coordinating Committee and the Economic Policy Council technical expertise on energy and energy-related technology and service exports.

The Department of Energy's Export Promotion Activities

The Department of Energy alone supports four key initiatives in energy export promotion. The Eastern European Initiative is developing a data base on the political and economic factors affecting energy use in Eastern European countries and providing technical assistance and training to these countries. The Energy Export Promotion Office is helping U.S. energy industries overcome the obstacles to exporting energy and energy-related technology and services. The Clean Coal Technology Export program currently is funding a retrofit project with Poland and is collaborating with the U.S. Agency for International Development and the Trade and Development Program to fund feasibility studies on energy-related trade opportunities. Finally, the Committee on Renewable Energy Commerce and Trade (CORECT) works with officials around the world to help them recognize the practical value of renewable energy and to facilitate U.S. industrial efforts in adapting proven renewable technologies. Photovoltaics in the Dominican Republic, wind systems in Guatemala, and geothermal development in Honduras are examples of CORECT's marketing efforts.

Federal Participation in the Technology Transfer Process

Developing and commercializing new technologies is primarily the responsibility of U.S. private industry. The most important role that the Federal Government can play in this area of technology transfer is to provide an economic and regulatory environment conducive to industry's undertaking such investments. However, the Government can play a much greater role in transferring technologies that result from federally funded R&D activities to U.S. industry for potential commercial application.

Despite the number of laws and policies that have been passed to promote technology transfer, a clear understanding of the importance of technology transfer within the overall context of Federal missions does not exist within the Government.

If technology transfer is to improve, the Federal Government must become more active in technology transfer with U.S. industry, State and local governments, and other organizations. Thus, the National Energy Strategy supports a commitment by the Federal Government to maintain strong support for basic and applied research while increasing efforts to transfer the results of this research to U.S. industry for practical application. This effort includes supporting cost-shared precompetitive research on generic, enabling technologies that have the potential to contribute to a broad range of government and commercial applications.

Policy Integration

The Administration is committed to ensuring the full implementation of technology transfer policies and legislation in all Federal agencies. In the last year, for example, the Department of Energy revamped its technology transfer strategy. Under this new strategy, technology transfer is a priority mission for all levels of departmental management, encompassing all of the Department's R&D programs (basic science, applied energy, environmental restoration and waste management, and defense). The new strategy also involves all of the Department's laboratories, including its Government-owned, contractor-operated laboratories and Government-owned, Government-operated laboratories. Under this enhanced technology transfer program, the performance of all Department of Energy programs and laboratories will be measured, in part, by their success at transferring technologies and know-how to the private sector.

The Environmental Protection Agency and the Department of Commerce also have made significant improvements in their technology transfer programs. Efforts are continuing to establish and integrate these strategies into all facets of Federal programs. Thus the National Energy Strategy calls for more aggressive efforts by agencies in the conduct of technology transfer as a mission of the Federal Government.

Budget Integration

The National Energy Strategy encourages the Administration and Congress to provide adequate funding for technology transfer, including support for cost-shared programs that help demonstrate the technical feasibility of generic, enabling technologies and that provide technical assistance for the development of spinoff applications by industry. By reducing the technical uncertainties of innovative technologies and concepts, private industry will be better able to pursue the commercial development and application of new, privately funded technologies. Funding to support all technology transfer activities, including outreach activities, patents, and licensing, will need to be integrated into the budgeting process as part of the National Energy Strategy action to reallocate budgets to support the Strategy's objectives.

Transfer of Federally Funded Technology

Communication and interactive relationships are fundamental to the process of technology transfer. Such communication requires that technology developers understand the needs of the potential markets for their technology; those involved in commercializing or using the technology must understand its capabilities. This matching of needs to capabilities, or linking market pull with technology push, is important for ensuring market acceptance of a new technology.

With the rapid pace of technological change in today's market environment, it is becoming increasingly important that this process of interaction be fast and accurate. Administrative procedures for collaborative R&D projects between U.S. industry and the Federal Government need to be simplified. Existing approval processes for these projects are sometimes too complex and too slow, the result of layers of bureaucracy and burdensome procedures.

Four broad categories of nonfinancial technology transfer services are particularly important for accelerating the transfer process: (1) intelligence gathering and dissemination, such as hot lines, technical bulletins, and information clearinghouses; (2) technical assistance, such as personnel exchanges, use of laboratory facilities, technical consulting, and extension agent services; (3) independent validation and testing, used to evaluate new technologies and verify performance claims; and (4) brokering activities, such as those performed by economic development agencies, licensing offices, and industry associations.

An equally broad array of organizations provide these services—Federal agencies, State and local governments, universities, trade and professional associations, and industry. However, the activities of these service providers often are not well coordinated. As a result, efforts are duplicated; services are poor in quality or completely lacking; and, worse, opportunities to transfer technology are missed.

Federal Approval Processes

The National Energy Strategy seeks to ensure that Federal approval processes for procurement and for technology transfer activities are sufficiently fast and flexible to allow timely development of collaborative relationships with U.S. industry. The administrative procedures used in the Department of Energy's High-Temperature Superconductivity Pilot Centers can be used as a model for other collaborative arrangements. By using model agreements and streamlined approval processes, approvals for cost-shared projects at these pilot centers have been granted in as little as a day. The Department of Energy has used this experience to design a fast and responsive process for the Cooperative Research and Development Agreements that are authorized by the National Competitiveness Technology Transfer Act. The National Energy Strategy supports continued efforts to streamline other Government approval processes and reduce their complexity and paperwork burden. This approach recognizes the attendant advantages in speed and flexibility in decentralizing approval processes wherever possible.

National Technology Transfer Infrastructure

The National Energy Strategy seeks to reform the infrastructure of technology transfer services and service providers to improve the delivery of these services nationwide. If the resources of Federal, State, local, and tribal governments and the private sector are used more effectively, the process of transferring technology, especially to small businesses with regionally specific needs, can be made more effective. States will be encouraged to continue to develop programs that take into account the individual characteristics of the States; Federal programs, such as regional generic technology centers, will build upon these State initiatives. Through better linkages, the return on existing investments in technology transfer services will be increased and accelerated.

The President's Science Advisor will convene, with support from the Department of Energy and other relevant agencies, a high-level panel to review and identify methods for more effectively integrating National Laboratory activity into the broader requirements of both the Federal and industrial sectors, especially as they affect economic competitiveness and national security.

Education: Investing in Human Resources

The ability of the United States to confront its energy challenges depends as much on the successful development of human resources as it does on the wise use of natural resources. A scientifically literate public is needed to make well-reasoned decisions about energy options. A well-educated cadre of competent professionals is needed to carry out critical energy responsibilities. Both are needed to successfully implement the National Energy Strategy over the long term.

The key to developing human resources in energy fields is education—not just in the narrow sense of teaching citizens about energy topics, but in the broad sense of instilling in young people and adults a foundation of scientific knowledge, a context in which energy issues can be evaluated.

Goals and Approaches

The National Energy Strategy calls for pursuing two goals: first, improving the science literacy of Americans, and second, ensuring an adequate science and technology work force. The accompanying table shows the approaches that are being taken to achieve these goals.

A common strategic approach to achieving both these goals is improving the Nation's precollege mathematics and science education system. The elementary and secondary school years are when young people acquire the knowledge about and interest in science that forms the basis of science literacy. These are also the years when students begin to drop out of the "science pipeline," foreclosing their options for further education and careers in mathematics and science.

Expected Results

Improving precollege mathematics and science education will ensure that future generations of Americans understand the basic scientific concepts that underlie energy issues. This also will help ensure that the Nation has an adequate supply of scientists, engineers, and technicians, by motivating more students to study these subjects. By "priming the pump" in the early grades, it is hoped that more researchers, engineers, and technicians will emerge at the other end of the science pipeline.

Improved Science and Energy Literacy

The National Energy Strategy cannot be successfully implemented if the public does not understand and support the tradeoffs and choices that must be made. To make well-reasoned personal and public policy decisions about the risks and benefits of a wide range of energy issues—from conservation to hazardous waste disposal—the average citizen must possess at least a basic understanding of energy-related subjects. Currently, however, adults, schoolchildren, and school teachers generally lack knowledge of energy-related issues. For instance, in one study, only 32 percent of teachers and high-school seniors correctly chose wind as the renewable energy source among wind, natural gas, and coal; only 19 percent knew that petroleum supplies most of the Nation's energy; and only 16 percent knew that coal is used to produce electricity.

The main obstacle is not a lack of information on energy technologies and processes, an abundance of which is readily available. The difficulty lies in the fact that many school-age children, as well as adults, often cannot understand this information or place it in context because they lack a basic science education. Students need a strong foundation in mathematics and science in the early grades, then build on this foundation through adulthood.

The President and the Governors recognized the need to reform mathematics and science education in the six National Education Goals developed after the 1989 Education Summit. Goal 4 states:

Goals and Approaches—Education

Goal	Approach
Enable Americans to better understand of the role of energy in their lives, including its attendant costs and benefits	• Improve the precollege mathematics and science education system. Ensure that students, teachers, and the public have a solid foundation of knowledge in mathematics and science. Provide better information and opportunities to learn about energy-related topics
Ensure that the United States has a reliable supply of highly skilled scientists and technicians in energy-related fields	• Improve the precollege mathematics and science education system. Continue traditional support for undergraduate and graduate programs in energy-related fields, with emphasis on increasing the participation of all groups including those underrepresented in mathematics and science groups

"By the year 2000, U.S. students will be first in the world in science and mathematics achievement." If the Nation is to achieve this goal, reform efforts must encompass not just the most talented students, but average and low-achieving students as well. Reforms must be widespread and must extend to inner-city and rural students, female students, minority students, students with disabilities, and students from other groups underrepresented in science and technology.

The United States cannot boost the achievement of its students unless its teachers are prepared to do so. The Nation needs a reliable supply of fully qualified teachers, well trained in mathematics and science and knowledgeable about the role of energy in the economy and the environment. Qualified, fully certified teachers in critical mathematics and science subjects, especially physics, chemistry, and mathematics, are in short supply. Some 7,100 high schools (out of 16,000) did not offer a physics course in 1986, primarily because they had no qualified teachers, and demographic trends suggest that shortages may worsen. A large percentage of current mathematics and science teachers are approaching retirement age; the average age of high-school chemistry and physics teachers is almost 50.

Too few talented young people, especially females and minorities, are choosing to become mathematics and science teachers. Certification procedures make it difficult for people with mathematics and science backgrounds who are not teachers to move into the teaching profession. At the same time, experienced teachers are leaving the profession for higher paying jobs in the private sector. Many elementary and secondary teachers lack content knowledge, confidence, and hands-on science experience. In some school districts, there are no formal opportunities for teachers to become familiar with new developments in mathematics and science or few incentives for teachers to reach beyond the classroom and infuse new material into the curriculum. In many classrooms, teachers must work with equipment and materials that are obsolete or out of order; some teachers do not have access to science equipment and materials.

American elementary and secondary schools tend to give less emphasis to mathematics and science than their counterparts in other industrialized countries. Because the curricula in U.S. schools are determined by States and local school districts, requirements vary widely. In some cases, students may elect to study mathematics and science minimally and sporadically, without sequence or integration and without consideration of what courses are needed to enable them to prepare adequately for the workplace or for advanced study. In too many classrooms, the mathematics and science curricula are out of date, uninteresting, and irrelevant. Few pathways exist for rapidly transferring "frontier" science to the classroom. Few opportunities exist for students to observe "live" science or to exchange ideas with scientists.

Many parents believe that mathematics and science are "not for everyone" and do not encourage their children to pursue courses or careers in these fields. Negative images of mathematics and science among the media, peers, and the public often render these subjects unappealing to young people.

While targeting precollege education, the Nation also must undertake a range of outreach efforts to transmit more and better general scientific and energy-specific information to adult citizens. The U.S. adult public has a very limited understanding and knowledge of scientific and technical subjects. For example, 55 percent of American adults believe electrons are larger than atoms; 55 percent believe the Earth takes longer than a year to go around the Sun. This lack of basic scientific and technical literacy makes it difficult to explain energy and environmental policies and to solicit public input on those policies.

Unbiased, inclusive, and objective energy education programs that convey a complete understanding of the advantages and disadvantages of each energy source in a common environmental context are not widely available. Informing the general public of energy-related issues and choices often is left to advocacy groups and the mass media.

Reforming mathematics and science education so that U.S. students are first in the world in less than a decade will require concerted efforts from all sectors of society: Federal, State, and local governments; educators; parents; the scientific community; business and labor; the media; museums; and community groups. Coordinating Federal efforts is one part of the solution. The Federal Government has tremendous potential to help improve mathematics and science education. While only 6 percent of the total funding for elementary and secondary education comes from the Federal level, the Federal Government can provide leverage far beyond its share by expanding and making better use of education programs and scientific resources and facilities across the Government.

Recognizing this potential, the President's Assistant for Science and Technology convened a Committee on Education and Human Resources (CEHR) under the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET). CEHR is chaired by the Secretary of Energy. Its two vice-chairmen are the Deputy Secretary of Education and the Assistant Director for Education and Human Resources, National Science Foundation. CEHR representation includes all Federal agencies with a significant responsibility for mathematics and science activities. The Committee is charged with coordinating policies and programs on mathematics and science education across the Federal Government. Several of the actions below are part of the overall Federal strategy being developed and coordinated by FCCSET-CEHR.

Executive Order

FCCSET-CEHR has endorsed a proposed Executive Order making mathematics and science education a primary mission of all Federal agencies involved in scientific research and development. This order would give explicit authority for agencies to engage in activities such as allowing staff to volunteer in schools, lending surplus equipment to schools, and opening the doors of their facilities to students and teachers. It would encourage and allow Federal agencies to take the following actions.

Partnerships for Precollege Reform

The Department of Energy has recently developed models of public and private partnerships that aim to open up the resources and experts of the National Laboratories to classroom teachers and students. These partnerships can be replicated by other Federal agencies with unique scientific facilities. Several Department of Energy laboratories are working with nearby school districts, universities, businesses, and other partners to reform precollege science programs in a particular geographic area, using Federal facilities and scientists to provide hands-on experiences in cutting-edge science. Fermi National Accelerator Laboratory and Argonne National Laboratory, for example, collaborated with the Chicago Public Schools, the State of Illinois, and a consortium of colleges, universities, and businesses to establish the Academy for Mathematics and Science Teachers, which has already begun to reach all of the 15,000 teachers in the Chicago system who teach mathematics and science, providing them with cutting-edge pedagogic, research, and workplace experiences in their fields of interest. Other laboratories are conducting precollege mathematics and science education programs that target inner-city, rural, disadvantaged, disabled, and other students or teachers traditionally underrepresented in the science and technology work force.

Curriculum Support

The Federal Government is helping to develop and update mathematics and science curriculum materials to ensure that they reflect recent scientific and technological developments. The Federal Government will ensure that these materials are disseminated widely through the Department of Education's National Diffusion Network and other appropriate channels.

Quality and Currency

The Federal Government and the private sector will use their scientific facilities and personnel to provide model, "hands-on" opportunities for students, teachers, and the community to participate in exciting and highly visible scientific projects and to develop experiments that can be conducted in school laboratories. For example, the Federal Government, through FCCSET-CEHR, will assemble an inventory of successful mathematics and science education partnership programs and of laboratory and other resources that are available for schools, and will help disseminate this inventory to teachers, parents, administrators, and others who can utilize these programs and resources. Federal and private-sector laboratories and scientific facilities also will encourage scientists and other professionals to volunteer as expert teaching partners in the classroom, thus bringing cutting-edge science into the instructional process.

Positive Images Through Mentoring

The Federal Government, working with the private sector, will encourage mathematics and science mentor programs using scientists and other professionals, college students, and student peers. Under these mentor relationships, scientists and others will work with schools, community groups, and professional organizations, sharing information on science and technology and advising on careers and courses. In addition, Federal agencies will work with mass media to sponsor and promote programming and other communication activities that project positive images of mathematics and the sciences.

Teacher Supply

The Federal Government is encouraging young people to become mathematics and science teachers, for example, by providing more summer internships for students. Appropriate Federal, State, and professional bodies will continue to work on streamlining certification procedures so that mathematics and science experts can serve as educational resources or assume new or temporary careers as credentialed teachers. The Department of Energy will continue to fund its model programs in alternative methods of teacher certification.

Teacher Preparation and Enhancement

FCCSET-CEHR has identified the improvement of precollege teaching as its highest priority. The Federal Government is taking steps to make the Nation's mathematics and science teachers full-share partners in the scientific community and provide them with excellent training and research experiences that will enable them to offer superior, hands-on instruction in mathematics and science. For example, the Department of Energy has developed the DOE Teacher Research Associates Program, which provides summer research opportunities at Department of Energy laboratories for mathematics and science teachers selected nationally.

FCCSET-CEHR

To effectively leverage Federal funds in the precollege area, close linkages with the States and the private sector must be developed. As noted above, FCCSET-CEHR is one way for the Federal Government to work with the States and the private sector in overcoming the obstacles cited above and achieving the National Education Goals. Phase I of CEHR's work resulted in a baseline inventory of Federal activity in mathematics and science education and a coordinated budget submission. In Phase II, which began in January 1991, the Committee is assessing the effectiveness of the Federal programs included in the baseline, examining the need for increased attention on technician training programs at two-year colleges, and determining the extent of the Federal effort in public science literacy. The Department of Energy will continue to support this interagency effort.

Public Science Literacy

The Federal Government can play a role in advising, supporting, and developing materials and programming, including those presented by mass media, to educate adults on science topics. The Department of Energy will continue to fund such programs and will encourage the producers of such programs and other science writers to interact with Department of Energy laboratories to obtain the most current information for this type of public dissemination.

Federal agencies will help support television and other mass media programs to educate people about science. The Department of Energy will continue to cosponsor Public Broadcasting System programs, such as "FUTURES" and "The New Explorers," that provide scientific information and link preparation in mathematics and science to careers and workplace requirements.

Parent-Child Programs

Parent-child experiences, such as museum visits, are a potential way to inform adults about scientific and technical issues, including energy options. In 1990, the Department of Energy began a program with science museums, focused on energy-related sciences. The Department's laboratories also will continue to conduct "hands-on" science activities for parents and children.

Energy Education

The Federal Government, primarily through the Department of Energy, will continue its traditional role of providing educational programs and materials on specific energy technologies, on fuels, on basic energy sciences, and on the impact of energy use on the environment.

School Curriculum

The Department of Energy will work with private-sector organizations and teachers associations to integrate energy sources and options into school curricula at all levels. The information will focus on risk assessment—the ability to understand the relative pros and cons or risks and benefits of new or emerging technologies, including energy and environmental concerns. Public science announcements on scientific or technical facts also will be used.

Evaluation

Evaluations of the programs and materials developed by the Department of Energy for use in adult literacy and precollege education activities will be conducted in Phase II of the FCCSET-CEHR process.

Adequate Work Force

About 10 percent of the Nation's 4 million scientists and engineers are involved in energy-related activities, including:

- The vast majority of health physicists, petroleum engineers, and nuclear engineers
- Almost one-half of the earth scientists and mining engineers
- More than one-fourth of the chemical engineers and physicists.

The Department of Energy alone employs about 70,000 science and technology specialists. The mere replacement of workers lost through attrition requires a large pool of qualified candidates. Even for nontechnical and nonscientific jobs, the energy sector needs workers who have a solid education in mathematics and science, good analytical skills, adaptability to changing technology, and an understanding and appreciation of the role of science in modern society.

In a world where new technologies are rapidly rivaling natural resources as solutions to energy opportunities, the international competitive position of the United States depends not just on the quantity of our scientists, engineers, and technicians, but also on their quality. Without bright minds engaged in scientific research and technical application, the Nation's energy, conservation, and environmental problems could outpace its ability to solve them. We need well-trained specialists to design, build, and operate technically advanced equipment and systems. We also need scientists to conduct the fundamental research that leads to major innovation.

Unless a higher percentage of students study mathematics and science at all levels of education, people with the necessary scientific and engineering backgrounds will not be available to fill critical jobs in energy-related and other high-technology fields. Shortages are particularly serious in the energy sector. The National Laboratories and other research contractors already are having difficulty finding, recruiting, and retaining scientists and engineers in such critical areas as accelerator physics, health physics, laser and optical science, exploration geophysics, and atomic and nuclear chemistry.

Serious shortfalls of Ph.D.'s are projected in the next 15 years in such fields as the natural sciences, nuclear-related fields, and engineering. The number of degrees awarded in nuclear engineering has declined annually since the early 1980's, and foreign nationals, who are not eligible for employment in Department of Energy programs requiring a security clearance, make up an increasing percentage of these graduates. Similar situations are reported in other fields, including petroleum engineering, in which the number of doctoral degrees awarded by U.S. universities has averaged only 22 per year since the early 1980's.

The Department of Energy estimates that to meet its currently planned programs in such areas as environmental remediation, waste management, and new production and other advanced production reactor development, it would absorb almost half the U.S. citizen graduates in nuclear engineering each year from 1991 to 2015, assuming no change in 1988 graduate rates. The Department also projects a doubling, or even trebling, of the demand for nuclear-trained engineers after the year 2000.

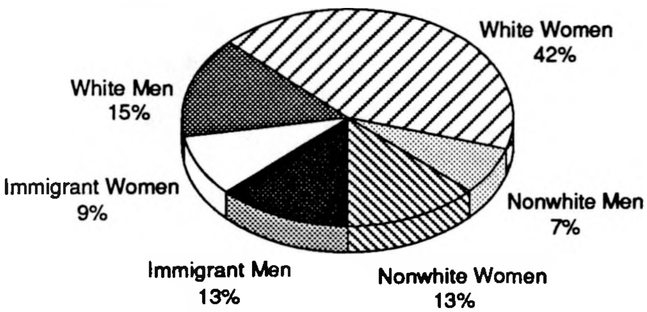
Changes in the demography of the work force suggest that shortages of scientific professionals may become acute. As shown in Figure 59, the portion of women and minorities in the work force is growing; by the year 2000, female, minority, and immigrant students are expected to make up 85 percent of the net new entrants in the labor force. This means that the United States will be relying more on minorities, women, and persons with disabilities—groups that have historically been proportionately underrepresented in the science and technology work force—to fill the gap.

Women make up only 11 percent of all employed scientists and engineers, though they account for 51 percent of the total population. In 1988, women earned only 16 percent of the doctoral degrees in physical sciences and 7 percent in engineering. The number of minority candidates pursuing advanced degrees in mathematics and science is alarmingly low. Black Americans earned only 1 percent of the 1988 doctorate awards in science and engineering, and Hispanic Americans also earned just 1 percent. Together, these groups represent 20 percent of the U.S. population. New efforts must be made to increase these percentages for all underrepresented groups.

The shortfall of students with advanced degrees has its roots in precollege education. Students who receive inadequate preparation in mathematics and science in elementary and secondary school are difficult to reclaim. As Figure 60 shows, by the time a given group of 4,000 seventh-graders graduates from high school, the pool of potential scientists and engineers from this group includes only 283 boys and 217 girls.

Interest among college students in pursuing a major in the sciences has declined by one-third over the past two decades; interest in engineering

Figure 59. The Changing Labor Force (Net New Workers, 1985–2000)



Source: U.S. Department of Labor, *Work Force 2000: Work and Workers for the 21st Century*, 1987.

is down by one-fourth since 1982; and interest in computer science has fallen by more than two-thirds. Foreign-born students, who are not eligible for many Department of Energy jobs, make up a greater share of graduate students in the sciences. Foreign graduate students make up more than half of the enrollment in graduate programs in engineering. In 1986, foreign nationals earned four times as many doctorates in science and engineering fields as all U.S. minorities and women combined.

Undergraduate courses and curricula in scientific and technical fields are frequently out of date. Laboratory-based instruction, which is key to science and engineering education, often is removed from the cutting edge of science. Introductory course curricula often serve to deter students from further studies in mathematics and science.

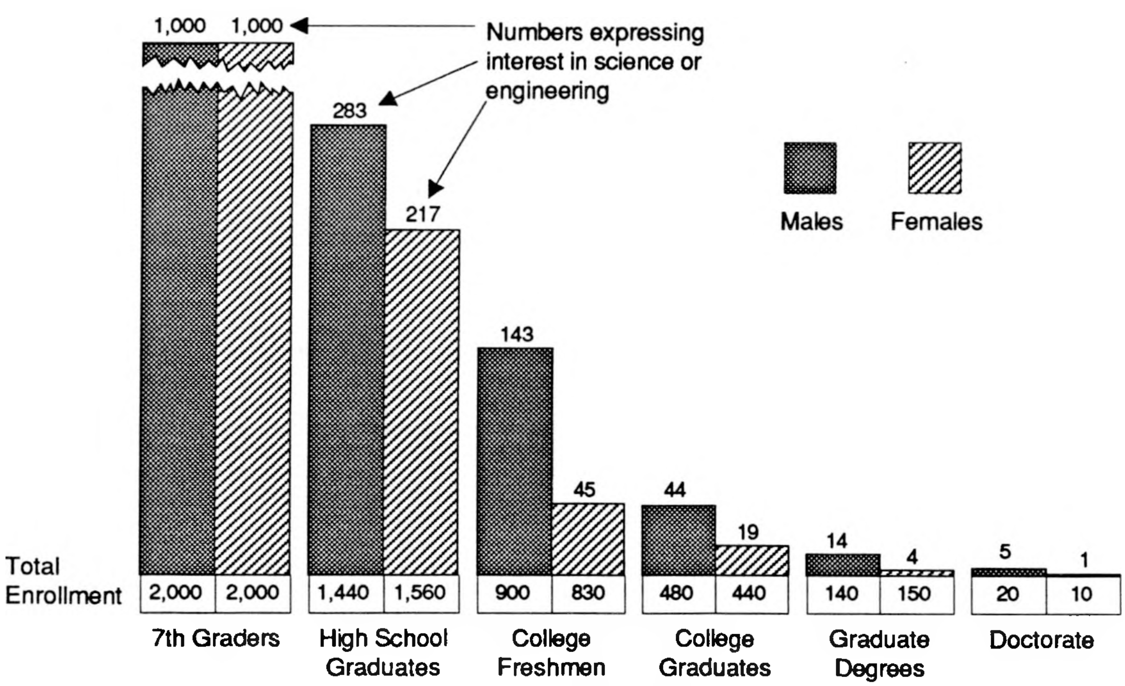
Research instrumentation available to university scientists is less likely to be state of the art, compared with instrumentation available at Department of Energy and industrial laboratories. This leads to out-of-date instruction on advances in science and engineering.

U.S. industry faces increasingly intense international competition in science and technology from the same countries whose school-age children consistently excel in mathematics and science. U.S. workers are not adequately prepared in new workplace technology. Some 30 million workers may need significant retraining to keep pace with constantly changing and more technologically demanding job requirements. U.S. industry has dealt with the problems of a poorly prepared entry-level work force by investing significant sums—$25 billion in 1989 alone—in what must be characterized as remedial education. This education also includes programs to provide new workers with training in high-school mathematics to enable them to effectively use computers and other automated systems.

Technical Work Force Pipeline

The most important step the Nation can take to produce scientists, engineers, and technicians is to "prime the pump" by improving precollege mathematics and science education. Thus, the actions listed above to improve science and energy literacy

Figure 60. Pool of Potential Scientists and Engineers Among U.S. Students



Note: Statistics based on a National Science Foundation study completed in 1986.

also apply to the goal of having a reliable supply of skilled scientists and technicians.

Science Degrees

Colleges and universities play a vital role in helping the Nation prepare the next generation of scientists, engineers, technicians, and other professionals. The Department of Energy's support of higher education benefits the Nation as well as the Department. More than one-fourth of the doctoral degrees in nuclear engineering awarded to U.S. citizens in 1988 were funded through Department of Energy graduate fellowships. Most of these graduates join the Department's research and development community, compete for Department of Energy grants, or work for the nuclear industry. The Department has initiated several actions to ensure a qualified future work force for the energy sector, including opportunities for advanced education for students from all groups.

Fellowships

The Department of Energy will expand the number of undergraduate and graduate fellowships and traineeships in energy-related fields of critical national need. These include nuclear engineering, environmental restoration and waste management, and health physics.

Specialty Support

The Department of Energy is the sole or major source of funds to support graduate students and research assistants in many other specialty fields. The Department will continue to support these activities.

Undergraduate Curriculum

The Federal Government, primarily through the National Science Foundation, is increasing its undergraduate curriculum and materials development programs in the sciences. The Department of Energy is creating new undergraduate curricula for specialty energy fields such as environmental restoration and waste management.

Undergraduate Equipment

The Federal Government, through the National Science Foundation and the Federal science mission agencies, is expanding its instrumentation programs. Federal and industrial laboratories will provide expanded opportunities for university faculty and students (including undergraduates) to use their unique facilities and state-of-the-art instrumentation.

Minority Institutions

The Federal, State, and local governments are expanding support to the Historically Black Colleges and Universities (HBCU's); other institutions that serve large numbers of Hispanic, Native American, and other minority students; and universities with special programs for students with disabilities. These institutions contribute to recruiting, educating, and graduating scientists and engineers from these groups. The Department of Energy, for example, is expanding support for HBCU participation in energy-related programs and establishing additional formal research partnerships between the National Laboratories and these institutions.

Student Support

The Federal Government will provide additional programs, such as scholarship assistance, research appointments, summer job opportunities, and counseling, to help students from all groups pursue energy-related education and careers.

Mentor Programs

Federal laboratories and scientific facilities will encourage their minority, female, and disabled employees to become involved in mentor and volunteer programs to encourage students from all groups to participate in mathematics and science programs.

Technical Training

Federal agencies, including the Department of Energy, will strengthen their on-the-job training programs and develop policies that integrate workplace needs with lifelong learning. The Department will widen the opportunities for employees in energy-related fields to receive the training necessary to keep abreast of new scientific and technological developments in their fields. The Department will work with community and junior colleges, vocational and technical schools, four-year institutions, and business and industry to develop programs for retraining technical workers in energy-related fields. In addition, the Department is examining ways to improve the participation of community colleges and two-year colleges in Department of Energy programs, including formal partnerships involving these colleges and the Department's laboratories and contractors.

List of Abbreviations and Acronyms

List of Abbreviations and Acronyms

The following abbreviations and acronyms are used in this report:

ALMR	advanced liquid-metal reactor
ALWR	advanced light-water reactor
ANWR	Arctic National Wildlife Refuge
ARAC	Acid Rain Advisory Committee
Btu	British thermal unit
C	Celsius or Centigrade
CAAA	Clean Air Act Amendments of 1990
CAFE	corporate average fuel economy
CCT	clean coal technology
CEES	Committee on Earth and Environmental Sciences
CFC	chlorofluorocarbon
CFR	Code of Federal Regulations
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
CORECT	Committee on Renewable Energy Commerce and Trade
CPE	centrally planned economy
DOE	Department of Energy
EIA	Energy Information Administration
EIS	environmental impact statement
EOR	enhanced oil recovery
EPA	Environmental Protection Agency
EPC	Economic Policy Council
ETBE	ethyl tertiary butyl ether
F	Fahrenheit
FCCSET-CEHR	Federal Coordinating Council for Science, Engineering, and Technology—Committee on Education and Human Resources
FERC	Federal Energy Regulatory Commission
FGD	flue-gas desulfurization
FR	Federal Register
GATT	General Agreement on Tariffs and Trade
GHG	greenhouse gases
GNP	gross national product
GRI	Gas Research Institute
GW	gigawatt
GWh	gigawatthour
GWP	global warming potential
HBCU's	Historically Black Colleges and Universities
HCFC	hydrochlorofluorocarbon
HOV	high-occupancy vehicle
IFE	inertial fusion energy
INEL	Idaho National Engineering Laboratory
IPCC	Intergovernmental Panel on Climate Change
IRP	integrated resource planning
ITER	International Thermonuclear Experimental Reactor
IVHS	intelligent vehicle-highway systems
kW	kilowatt
kWh	kilowatthour
LDC	local distribution company, or less developed country
LNG	liquefied natural gas
MACT	maximum achievable control technology
Maglev	magnetic levitation
MFE	magnetic fusion energy
MMBD	million barrels per day
MOU	memorandum of understanding
MRS	monitored retrievable storage
MSW	municipal solid waste
MTBE	methyl tertiary butyl ether
MW	megawatt
N_2O	nitrous oxide
NAAQS	National Ambient Air Quality Standards
NCRA	National Cooperative Research Act of 1984
NCTTA	National Competitiveness Technology Transfer Act of 1989
NEPA	National Environmental Policy Act
NGPA	Natural Gas Policy Act of 1978
NO_x	nitrogen oxides
NRC	Nuclear Regulatory Commission
NSPS	New Source Performance Standards

NWPA	Nuclear Waste Policy Act of 1982
O_2	oxygen
O_3	ozone
OCS	Outer Continental Shelf
OEC	Optional Expedited Certificates
OPEC	Organization of Petroleum Exporting Countries
ORNL	Oak Ridge National Laboratory
PMA	power marketing administration
ppbv	parts per billion by volume
ppmv	parts per million by volume
PSD	Prevention of Significant Deterioration
PUHCA	Public Utility Holding Company Act of 1935
PURPA	Public Utility Regulatory Policies Act of 1978
PV	photovoltaic
quad	quadrillion Btu (10^{15} British thermal units)
R&D	research and development
RCRA	Resource Conservation and Recovery Act of 1976
SEAB	Secretary of Energy Advisory Board
SO_2	sulfur dioxide
SO_x	sulfur oxides
SPR	Strategic Petroleum Reserve
tcf	trillion cubic feet
U & C FFRDC's	university and college federally funded research and development centers
UNEP	United Nations Environment Program
USGCRP	U.S. Global Change Research Program
UV	ultraviolet
VOC	volatile organic compound
WEPCO	Wisconsin Electric Power Company
WMO	World Meteorological Organization
WTE	waste-to-energy

APPENDIX A

Global Energy Assessment

APPENDIX A

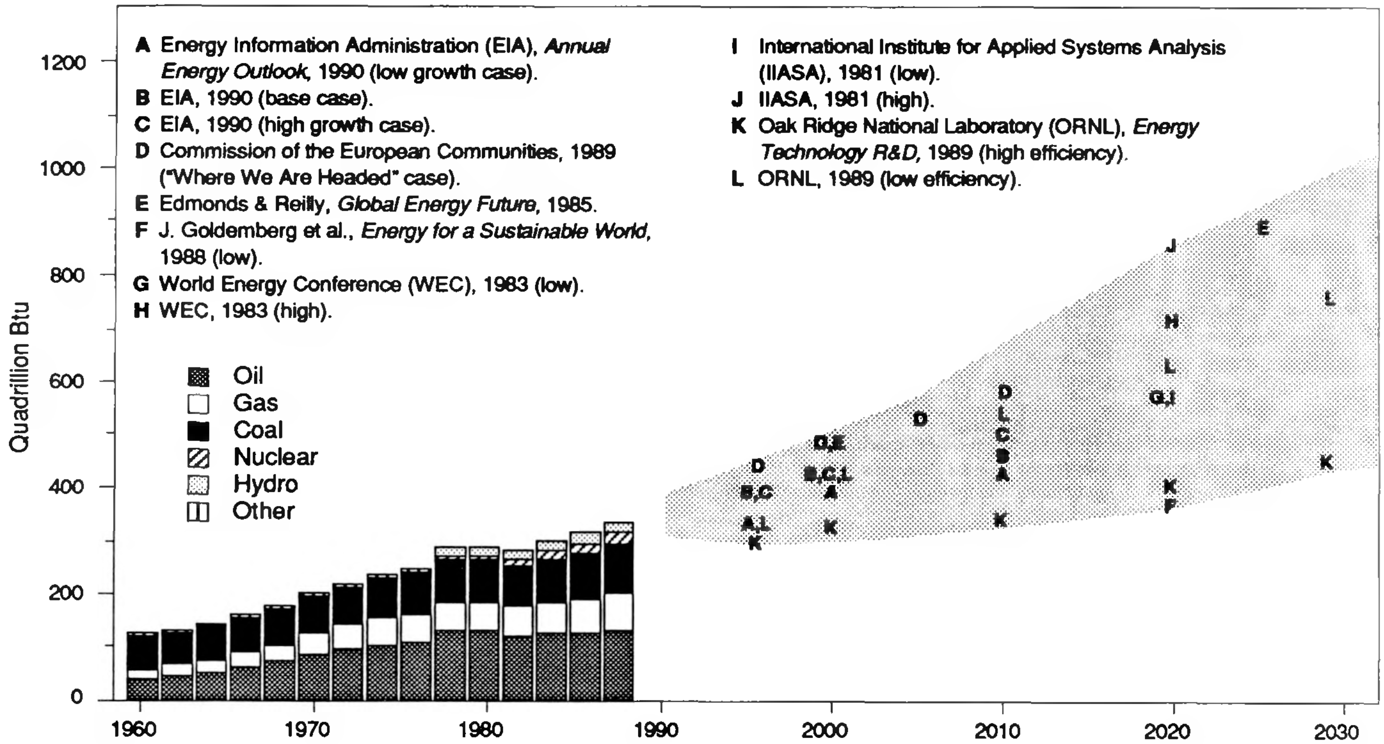
Global Energy Assessment

Any successful National Energy Strategy must be established within a larger framework of global energy and energy-related considerations.

While the future is uncertain and unpredictable, broad, global trends often reveal themselves in ways that are useful and important to strategy development. Expert studies of global energy issues can anticipate problems, indicate the likely limits of future changes, and help focus attention on policy and technology options that have the greatest potential for meeting objectives. Accordingly, the Department of Energy undertook an assessment of an array of recent studies about U.S. and global energy futures. The sources of information used represent a variety of expert opinion, in and outside government. The documents cited are drawn from literature in the public domain.

This appendix presents the results of this assessment as a series of "findings." These findings are not forecasts of the future, nor do they represent any official view. Rather, they represent a synthesis of expert opinion that, in general, appears to be widely supported among the sources used.

Figure A–1. Historical and Projected World Energy Consumption, 1970–2030



Note: Differences in projections are caused, in part, by varying assumptions concerning energy prices, economic growth, consumer and producer behavior, and rates of technological change, including replacement of capital stock. The shaded area represents an envelope bracketing these differences.

Assessment Sources

The major sources reflected in this assessment include the following:

A New Prosperity: Building a Sustainable Energy Future, 1981.
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World Energy Conference (WEC), *Energy 2000–2020: World Prospects and Regional Stresses,* 1983.

World Energy Demand

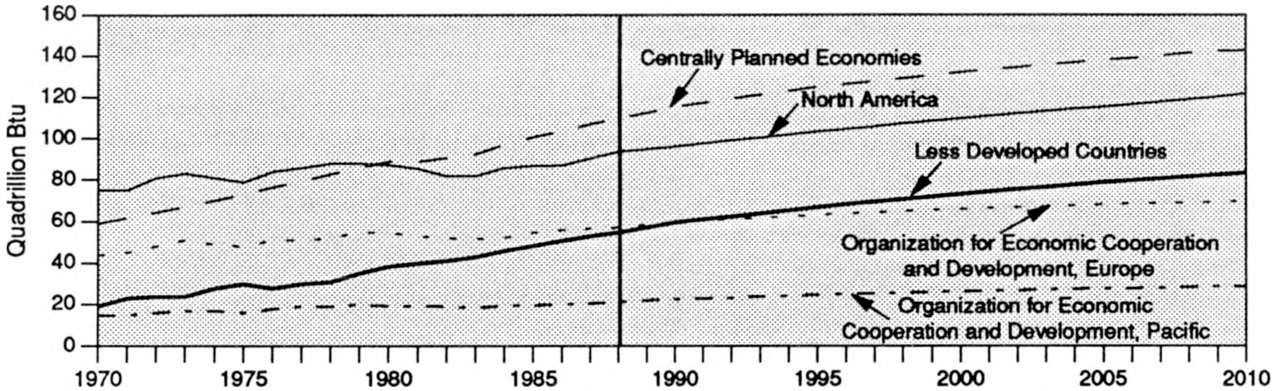
***Sources suggest** that global population growth, industrialization, and urbanization, especially in developing and newly industrialized countries, will drive world energy demand upward, particularly for oil, coal, and natural gas.*

For the last decade, world energy demand has been close to 300 quadrillion British thermal units (quads) annually; in 1988, global demand reached 337 quads (Figure A–1). Oil is the largest energy source consumed worldwide, followed by coal, natural gas, and nuclear energy. The centrally planned economies now consume about one-third of the world's energy every year, a little more than one-fourth is consumed in North America, and the remaining consumption is split among the Organization for Economic Cooperation and Development, European and Pacific, and less developed countries.

Worldwide energy demand is projected to grow substantially in the next 20 years (Figures A–2 and A–3). In the near term, world energy consumption patterns will be influenced by economic cycles, demographics (population and industrial growth in less developed countries), technological advances (improvements in energy utilization and conversion devices, changes in fuel mix patterns), and environmental issues. Rising oil demand will account for a large portion of increasing world energy demand in the near term, particularly in less developed countries, where population expansion and increasing urbanization and industrialization are resulting in greater energy consumption. As newly industrialized nations begin to expand their manufacturing bases, more energy, especially petroleum and other portable fuels, will be needed to create new infrastructures for rapidly expanding cities and urban transportation systems. Increasing demand for electrification in some less developed countries will also be met in part by oil, particularly in those regions without indigenous coal resources.

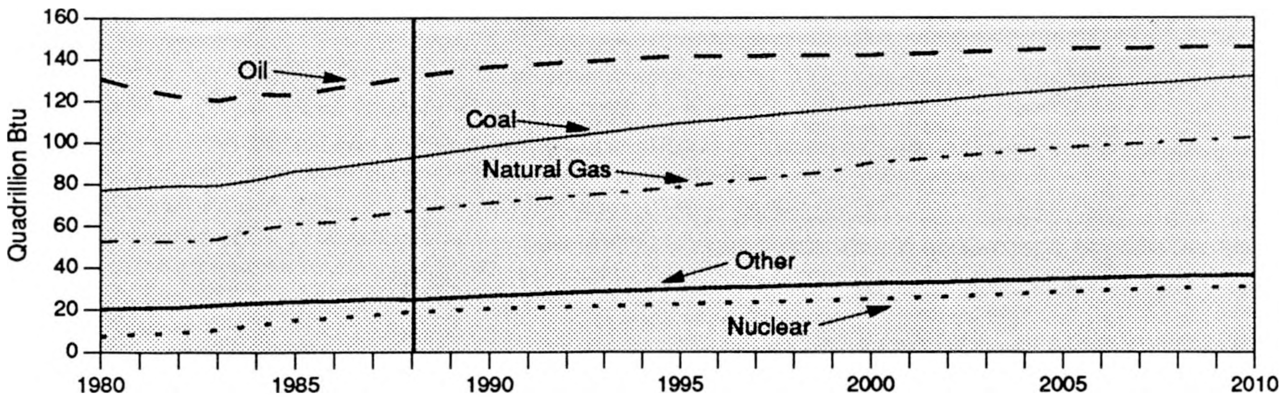
Long-term projections of worldwide energy consumption show global demand for energy continuing to rise, more than quintupling by the year 2050 from the 1975 level (Figure A–4). The demand for electricity will experience the largest long-term growth, primarily because of the pro-

Figure A–2. World Energy Consumption by Region, 1970–2010



Source: Energy Information Administration, *International Energy Outlook,Source: Energy Information Admin*

Figure A–3. World Energy Consumption by Type, 1980–2010



Source: Energy Information Administration, *International Energy Outlook 1990.*

jected rising price advantage of coal, nuclear, and hydro-based electricity over oil and gas during this period. The demand for coal will rise to meet increasing demand for electricity generation; hydro and nuclear power will also continue to make significant contributions to worldwide electricity generating capacity. The large U.S. and Soviet Union economies are projected to retain their position as the major consumers of energy through the year 2010. However, the U.S. share of the global market as an energy consumer will continue to decrease over the long term, as the developing nations secure a growing portion to fuel their rapid economic growth.

United States Energy Demand

***Sources suggest** that U.S. energy demand will grow moderately over the coming decades.*

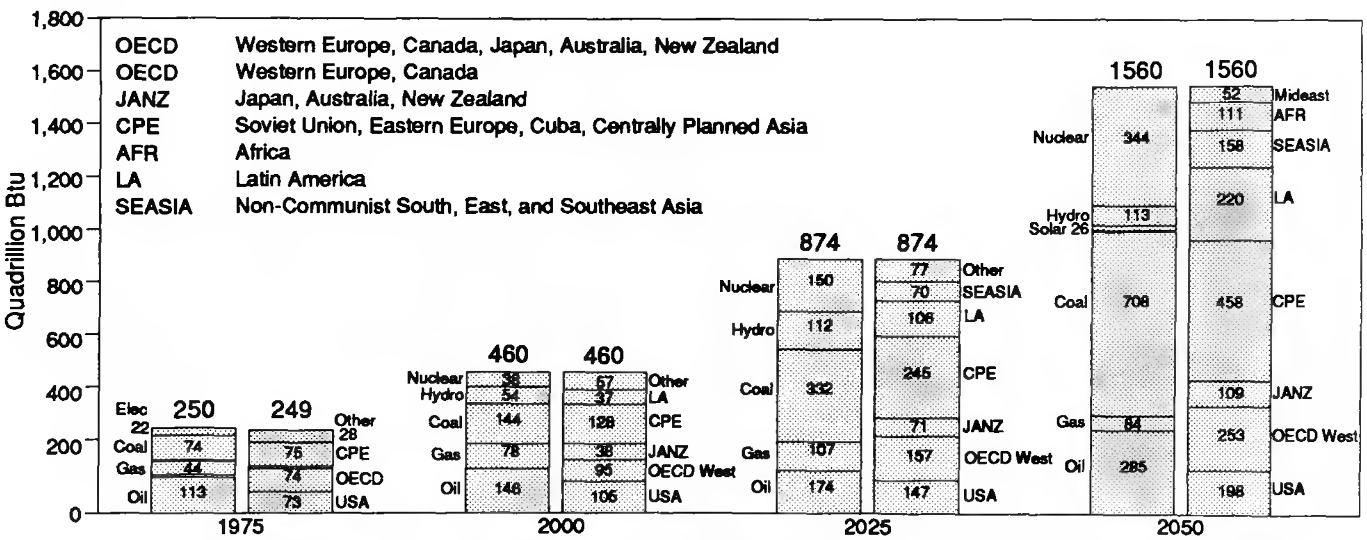
With some exceptions, most forecasts of U.S. primary energy consumption show moderately growing demand over the longer term, with growth rates ranging from about 0.5 to about 1.5 percent per year. Like the rest of the world, U.S. energy consumption patterns will be influenced by changing demographics, global energy and economic markets, increasing international competitiveness, and technological progress. There is little consensus about these and other factors. Accordingly, different assumptions have led to a wide range of independent estimates of future U.S. energy demand, as shown in Figure A–5.

World Energy Supplies

***Sources suggest** that absent major geopolitical disruptions, supplies of energy are adequate to meet increasing world energy demand well into the 21st century.*

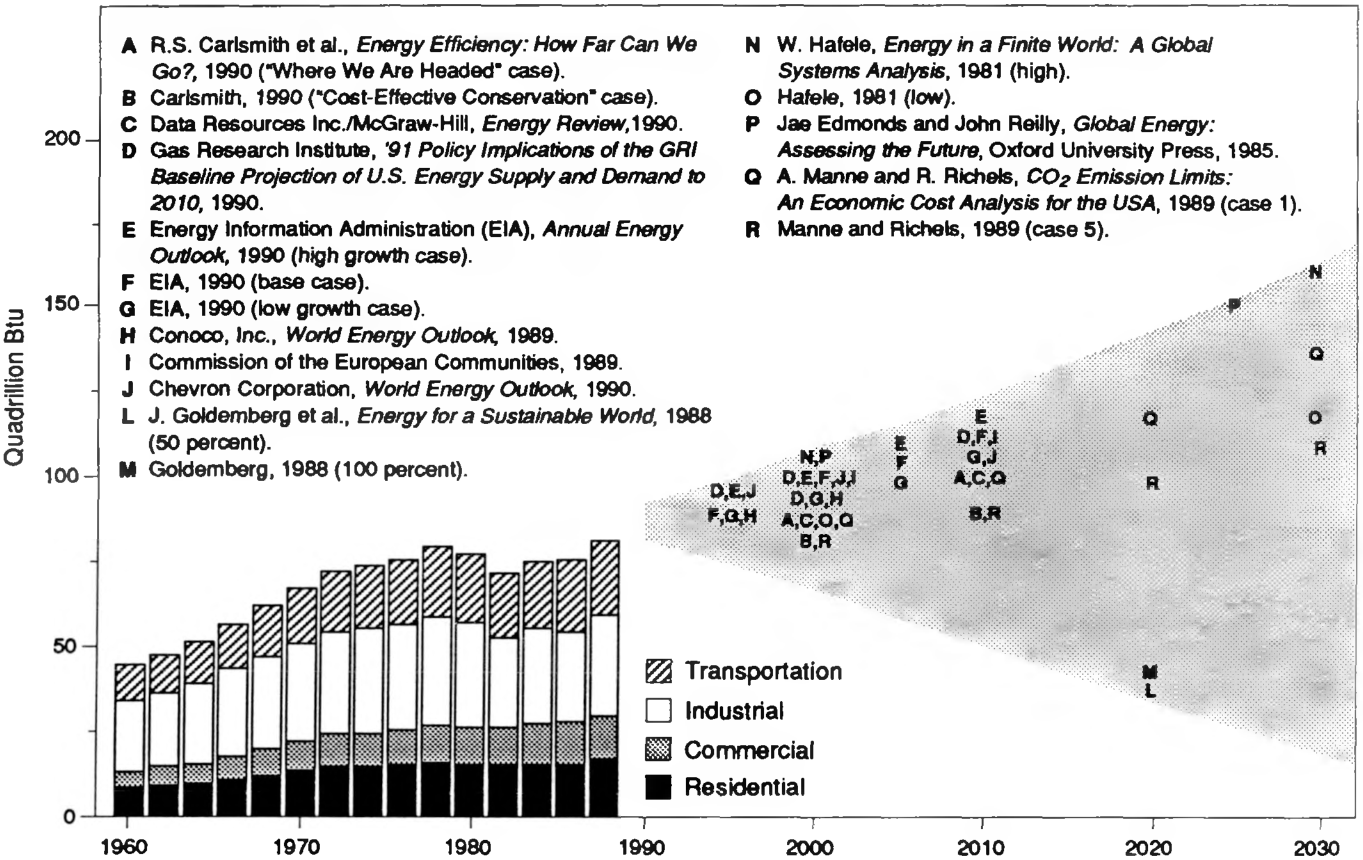
Proved worldwide energy resources are large (Figure A–6) and should be sufficient to fuel the needs of the developing world. The largest remaining known reserves of crude oil, used for producing transportation fuels, are located primarily in the Middle East, along the equator, and in the Soviet Union. U.S. proved oil reserves currently account for only about 3 percent of the world total. Large reserves of natural gas exist in the Soviet Union and the Middle East. Coal is the most abundant resource on Earth and the primary fuel for electricity in the United States, which has the largest proved reserves.

Figure A–4. Projected Energy Demand, by Fuel and Region, 1975–2050



Source: Edmonds & Reilly, *Global Energy—Assessing the Future,* Oxford Press, 1985.

Figure A-5. Projections of U.S. Primary Energy Consumption



Note: Differences in projections are caused, in part, by varying assumptions concerning energy prices, economic growth, consumer and producer behavior, and rates of technological change, including replacement of capital stock. The shaded area represents an envelope bracketing these differences.

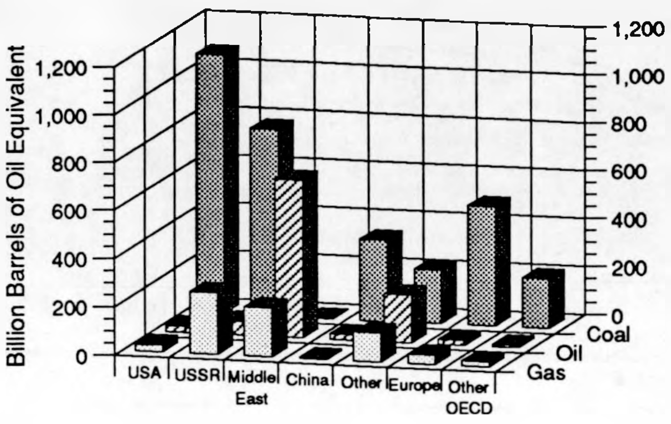
Global energy supplies have been ample enough to provide fuel for expanding economic growth all over the world. Annual world consumption is still currently less than 1 percent of combined world reserves. Given the projected demand for world energy in the near term, these resources should provide reliable supplies of energy well into the future.

In the long term, should supply and demand factors dictate rising prices, new oil industries (shale oil, synthetic oil) will receive considerable attention. With higher oil prices, supplies produced from these sources will begin to expand rapidly (Figure A–7). Unconventional oil resources could add as much as 625 billion barrels of oil to present world oil reserves, which are currently estimated at about 990 billion barrels.[1] Significant additions to future natural gas supplies are expected, as well, to come from the North West Shelf project in Australia, the Troll-Sleipner complex in Norway, and from the Soviet Union.

World Oil Demand

***Sources suggest** that oil will remain the dominant international transportation fuel for the foreseeable future. Major sources of growth for oil demand will arise from increased use in transportation, oil-fired power generation, and, to a lesser extent, portable heating fuels (for example, kerosene) in developing countries.*

Figure A–6. Proved World Energy Reserves

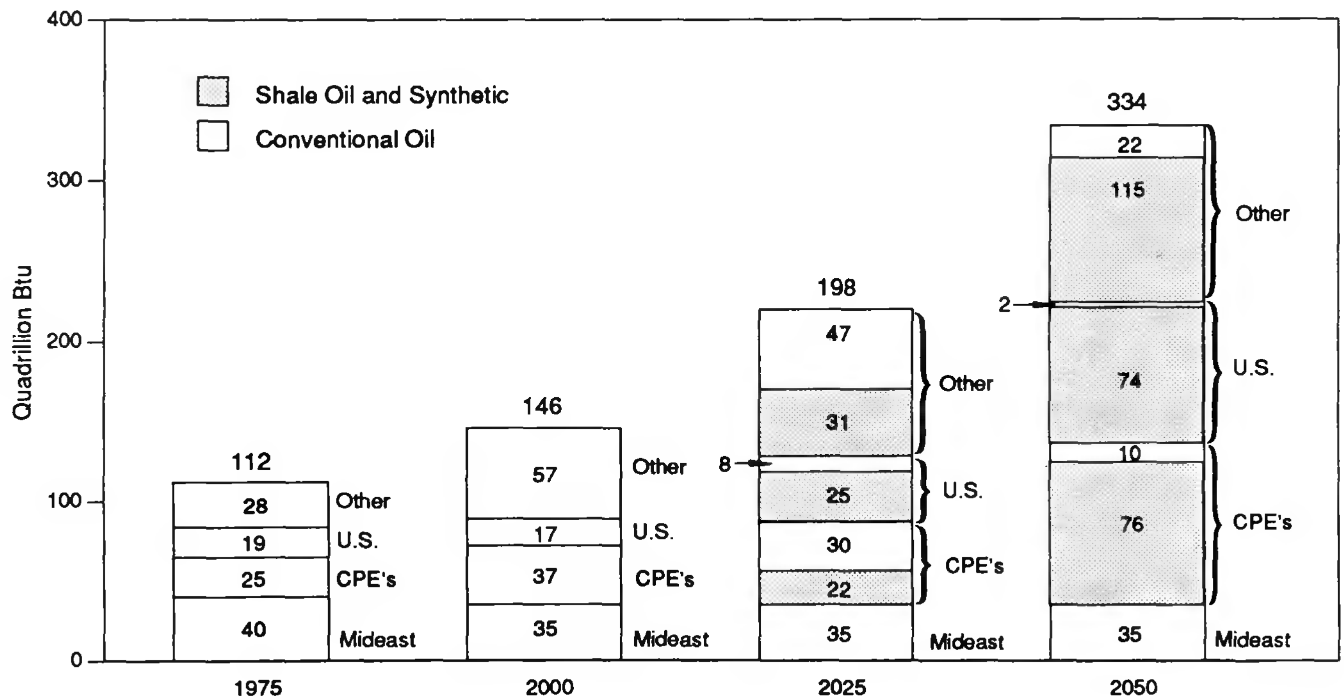


Source: Energy Information Administration, *International Energy Annual 1988.*

In the near term, the general consensus drawn from the studies is that petroleum will continue to dominate as the transportation fuel of choice for the next two decades, and will maintain a significant role until 2030 and perhaps beyond. Growth in oil demand during the next 20 years is expected to proceed at a somewhat slower rate than for other energy resources. World oil demand will account for a large portion of the global demand for energy, with some of the fastest growth in the developing nations (Figure A–8). The intensity of oil use in these countries will remain high for the next decade as they build a manufacturing base and transportation infrastructures. Less developed countries, which also rely on oil as a major fuel source for electrification, may experience problems in shifting from oil to other fuels to produce electricity.

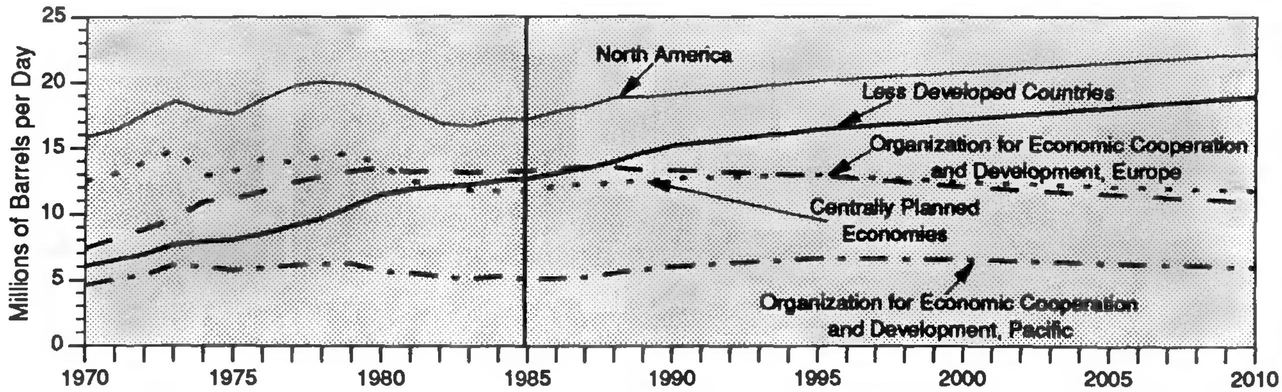
For the long term, most studies agree that beyond 2010 the role of petroleum as the single most important fuel source will begin to diminish. While continuing to grow in absolute terms, oil's relative

Figure A–7. Projected Regional Supplies of Oil, 1975–2050



Source: Edmonds & Reilly, *Global Energy—Assessing the Future,* 1985.

Figure A–8. World Oil Consumption, 1970–2010



Source: Energy Information Administration, *International Energy Outlook*, 1990.

share of total energy use will decline. The world will see increased use of alternative fuels, natural gas, and electricity (Figure A–4). Alternative fuels that offer substantial potential to supplement petroleum-derived transportation fuels include alcohols produced from renewable sources, natural gas, electricity, liquefied petroleum gases, hydrogen, and, to a lesser extent, solar energy. The extent of market penetration for these alternative fuels will be strongly dependent upon their environmental benefits, safety, performance, and cost-competitiveness with conventional petroleum-fueled vehicles. Even optimistic estimates project significant market penetration of alternative-fuel vehicles only after extended periods of high oil prices have stimulated increased development efforts, by 2010 and beyond.[2]

Persian Gulf

***Sources suggest** that global reliance on Persian Gulf oil will increase. The vast majority of the world's most economic, known reserves are concentrated in this region.*

Approximately 65 percent of total world oil reserves are located in the Middle East. Although the high oil prices of the late 1970's stimulated greater oil exploration and production during the last 10 years in countries that are not members of the Organization of Petroleum Exporting Countries (OPEC), petroleum from these non-OPEC sources is projected to decline as the end of the century nears. OPEC has steadily expanded its market share since 1986, as nations with more expensive oil are opting for increased imports of cheaper Middle Eastern oil to meet stronger-than-anticipated demands for petroleum.[3]

Several important regions of the globe are currently undergoing transitions that will increase world reliance on Persian Gulf imports. In the Soviet Union, economic reforms, if sustained, may reduce energy sector capital investments with the objective of channeling more funds toward increased production of consumer goods. As a result, crude and gas condensate production may suffer declines. Over the long term, economic reforms will promote revitalization and stabilization of Eastern European economies, which will be accompanied by an increase in the demand for energy. The longer term increase in energy demand is expected to be met, at least in part, by an increase in imported energy, especially Middle Eastern oil.[4]

Other developments in Europe include the implementation of the unified European Community, with a single internal energy market to start in 1992. The European Community now accounts for about 14 percent of world energy consumption and imports 45 percent of its energy supply. European policymakers are taking steps now to remove restrictive national barriers, which will increase the ease of energy exchanges across borders. By exploiting the advantages of a large, single market, energy prices will be reduced and European competitiveness in world markets increased. As a single entity, the European Community may become a stronger competitor for world energy resources, reflected by increased dependence on Persian Gulf exports.[5]

***Sources suggest** that the geopolitical stability of the Persian Gulf region will remain at risk indefinitely.*

The Persian Gulf has been a region of continuing geopolitical instability and volatility. Although minor oil-supply crises erupted in the 1950's because of fighting between Israel and Egypt and the closing of the Suez Canal, the most dramatic effects were felt worldwide after the resumption of the Arab-Israeli conflict in 1973. Arab nations announced their intentions to cut exports to any country that aided Israel, including the United States. The production curtailments resulting from this embargo reduced Arab oil supplies worldwide by about 5 million barrels per day.

In 1978, conflict again erupted with the Iranian revolution and the mass exodus of that country's oil field operators, which resulted in a sharp decline in oil output from Iran. The resulting shortfall in oil, about 3.7 million barrels per day, and the lack of spare capacity anywhere in the world at the time were major factors in the ensuing oil price shocks and economic recession that followed.

The most recent Middle East conflict, the 1990 Iraqi invasion of Kuwait, again threatened the stability of oil markets worldwide with the loss of about 4.3 million barrels per day of production. An end to the long history of violent conflict in the Persian Gulf region is not yet in sight. The region will likely remain at risk indefinitely, until long-term and underlying sources of conflict and tension are resolved.

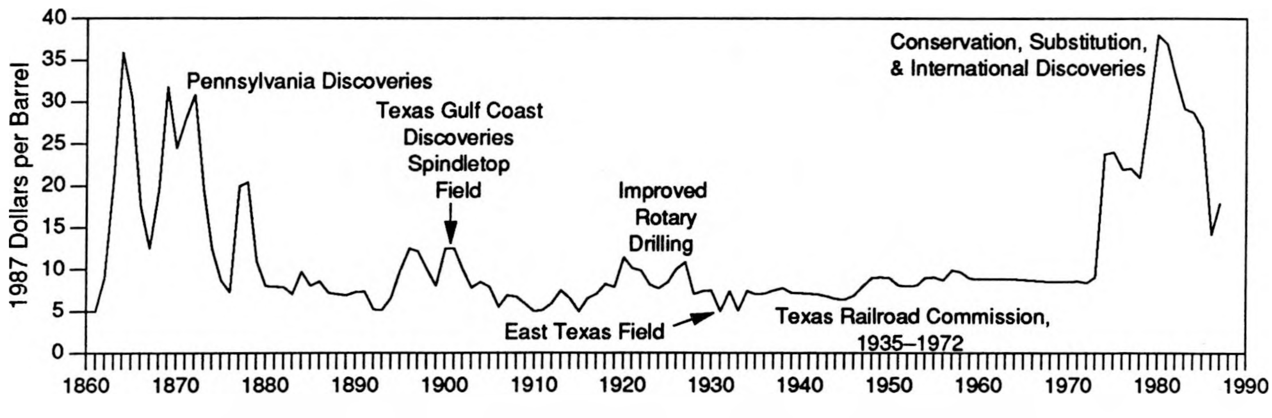
World Oil Prices

***Sources suggest** that world oil prices, over the long run, will rise moderately. Prices at any time, however, can be expected to be volatile. Historical data over 130 years suggest that significant and lasting price runups will likely occur at least once every 15 years.*

Most near-term studies predict that the price of oil will more than double by the year 2010.[6] History shows that, while it is difficult for oil cartels to create and sustain inflated oil prices over the long term, shortrun price cycles are often punctuated by periods of volatility (Figure A–9). Over the longer term, however, average prices of petroleum are likely to remain reasonable. Confidence in this view is aided by the following perspectives:

- Historical studies of natural resources and commodity prices show that volatile excursions to higher levels are rarely sustained over the longer term.

Figure A–9. Historical Crude Oil Prices, 1860–1990



Source: Oak Ridge National Laboratory, *Energy Technology R&D—What Could Make a Difference?* 1989.

- Cartels are inherently unstable.

- Technologies for unconventional oil recovery are viable at moderately higher oil prices, placing "caps" on the sustainability of high price excursions.

- Technologies for alternative fuels, fuels substitution, and increased efficiency become increasingly competitive at higher prices, placing strong downward pressures on world oil prices through reduced demand.

Oil Price Volatility

***Sources suggest** that the economic growth and stability of free-market economies are vulnerable to world oil-price volatility. Oil importing, developing countries are placed at particular risk.*

Because of the increased economic growth that occurred simultaneously in the United States, Japan, and Europe in the late 1960's and early 1970's, worldwide demand for oil was at a peak when the Arab oil embargo began in 1973. Within the first few months after the embargo began, oil prices tripled, precipitating one of the worst worldwide recessions in 50 years. Another abrupt price shock was triggered in 1979 by the Iranian revolution, in which oil prices doubled and remained high for several years, causing an inflationary recession. The abrupt price changes of the 1970's and the serious economic consequences that followed brought about a moderation in the demand for oil, an increase in oil production, and increased development of other energy supplies, that is, gas, coal, nuclear, and hydroelectric power.

As history shows, energy consumers and producers worldwide have responded to oil price shocks by taking measures to adjust supplies and by making substantial improvements in the efficiency of energy use. The Organization for Economic Cooperation and Development countries have made the greatest improvements in efficiency, and continued gains will contribute significantly to the overall stability of world oil markets. Developing nations are the most vulnerable to abrupt oil shocks and supply interruptions because they depend heavily on reliable energy supplies to fuel their newly expanding economic growth. They are also the least able to undertake energy-efficiency improvements that require high capital investments.

Large oil price fluctuations are economically disruptive for all free-market economies, and they will continue to be a major concern in maintaining a healthy world economy. Recent projections (Figures A–10 and A–11), which model the effects of oil price volatility on economic growth, demonstrate the magnitude of shortrun price shocks on the gross national product. As shown in these figures, simulated price shocks occurring around 2003 to 2005 in which the world price of oil rises temporarily to $70 dollars a barrel would result in a decrease of nearly $350 billion dollars (1982 dollars) in gross national product for the United States over the same period.

Notes

1. EIA, *International Energy Outlook 1990; Estimates of Undiscovered Conventional Oil & Gas Resources in the U.S.*, USGS and Minerals Management Service, 1989.

2. GRI, *Baseline Projection of U.S. Energy Supply and Demand to 2010,* 1989; Public Citizen, *Power Surge: Status and Near Term Potential of Renewable Energy,* 1989; Interlab Paper on Renewable Energy, *Potential of Renewable Energy,* 1989; Renew America, *Sustainable Energy,* 1989.

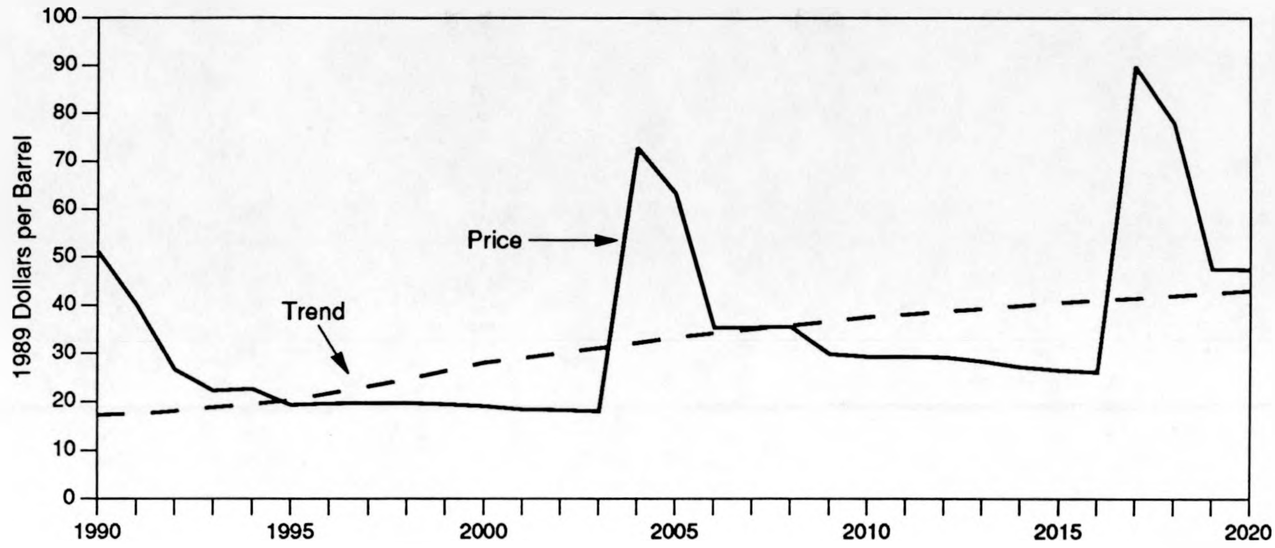
3. Chevron, *World Energy Outlook,* 1990; Conoco, *World Energy Outlook,* 1989; EIA, *International Energy Outlook,* 1990.

4. LPI Consulting, *Soviet Oil & Gas, Recent Developments,* 1990.

5. Commission of European Communities, *Energy in Europe: Major Themes,* 1989.

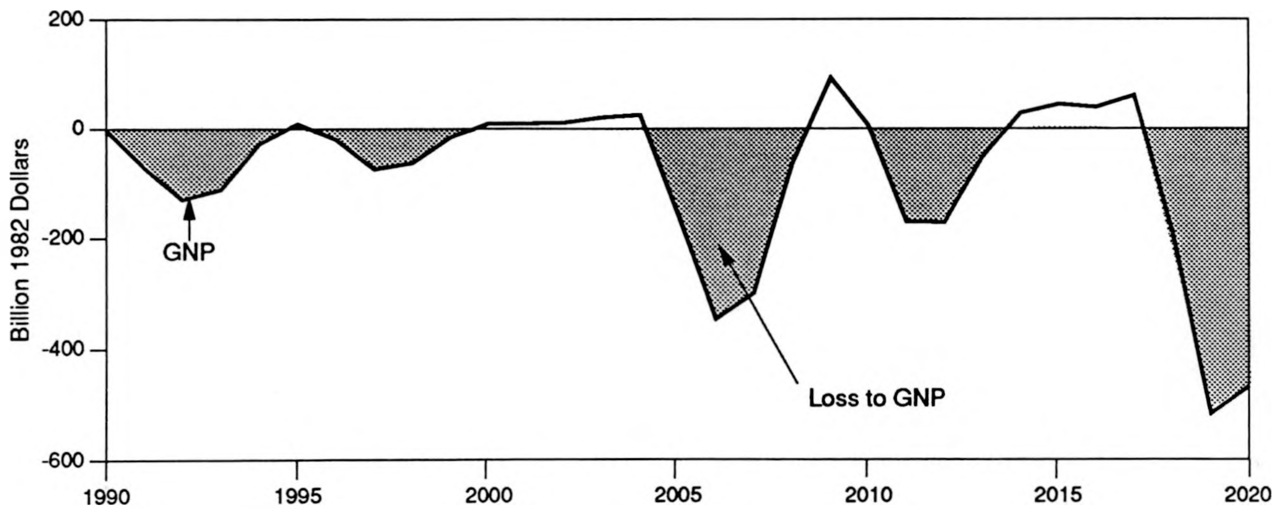
6. GRI, 1989; DRI, *Energy Review,* 1989; EIA, *Annual Energy Outlook,* 1990.

Figure A-10. A Hypothetical Volatile World Oil Price Path



Source: Energy Information Administration.

Figure A-11. Estimated Macroeconomic Losses From a Hypothetical Volatile World Oil Price Path



Source: Energy Information Administration.

APPENDIX B

National Energy Strategy Development Process: From Information Gathering to Strategy

National Energy Strategy Development Process: From Information Gathering to Strategy

The National Energy Strategy is the result of a top-down, bottom-up development approach, grounded in sound analysis and formulated through an interactive process of widespread participation. As such, it owes both its existence and content to the significant efforts of many contributors:

- The President of the United States, who recognized the need and articulated the commitment.
- The public, who early in the process helped define the universe of goals, options, and obstacles.
- The Department of Energy (DOE), which provided oversight and coordination of the process.
- The scientific, technological, and interagency community, who assessed our national and world energy future; refined and analyzed potential options in terms of their benefits, drawbacks, and economic impacts; and debated their tradeoffs.

This appendix provides a chronological overview of that process.

The Public Hearing Process: Establishing a Dialog With the Public

Following the President's July 26, 1989, guidance (see box on the next page), Secretary of Energy Admiral James D. Watkins launched an extensive and wide-ranging public interaction process, designed to solicit from the American people their views on a wide range of energy-related issues and options. A major component of this effort was a yearlong series of 18 high-level public hearings, hosted by either the Secretary or Deputy Secretary of Energy and frequently cochaired by other Cabinet officials. Witnesses representative of the interested public were invited to testify.

First Round of Hearings

The first five hearings, held in August and September of 1989, were designed to set the stage, seek information, and to define the nature and scope of the issues. Questions that witnesses were asked to address were:

- What should the priorities be for the National Energy Strategy?
- How can we best meet environmental and economic objectives for the Nation?
- What should DOE's research and development priorities be?
- What do you expect from the Federal Government by way of energy policy leadership?

Second Round of Hearings

A second round of 10 hearings was held from December 1989 through February 1990. These hearings were organized around specific energy-related themes: the domestic energy resource base, national security, environment, transportation, industrial productivity, international competitiveness, agriculture, energy regulations, science, and taxes. To reinforce the goal of building a national consensus, DOE invited other Cabinet Members to cochair these hearings.

Interim Report

By April 1990, after 7 months of gathering information, the Department of Energy had reviewed all the comments made in the 15 public hearings and all the written submissions sent to DOE from

> **The President's Charge**
>
> *On July 26, 1989, President Bush directed the Department of Energy to begin the development of a comprehensive National Energy Strategy. The President stated:*
>
> We cannot and will not wait for the next energy crisis to force us to respond.
>
> Our task—our bipartisan task—is to build the national consensus necessary to support this strategy and to make this strategy a living and dynamic document, responsive to new knowledge and new ideas, and to global, environmental, and international changes.
>
> A keystone of this strategy is going to be the continuation of the successful policy of market reliance. And it's not going to be easy. We must balance—achieve balance—our increasing need for energy at reasonable prices, our commitment to a safer and healthier environment, our determination to maintain an economy that is second to none, and our goal to reduce dependence by ourselves and our friends and allies on potentially unreliable energy suppliers.
>
> I am confident that America's can-do attitude and scientific know-how and old fashion plain common sense will prevail. By acting now, we can bequeath a legacy to the next century of a cleaner, more prosperous and, yes, more secure America.
>
> *President George Bush*
> *The White House*
> *July 26, 1989*

the public. What DOE had heard from the public was summarized in the *Interim Report on the Development of a National Energy Strategy*.

The *Interim Report* was not a draft of the National Energy Strategy, but rather a summary of the dialog DOE had with the public. The report offered, without taking sides, a wide range of views on the problems, prospects, and preferences associated with energy production, transportation, and use. It represented neither a consensus nor a uniform point of view. Rather, it expressed the wide range of disparate perspectives that were expressed through the public hearing process.

The *Interim Report*, similar to this final report, had 18 sections surrounding 4 basic themes—securing energy supplies, increasing energy efficiency, respecting the environment, and fortifying our foundations. From the public record, it identified 49 goals, 449 obstacles, and 756 options.

The commitment to maintain a public dialog did not stop with the publication of the *Interim Report*. DOE requested more information from the public. Specifically, DOE asked the public for their comments on the *Interim Report* in three areas:

- The extent to which the *Interim Report* surrounded the issues.
- The adequacy of the stated goals and identified obstacles.
- The completeness of the range of obstacles.

Third Round of Hearings

DOE began the third and final round of hearings in June 1990. Additional information was needed on the effects of energy production, transportation, and use on public health. Also, a more complete understanding was needed of energy pricing as a policy tool to achieve energy and environmental objectives. These final hearings were held in the summer of 1990, completing a full year of soliciting public input on what our energy future should be.

A complete list of all 18 hearings, dates, cities, themes, and cochairs is on page B–5.

Statistics

In total, 499 witnesses representing 43 States, 2 U.S. territories, and 2 Canadian provinces submitted testimony at the 18 hearings. These witnesses represented an impressive cross section of all interested parties: labor, management, environmentalists, producers, Native Americans, Eskimos, farmers, residential consumers, large industrial consumers, conservationists, auto manufacturers, truckers, railroads, alternative fuel advocates, and others.

In addition, more than 2,000 written comments were submitted directly to DOE for review. Whether submitted in person at a public hearing or sent directly to DOE, every written suggestion on what DOE should do to develop a National Energy Strategy was reviewed. In total, DOE reviewed more than 29,000 pages of written material, covering virtually every aspect of energy policy.

Laboratory White Paper Workshops—More Public Review

In late June 1989, DOE invited the National Laboratories to Washington, D.C., to discuss plans for the development of a National Energy Strategy. The Department asked the National Laboratories to provide advice and counsel on a range of issues that were deemed to be of special importance to the development of the Strategy. The labs subsequently sent to DOE a series of white papers on the subjects of energy efficiency, renewable energy, global climate change, and technology transfer.

In June and July 1990, DOE held three workshops on the following laboratory white papers: *Energy Efficiency, How Far Can We Go?*, *The Potential of Renewable Energy*, and *Energy Technology for Developing Countries*. These workshops differed from the public hearings in format and focus. Where the hearings had been largely formal, the workshops were free flowing and open to the public on a first-come-first-serve basis.

Since each white paper represented the best thinking of a team of National Laboratory analysts familiar with the particular issue, the purpose of the workshops was to review the papers chapter by chapter with the public. Were the assumptions about the economic, technological, and behavioral factors made by the analysts relating to these issues consistent with the assumptions made by others outside of government?

The commitment by DOE to a public review of the analytical work of the National Laboratories reflects DOE's insistence that the development of the Strategy be as open a process as possible.

Analyzing the Issues and Options

The information gathered through the public hearing process and the workshops served as a key resource for several sets of analytical activities. These activities were designed to measure, evaluate, and select from the broad range of potential Strategy options a discrete set of options to be analyzed. An overall picture of what energy we need, where it could come from, and what the consequences of energy supply and demand choices are, was the objective of the analytical effort.

The analytical goals for the Strategy were to identify market inefficiencies and security and environmental vulnerabilities. Where market inefficiencies, failures, and vulnerabilities were found to exist, their effects were to be, to the maximum extent possible, quantitatively analyzed.

Areas of Options Analyses

There were three areas of analysis. The first area dealt with interagency concerns, the second area dealt with DOE concerns, and the third area dealt with modeling efforts, including developing a National Energy Strategy Current Policy Base case.

Interagency Analysis: Economic Policy Council

DOE worked closely with other Federal agencies to analyze selected options identified in the public record. The box at right identifies those agencies that participated in the interagency analysis process. The Economic Policy Council (EPC) Working Group (Assistant Secretary level) was chaired by the Deputy Secretary of Energy and directed its efforts at options having broad national policy implications and significant interagency effects. Three areas of focus were the following:

- **Energy Security**. This group focused on petroleum supply and demand options; the goal is to reduce U.S. vulnerability to oil market disruptions.

Schedule of National Energy Strategy Hearings 1989–90

August 1	Washington, DC
August 8	Tulsa, OK*
August 23	Boise, ID*
August 28	Seattle, WA
September 8	Louisville, KY
December 1	Providence, RI (Energy and Productivity in Industry: A New England Perspective)
December 4	Houston, TX (Our Domestic Energy Resource Base with Manuel Lujan, Jr., Secretary of the Interior)
December 8	Omaha, NE (Agriculture as a Consumer and Producer of Energy with Clayton K. Yeutter, Secretary of the U.S. Department of Agriculture)
December 11	Detroit, MI (Transportation and Energy with Elaine L. Chao, Deputy Secretary of Transportation)*
December 13	Washington, DC2 (Energy, Defense, and Security Interests with Donald J. Atwood, Deputy Secretary of Defense)
December 14	Atlanta, GA (Energy and the Environment with William K. Reilly, Administrator of the Environmental Protection Agency)
January 11	Honolulu, HI (Energy Supply and International Competitiveness)
January 22	Washington, DC3 (Oil and Gas Regulation with Martin L. Allday, Chairman of the Federal Energy Regulatory Commission)
February 2	New Orleans, LA (Tax Policy with John E. Robinson, Deputy Secretary of the Treasury)*
February 9	Washington, DC4 (Science with D. Allan Bromley, Office of Science and Technology Policy, White House)
July 6	Bethesda, MD (Public Health with James O. Mason, Assistant Secretary, Public Health, Department of Health and Human Services)
July 20	Washington DC5 (Pricing with Richard L. Schmalensee, Council of Economic Advisors)
August 27	Fairbanks, AK (with R. Thomas Weimer, Chief of Staff, Department of the Interior)*

* Chaired by W. Henson Moore, Deputy Secretary, DOE

- **Electricity**. This group analyzed electricity generation, transmission, and use options; the goals are to provide more reliable, lower cost service to consumers; increase efficiency in the electricity sector; and foster fuel and technology diversity, including renewable energy technologies, in electricity generation and use.

- **Environment**. This group focused on the interaction between energy and environmental regulatory and statutory policy; the goal is to improve environmental quality through policies that emphasize clean, efficient energy sources and technologies, without sacrificing economic growth or affordable energy.

DOE Internal Analysis

In parallel with the Economic Policy Council-National Energy Strategy analysis, the Department of Energy conducted an internal analysis of science and technology options. These options were also reviewed by the EPC. This ad hoc group focused on the application and management of technology development on the future of U.S. economic and energy security. New technology is also a prerequisite to achieving global environmental objectives; the goal is to expand the roles that energy science and technology play in achieving energy, economic, and environmental objectives.

Current Policy Base Case

Concurrent with the interagency and DOE analyses, a Current Policy Base case was developed based on the assumption that no major changes in energy policy will occur in the next 40 years (see Appendix C). The National Academy of Sciences is reviewing DOE's use of models for the National Energy Strategy and has been asked by Secretary Watkins to provide guidance to DOE on building a better National Energy Modeling System.

Members of EPC–NES Working Groups

The White House
Office of the Vice President
U.S. Department of Agriculture
U.S. Department of Commerce
U.S. Department of Defense
U.S. Department of Education
U.S. Department of Housing and Urban Development
U.S. Department of the Interior
U.S. Department of Justice
U.S. Department of Labor
U.S. Department of Transportation
U.S. Department of the Treasury
U.S. Department of State
Assistant to the President for Science and Technology
Council of Economic Advisors
Council on Environmental Quality
Environmental Protection Agency
Federal Energy Regulatory Commission
National Science Foundation
National Security Council
Nuclear Regulatory Commission
Office of Management and Budget
U.S. Trade Representative

Option Analyses Review

Consistent with the Secretary's requirement that the development of the National Energy Strategy be an open process, DOE sought comments on the option analyses. Two types of reviews were established. The first process relied on solicited comments from scientific and technical experts, the second on both solicited and unsolicited comments from the public.

Secretary of Energy Advisory Board

In January 1990, the Secretary of Energy established the Secretary of Energy Advisory Board (SEAB) to advise the Secretary on the research, development, and national defense responsibilities, activities, and operations of DOE. The membership was to be broadly representative of diverse viewpoints and expertise. Members came from the private sector, nonprofit groups, academia, and State and local governments.

Upon completion of the first draft of option analyses, a group of SEAB members volunteered their time to provide an independent assessment of the Strategy analyses. These members reviewed and commented on the options in their areas of expertise.

Public Review of Options

In the fall of 1990, DOE made available to the public a summary of the analyses of the National Energy Strategy options. These summary options were reviewed by trade organizations, environmental groups, energy producers, consumers, conservationists, and others.

Based upon the comments from both SEAB and the public, the DOE and EPC Working Group analysts revised and fine-tuned their analyses.

Final EPC Principals Review

Before the National Energy Strategy was submitted to the President, a final review was undertaken by the Economic Policy Council principals. Four Cabinet meetings were conducted, two of which were led by the President. The product of these meetings is a comprehensive package of action items that meet the President's goals of balancing the Nation's need for energy at reasonable prices, reducing reliance on insecure energy supplies, maintaining an economy second to none, and committing to a safer, healthier environment.

APPENDIX C

The National Energy Strategy Scenario: Methodology, Assumptions, and Results

The National Energy Strategy Scenario: Methodology, Assumptions, and Results

Appendix C describes the analysis used to estimate the integrated effects of the National Energy Strategy actions and summarizes the results. The analysis draws on and complements a large body of other, independent analyses of separate Strategy actions. These other analyses form the basis for the integrated analyses, but are not described here. The focus here is on the methods used and insights gained regarding the *combined* effects of the Strategy's actions, as suggested by the use of energy modeling tools.

The energy modeling tools used in this analysis represent the best currently available to the Department of Energy. All modeling results, however, have limitations, and it is recognized they become particularly significant the further into the future one attempts to explore. Accordingly, the results of the modeling analysis were taken into consideration with caution. It is emphasized that use of energy modeling was undertaken to provide additional perspective, and not to make precise projections or forecasts. In addition, the information gained by this effort was but one of many factors considered in the overall Strategy analysis.

While many of the figures in Appendix C appear to be precisely drawn, they represent only one set of many possible future scenarios examined. The more important aspect of this kind of modeling analysis is not the projection itself, but instead the observed changes among the projections resulting from the Strategy's actions. These changes were tested under a number of varying assumptions.

Appendix C is organized into three sections. The first section presents an overview of the analysis process, including descriptions of how the baseline for the analysis was developed, how the results of the other independent analyses were incorporated, and the identification of key measures used to assess the Strategy's estimated effects. The second section describes the Current Policy Base case—the baseline or analytical point of departure for the analyses. Two alternative baselines are also described that are used to address uncertainty issues—a low economic growth case and a volatile world oil prices case. The third section describes the combination of actions comprising the National Energy Strategy—their impacts on energy markets, the environment, and the economy.

Analysis Process

The National Energy Strategy analysis process consisted of four steps: (1) narrowing of options identified by the public, (2) development of baseline projections of future energy supply and demand to provide an analytical frame of reference, (3) indepth analyses of narrowed options, and (4) integration of these analysis within a modeling framework.

Narrowing of Options

The National Energy Strategy process of public hearings, described in Appendix B, identified hundreds of energy policy options. These are reported in the *National Energy Strategy Interim Report: A Compilation of Public Comments*. The first step in the analysis process was to narrow these candidate options. Options affecting all fuels and energy-consuming sectors of the economy were considered for analysis.

Baseline Energy Projections

A set of baseline projections of future energy supply and demand was established using numerous independent model results and analyses. Because the function of this baseline is to provide an analytical frame of reference for the analyses, the projections assume no changes in current Federal energy policies. As such, the baseline is characterized as the "Current Policy Base" case.

This baseline should not be interpreted as a forecast of the future. Rather, it is a hypothetical projection based upon a set of specific assumptions about markets, technologies, and resources. The paramount assumption in this baseline is the embodiment of "current law and regulation," that is, the lack of changes in Federal policies. In this sense, this baseline is a most unlikely energy future, especially over a 40-year time horizon. However, it is a necessary assumption for a point of departure for analysis of proposed changes to current energy policy.

A key to understanding the baseline is the set of underlying assumptions. Both these assumptions and the baseline are discussed in the "Current Policy Base Case" subsection of this appendix.

The Current Policy Base case was constructed with the aid of many diverse analytical tools and the judgments of experts both inside and outside the Department of Energy. The starting point for this case was the *Annual Energy Outlook 1990* "base case forecast" (Energy Information Administration 1990). Departmentwide modeling groups were formed to revise assumptions in that forecast (where appropriate) and to develop assumptions for extending the projection out to the year 2030. Detailed sector and fuel-specific models maintained by the Energy Information Administration and the Department of Energy's National Laboratories were used to generate independent supply-and-demand projections. These independent projections were then integrated through the National Energy Strategy integrating model to provide price and quantity feedbacks among sectors to "clear" energy markets (that is, to balance energy supply and demand). The sector and fuel-specific results of this integration process were then fed back into the detailed models to provide a check on the integrating model results.

The combination of detailed models and the integrating model was used to make best use of the current set of Department of Energy tools. It was determined that no single model existed that could provide the level of detail necessary for the current policy baseline, as well as the integrated analysis of the full slate of energy policy options. However, the modeling "system," consisting of the many models assembled for this analysis, did provide both sufficient detail and flexibility to produce a set of baseline projections and address the most important "what if" questions.

Internal consistency could be maintained within this system of models because of the nature of the models themselves. The majority of these tools are structural simulation models. This makes it possible not only for the results of models to be shared among each other, but also to have them all driven by the same underlying assumptions and projected changes in market structure. Information developed with the detailed models was transferred to the integrating model by carefully calibrating the structure of the integrating model. Through this type of information sharing, consistency was maintained among the models, despite differences among the models.

A key step in developing baseline projections of future energy markets was the identification of the major factors that determine the demand and supply of energy. There are basically four types of assumptions underlying the projections: (1) behavioral factors, which assume energy consumers minimize energy costs; (2) economic factors, which include gross national product (GNP) growth rates, world oil prices, and other assumptions; (3) energy resources, which include proved reserves and undiscovered resources; and (4) energy technologies data, which include information on costs of both energy-consuming and energy-producing technologies, information on the performance of these technologies, and information on when they will likely become commercially available.

Independent Analyses

The full set of National Energy Strategy actions, referred to as the Strategy "scenario," covers a broad range of issues—affecting virtually every fuel- and energy-consuming sector of the economy. Actions were analyzed by groups of experts from the Department of Energy, the National Laboratories, and other Federal agencies. Because of the differences in energy type, sector structure, and the nature of problems facing each sector, these groups selected models or other tools best suited for the examination of the particular action. Many different models and other tools were therefore used in the evaluation of impacts of Strategy actions on energy supply and demand. These models and tools were not necessarily the same as those used in the development of the Current Policy Base case. Many of the baseline development tools lacked sufficient policy detail to be useful in the analysis of actions, so additional tools were identified. Consistency among the tools was maintained through use of the detailed assumptions and results of the Current Policy Base case.

The analyses used the Current Policy Base case as the starting point for the quantitative analysis of impacts of each action on energy markets. Information on demand, supply, and prices for each type of energy from the Current Policy Base case were used to quantify the impact of a specific action on supply or demand. For example, the oil recovery technologies research and development (R&D) analysis used the oil prices in the Current Policy Base case in the examination of the effect of R&D programs on oil production. The natural gas regulatory reforms analysis used Current Policy Base case demand, supply, and gas price information as a point of departure to determine the effect of these reforms on prices, demand, and supply. Once the independent analysis of each action was complete, the results were integrated to see the estimated combined effects.

Integration

Many policy actions affect more than one sector or fuel; changes in one sector often affect fuel prices, which in turn affect energy demand and supply in other sectors. In addition, policy actions usually do not work in isolation from other actions; some actions may work in tandem, while others may work at odds with one another. The purpose of analyzing the actions in combination, or "integrating" them, is to provide an understanding of these effects, or to provide perspective.

Examples of such policy interactions abound. For example, nuclear power actions may result in substantial new nuclear capacity when analyzed in isolation, but when combined with utility demand-side conservation investments, the expansion in nuclear generating capacity may be somewhat less because of electricity conservation. The oil and gas tax incentive actions are projected to increase oil production from enhanced oil recovery (EOR) by themselves only marginally. However, when combined with the oil recovery technologies R&D action, the economics of EOR improve significantly, and the contribution of oil from EOR to total U.S. oil production increases substantially.

It is important to note that not all Strategy actions were quantitatively integrated. Some have important but relatively small direct impacts (for example, stimulation of mass transit and ride sharing); others have minor direct effects but major indirect effects (for example, technology transfer); still others could not be rigorously quantified because of lack of data (Alaskan North Slope development). In general, those actions having significant direct impacts that could be quantified were analytically integrated.

The National Energy Strategy integrating model provided a systematic and consistent framework for the analysis of Strategy actions. Because this model has demand representations by sector and end-use, supply representations by energy types, and market clearing mechanisms for demand and supply, it can simulate both the price effects and the interfuel competition effects of each action on energy markets. Economic, energy security, and environmental impacts of individual Strategy actions were evaluated through equilibration of supply, demand, and prices.

Key Measures

Economic Measures

A National Energy Strategy action can affect energy demand and supply. These changes in energy markets are mostly due to movements in energy prices resulting from improved efficiency; changes in technology costs and performance; or R&D and technology transfer; or economic incentives.

The impacts of a Strategy action on the general economy can be estimated at both the macroeconomic and microeconomic level. At the macroeconomic level, the Energy Information Administration-Data Resources Incorporated (EIA-DRI) macroeconomic model was used to quantify the impacts of the Strategy actions on GNP. At the microeconomic level, both the consumer and producer surpluses were used to estimate the impacts of Strategy actions—both individually and on a combined basis.

Energy Security Measures

Energy security is measure of the vulnerability of an economy to a disruption of oil supplies and the resulting escalation in the price of oil. Quantitatively, the risks associated with oil vulnerability are indicated by the economic losses that would result from an oil price shock resulting from an oil supply disruption. In general, an economy that uses relatively less oil per dollar of GNP and is more diversified would be less vulnerable to an oil supply disruption.

For a supply disruption of a given size, the impacts on world oil prices would be smaller if total demand for oil was relatively smaller. This implies that reducing the volume and share of oil in total primary energy consumption could reduce the exposure to the risks of an oil supply disruption on the economy. The effectiveness of a National Energy Strategy action in improving energy security is, therefore, suggested by its potential to reduce oil vulnerability, as defined above.

Environmental Measures

Energy-related pollutant emissions that could be reasonably quantified with existing National Energy Strategy tools include carbon (CO_2 and CO), methane (CH_4), nitrogen oxides (NO_x), sulfur oxides (SO_x), and volatile organic compounds. SO_x and NO_x are believed to be major sources of acid rain, while NO_x, CO, and volatile organic compounds are major contributors to urban smog. CO_2, CO, and CH_4 are climate change gases that contribute to greenhouse warming potential (GWP). A "GWP index," taking into account the fact that different gases have substantially different global warming potential, was used to estimate climate change impact. This issue is discussed in "Energy and Global Environmental Issues."

The impact of National Energy Strategy options on the environment was estimated on the basis of reductions of selected emissions, as well as decreased greenhouse warming potential.

Current Policy Base Case

The Current Policy Base case depicts a hypothetical U.S. energy future to the year 2030, in which no major shifts in energy policies are assumed to occur. Its purpose is not to predict the actual future. In fact, because it represents essentially a "frozen policy" case, the future it shows is very unlikely. The purpose of this Current Policy Base case is simply to provide a common baseline for analysis. This baseline can then be used to analyze the likely future effects (in terms of price, supply, energy security, environmental factors, and timing) of various combinations of policies that could be adopted as interacting elements of U.S. energy policy. Two overarching principles are represented in the Current Policy Base case. First, it embodies a free-market economy, where choices promote economic efficiency unless otherwise constrained. Second, and importantly, it reflects "current laws and regulations." Trends that either promote or impede certain technological choices are assumed to continue in the Current Policy Base case.

The Current Policy Base case includes the effects of current laws, enacted through the summer of 1990. Legislation enacted after September 1990, but not yet implemented, is considered to be included in the National Energy Strategy actions case in the "Integrated Analysis of the National Energy Strategy" subsection of this appendix. Such legislation includes extensions of ethanol production credits, oil and natural gas production incentives, and the 1990 amendments to the Clean Air Act. The Current Policy Base case presumes that no new laws or policies affecting energy use will be implemented during the next 40 years. Of course, this would be a totally unrealistic assumption if one were attempting to forecast the most likely future; but it makes the Current Policy Base case very useful for analyzing alternative policies objectively. An equally sweeping assumption in this baseline is that there will be no major changes in the structure of the U.S. and world economies. The Current Policy Base case does not take into account the possibility of wars or major national disasters. It takes a reasonably optimistic view of future technical promise, but it tries not to engage in "wishful thinking."

The Current Policy Base case 40-year time horizon is unusually distant. Yet this is necessary to evaluate the possible long-term consequences of policy decisions facing the Nation today. For example, if nuclear powerplants should be allowed to be retired and not replaced with new nuclear plants as a source of U.S. electricity generation, few of the consequences of that action would become apparent until after 2010. The effects of improving automobile mileage or appliance efficiency emerge only gradually over many years, because capital stocks turn over slowly. Remote time horizons are also needed to gauge the consequences of successful R&D on energy markets.

These Current Policy Base case projections have been built up from detailed studies of consumer behavior, demographics, economic trends, the best available data on resources, and the expert judgments of specialists in technological development.

Many of the assumptions made in the Current Policy Base case about technologies, consumer and investment behavior, energy resources, oil prices, and economic growth are subject to great uncertainty. Any analytical baseline must accept some such uncertainties; but a set of alternative baselines (or "sensitivity" analyses from the Current Policy Base case) have also been developed to gauge the effects of foreseeable variations in two major assumptions—those about world oil prices and economic growth. These alternative cases have been used in the Strategy analysis to determine to what degree changes in these basic assumptions would alter the effectiveness of policy actions. These sensitivity cases include volatile oil prices and lower growth for the U.S. economy.

Key Assumptions

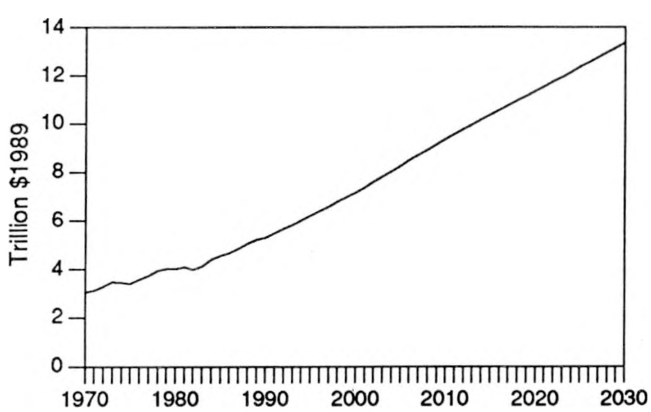
Many assumptions about technologies, energy prices, consumer behavior, energy resources and other factors underlie the Current Policy Base case. As mentioned above, the single most important assumption is that Federal energy policies will not change in the 40-year time frame. However, several other assumptions are important enough to warrant discussion:

Free Market. The Current Policy Base case embraces the unique abilities of a free-market economy. Market choices promote economic efficiency unless otherwise constrained. To the extent that current laws and regulations have fostered trends that either promote or impede certain technological choices, however, this case projects these trends as continuing.

GNP Growth Rates. The U.S. economy is assumed to expand by 2.3 percent per year in the long run, but not at a constant rate over 40 years. The economy is projected to grow on average at a rate of 3.1 percent annually from 1990 to 1995, but a subsequent decline in the population growth rate causes the economic growth rate to average 2.9 percent from 1990 to 2010, and 1.8 percent from 2010 to 2030. Several other macroeconomic variables (industrial production, occupied housing stock, vehicle travel, airline travel, disposable income, and commercial floor space) are also linked to GNP and to population projections. Beyond 1996, these variables were derived from a run of the quarterly macroeconomic model of Data Resources Incorporated, using assumptions about energy prices from the Current Policy Base case and assumptions about economic growth and labor productivity provided by the U.S. Council of Economic Advisors. Economic output assumptions are depicted in Figure C–1. A sensitivity case embodying lower rates of economic growth is presented in later in this section.

World Oil Prices. Beyond the current short-term price spikes and declines prompted by the Iraqi conflict, the Current Policy Base case assumes that world oil prices will stabilize at a lower level, but then rise again more slowly—to about $28 per barrel (in constant 1989 dollars) by the year 2000. Over the remaining 30 years, they climb to more than $47 per barrel (again in 1989 dollars). These oil price assumptions are consistent with those used in a study completed recently by the Energy

Figure C–1. Economic Growth Assumptions
Current Policy Base

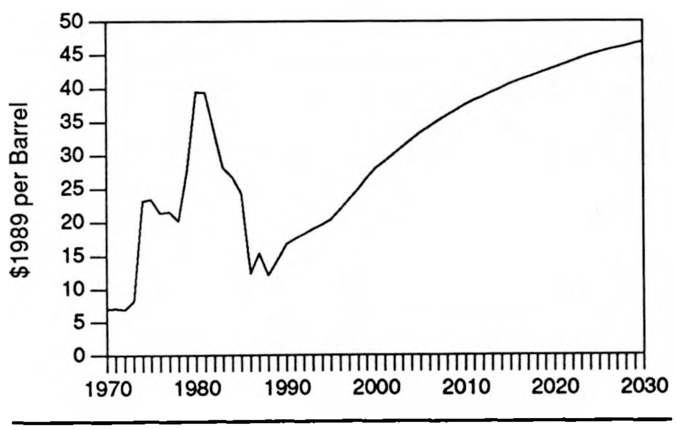


Information Administration (EIA) on the size of the Strategic Petroleum Reserve, and those published (through 2010) in EIA's *Annual Energy Outlook 1990*. World oil price assumptions are depicted in Figure C–2. A sensitivity case embodying oil prices that fluctuate considerably is presented later in this section.

Energy Conservation and Efficiency. The Current Policy Base case assumes steady gains in the energy efficiency of the U.S capital stock and a steady decline in energy consumption per unit of GNP. The fuel efficiencies of vehicles and aircraft are assumed to rise, and new homes and appliances are expected to be much more energy efficient than the existing capital stock. Homes are projected to use 10 percent less energy, and commercial buildings to use 17 percent less energy by 2010. Industrial energy use is expected to fall nearly 30 percent per unit of output by 2010, though automobile ownership turns over very slowly, and consumers are assumed to maintain their preferences for large cars with energy-consuming options. Nevertheless, fleet efficiency is projected to rise slowly, with the average climbing from about 19 miles per gallon today to 21.3 miles per gallon by 2010. The National Energy Strategy includes policy actions that result in more rapid efficiency gains in buildings, transportation and industry.

U.S. and World Oil Resources. The Current Policy Base case makes no explicit assumptions about world oil resources except for the general assumption that they are sufficiently large so that the United States will be able to import large quantities with only a moderate impact on world oil prices. The Current Policy Base case is more explicit about low-cost oil resources within the United States, which are assumed to be in the range of 80 billion barrels. Low-cost resources are defined as the total resources that are likely to be producible economically within a given time frame at costs that equal or are lower than prevailing oil prices. The National Energy Strategy includes an oil recovery technologies R&D option that results in substantially greater recovery of these resources through improved oil production technologies.

Figure C–2. World Oil Price Assumptions
Current Policy Base



Natural Gas Resources. A key assumption in the Current Policy Base case is the size of domestic resources of "low-cost" natural gas ($5 per million British thermal units or less). This assumption was based on several evaluations of undiscovered gas resources that ranged from 300 to 900 trillion cubic feet.

Oil and Gas from Restricted Areas. The Current Policy Base case also assumes no development and production of oil or gas from the Arctic National Wildlife Refuge coastal plain and no further leasing of mineral rights in restricted areas of the Federal Outer Continental Shelf. This stipulation is based on the presumption that some policy intervention or change in public attitudes would be necessary to permit gas and oil development to resume in these areas. The National Energy Strategy includes policy actions that allow for environmentally safe exploration and production in these regions.

Alternative Transportation Fuels. After 2010 the Current Policy Base case assumes that long-term "stable" oil prices will be higher than those that have been experienced at any time other than in 1981-80. Under such circumstances, economic production of alternative transportation fuels may become possible. In the Current Policy Base case, nevertheless, there are no methanol imports, and domestic alcohol production is projected to be a relatively minor 250,000 barrels of oil equivalent per day by 2010. This is due to obstacles in the marketplace that may prevent the widespread use of alternative fuels, even when the fuels become economically competitive. These obstacles include the fact that fuel production, vehicle manufacture, and fuel distribution infrastructure would all need to be simultaneously developed. The National Energy Strategy includes policy actions that remove these obstacles and facilitate the widespread use of alternative fuels.

Nuclear Power. The Current Policy Base case deliberately assumes that no new nuclear powerplants are ordered, and that the licensed lifetimes of existing plants are not extended. This is based on the proposition that some policy intervention and a major change in the climate of public opinion would be needed to make new nuclear orders feasible. In addition, operators of existing plants who might propose to continue them in service beyond the licensing periods originally envisioned would have to comply with Nuclear Regulatory Commission regulations that have yet to be promulgated. The National Energy Strategy includes policy actions that have the potential to revive the option of nuclear power for electricity generation.

Renewable Energy. Energy production from nondepleting sources is assumed from the outset to be the most rapidly growing form of energy in the United States over the next 40 years. Because renewable energy supplies start from a very small base, however, renewables still are projected to reach only a 9-percent share of the Nation's total primary energy supply in 2010 (versus an 8-percent share today) and a 12-percent share by 2030. The renewable energy sources that are assumed to achieve commercial significance by then are very diverse. It is assumed that the costs of geothermal power, wind energy, photovoltaic, and solar thermal power will decline considerably over the next four decades—making them more price-competitive. Hydroelectric power, however, is projected to grow only slightly because of the difficulty in licensing (and relicensing) hydroelectric facilities. The potential contribution of renewable technologies for widely dispersed end-uses, additional contributions to electric power generation and various types of alcohol as economically and technically feasible liquid fuels for transportation is quite large. The National Energy Strategy includes policy actions that reduce the costs and accelerate the penetration of these renewable technologies. In addition, the Strategy includes actions to reform the hydroelectric licensing process.

Clean Coal Technology. The Current Policy Base case does not by any means assume that the technologies for generating electric power will stand still. In addition to the changes in renewable technologies discussed above, it counts on advanced systems based on steam-injected gas turbines becoming available during the 1990's. After the year 2000, it is anticipated that a number of advanced clean coal technologies will compete for the power generation market; these technologies are expected to include pressurized fluidized-bed boilers, as well as integrated gasification–combined-cycle generators. These new technologies have several key benefits, including lower costs, higher efficiencies and extremely low levels of SO_x and NO_x emissions. The National Energy Strategy includes a policy action that accelerates the penetration of these clean coal technologies.

Baseline Summary

Overall Energy Use

For the period between 1990 and 2030, this country is projected in the Current Policy Base case to increase its consumption of primary energy (including what is used to generate electricity) at an average rate of about 1.3 percent per year. This is substantially less than the assumed growth in the national economy as a whole, but considerably more than twice the rate of U.S. population growth (0.5 percent per year). Electricity consumption is expected to rise rapidly in this period: it climbs on the average of about 2.6 percent each year over the period between 1990 and 2010 and 1.6 percent per year after 2010. These growth rates are summarized in Table C–1. Figures C–3 and C–4 show total primary energy consumption and consumption by fuel.

The figures indicate that the economy is expected to become substantially more energy efficient than it is today. All sectors—buildings, industry, and transportation—are expected to be more efficient. However, the most critical element in the outlook for future U.S. energy demand from a policy perspective is not the aggregate total of energy consumption, but a breakdown of the types of energy inputs that are foreseen as being required—as well as where that energy will come from. This aspect is treated in the following sections.

Table C–1. Growth Rates for Basic U.S. Energy Factors: Current Policy Base Case

Period	U.S. Population	U.S. GNP	Primary Energy Demand	U.S. Electricity
1990–2000	0.7	3.0	1.6	2.9
2000–2010	0.5	2.7	1.7	2.2
2010–2020	0.4	1.9	1.1	1.9
2020–2030	0.2	1.6	0.9	1.4

Figure C–3. Primary Energy Consumption
Current Policy Base

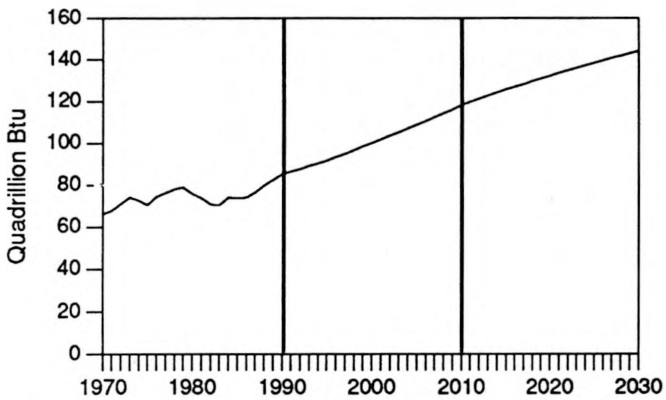
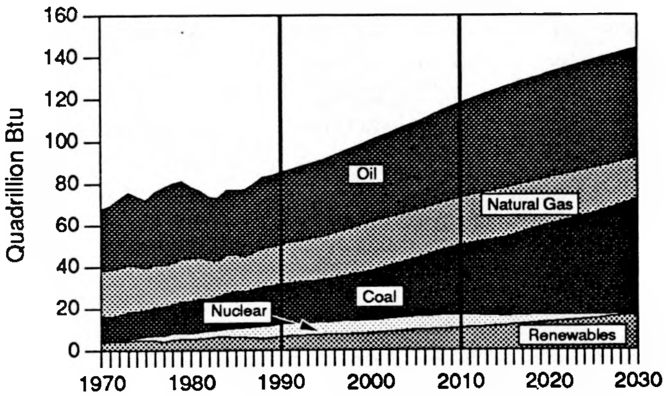


Figure C–4. Primary Energy Consumption by Fuel
Current Policy Base



Oil

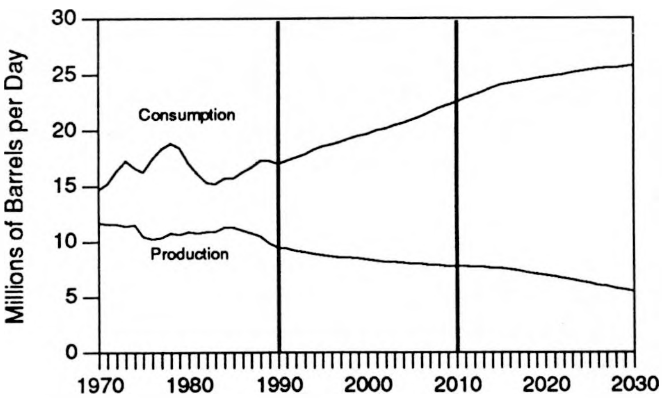
Under any of the cases examined in this report, U.S. domestic oil production is projected to decline, and oil imports are projected to rise. Oil consumption and production are shown in Figure C–5.

Oil Production

The current policy projection of a continuing falloff in U.S. oil output is rooted in recent history. Proved reserves of U.S. crude oil peaked in 1970 at 39 billion barrels; domestic oil production (including natural gas liquids) peaked the same year at 9.5 million barrels per day. Both reserves and production have been declining since then, despite sharply higher oil prices and up to 2 million barrels per day of additional production from Alaska's North Slope. Only during the period between 1981 and 1984 did U.S. oil production stabilize, in the aftermath of very high oil prices. However, U.S. oil production resumed its decline in 1985, even before the oil price collapse of 1988.

The Current Policy Base case shows the combined total of U.S. crude oil and natural gas liquids from domestic sources declining by about one-half over the period being considered—from 9.0 million barrels per day in 1990 (excluding refinery gains) to 6.8 million barrels per day in 2010, and only 4.4 million barrels per day by 2030. This translates into an average annual decline of 1.8 percent per year, much slower than the 5-percent per year drop recorded between 1985 and 1990. The slower

Figure C–5. Oil Consumption and Production
Current Policy Base



rate of decline is caused by higher real oil prices and by the increased levels of enhanced oil recovery. Enhanced oil recovery production rises from only 400,000 barrels per day in 1990 to more than 1,100,000 barrels per day by 2010. After 2010, as oil prices exceed $40 per barrel, oil production from high-cost sources such as tar sands becomes economical, with production reaching 1.2 million barrels per day by the year 2030. Despite rising oil prices, production of synthetic oil from coal and oil shale does not become economical before 2030.

Oil Consumption

U.S. oil demand can be divided conceptually into two major components. The first is a transportation component that chiefly comprises gasoline, jet fuel, and middle distillates such as diesel oil, but also including some heavier oil used by maritime vessels. The second is a nontransportation fuel component that includes home heating oil and various types of industrial or commercial grade liquid fuels.

In addition, a certain amount of crude oil is directed ultimately into nonenergy uses—such as the production of petrochemicals, plastics, and road surfacing material. The transportation component is based primarily on commercial and personal transportation, but it also includes fuel for engines used in construction, agriculture, and mining. The nontransportation fuel component includes electric power generation, a variety of industrial fuel applications, and home heating oil for use in residential and commercial buildings.

While there are many substitutes for oil in its nontransportation uses, there are now few practical ways to replace it directly in its mobile applications. In the United States, the use of transportation services (as measured by vehicle- and passenger-miles traveled) has continued to grow through two oil shocks and two recessions, with only momentary pauses. The Current Policy Base case projections reveal that the transportation sector will continue to be a crux of the U.S. energy challenge.

Since the early 1970's, motor vehicle and airplane fleet vehicle efficiency have increased steadily. Average fleet efficiency changes slowly, however, because only a small portion of the total fleet is replaced by new vehicles each year. Although less efficient equipment is being replaced constantly by new equipment that is capable of operating more efficiently, these efficiency savings do not cancel out the growth in aggregate demand that is foreseen as the entire capital stock of the transportation sector expands and is used more intensely. In the Current Policy Base case, transportation oil use grows 40 percent by 2010, with highway fuels rising more than 30 percent and jet fuel climbing more than 70 percent.

The amount of oil used by nontransportation sources varies more than that used for transportation purposes, and is more sensitive to fluctuations in prices. Through most of the 1950's and 1960's, oil increased its market share within nontransportation markets at the expense of coal and noncommercial fuels such as wood. When oil prices skyrocketed in the 1970's, consumers had a substantial incentive to look for ways of converting to other fuels. In 1978, the U.S. burned 1.7 million barrels per day of oil for power generation (about 10 percent of total U.S. oil use). However, by 1985 this figure had fallen to about 475,000 barrels per day—less than one-third of the amount used for this purpose only 7 years previously. Industrial oil consumption in the United States declined 26 percent between 1979 and 1985, even though much industrial oil consumption involved nonsubstitutable uses. Conversely, falling oil prices in the mid-1980's permitted the use of oil as a generating fuel to climb back to about 700,000 barrels per day during 1988 and 1989. In the Current Policy Base case, nontransportation oil use grows slightly over 10 percent by 2010, with most of the growth in industry.

In the Current Policy Base case, future oil consumption is projected to grow very slowly in the aggregate—at an annual rate of only about 1.3 percent per year through 2010, and 0.7 percent thereafter as oil prices continue to rise. This is well under half the anticipated growth rate for GNP, and substantially below the growth rate for total energy consumption. Overall, U.S. oil consumption rises from 17.4 million barrels per day (MMBD) in 1990 to 22.6 MMBD in 2010 and 25.8 MMBD by the year 2030.

Net Oil Imports

With U.S. oil production continuing to decline and demand rising slowly, net oil imports rise in the Current Policy Base case projections from about 7.6 million barrels per day in 1990 to 14.8 million barrels per day in 2010 and 20 million barrels per day by 2030. This would mean importing roughly 7 out of every 10 barrels of oil this country uses in 2010 and 8 out of every 10 in 2030.

Natural Gas

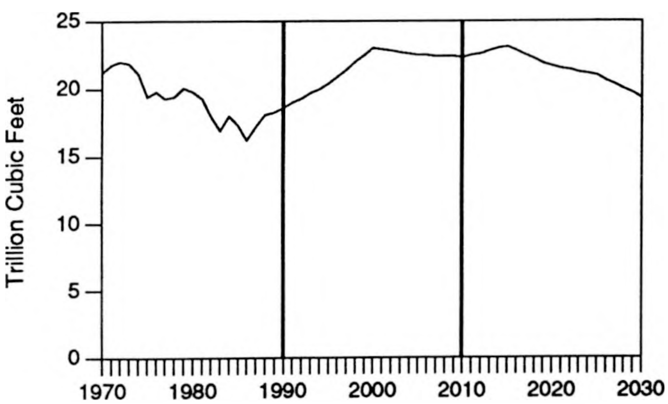
There are strong indications that the production and consumption of natural gas within the United States will rise over the next two decades. Projected gas consumption is shown in Figure C–6.

Domestic Gas Production

For natural gas, the response to current prices and drilling rates in terms of domestic production and the "proving" of additional reserves differs substantially from the situation for oil as described above. A "bubble" of natural gas supply continues to exist in this country and additional production in the future from formerly price-controlled "old" gas may be expected with some confidence.

Despite some major obstacles to growth in U.S. consumption of gas (detailed under "Natural Gas" in this report), the Current Policy Base case projects that production of natural gas will rise substantially over the next few years in response to higher demand over the next 20 to 30 years.

Figure C–6. Natural Gas Consumption
Current Policy Base



However, in the long run, it is expected that low-cost natural gas resources will be depleted. Consequently, even as natural gas production rises, long-term prices for this fuel are projected to rise rapidly and make possible exploitation of the very large higher-cost resources in tight sands and other unconventional sources, that are known to exist. Eventually, however, the Current Policy Base case projection shows higher prices decreasing demand. Consumption (and total production) declines slowly after 2015.

U.S. production of natural gas from existing areas of development is expected to be supplemented by the introduction of natural gas from Alaska's North Slope (starting in 2005). Alaskan gas production is projected in the Current Policy Base case to reach 1.3 quads (1.2 trillion cubic feet) by 2010, and begin to decline after 2020.

The natural gas production projections are rooted in a series of estimates of undiscovered natural gas resources, made by the U.S. Geological Survey, the Department of Energy, and the Potential Gas Committee. They judge undiscovered resources of "low-cost" gas (that is, gas recoverable at a market price of less than $5.00 per million British thermal units) to be 300 to 900 trillion cubic feet (tcf). Natural gas production over the life of the Current Policy Base case is about 700 tcf, and current proven reserves of natural gas are 168 tcf.

Gas Consumption

Consumption patterns for gas tend to respond readily to price trends. During the 1990's, gas consumption is seen rising rapidly—making particular inroads into the growing fuel market for electric power generation. Advanced turbine technologies—such as gas-turbine–combined-cycle installations and steam-injected gas turbine units—combine low capital costs with very high operating efficiencies. After 2015, however, the prospect of steadily rising prices for natural gas decreases its share in electric utility and some industrial markets, with coal and coal gasification taking its place. Even at relatively high prices, however, natural gas retains a strong presence in most markets—especially residential and commercial buildings—where fuel-switching is generally more difficult.

Gas Imports

Pipeline imports (largely from Canada) rise from about 1.4 tcf at present to 2.3 tcf in 2005, but diminish thereafter. As in the United States, Canadian low-cost gas reserves are presumed to decline by early in the next century. After 2005, increasing volumes of pipeline gas are presumed to be available from Mexico. Imports of liquefied natural gas rise from less than 0.1 tcf now to 1.4 tcf per year in 2010, and to 2.4 tcf per year by 2030. The bulk of the growth in liquefied natural gas is assumed to come after 2000.

Coal

Without nuclear power, and with gas prices rising in the long term, electric utilities are projected to turn increasingly to coal for base-load power generation. As shown in Figure C–7, this leads to substantially higher total coal consumption. The United States has enormous reserves of this fuel, equivalent to more than 250 years of coal production at current levels.

In the Current Policy Base case, coal consumption nearly triples by the year 2030. Consumption rises from about 900 million tons (19 quads) today to nearly 1,550 million tons in 2010 to nearly 2,600 million tons by 2030. Advanced clean coal electricity generation technologies such as pressurized fluidized-bed and integrated gasification–combined-cycle plants greatly increase the efficiency of this coal use and result in substantially lower emissions than would otherwise be the case. Coal accounts for almost 55 percent of electricity generation today, but by 2030 this share is projected to reach 75 percent.

Nuclear Power

No new nuclear plants have been ordered since 1978. Given the potential for cost overruns, safety-related design changes during construction, and local opposition to new plants, most utility executives suggest that none will be ordered in the foreseeable future unless there is some change in the climate of public opinion, standardization of designs, and a streamlined licensing process.

Assuming that no new nuclear powerplants are built over the next 40 years and that existing plants are not relicensed at the expiration of their 40-year licenses, nuclear power output is projected to rise only slightly through 2010 (because of the expected completion of three additional plants under construction and slightly higher operating efficiencies), but declines sharply over the following 20 years. As shown in Figure C–8, nuclear generation rises from about 550 billion kilowatt-hours (kWh) today to 594 billion kWh in 2010, but declines to only 35 billion kWh by 2030, as only 5.7 gigawatts (GW) of capacity (about 6 large plants) remain operating. Results for National Energy Strategy options to revitalize the nuclear option for power generation are presented under "Nuclear Energy."

Figure C–7. Coal Consumption
Current Policy Base

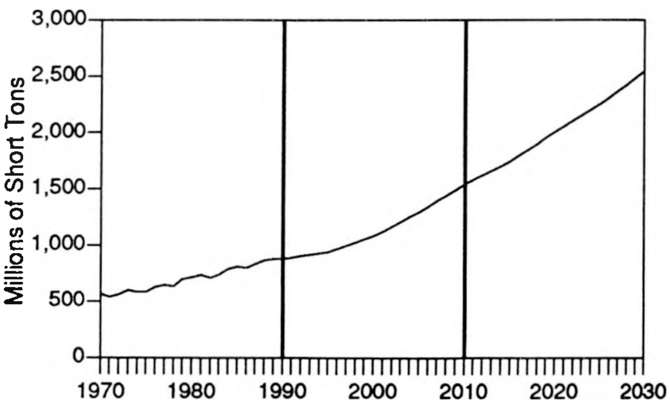
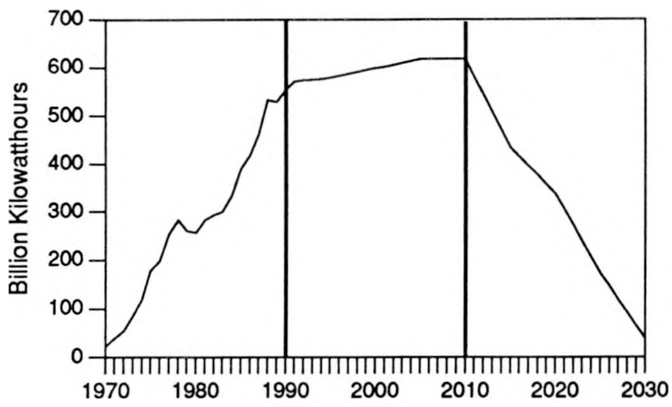


Figure C–8. Nuclear Electricity Generation
Current Policy Base



Renewable Energy

An alternative to fossil fuels and nuclear power in the electric power generation market is renewable energy technologies. The most common and important form of renewable energy today is large-scale hydroelectric power generation, which is of particular importance in the Western United States.

Large-scale hydroelectric projects have become increasingly difficult to carry through in recent years, however, because of competing uses for land and water. Relicensing requirements for existing hydroplants may even lead to the removal of some dams to protect or restore wildlife habitats. On the other hand, studies have suggested that the capacity of many existing small hydroplants could be increased considerably by upgrading. These issues are discussed at length elsewhere in this report. Absent policy changes, the contribution of hydro would grow only 0.2 percent per year—from 3.2 quads in 1990, to 3.4 quads in 2010, and 3.5 quads by 2030.

Other renewable energy sources (such as biomass, geothermal wind, or solar energy) are relatively expensive—and economical only in localized areas. Furthermore, wind, solar, and biomass energy require large land areas to produce significant amounts of energy. The Current Policy Base case assumes that ongoing energy R&D will reduce the cost of these renewable energy resources.

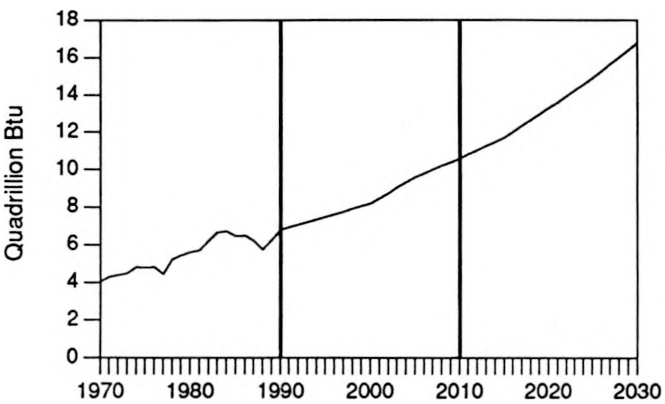
Output of geothermal energy is projected to rise nearly tenfold, from about 20 billion kWh to 184 billion kWh in 2030. This equates to nearly 3 percent of all U.S. generation of electricity at that time. Output of wind energy also increases substantially by 2030, to 110 billion kWh. This is about 1.7 percent of 2030 electrical generation. Overall, renewable sources in the Current Policy Base case account for about 12 percent of the Nation's electricity generation by the end of the next four decades. This is up only slightly from renewable energy's 11-percent share in 1990, but the apparently modest size of the percentage increase is explained by the fact that existing generation capacity in this country is already quite large—and that hydroelectric output is presumed to rise only about 9 percent through 2030.

In addition, about 9 percent of 2030 energy demand in the residential and commercial sectors is projected to be met with dispersed sources of renewable energy (such as wood and solar water heaters). This represents about 2.2 quads of energy, or more than double current usage. End-use consumption of renewable energy in industry for direct combustion also more than doubles, growing from 1.8 quads today to 4.4 quads in 2030. This would account for about 11 percent of total industrial energy consumption in 2030. (Industrial use of renewable energy already includes considerable use of wastes within the pulp and paper industry.)

Finally, alcohol fuels make inroads late in the Current Policy Base case, with less than 100,000 barrels per day of production being projected by 2010, and more than 250,000 barrels per day by 2030. Alcohol fuels are expected to be used as gasoline additives. "Conventional" alcohol production—making ethanol from corn by means of current technology—is not an economically attractive option, even at the higher oil prices projected. Without significant technological advances, production of methanol from biomass is also not economical. Results for National Energy Strategy policy actions to facilitate the wider use of alternative fuels and economic production of biomass alcohol fuels are presented under "Transportation Energy Use."

Overall, renewable energy's contribution rises from about 8 percent of U.S. primary energy consump-

Figure C-9. Renewable Energy Consumption
Current Policy Base



tion today to 12 percent by 2030 in the Current Policy Base case. This is shown in Figure C–9. The modest performance of renewable energy for power generation is largely due to competition from advanced coal technology. Advanced coal technologies and some renewable technologies will compete for the utility baseload market after 2005. In the Current Policy Base case, nuclear power is ruled out by assumption, and coal costs are significantly lower than costs for renewable energy. As a result, coal picks up the predominant share of the market lost by retiring nuclear powerplants. However, selected renewable technologies are projected to compete favorably in various other power generation markets, including peak power and some intermediate applications.

Electricity

Electricity consumption is projected to rise faster than any other end-use fuel, reflecting the increasing electrification of the economy. As shown in Figure C–10, consumption is projected to rise from 2,700 billion kWh (9.2 quads) in 1990 to nearly 4,500 billion kWh (about 15 quads) in 2010 and more than 6,200 billion kWh (about 21 quads) by 2030. This is due both to the inherent advantages of electricity for many applications as well as the relative stability of electricity prices in the current policy future. Average electricity prices rise only 10 percent by 2010 and 16 percent by 2030.

Electricity prices rise much more slowly than fossil fuels for a number of reasons. First, a large share of the energy used to generate electricity is coal and nuclear, both of which are projected to have low fuel costs. Second, and more importantly, the capital costs for many generation technologies remain constant or fall in the Current Policy Base case because of extensive research and development currently under way. As the price of electricity is more dependent upon capital costs than fuel costs, this factor keeps the costs of generating electricity relatively low. Finally, the effects of the 1990 Clean Air Act Amendments are not included.

The mix of fuels used to generate electricity is projected to change substantially in the long term under the Current Policy Base case as nuclear virtually disappears. This is shown in Figure C–11. In the year 2000, the share of coal is expected to be 50 percent, while nuclear's share is 16 percent and renewables' share is 12 percent. In 2010, the share of coal is projected to reach 59 percent, while nuclear decreases to 13 percent and the renewables share is 12 percent. By 2030, the coal share exceeds 75 percent, while nuclear plummets to a mere 1 percent and renewables increases to 15 percent. The result is an unbalanced electricity generation system dominated by a single fuel. Apart from the potential reliability problems inherent in overreliance on any single fuel, it is unlikely that these vast quantities of coal could be mined without causing substantial environmental stress.

Figure C–10. Electricity Consumption
Current Policy Base

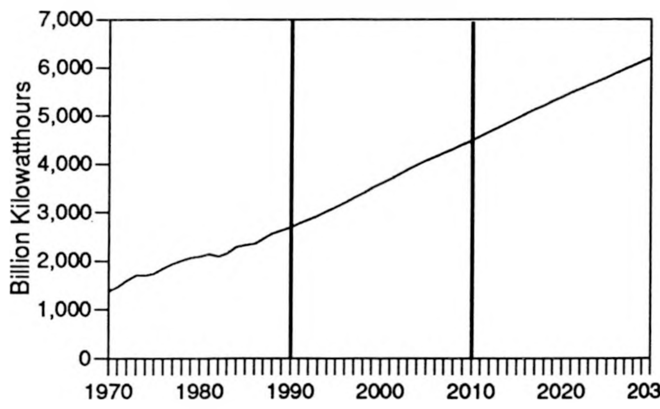
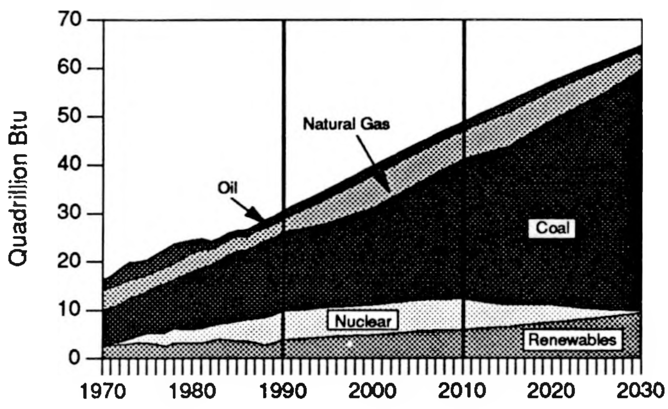


Figure C–11. Energy Input to Electricity Generation
Current Policy Base



Transportation Energy Use

Transportation energy use is expected to be dominated by petroleum fuels for the foreseeable future in the Current Policy Base case. Oil use is projected to rise substantially as demand for travel outplaces efficiency gains. Highway passenger travel is projected to increase 80 percent over 40 years, while highway freight travel and air travel both more than double. Without large increases in fuel prices or government conservation policies, highway fleet efficiencies rise only slowly because of consumer preferences for large vehicles and the slow turnover of stocks. Average onroad passenger vehicle efficiency is expected to rise from about 19 miles per gallon (mpg) today to 21.3 mpg in 2010 and only 23.2 mpg by 2030. The net result of rapidly rising travel and only slowly rising efficiencies is shown in Figure C–12. Transportation oil demand rises from 21.6 quads (11 MMBD) in 1990 to about 30.4 (15.5 MMBD) in 2010 and over 35 quads (18 MMBD) by 2030. This represents 70 percent of future U.S. oil consumption and is the single largest contributor to the extremely high levels of oil imports projected in the Current Policy Base case.

Residential Energy Use

Energy consumption in the residential sector is more balanced among fuels, with gas, electricity, oil, and renewables all having significant market shares. Residential primary energy use, depicted in Figure C–13, rises modestly—from 18.2 quads in 1990 to 23.3 quads in 2010 and 27 quads by 2030. This rate of growth is far less than the growth in housing stock; under the current policy assumptions, the average home is 27 percent more efficient in 2010 and 15 percent more efficient by 2030.

Oil use in homes declines as oil heating systems are slowly retired and few new houses are built with oil heat. The oil share drops from about 15 percent at present to 8 percent in 2010 and 6 percent by 2030. Electricity captures the bulk of the growth in total residential energy consumption, as electricity prices rise much more slowly than oil or gas, and more new houses have electric heat pumps, air conditioning, and more appliances. The electricity share of residential demand is projected to rise from 30 percent in 1991 to 39 percent in 2010 and 45 percent by 2030.

Commercial Energy Use

Energy consumption in the commercial sector today is split among electricity, gas, and oil. Commercial primary energy use, depicted in Figure C–14, rises much faster than residential consumption—from 13.8 quads in 1990 to nearly 21.3 quads in 2010 to more than 29 quads by 2030. This rapid rise is driven by the assumptions about commercial construction; the amount of commercial floor space is projected to rise by 55 percent by 2010 and more than double by 2030. This is a reflection of the expected continued growth in finance, services, and other commercial sector

Figure C–12. Transportation Oil Consumption
Current Policy Base

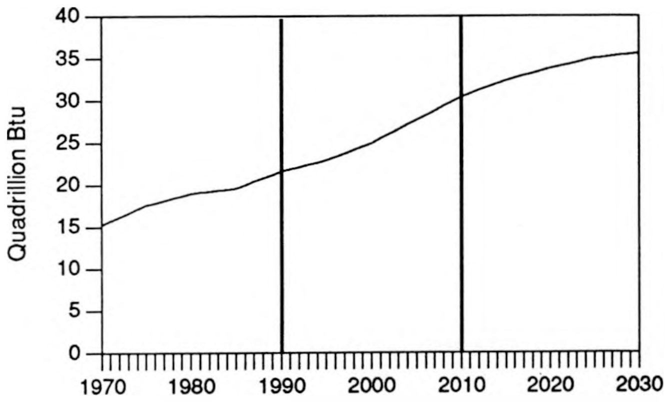


Figure C-13. Residential Primary Energy Consumption
Current Policy Base

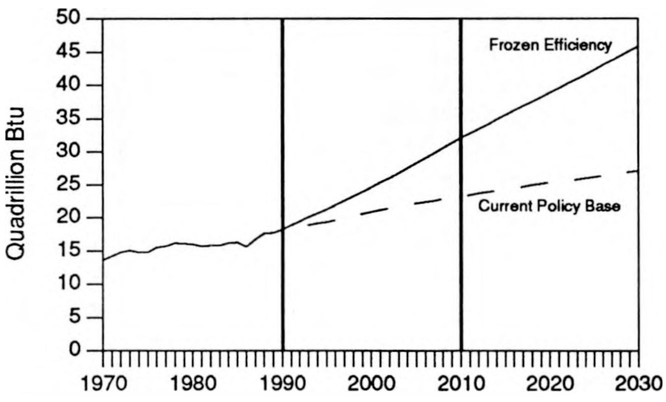
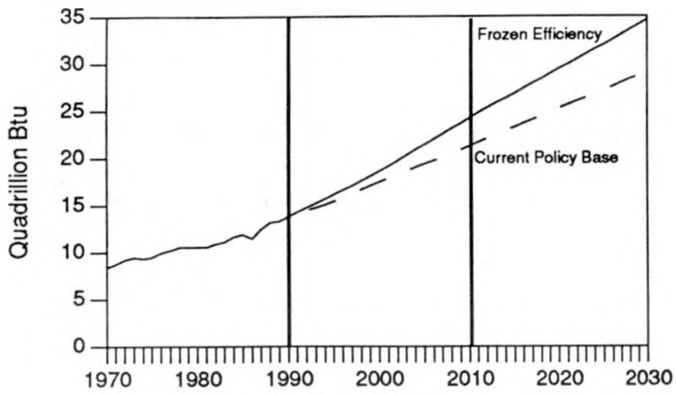


Figure C–14. Commercial Primary Energy Consumption
Current Policy Base



categories. Still, the rate of growth in consumption is far less than the growth in floor space; under the Current Policy Base case assumptions, average end-use efficiency is 17 percent higher in 2010 and more than 20 percent higher by 2030.

As in the residential sector, oil use in commercial buildings declines as oil heating systems are slowly retired and few new ones are installed. The oil share drops from about 14 percent at present to 9 percent in 2010 and 6 percent by 2030. Again, as in the residential sector, electricity captures the bulk of the growth in total energy consumption, as electricity prices rise more slowly than oil or gas and demand rises for lighting, electric heat pumps, and air conditioning. The electricity share of commercial consumption is projected to rise from 42 percent today to 57 percent in 2010 and nearly 65 percent by 2030.

Industrial Energy Use

The industrial sector is projected to realize the greatest efficiency gains among the four end-use sectors in the Current Policy Base case. Large gains in efficiency have already been realized in the last 15 years, but it is estimated that large opportunities for investment in conservation still exist. Average efficiency is expected to be 30 percent higher in 2010 and 40 percent higher in 2030. Nevertheless, total industrial energy consumption rises substantially, but far more slowly than industrial output. Primary energy use, depicted in Figure C–15, increases from 32 quads in 1990 to about 45 quads in 2010 to more than 55 quads by 2030. This rapid rise is driven principally by the assumptions about industrial output; output is projected to rise 80 percent by 2010 and more than 150 percent by 2030.

Unlike the residential and commercial sectors, the share of oil use in industry is projected to remain fairly constant as residual fuel competes favorably with gas as a boiler and cogeneration fuel. Electricity consumption, however, rises substantially, reflecting growth in industries requiring significant amounts of electricity. Electricity as a share of total industrial consumption is projected to rise from 13 percent today to 17 percent in 2010 and about 20 percent by 2030.

Emissions of Climate Change Gases

With nuclear power disappearing and coal consumption rising substantially, emissions of energy-related climate change, or "greenhouse gases," rise rapidly. Despite the increasing efficiency of coal use for power generation and the higher efficiency of the transportation sector, CO_2 emissions are projected to rise substantially in the long term. As shown in Figure C–16 carbon emissions are estimated to be 45 percent higher than today in 2010 and 95 percent higher by 2030. Emissions of methane are also projected to rise substantially because of higher coal production. Total global warming potential is also expected to rise.

Figure C–15. Industrial Primary Energy Consumption
Current Policy Base

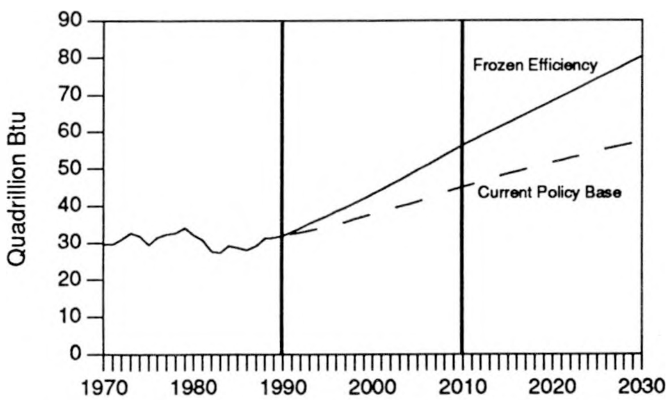
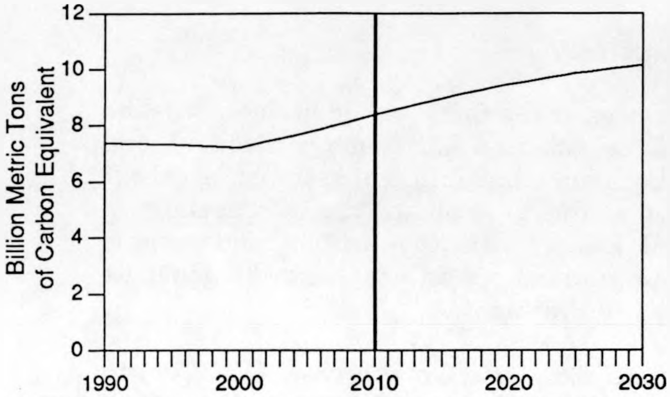


Figure C–16. Global Warming Potential
Current Policy Base



Emissions of Criteria Pollutants

SO_x emissions rise because of increased coal use. Emissions rise 20 percent by 2010 but then gradually fall after 2015 as conventional coal powerplants retire and are replaced with clean coal technologies.

NO_x emissions are more difficult to project because of the complexity of mobile sources (for example, automobiles), but are expected to rise steadily because of higher transportation fuel consumption in the long term. Emissions of volatile organic compounds and carbon monoxide associated with urban smog are not explicitly projected, but environmental specialists with the Department of Energy expect that these would be likely to rise as well in the Current Policy Base case.

Alternative Baselines

The Current Policy Base case is one of many possible projections of future U.S. energy markets. It is derived from an extensive set of assumptions such as economic growth rates, world oil prices, U.S. energy resources, and costs and performance characteristics of energy-consuming and -producing technologies. Most of these assumptions are generated on the basis of imperfect information; the exact numerical values of these assumptions, therefore, can have very wide ranges. To provide sensitivity analysis, two alternative baseline cases are provided that encompass some of the uncertainty underlying these two key assumptions.

Economic growth rates and world oil prices are two key factors that strongly affect both domestic demand and supply of primary energy. Assumptions on economic growth rates determine GNP, which reflects the level of various economic activities such as commercial growth, industrial production, and travel. All of these economic activities demand energy. In general, higher energy demand is associated with a higher level of GNP. Assumptions on the world oil price profile and the pattern of that profile make implicit assumptions about the availability of world petroleum reserves and the political and economic objectives of the Organization of Petroleum Exporting Countries. Because both world petroleum reserves and the objectives of the Organization of Petroleum Exporting Countries are subject to great uncertainties, it is necessary to analyze the behavior of energy markets under a distinctly different world oil price path. The two alternative baselines presented here are a Low Economic Growth Rate case and a Volatile World Oil Price case. The assumptions for these cases are shown in Figures C–17 and C–18.

The Low Economic Growth case combines low growth assumptions with the Current Policy Base case. This alternative baseline case serves three important purposes. First, it provides a lower bound for energy demand that reflects income effects. Second, it provides an alternative view of the effectiveness of National Energy Strategy actions on energy markets under a different GNP environment. Finally, and most important of all, it allows Strategy goals and criteria associated with it to be

Figure C–17. Alternative Economic Growth Assumptions
Current Policy and Low GNP Growth Cases

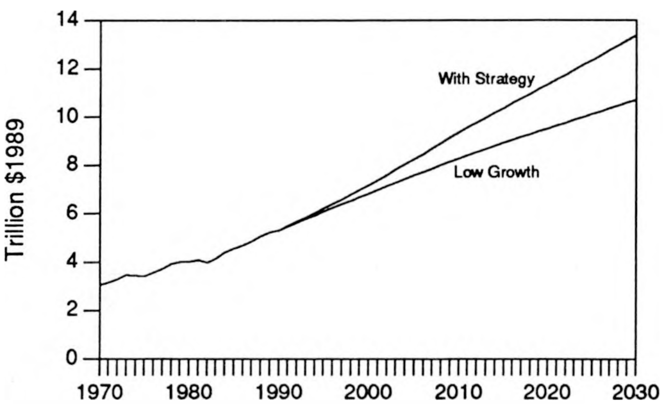
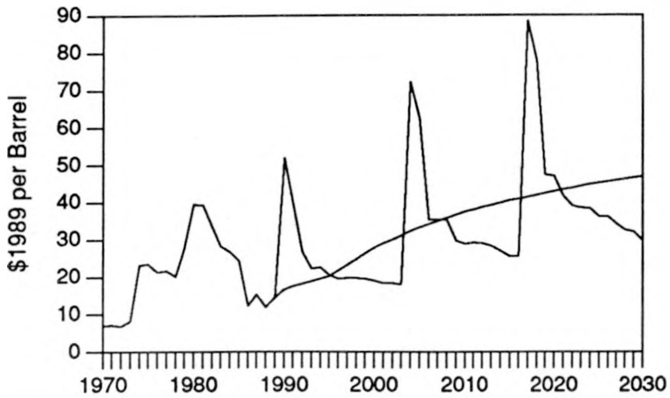


Figure C–18. Alternative World Oil Price Assumptions
Current Policy Base and Volatile Price Cases



reevaluated because of the differences in demand levels. For example, carbon emissions in the Low Economic Growth case are lower than in the Current Policy Base case; therefore, the requirement to further reduce carbon emissions under a low GNP future may also be lower.

A volatile oil price path is more consistent with real world experience. Historical oil price data over the past 90 years show that price swings of almost 60 percent (up or down) may occur from one year to the next. (For example, in 1974 the world oil price increased by about 62 percent from the 1973 level). Statistically, there is one chance in five that next year's price will be 20 percent above or below this year's price. Analyzing the Strategy actions in a volatile oil price environment is equivalent to analyzing these actions in a changing market economic environment. The competitiveness of non-oil energy increases as the price of oil rises, and vice versa. Using this alternative baseline, the effectiveness of Strategy actions can be evaluated by their ability to achieve Strategy goals in a volatile oil prices future.

The measure of the effectiveness of the National Energy Strategy is its ability to achieve balance among increasing energy needs, a healthy environment, reliance on market forces, and a strong economy under a variety of different future situations. It is therefore essential to compare the impact of various Strategy actions on energy markets under alternative market situations. Specifically, it is useful to examine the effect of Strategy actions in a much lower economic growth future, and in a volatile world oil prices future, as these extreme cases address two of the largest areas of uncertainty in U.S. energy markets.

Assumptions

The purpose of having two additional baseline cases is to examine U.S. energy demand and supply behavior under different assumptions about the future, and to evaluate the effectiveness of National Energy Strategy actions under these alternate assumptions in achieving the goals set forth by the President.

In the Low Economic Growth case, GNP growth rates are assumed to be 2.2 percent per year between 1990 and 2010, and 1.3 percent per year between 2010 and 2030. The Current Policy Base case assumes GNP growth rates of 2.9 percent per year between 1990 and 2010, and 1.8 percent per year between 2010 and 2030.

The Volatile Oil Price case assumes that there will be three price spikes in the National Energy Strategy analysis period. The first price spike occurs in 1990, the second in 2004, and the third in 2017. After each price spike, world oil prices are assumed to decline steadily to a level which is lower than in the Current Policy Base case. Every price spike is assumed to be caused by a supply disruption mainly in the Persian Gulf. High oil prices would stimulate production and encourage conservation, which will reduce oil prices. It should be noted that the purpose of creating a volatile price case is not to predict future oil market disruptions; instead, it is simply an attempt to capture the effect of price volatility on energy markets.

The Low Economic Growth case assumptions on growth are based on the Council of Economic Advisers' low labor-force growth and low productivity guidelines (July 1990). For the Volatile Oil Prices case, historical price data used to develop the price path are from Paul Mlotok and Michael Young, *International Oils*, Solomon Brothers Stock Research Pamphlet, April 1986, and Energy Information Administration, Department of Energy, *Petroleum Marketing Monthly*, various issues.

For the Low Economic Growth case, the EIA-DRI quarterly macroeconomic model was used to determine the relationship among GNP, housing stock, and industrial production index. These macroeconomic model outputs based on the Council of Economic Advisers' GNP assumptions are used as National Energy Strategy integrating model inputs.

For the Volatile Oil Price case, the Current Policy Base case was used as a baseline and the EIA-DRI macroeconomic model (with GNP inputs from the Council of Economic Advisers) was used to simulate the effect of volatile oil prices on macroeconomic variables such as GNP, housing stocks, and industrial production index. These macroeconomic model outputs were then used as National Energy Strategy integrating model inputs for the Volatile Oil Price Case.

Summary of Alternative Baselines

The Low Economic Growth case results in lower levels of total primary energy production (including electricity generating capacity), primary energy consumption, petroleum imports, and energy prices relative to the Current Policy Base case.

Total primary energy production, compared with the Current Policy Base case, is about 2 quads in 2000; this difference increases to nearly 6.5 quads in 2010, and more than 14 quads in 2030. Reductions in coal consumption contributes to the decline. This is due to low economic activities associated with low demand for electricity, which uses coal as primary inputs in electricity generation. Oil consumption is also significantly lower—nearly 1.5 quads (0.7 MMBD) less than the Current Policy Base case in 2000. Reductions in petroleum imports reflect the full effects of lower consumption of petroleum, as changes in petroleum production are relatively insignificant.

Relative to the Current Policy Base case, the Volatile Oil Price case shows a distinctively different pattern of energy supply and demand. In years with high prices, the Volatile Oil Price case shows higher primary energy production, lower primary energy consumption, and lower petroleum imports. In years with lower prices, the opposite is true.

When there is a price spike, domestic energy production rises, but consumption declines. Extended periods of lower oil prices, however, stimulate demand but discourage production.

The GNP level also fluctuates with the changes in oil prices. Overall, the net present value of GNP for the Volatile Oil Price case is estimated to be about $500 billion lower than that of the Current Policy Base case.

Electric generating capacity also reflects the impact of oil prices on total energy demand. For low-price years, the Volatile Price Oil case results in higher generating capacity than the Current Policy Base case; for high-price years, capacity is lower.

Related Economic and Energy Issues

The Current Policy Base case presents one possible outlook for the future U.S. energy situation. There are, however, several issues that are not addressed in the projections and should be discussed explicitly.

First, the infrastructure required to meet higher energy demand is assumed to be available at the right time when demand increases. An implicit assumption is that financial markets will provide the necessary capital for the construction of this infrastructure and that such construction will not be prevented because of environmental concerns.

For example, in the oil market, production of crude petroleum will decline, but consumption of end-use petroleum production will rise. Two issues arise as a result of this assumption. First, U.S. port facilities would have to be expanded to accommodate much larger volumes of petroleum imports. By the year 2000, compared with 1990, U.S. ports are projected to handle about 50 percent more petroleum imports, and by 2010, about 100 percent more. All else equal, the resulting increased volume of oil tanker traffic points to a higher probability of oil spills and pollution of U.S. coastlines. Second, higher demand for petroleum products implies higher demand for petroleum refining capacity. Additional refining capacity is expensive to obtain and frequently encounters resistance because of its impacts on local environments. In the electricity generation sector, net summer generating capacity, compared with the 1990 level, is projected to increase by about 45 GW in 1995, 110 GW in 2000, and more than 250 GW in 2010. This rate of growth in capacity could impose tremendous financial burdens on the electricity generation industry. In addition, coal is projected to assume an increasing market share, which implies higher carbon emissions and a larger global warming potential.

Second, the availability of energy resources at prices described in the Current Policy Base case is essential to economic growth and energy security. The U.S. economy and energy markets depicted in the Current Policy Base case projects that total energy requirements in the U.S. increase over time, even though some efficiency gains are obtained in the future. These energy requirements include not only the specific types of energy, but also the accompanying infrastructure. In addition, the projection indicates that a successful growth in the future U.S. economy relies heavily on imported petroleum. Imported petroleum as a share of total primary energy consumption is projected to increase from 19 percent in 1990 to 24 percent in 2000, 26 percent in 2010, and 30 percent by 2030. Higher oil imports and the increasing share of oil imports in total primary energy consumption increasingly exposes the U.S. economy to the threat of oil supply disruptions.

Uncertainties in the estimates of energy resources and the ability to control these resources in the future creates a potentially unstable environment for long-term economic growth. Fluctuations in petroleum prices may be caused by delayed supply responses to changing markets or simply by political reasons. Because an economy performs better under more stable conditions, reduction in consumption of unreliable energy sources would minimize the impact of market changes on the U.S. economy.

The third issue in the Current Policy Base case projection is environmental concerns. In addition to the infrastructure and environmental problems discussed above, another key concern is the acceptability of a continued increase in greenhouse warming potential. Energy-related emissions such as NO_x and carbon are projected to increase, causing greater environmental stress. However, it is implicitly assumed that these higher emissions levels do not result in losses in economic growth or increases in energy prices.

The assumptions on the availability of capital, infrastructure and resources, and the lack of economic losses from environmental stress, are suspect. However, they are appropriate for two reasons. First, limitations on the availability of capital, infrastructure, and resources, as well as quantitative losses from environmental stress, are extremely difficult to quantify. However, it is recognized that such limitations are real, so the purpose of several National Energy Strategy actions is to remove or mitigate such limitations. Examples include increased wholesale electricity transmission access, reform of the Public Utility Holding Company Act, and reforming the natural gas pipeline certification process. Other actions are designed to substantially reduce environmental degradation. The second reason that these assumptions are appropriate is that the Current Policy Base case explicitly assumes no future changes in Federal energy policies, even those designed to mitigate environmental stress.

Integrated Analysis of National Energy Strategy Actions

This section summarizes the results of the integrated analysis of the combined National Energy Strategy actions. These results are described as a series of differences in modeling estimations between the Current Policy Base case and the combined National Energy Strategy actions, which are referred to here as the Strategy scenario.

Energy

Total Energy Use

For the period between 1990 and 2030, the United States is projected in the National Energy Strategy scenario to increase its consumption of primary energy (including what is used to generate electricity) at an average rate of 1.3 percent per year. This is less than the rate in the Current Policy Base case. Electricity consumption is also expected to rise more slowly than in the frozen policy future; demand for electricity is 11 percent lower in 2010 and 13 percent lower in 2030. This reduction is due to several actions, including integrated resource planning, building standards, and industrial conservation R&D. These growth rates are given in Table C–2. Total energy consumption and consumption by primary fuel are depicted in Figures C–19 and C–20.

The figures above indicate that the economy, as in the current policy future, is expected to become more energy efficient than it is today. All sectors—buildings, industry, and transportation—are expected to be even more efficient than in the Current Policy Base case. Overall, the economy is projected to become 32 percent more energy efficient in the Current Policy Base case and 41 percent more efficient under the National Energy Strategy policy options.

Table C–2. Growth Rates for Basic U.S. Energy Factors: National Energy Strategy

Period	U.S. Population	U.S. GNP	Primary Energy Demand	U.S. Electricity
1990–2000	0.7	3.0	1.6	2.5
2000–2010	0.5	2.8	1.1	1.5
2010–2020	0.4	1.9	0.8	1.6
2020–2030	0.2	1.6	0.5	1.3

Oil

Under the National Energy Strategy actions package, domestic oil production increases relative to the current policy future, and in fact rises in absolute terms in the midterm. This turnabout is due to the enhanced oil R&D, access to the coastal Arctic National Wildlife Refuge, and access to restricted Outer Continental Shelf areas. Oil consumption is lower because of the combined effects of alternative fuels, transportation conservation R&D, natural gas regulatory reforms, industrial conservation R&D, and other oil demand reduction actions. As a result of the higher production and lower consumption levels, oil imports are lower than in the Current Policy Base case. These changes are depicted in Figure C–21.

Oil Production

The National Energy Strategy Actions case projects U.S. crude oil and natural gas liquids production from domestic sources to rise from 8.8 MMBD in 1990 (excluding refinery gains) to 9.3 MMBD in 2000, 10.9 MMBD in 2005, and 10.6 MMBD in 2010. This represents about 3.8 additional MMBD of production in the 2005-to-2010 period relative to the Current Policy Base case. This jump in production is the result of the three oil supply actions listed above. Enhanced oil recovery production rises from 0.4 MMBD in 1990, to 2.7 MMBD in

Figure C–19. Primary Energy Consumption
National Energy Strategy Scenario

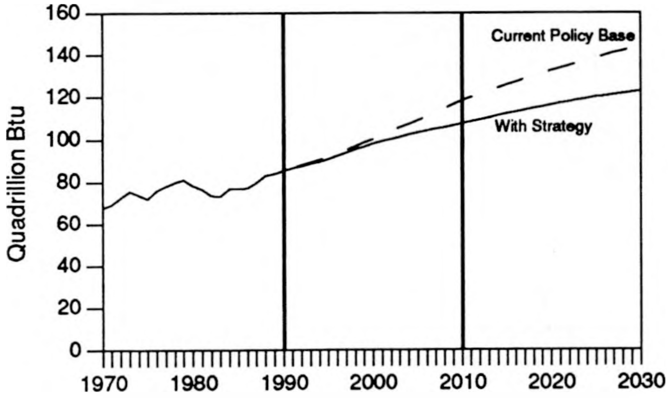


Figure C–20. Primary Energy Consumption by Fuel
National Energy Strategy Scenario

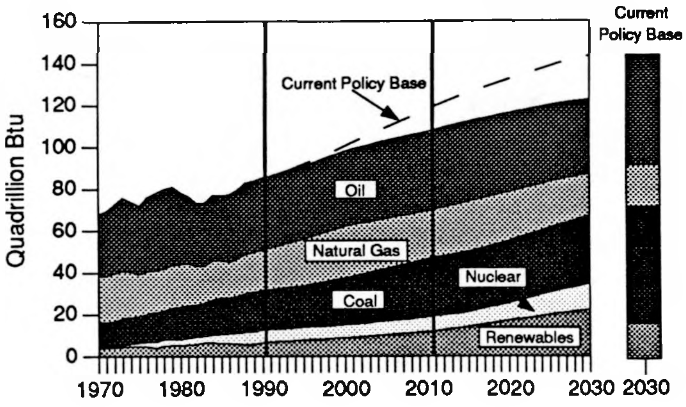
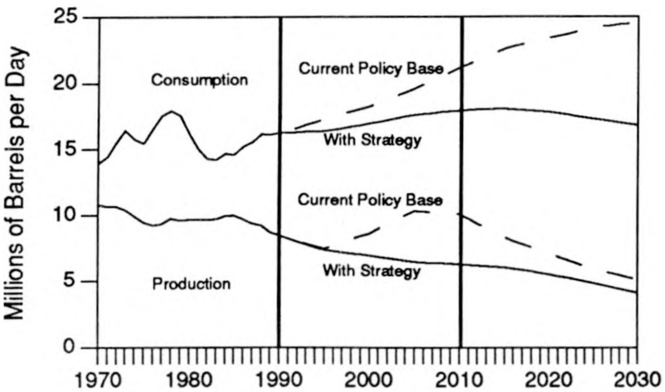


Figure C–21. Oil Consumption and Production
National Energy Strategy Scenario



2005, and 3.4 MMBD by 2010. This is the result of transfer of existing recovery technologies as well as the commercialization of new technologies. The oil enhanced R&D action results in higher production from conventional lower 48 resources. Production from the Arctic National Wildlife Refuge, based on the risked mean resource level, reaches nearly 0.8 MMBD by 2005 and declines slowly thereafter. Production from the restricted Outer Continental Shelf is 0.1 MMBD by 2010, but reaches 0.4 MMBD by 2015. This is due to lease scheduling assumptions of the Outer Continental Shelf access action.

Oil Consumption

The National Energy Strategy Actions case projects U.S. oil consumption to rise far less rapidly than in the Current Policy Base case. Demand grows at an annual rate of about 0.5 percent per year through 2010 (less than half the rate in the Current Policy Base case) and actually *falls* by 0.3 percent thereafter (versus a 0.8-percent-per-year increase). Total demand is estimated to rise from about 17 MMBD in 1991 to 18.4 MMBD in 2000 and to 19.2 MMBD in 2010, and fall to 17.8 MMBD by 2030. This represents savings relative to the current policy future of 1.3 MMBD in 2000, 3.4 MMBD in 2010, and 8 MMBD in 2030. This reduction in consumption is the result of the oil conservation and fuel-switching actions listed above.

As noted in the "Current Policy Base Case" subsection of this appendix, the bulk of U.S. oil consumption occurs in the transportation sector; the majority of the oil demand reduction in the National Energy Strategy scenario is also in transportation. Alternative fuels, transportation R&D options, and widespread use of reformulated gasoline resulting from the 1990 Clean Air Act Amendments cause 95 percent of the total oil savings. Passenger vehicle efficiency increases by 14 percent by 2010, and by nearly 50 percent by 2030 relative to the current policy base case. The long-term efficiency gains are due to successful development and market penetration of more efficient propulsion technologies after 2010. These efficiency gains are complemented by switching from oil to alternative fuels (including methanol and compressed natural gas) and production of alcohol fuels brought about by the biofuels production R&D action. Alternative fuels consumption and oxygenates in reformulated gasoline reach 1.6 quads in 2000 and 4.3 quads by 2010, displacing 2.4 MMBD of petroleum fuels in 2010.

Oil consumption is also reduced in other sectors. The natural gas actions result in less oil consumption in residential and commercial buildings as well as switching from oil to gas in the electric utility industry, in those few areas that still rely heavily on oil.

It should be noted that the large reductions in oil consumption have only a minor impact on domestic oil production. This is because imported oil is the marginal source; all else being equal, a reduction in demand will result in an approximately equal reduction in imports. However, the increase in oil production is somewhat less in the National Energy Strategy scenario case than when the oil supply actions are considered independently. This is due to the oil demand actions. As discussed below, those options cut oil consumption and thus imports, which in turn results in a lower world oil price. Producers see the lower price and hence cut back somewhat on investments in new domestic production capacity.

Net Oil Imports

The reductions in oil consumption, coupled with the higher production levels, result in lower U.S. oil import levels relative to current policy. Imports are projected to reach 8.3 MMBD in 2000, about 7.8 MMBD in 2010, and less than 11.6 MMBD by 2030. This represents a savings of 3 MMBD in 2000, 7 MMBD in 2010, and more than 8 MMBD in 2030; or, put another way, more than a 40-percent reduction in U.S. dependency on imported oil relative to the Current Policy Base case. The Current Policy Base case projects importing roughly 7 out of every 10 barrels of oil in 2010 and 8 out of every 10 in 2030. Under the National Energy Strategy scenario, the figures are 4 out of 10 in 2010 and 6 out of 10 in 2030.

This cut in the growth of U.S. demand for imported oil is projected to have a significant impact on world oil prices. Prices are expected to decline by more than $1.50 per barrel (in 1989 dollars) in 2000 and more than $5.00 in 2010. This price decrease causes some backsliding in the effectiveness of conservation. Investments in energy efficient capital stocks are somewhat lower than if prices were unaffected by U.S. oil imports. In fact, long-term industrial oil consumption rises slightly under the National Energy Strategy scenario as the decline in residual oil prices more than compensates for the availability of efficient capital stocks. However, demand reductions still occur in the transportation sector because of more efficient vehicles and the widespread use of alternative fuels.

Natural Gas

Under the National Energy Strategy scenario, natural gas consumption increases in the midterm and backs out a significant amount of oil use relative to the current policy future. This is due to the combined impacts of the natural gas regulatory reforms and alternative fuels actions. These changes are depicted in Figure C–22.

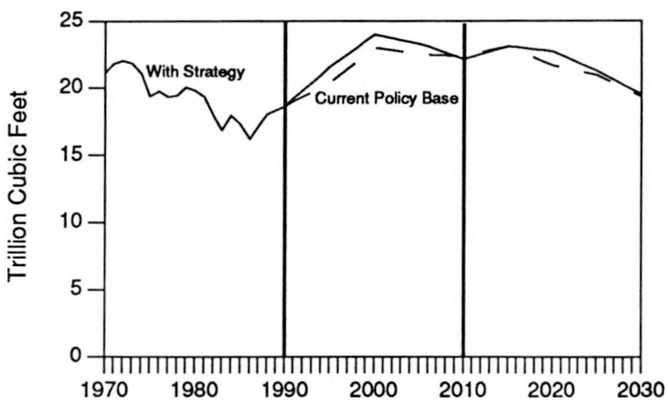
Gas Consumption

The National Energy Strategy Actions case projects gas consumption to rise in the short- and midterm relative to the Current Policy Base case. Total demand is estimated to rise from about 18.5 tcf in 1990 to 21.8 tcf in 1995 and 24.2 tcf by 2000, backing out significant quantities of oil in industry and electric utilities. The changes in demand represent increases relative to the current policy future of more than 1 tcf. After 2005, gas consumption is slightly lower in buildings, industry, and electric utilities because of the effects of National Energy Strategy conservation actions. However, the share of gas in these markets is higher than the shares in the Current Policy Base case; the markets *themselves* are smaller, resulting in lower gas demand. Gas demand in the transportation sector also increases as use of compressed natural gas in fleet vehicles becomes more widespread because of the Strategy's alternative fuels actions. Compressed natural gas consumption rises from negligible levels today to 0.3 tcf in 2000 and 0.5 tcf by 2010.

Domestic Gas Production

Gas production is driven by gas consumption. Gas production is projected to increase under the National Energy Strategy actions by 1.1 tcf in 1995 and 1.2 tcf in 2000, essentially matching the increases in consumption. However, the natural gas regulatory reforms actions also stimulate production through pipeline certification reforms, deregulation of sales rates, and rate design changes. The result is an increase in both gas production and transportation capacity and a drop in average gas production costs in the long term. These lower costs result in slightly lower long-term gas prices despite the higher production levels. These actions make it possible both to produce more gas and reduce consumer energy costs.

Figure C–22. Natural Gas Consumption
National Energy Strategy Scenario



It should be noted that the long-term increase in gas consumption under the full set of Strategy actions is less than under the gas regulatory reform actions alone. This is due principally to the lower overall demand for energy in the National Energy Strategy scenario case caused by the conservation actions. In addition, nuclear power and renewable technologies reduce the use of gas for electricity generation in the long term under the combined Strategy actions relative to the gas actions alone. Transportation gas consumption under the Strategy scenario is also higher because of compressed natural gas consumption in transportation resulting from the alternative fuels actions. Production of gas, unlike oil, follows demand; changes in consumption generally result, after a time lag, in roughly commensurate changes in production. Gas production is therefore higher in the short term and lower in the long term under the total combined Strategy actions than under the gas actions alone.

Gas Imports

Pipeline imports are largely unaffected by these actions, as Canadian imports continue to enjoy competitive advantages in local markets. However, imports of liquefied natural gas fall slightly relative to the Current Policy Base case as more capital is invested in domestic production capacity and less in liquefied natural gas facilities under the National Energy Strategy scenario. In the very long term, liquefied natural gas imports are projected to still make a significant contribution as domestic gas supplies become more expensive.

Coal

With the resumption of orders for nuclear power plants, coal consumption falls sharply under the National Energy Strategy scenario. As shown in Figure C–23, total coal consumption rises from 19 quads today to about 28 quads in 2010, but only 32 by 2030. (In the Current Policy Base case, coal consumption nearly triples by 2030—reaching over 50 quads). Coal accounts for almost 55 percent of electricity generation in 1990, but by 2030 this share falls to less than 50 percent (versus 75 percent in the Current Policy Base case). The National Energy Strategy clean coal technology actions accelerate the introduction of advanced clean coal electricity generation technologies such as pressurized fluidized-bed and integrated gasification–combined-cycle plants. These technologies greatly increase the efficiency of the still-substantial electric utility coal use and result in lower emissions of SO_x, NO_x, and carbon per ton of coal burned than would otherwise occur.

Total clean coal technologies capacity is substantially lower under the National Energy Strategy scenario case than under the clean coal actions alone. This is due to competition from nuclear and renewable technologies as well as lower electricity demand resulting from the integrated resource planning and end-use conservation actions. Despite this much lower capacity level, however, it is worth noting that the availability of these technologies allows utility managers greater flexibility in meeting the emission reduction targets of the 1990 Clean Air Act Amendments, especially in the 2000 to 2010 period before nuclear makes inroads into the new base-load power market.

Nuclear Power

Nuclear power makes a complete turnaround under the National Energy Strategy scenario. As shown in Figure C–24, nuclear electricity generation rises from about 550 billion kWh today to 650 billion kWh in 2010, and 1195 billion kWh from the equivalent of 195 large plants by 2030. This contrasts sharply with the Current Policy Base case in which nuclear generation reaches 594 billion kWh in 2010 and falls to only 35 billion kWh (about six large plants) by 2030. This new nuclear capacity backs out substantial quantities

Figure C–23. Coal Consumption
National Energy Strategy Scenario

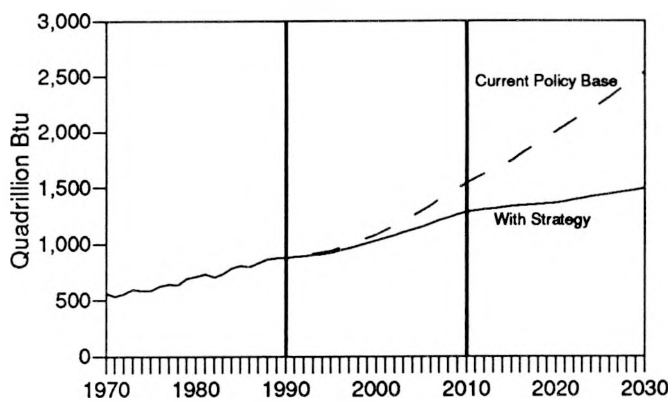
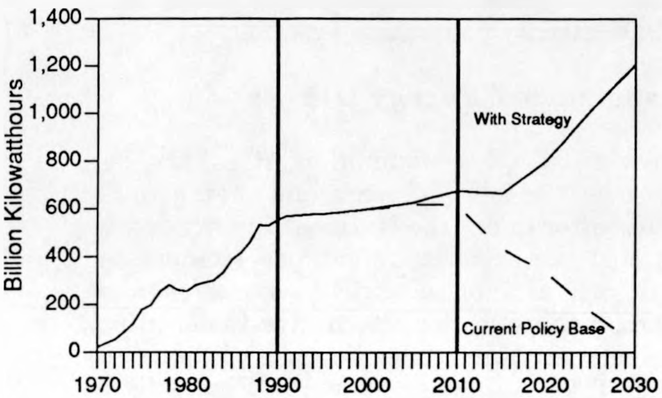


Figure C–24. Nuclear Electricity Generation
National Energy Strategy Scenario



of coal consumption, thereby greatly reducing carbon emissions in the long term.

The nuclear capacity projected above is substantially (33 percent) lower than under the nuclear actions alone case. This is due to competition from other technologies as well as lower electricity demand resulting from the integrated resource planning and end-use conservation actions. Despite this lower capacity level, however, nuclear makes a sizable contribution to reducing total carbon as well as other environmental emissions.

Renewable Energy

Under the National Energy Strategy scenario, total renewable energy production increases substantially relative to the current policy future. Electricity generation from renewable sources, as well as biofuels consumption in transportation, increases more than 30 percent over the Current Policy Base case levels by 2030. This jump is due to a combination of measures including municipal solid waste, hydroelectric regulatory reforms, biofuels production R&D, and transportation R&D actions.

Hydroelectric capacity is projected to significantly expand under the National Energy Strategy actions. Problems with licensing new facilities and relicensing existing plants are expected to be resolved, and generation from many existing federal hydro plants is increased through improved operation and maintenance and capacity additions.

Base-load hydro capacity is projected to increase from about 75 GW today to 81 GW in 2000, 87 GW in 2010 and 97 GW by 2030. This represents additional capacity relative to the Current Policy Base case of 3 GW in 2000, 9 GW in 2010, and 16 GW in 2030. Generation from these facilities is 12 percent higher in 2010 and 20 percent higher in 2030.

Municipal solid waste capacity also increases under the National Energy Strategy actions. Capacity is projected to rise from about 4 GW in 1991 to 28 GW in 2010 and 55 GW by 2030. This represents additional capacity relative to the Current Policy Base case of 14 GW in 2010 and about 40 GW in 2030.

Alcohol fuels consumption expands under the National Energy Strategy options. Demand is projected to be 0.5 quad in 2010 and 3.8 quads by 2030. This is over a sevenfold increase from the Current Policy Base case. This rapid increase in biofuels consumption is a result of new vehicle technologies resulting from the transportation conservation R&D action, lower production costs for alcohol manufacture because of the biofuels production R&D action, and higher demand for alcohol fuels caused by the alternative fuels actions.

Overall, the renewable energy contribution rises from about 8 percent of U.S. primary energy consumption today (6.8 quads) to 18 percent (about 22 quads) by 2030—as opposed to 12 percent (about 16.8 quads) by 2030 in the Current Policy Base case. The projected consumption levels are depicted in Figure C–25.

Electricity

Electricity consumption rises more slowly under the National Energy Strategy scenario. Total consumption, shown in Figure C–26, is expected to rise from about 2,700 billion kWh (9.2 quads) in 1990 to about 4,000 billion kWh (13.7 quads) in 2010, and more than 5,300 billion kWh (18.4 quads) by 2030. This is a 12-percent reduction in 2010 and a 14-percent reduction by 2030 relative to the Current Policy Base case. This cut in electricity demand is caused by the integrated resource planning, buildings standards, and industrial conservation R&D actions. Reductions

Figure C–25. Renewable Energy Consumption
National Energy Strategy Scenario

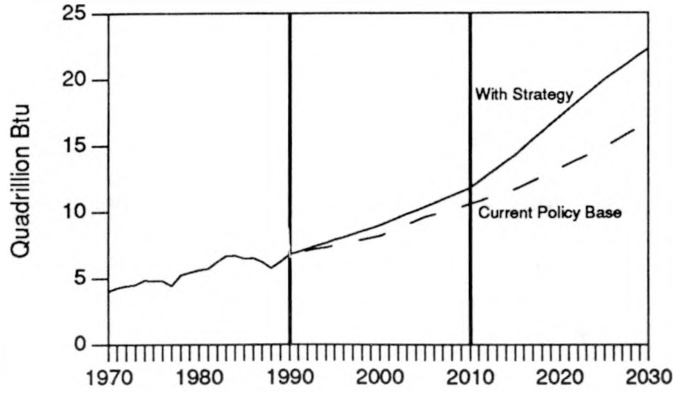
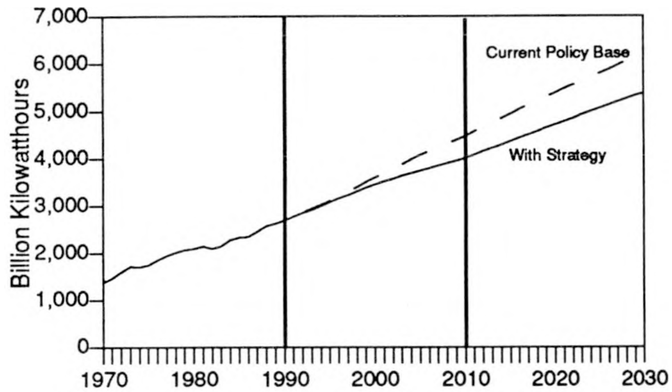


Figure C–26. Electricity Consumption
National Energy Strategy Scenario



in electricity demand also substantially cut primary energy demand; energy inputs to generation fall by 4.5 quads in 2010 and about 7.0 quads in 2030.

The mix of fuels used to generate electricity is projected to change in the long term under the National Energy Strategy actions. This is shown in Figure C–27. In 2010, the share of coal has dropped from 59 percent (28.9 quads) without the Strategy actions to 54 percent (24.0 quads) with the Strategy actions, while nuclear has increased from 13 percent (6.4 quads) to 16 percent (7.0 quads) and the renewables share has jumped from 13 percent (6.0 quads) to 16 percent (7.1 quads). By 2030, the coal share has fallen from 75 percent (50 quads) to 49 percent (29 quads), while nuclear has leaped from 1 percent (0.4 quads) to 22 percent (12.5 quads) and renewables has grown from 15 percent (9.4 quads) to 21 percent (12 quads). The result is a more balanced and hence more reliable electricity generation system.

Transportation Energy Use

Transportation oil consumption rises far less quickly over the next 20 years and then actually falls thereafter under the National Energy Strategy actions; nonpetroleum fuel use (compressed natural gas, alcohol, electricity) becomes more widespread through the alternative fuels actions and vehicle efficiencies rise because of the transportation R&D action. As shown in Figure C–28, oil demand is projected to rise from 21.4 quads (11 MMBD) in 1990 to 23.8 quads (12 MMBD) in 2010 (versus 30.4 quads without National Energy Strategy actions) and then falls to 19 quads (10 MMBD) by 2030 (as opposed to rising to more than 35 quads in the current policy future). This reduction in consumption represents most of the reduction in total oil consumption under the Strategy scenario and is the single largest contributor to the cut in oil imports projected.

Alternative fuels consumption is projected to rise. Alcohol use (both imported methanol and domestic biofuels) rises to 0.2 MMBD of oil equivalent in 2010 and 1.8 MMBD of oil equivalent by 2030—roughly five times the level without Strategy actions. Compressed natural gas use increases from negligible levels today to about 0.5 tcf by 2010. Electric vehicle consumption rises from near zero to 0.1 quad in 2010 and 0.4 quads by 2030. These gains are due to the National Energy Strategy alternative fuels, biomass production R&D, transportation vehicle R&D actions, and the Clean Air Act Amendments. The R&D action, also results in substantially higher fuel efficiencies in the sector. Fleet passenger vehicle efficiency is projected to rise to 24.0 mpg in 2010 and to 34.0 mpg by 2030. This is 14 percent higher in 2010 and 45 percent higher in 2030 than without the National Energy Strategy actions.

Residential Energy Use

Energy consumption in the residential sector falls about 4 percent relative to the Current Policy Base case, but the fuel splits change significantly under the Strategy actions. Total primary energy use, depicted in Figure C–29, is projected to rise from 18.2 quads in 1990 to 22.1 quads in 2010 and 25.4 quads by 2030. This rate of growth is less than the rate without Strategy actions; the average home is 7 percent more efficient in 2010 and 14 percent more efficient by 2030.

The natural gas regulatory reforms and buildings conservation actions result in some oil use being backed out by gas. However, the prices of petroleum fuels are significantly lower under the National Energy Strategy scenario because of the steep drop in U.S. oil imports; for this reason, less oil is backed out than would be the case if the natural gas actions were implemented in isolation. Electricity consumption falls because of the conservation actions and integrated resource planning; total energy demand also falls because of the other conservation actions.

Commercial Energy Use

Energy consumption in the commercial sector falls only slightly relative to the Current Policy Base case, but as in the residential sector, the fuel splits change significantly under the National Energy Strategy actions. Total energy use, depicted in Figure C–30, is projected to rise from 13.8 quads in 1990 to 20.5 quads in 2010 and about 27.7 quads by 2030. This rate of growth is again less

Figure C–27. Energy Input to Electricity Generation
National Energy Strategy Scenario

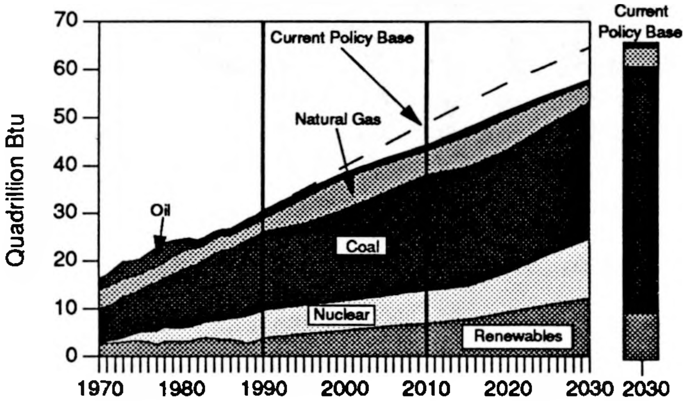


Figure C–28. Transportation Oil Consumption
National Energy Strategy Scenario

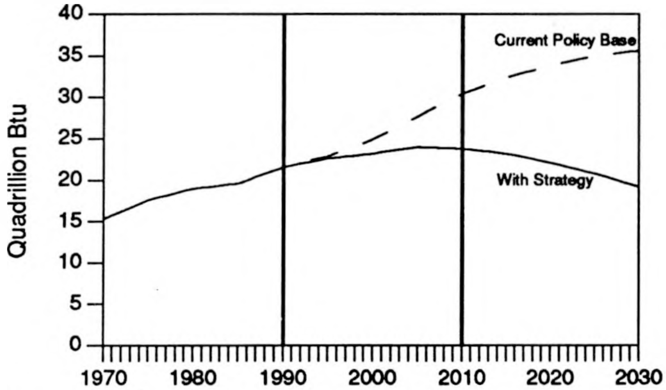


Figure C–29. Residential Primary Energy Consumption
National Energy Strategy Scenario

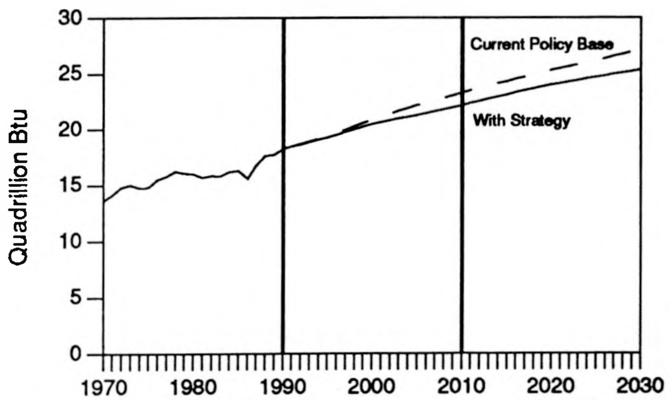
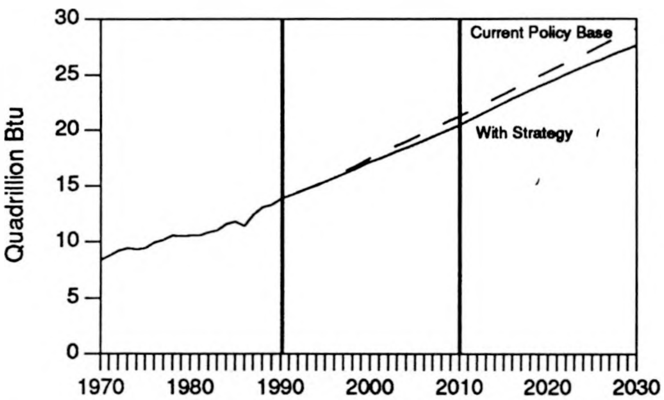


Figure C–30. Commercial Primary Energy Consumption
National Energy Strategy Scenario



than the rate without Strategy actions; the average commercial building is 20 percent more efficient in 2010 and 25 percent more efficient by 2030.

The natural gas and buildings conservation actions result in some oil use being backed out by gas. Again, as in the residential sector, lower oil prices result in less oil being backed out than would be the case if the natural gas actions were implemented in isolation. Electricity consumption also falls because of the conservation actions and integrated resource planning.

Industrial Energy Use

The industrial sector is projected to continue to realize the greatest efficiency gains among the four end-use sectors. Average efficiency is expected to be 33 percent higher in 2010 and nearly 50 percent (versus 40 percent higher without National Energy Strategy actions) in 2030. The efficiency gains beyond those in the Current Policy Base case are the result of the industrial conservation R&D and integrated resource planning options. Total industrial energy consumption is still projected to rise, but more slowly than without the National Energy Strategy actions. As depicted in Figure C–31, primary energy consumption increases from 32.1 quads in 1990 to about 40.8 quads in 2010 and about 48 quads by 2030.

Unlike the residential and commercial sectors, the share of oil use in industry is projected to remain fairly constant as residual fuel competes favorably with gas as a boiler and cogeneration fuel because of lower world oil prices resulting from lower import levels. However, the rate of growth in electricity consumption is projected to be substantially lower than without the National Energy Strategy actions. This is principally the result of the integrated resource planning action. Electricity as a share of total industrial consumption is projected to remain relatively constant at 13 to 14 percent.

Environment

Climate Change Emissions

The combination of new nuclear power plants, expanded use of renewable resources, electricity conservation through integrated resource planning, and the conservation actions in buildings, industry and transportation, causes emissions of energy-related climate change, or "greenhouse gases," to fall substantially relative to the current policy future. As shown in Figure C–32, total global warming potential (GWP), considering all climate change gases, stabilizes under the National Energy Strategy scenario. This result is discussed in detail under "Energy and Global Environmental Issues."

Emissions of Criteria Pollutants

SO_x emissions fall sharply in the National Energy Strategy scenario because of the Clean Air Act

Figure C–31. Industrial Primary Energy Consumption
National Energy Strategy Scenario

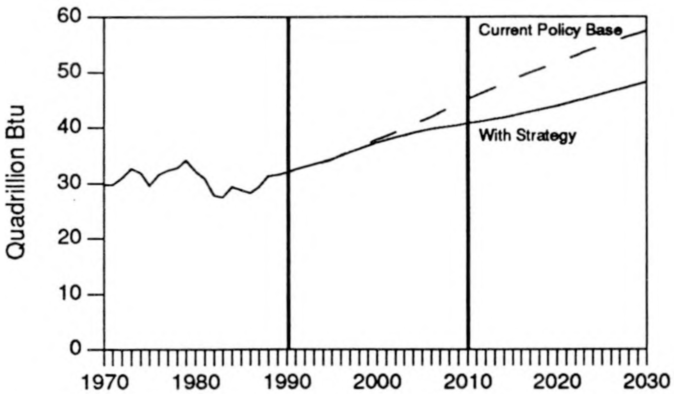
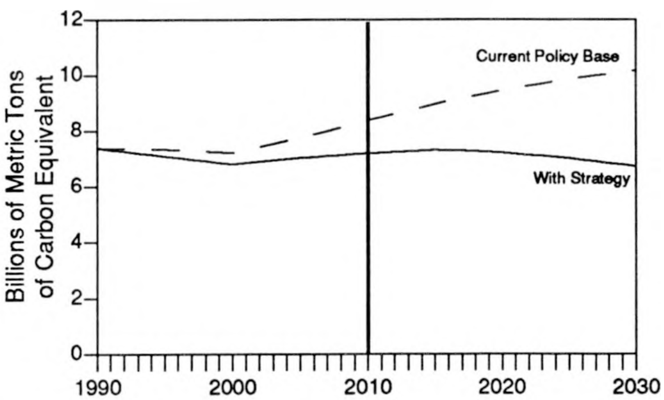


Figure C–32. Global Warming Potential
National Energy Strategy Scenario



Amendments, the electricity conservation actions and the more efficient clean coal technologies. Emissions fall nearly 40 percent by 2000 (versus rising 7 percent in the Current Policy Base case). Emissions continue to fall at a faster rate thereafter; by 2030, SO_x emissions are 45 percent lower than in the Current Policy Base case. One result of the National Energy Strategy actions is that electric utilities have more flexibility in meeting the emissions target of the Clean Air Act Amendments. Moreover, since electricity demand is substantially lower than in the Current Policy Base case, cost of compliance may be somewhat reduced.

NO_x emissions are projected to be substantially lower under Strategy actions. NO_x levels are 16 percent lower in 2010 and about 30 percent lower in 2030 relative to the Current Policy Base case. These reductions are due to lower electricity consumption and less oil use in transportation. Emissions of volatile organic compounds and carbon monoxide associated with urban smog are expected to be 20 percent lower in 2010 and 30 percent lower by 2030 than would be the case without National Energy Strategy actions. These reductions are discussed in "Energy and the Quality of Air, Land, and Water."

Economy

The economic objectives of the National Energy Strategy are to maintain an economy that is second to none and to reduce dependence on potentially unreliable energy suppliers.

The policy actions included in the National Energy Strategy enhance the U.S. energy position by improving technologies in both energy consuming and producing sectors. Adoption of more energy-efficient technologies not only reduces energy consumption but also frees up resources, which can be used for other productive investments.

The National Energy Strategy actions reduce energy costs to consumers. Compared with the Current Policy Base case, crude oil prices decline about $1.70 (in 1989 dollars) per barrel in 2000 and over $5 per barrel in 2010. Prices of natural gas, coal and electricity are all lower under the Strategy actions. The reductions in demand and increases in supply detailed in the previous sections both contribute to these lower energy prices.

The impacts of the National Energy Strategy actions on the U.S. economy are estimated to be positive. Improved energy efficiency and lower energy prices are projected to stimulate the economy. On the basis of analysis using EIA-DRI macroeconomic simulation model, real GNP (in 1989 dollars) is projected to be about $25 billion higher by 2000 than without the Strategy actions. By 2010, this improvement in economic output is projected to exceed $35 billion. The Strategy actions also result in economic benefits that cannot be quantified easily. For example, the infrastructure required to import and refine crude oil will be smaller. As a result, environmental risks associated with the importation of petroleum are expected to be lower.

U.S. energy security improves providing benefits to the economy. Energy security measures the vulnerability of an economy to a disruption of oil supplies. For a supply disruption of a given size, the impacts on world oil prices would be smaller if total demand for oil is smaller. As detailed previously, U.S. oil imports decrease by more than 3 MMBD in 2000, about 7 MMBD in 2010 and more than 8 MMBD by 2030. Additional energy security benefits of the National Energy Strategy actions derive the from diversification of both end-use energy consumption and electricity generation. Impacts on the economy of potential supply disruptions for any one type of energy would likely result in much smaller economic dislocation.

In summary, the macroeconomic analysis of the Strategy actions indicates that the significant improvements in energy security, the environment and energy diversity also have a significant positive impact on economic growth.

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