Chapter 1

Introduction: The Changing Context for Energy Technology Policy

CONTENTS

Boxes

Figures

Table

Chapter 1

Introduction: The Changing Context for Energy Technology Policy

In the 17 years since the Arab oil embargo of 1973-74, our perceptions of the role of energy in the United States and world economies have changed considerably. Throughout the 1970s, concern about energy price and availability spurred the development of a wide range of new energy supply and demand technologies. The dramatic increases in energy efficiency of the U.S. economy were second only to Japan's during that period. Those efficiency improvements coupled with the decontrol of oil and gas prices initiated during the late 1970s led to increases in supply and falling energy prices in the mid- 1980s. The result is that current policy concerns about energy are not driven by the sense of urgency about price and availability typical of the 1970s, but rather by other factors such as environmental quality, international competitiveness, and national security.

In addition, our understanding of how energy is produced and used has matured significantly since the 1970s, and we are much better equipped to make systematic, long-term decisions about energy policy and its interactions with other social, economic, and environmental policy. Today, a comprehensive, strategic national energy policy cannot be viewed as an end in and of itself. Rather, its direction must come from broader and more fundamental national goals of economic health, environmental quality, and national security. Therefore, as we consider the steps necessary to articulate a national energy policy, it only makes sense to develop it in ways that support these three and other related goals.

Congress currently is considering the President's National Energy Strategy and a wide range of other energy-related legislative proposals. The various options reflected in these proposals must be weighed in the context of the three overarching goals noted above. This is difficult, since the goals can conflict. For example, increased reliance on coal could cut oil import dependence, but exacerbate problems of air pollution and global climate change. Nonetheless, some energy options support all three goals, particularly those that improve efficiency of production and use.

New energy technology has always been a cornerstone of our strategies for dealing with current and long-term energy policy issues. Such technologies hold promise for cleaner and more efficient energy use, safer and more efficient recovery of energy supplies, and a smooth transition to a postfossil fuel era. Indeed, after two decades of mixed experiences with new energy technology, we understand much better the role of new energy technology in energy policy. In this overview report we review a number of the long-term U.S. energy technology and policy trends, discuss their interaction and implications, and finally consider a range of strategic energy technology policy options. Further, we reflect on some of these experiences and examine the risks and opportunities offered by major energy supply and demand technology options.

OTA has examined new energy technologies for the Congress since 1975 (see table l-l). This report, designed to be an overview of energy supply and demand, is drawn largely from past OTA reports. Hence, it is not an exhaustive analysis of any one factor. Rather, it tries to draw together the main thoughts of a whole series of OTA reports and other documents into a broad outline of the main directions the country could follow with energy. We expect the report will be used by Congress as a roadmap, not an encyclopedia.

THE ENERGY POLICY CONTEXT

Annual global energy use grew from about 18 quads (quadrillion British thermal units)--equivalent to about 800 million tons of coal or 8.5 million barrels of oil per day—to 333 quads from 1900 to 1989. Industrialized countries account for 70 percent of annual worldwide commercial energy consumption. Coal, oil, and natural gas combustion currently account for about 80 percent of this energy use, and these fuels will likely continue to dominate for another 50 years. Many developing countries still depend heavily on noncommercial fuels, e.g., wood, dung, and crop wastes, but as their economies develop, they increasingly incorporate fossil fuels,

Table l-l-OTA Reports That Address Energy Technologies[a]

Energy and Materials Program:

Energy Efficiency in the Federal Government: *Government by Good Example? OTA-E-492* (May 1991).
Energy in Developing Countries, OTA-E-486 (January 1991).
Rep/acing Gasoline: Alternative Fuels for Light-Duty Vehicles, OTA-E-364 (September 1990).
Energy Use and the U.S. Economy, OTA-BP-E-57 (June 1990).
Physical Vulnerability of Electric Power Systems to Natural Disasters and Sabotage, OTA-E-453 (June 1990).
High-Temperature Superconductivity in Perspective, OTA-E-440 (April 1990).
Electric Power Wheeling and Dealing: Technological Considerations for Increasing Competition, OTA-E-409 (May 1989).
Biological Effects of Power Frequency Fields Electric and Magnetic Fields-Background Paper, OTA-BP-E-53 (May 1989).
Oil *Production in the Arctic National Wildlife Refuge: The Technology and the Alaskan Oil Context, OTA-E-394* (February 1989).
Starpower: The U.S. and the International Quest for Fusion Energy, OTA-E-338 (October 1987).
U.S. Oil Production: The Effect *of Low Oil* Prices, OTA-E-348 (September 1987).
New *Electric Power* Technologies: Problems and Prospects *for the* 1990s, OTA-E-246 (July 1985).
U.S. Natural Gas Availability: Gas Supply Through the Year 2000, OTA-E-245 (February 1985).
U.S. Vulnerability to an Oil Import Curtailment: The Oil Replacement Capability, OTA-E-243 (September 1984).
Nuclear Power in *an Age of* Uncertainty, OTA-E-21 6 (February 1984).
Industrial Energy *Use,* OTA-E-198 (June 1983).
Industrial and Commercial Cogeneration, OTA-E-1 92 (February 1983).
Increased Automobile Fuel Efficiency and Synthetic Fuels, OTA-E-185 (September 1982).
Energy Efficiency of Buildings in Cities, OTA-E-168 (March 1982).
Solar Power Satellites, OTA-E-144 (August 1981).
Nuclear PowerPlant Standardization: Light Water Reactors, OTA-E-134 (April 1981).
World Petroleum Availability: 1980-2000, OTA-TM-E-5 (October 1980).
Energy from Biological Processes, OTA-E-124 (September 1980).
An Assessment of Oil Shale Technologies, OTA-M-1 18 (June 1980).
The Future of Liquefied Natural Gas Imports, OTA-E-110 (March 1980).
Residential/ Energy Conservation, OTA-E-92 (July 1979).
The Direct *Use of Coal,* OTA-E-86 (April 1979).
Application of Solar Technology to Today's Energy Needs, OTA-E-66 (September 1978).
Enhanced Oil Recovery Potential in *the* United *States,* OTA-E-59 (January 1978).
Gas Potential From Devonian Shales of the Appalachian Basin, OTA-E-57 (November 1977).
Analysis of the Proposed National Energy Plan, OTA-E-51 (August 1977).
Nuclear Proliferation and Safeguards, OTA-E-48 (June 1977).

Oceans and Environment Program:

Changing by Degrees: Steps To Reduce Greenhouse *Gases,* OTA-O-482 (February, 1991).
Facing America's Trash: What Next for Municipal Solid Waste, OTA-O-424 (October 1989).
Catching Our Breath: Next Steps for Reducing Urban Ozone, OTA-O-41 2 (July 1989).
Oil and Gas Technologies for the Arctic and Deepwater, OTA-O-270 (May 1985).
Acid Rain and Transported Air Pollutants: Implications for Public Policy, OTA-O-204 (June 1984).

International Security and Commerce Program:

Energy Technology Transfer to China-A Technical Memorandum, OTA-TM-ISC-30 (September 1985).
Technology and Soviet Energy Availability, OTA-ISC-153 (November 1981).

[a]Available through the U.S. Government Printing Off ice, Washington, DC.

SOURCE: Office of Technology Assessment, 1991.

especially coal and oil, in their industrial and commercial sectors.[1]

he United States currently consumes about 81 quads of energy. Many analysts project that over 100 quads of total energy will be required by 2010, assuming moderate economic growth. The baseline scenario in this report, which includes noncommercial energy, increases from 84 quads in 1990 to 112

[1]See Us. Congress, Office of Technology Assessment *Energy in Developing Countries, OTA-E-486* (Washington, DC: U.S. Government Printing Office, January 1991).

in 2015. The National Energy Strategy's Current Policy Base projects U.S. energy consumption will reach approximately 115 quad by 2010.[2] With no changes in policy, the sources of energy we use to fuel the economy are expected at that time to be very similar to what they are today: about 40-percent oil, 23 percent each for natural gas and coal, and 14-percent renewable and nuclear power.[3] Still, some important features of U.S. energy supply and demand balance are changing and, in turn, are changing the environment within which policy decisions will be made, especially decisions about technology.

various "national energy plans" have been initiated frequently since 1939 (see box l-A), usually instigated by concerns over resource shortages. Perhaps the lesson to be learned from this repeated attention is that energy policy must be fundamentally grounded in long-term strategies but must also accommodate short-term perturbations. Oil price disruptions have been the major perturbations in recent years, such as the 1990 price increase stemming from the Persian Gulf crisis.

However, reducing vulnerability to oil supply shortages will require more than a large petroleum reserve. Without policy action, imports of oil are very likely to increase substantially. Increasing dependence on imports, especially those from unstable regions, will necessitate a gigantic and extremely expensive reserve to maintain present protection against an extended import supply disruption. Increasing efficiency and fuel flexibility in the transportation fleet, the sector most dependent on oil, will be increasingly attractive. These measures would also serve the vital goal of reducing air pollutant emissions. Far greater changes will be required if major carbon dioxide (CO_2) emissions reductions are required to minimize climate change. Major changes in energy systems require decades and steady commitment from political leaders, industry, and citizens, and planning now for such changes would be prudent.

If the United States wishes to succeed in easing oil import dependence, cutting emissions, and increasing energy productivity, we must establish long-term efficiency and supply goals, and stick to the plan to achieve those goals through periods of both crisis and calm and through periods of varying oil prices. During the past decade, steady supplies, easy efficiency gains, and a retreat in the price of oil seduced us into largely abandoning efforts to push research in energy efficiency and alternative supplies. The war in the Middle East generated concerns over energy security reminiscent of the 1970s. Nonetheless, as the current crisis passes, we may be once again beguiled into a false sense of energy complacency.

TRENDS SHAPING ENERGY POLICY AND TECHNOLOGY CHOICES

The trends that have significant implications for long-term energy policy choices are: 1) the declining energy intensity of the U.S. economy between the 1970s and mid- 1980s, 2) the sharply increasing U.S. reliance on foreign sources of oil, 3) the changing structure of the electric utility industry, and 4) the changing relationship between energy and the environment. This section discusses these trends and three areas of particular interest for energy technology policy: nuclear power, renewable energy, and research and development.

Declining Energy Intensity

For many years most observers believed that energy use and the gross national product (GNP) were firmly linked, moving upward in lock step. We learned from the energy shocks of the 1970s, however, that ingenuity can substitute for supply when the price is right. In the 1970s as energy prices rose, consumers responded by shifting their market basket of purchases and by developing more efficient ways to provide energy services. The energy intensity of the economy, the energy consumed per unit of GNP produced, fell 2.5 percent per year between 1972 and 1985, most of which was due to improved efficiency (see figure l-l). The other major factor was the changing structure of the U.S. economy (e.g., the decline in energy-intensive industries, replaced by energy-intensive imports). OTA addressed these issues in its 1990 background paper Energy *Use and the U.S. Economy.*

[2] *National Energy Strategy: Powerful Ideas for America,* 1st ed. 1991/1992, DOE/S-0082P (Washington DC: U.S. Government Printing Office, February 1991), p. C-9.

[3] See the U.S. Energy Information Administration, *Annual Energy Outlook 1990* (DOE/EIA-0383(90), Jan. 12, 1990.

Box 1-A--National Energy Strategy: A Historical Note

In 1939 President Franklin Roosevelt appointed a National Resources Planning Board to examine the Nation's resources policy options. The Board recommended Government support of research to promote "efficiency, economy, and shifts in demand to low-grade fuels" and that a "national energy resources policy" should be prepared that "would be more than a 'simple sum' of policy directed at specific fuels."[1]

Later efforts included : a refinement of the Board's recommendations in 1947 by President Truman's National Security Board; Truman's Mat erials Policy Commission of 1950-52 (known as the Paley Commission after its Chairman William s. Paley); President Eisenhower's 1955 Cabinet Advisory Committee on Energy supplies and Resources Policy the 1961 National Fuels and Energy Study commissioned by the U.S. Senate during President Kennedy's term; President Johnson's 1964 "Resources Policies for a Great Society Report to the President by the Task Force on Natural Resources"; President Nixon's 1974 "Project Independence Blueprint"; President Ford's 1975 Energy Resources Council reflected in his omnibus proposal "Energy Independence Act of 1975' '; President Carter's 1977 "National Energy Plan"; President Reagan's 1987' 'Energy Security" report; and, of course most recently, President Bush's 1991 "National Energy Strategy (NES)."

The major stated goals of the NES are the following:

- encourage the adoption of cost-effective energy efficiency technologies in all sectors, including electricity generation;
- increase the use of renewable energy in electricity generation and the residential and commercial sectors;
- in the industrial sector, increase fuel flexibility and decrease waste generation, particularly by recycling wastes and increasing their use as process feedstock;
- in the transportation sector, expand the use of alternative fuels, accelerate the scrappage of older, leas efficient automobiles, promote mass transit and ride sharing, and evaluate whether the corporate average fuel economy (CAFE) standards should be changed
- reduce U.S. vulnerability to fossil-fuel supply disruptions by improving and implementing advanced oil recovery technology, increasing U.S. and global oil and natural gas production generally, and expanding stocks (a major focus of supply expansion will include increased outer continental shelf (OCS) and Arctic National Wildlife Refuge (ANWR) exploration and development);
- revive the growth of nuclear power by standardizing powerplant design, accelerating the introduction of advanced designs, reforming the powerplant licensing process to hasten the growth of new nuclear capacity, and site a permanent waste facility, and
- enhance Federal research and development to reduce oil use, increase oil supplies, and develop alternative fuels.

The above list of NES goals is not complete, but it represents the key elements of the plan. There have been disputes over the goals of the strategy, whether the policy approaches suggested m the document match these goals, and whether it offers a viable mix of demand control and supply enhancement options. These issues are for policymakers to resolve. For its part, the NES is a broad plan that premises to affect the way Some of our most important economic, environmental, and national security policies develop m the coming years.

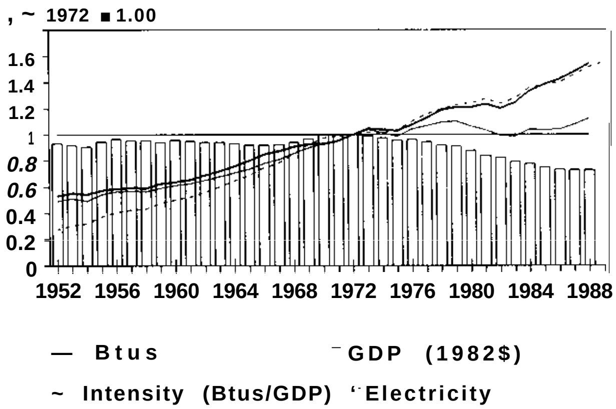
[1] Energy Resources and National Policy. Report of Energy Resources Committee to the Natural Resources Committee, (Washington, DC: u.s. Government Printing Office, *1939); also summarized in C. Goodwin (ed.), Energy Policy in Perspective (Washington, DC: Brookings Institution, 1981).*

Technology was at the heart of this changing intensity-technology ranging from dramatically increased efficiency in delivery of traditional energy services, e.g., heating, cooling, industrial processes, and transportation, to entirely new services that changed our lifestyles, e.g., improved airline travel, personal computers, and fax machines. In chapter 2 we examine the changing nature of U.S. energy demand and the implications of technology on demand growth and efficiency improvement.

Sharply Increasing Dependence on Foreign Oil

Today, the United States consumes about 17 million barrels of oil per day, 13 percent greater than in 1983. At the same time, the level of domestic oil production has declined, due to depletion of low-cost resources and a lack of new discoveries. The net result is that imports rose from about one-third of total U.S. consumption in 1983 to nearly 45 percent

Figure I-I—Index of U.S. GDP, Energy Intensity, Energy Use, and Electricity Use



SOURCE: U.S. Energy Information Administration, Month/y Energy Review, *March 1991, DOE/EIA-0035(91 /03)* (Washington DC: U.S. Government Printing Office, Mar. 28, 1991).

in 1990. This is addressed in OTA's 1987 report *U.S. Oil Production: The Effect of Low Oil Prices,* and in its 1989 report *Oil Production in the Arctic National Wildlife Refuge: The Technology and the Alaskan Oil Context.*

Moreover, the fraction of total imports coming from Persian Gulf nations has increased from about 4 percent of total U.S. consumption (10 percent of total U.S. oil imports) to over 10 percent (26 percent of current U.S. imports), as shown in figures 1-2 and 1-3. As the Soviet Union, the United States, and other non-OPEC (Organization of Petroleum Exporting Countries) nations deplete their lowest-cost oil reserves over the next decade or two, the geopolitics of energy will increasingly focus on the comparatively vast resources in the Middle East. OPEC[4] controls three-quarters of proved world crude-oil reserves, including all major recent additions. At least part of the rationale for Operation Desert Storm was due to our dependence on that region's oil reserves or, in President Bush's words, "U.S. economic interests there. "

In this case, the disruption was minor because Iraq and Kuwait provided less than 5 percent of U.S. supply, and Saudi Arabia was willing and able to compensate for the shortfall. In the future, however, major U.S. supplies could be interrupted or lost, with limited replacements available only at great economic or political cost. For example, if the recent Gulf War had also interfered with Saudi Arabian oil exports, U.S. supply losses would have been much more severe.

Dependence on imported oil also strains our international balance of payments considerably. In the first half of 1990, the U.S. imported 24 billion dollars' worth of oil, an amount equal to 57 percent of our total trade deficit for that period. High levels of oil imports do not by themselves lead to poor trade balances (Japan is one counter example), but such a high cost warrants strenuous efforts to ensure that oil is used with optimal efficiency. Many opportunities for increasing energy efficiency are noted in this report.

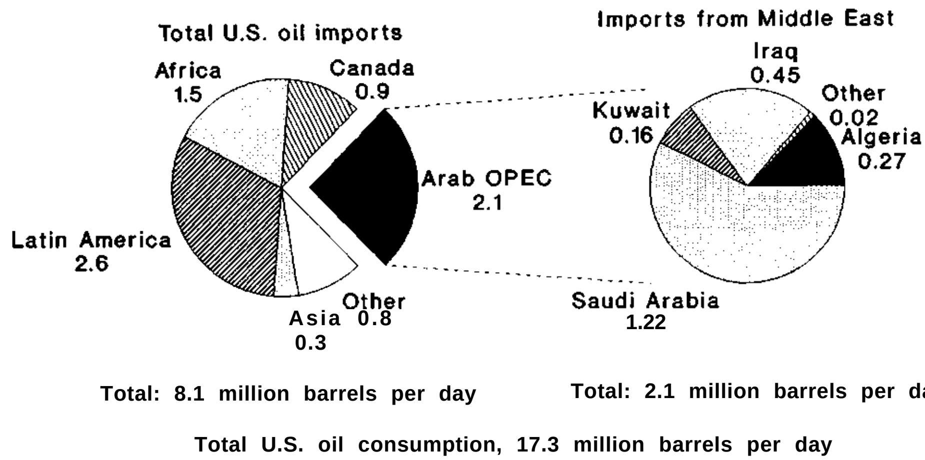
In addition, even in peacetime, the Pentagon spends many billions of dollars to protect oil supplies. With the conclusion of Operation Desert Storm, military expenditures linked to preserving oil supplies rose substantially. Rebuilding the war-torn countries of the Middle East may also prove very expensive. These are part of the costs of imported oil, even though they are not reflected in the price of oil and oil products.

Some characteristics of today's U.S. oil use, domestic supply, and import dependence are similar to those of the 1970s, e.g., the almost total reliance of our transportation sector on oil. Other features, however, have evolved considerably, including the efficiency of oil use in many industries, lower dependence of electric utilities on oil, diversification of world oil supplies (albeit not reserves), international agreements on oil sharing, the strategic petroleum reserve, changes in energy regulation (e.g., removal of oil price controls and restrictions on natural gas use), and the emergence of active spot and futures markets for oil supply. (See box l-B.)

All of these changes have had an effect on the possible future of oil use and of U.S. dependence on imported oil. Despite these changes, the U.S. economy is and will be increasingly dependent on foreign supplies of oil for years to come. This dependence will continue to threaten our national security, and it promises to continue aggravating our balance of payments.

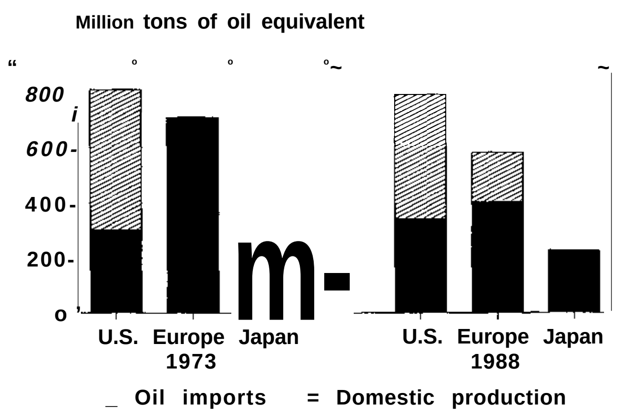
[4]The members of OPEC include: Saudi Arabia, Iraq, Kuwait, Qatar, Venezuela, Iran, Libya, United Arab Emirates, Algeria, Ecuador, Gabon, Indonesia, and Nigeria.

Figure 1-2—U.S. Oil Imports, 1989 (millions of barrels per day)



SOURCE: U.S. Central Intelligence Agency, *International Energy Statistical Review, 1990.*

Figure 1-3-Total Oil Use and Imports U.S., Europe, and Japan, 1973 and 1988



SOURCE: U.S. Energy Information Administration, International *Energy Annual 7988,* DO13EIA-00219(88) (Washington DC: U.S. Government Printing Office, Nov. 7, 1989).

Change in the Electric Utility Industry

The U.S. electric utility industry has weathered dramatic change in the last two decades. A dominant factor precipitating change in the 1970s was the price of fuel. On average, utilities had to pay over 200 percent more in real dollars for fossil fuels in 1984 than in 1972. In addition, the construction costs of new powerplants, particularly nuclear, rose dramatically due to a combination of factors: increased attention to environmental and safety issues (contributing to extended construction leadtimes and added equipment costs), high inflation and interest rates, delays in construction schedules and, in some cases, poor management. The higher costs of fuel and capital meant higher electricity costs, and utilities sought higher rates for the first time in decades. Most utilities (and industry analysts) seriously underestimated the price elasticity of electricity demand. Demand growth plummeted from 7 percent a year in the early 1970s to less than 2.5 percent by the end of the decade. Though consumers began using electricity more frugally, powerplant construction schedules did not shrink accordingly, and an oversupply of capacity resulted, adding to utilities' problems.

The outlook for the electricity generating industry has improved. The demand for electricity has risen substantially (see figure 1-4) and fuel costs have stabilized. However, the industry continues to change, as evidenced by:

- the emergence of an independent power producer industry and other signs of increasing competition in the industry (e.g., a number of major mergers and acquisitions and proposals to modify the Public Utility Holding Company Act);
- the accelerating trends of least-cost planning, integrated resource planning, and other innovative State regulation;
- increased attention to demand-side management and investment;
- the restoration of natural gas as an important fuel for electric power generation;

Box 1-B-Changes in U.S. Oil Supply and Demand Since 1973

Energy Efficiency of the US. Economy As noted above, energy efficiency has risen considerably in all sectors of the economy, often through permanent structural changes driven by economics. Changes include improvements in both the efficiency and flexibility of energy-using technologies.[1] For example, automobile, industrial boiler, and electric powerplant fuel efficiency have all improved substantially. Nonetheless, many opportunities still remain, although they may be more difficult to secure without higher energy prices,[2]

Strategic Petroleum Reserve (SPR,): "The United States now has an SPR containing approximately 585 million barrels of crude oil,[3] the equivalent of about 100 days of oil imports at current levels. Similarly, Europe and Japan have also added to their strategic storage, although not to the same extent as the United States.

Diversified World Oil Production: Sources of world oil production have become substantially more diversified since the 1970s, with the OPEC share of the world oil market declining from 60 percent in 1979 to approximately 35 percent today. For several years, at least, no single country or cohesive group of countries will be able to control as large a share of the world market as was possible previously. Eventually, however, OPEC will regain substantial market share, especially as U.S. and Soviet production declines.

Concentrated World Oil Reserves: Despite diversified world oil production, nearly all recent reserve additions have been in the Middle East. Moreover, the costs of exploration, field development, and production in the Middle East remain considerably below that of other oil producing regions and are likely to remain so.

Increased Flexibility of Oil Use: A considerable portion of any increase in oil consumption both in the United States and in the remainder of the free world is reversible. For example, much of the increase in US. oil use in transportation over the last decade involves changes in consumer behavior, e.g., increased driving, that could be quickly reversed in case of an oil shortage or large price increase. In the industrial sector, many of the shifts to oil for a boiler fuel can be rapidly reversed with a shift back to coal or natural gas. Similarly, in the electric utility sector, a substantial portion of any increased oil use is likely to involve the use of existing oil-fired generating capacity-removed from baseline service when oil prices rose in the 1970s--in favor of coal, gas, or even nuclear plants. As long as the industry retains excess generating capacity, this use can be readily reversed, and even with diminishing capacity, fuel switching capability is much more common now than in the 1970s.

New International Oil Trading Mechanisms: Most of the world's oil is now traded through spot markets, in contrast to the long-term contracts of the 1970s. Coupled with an active futures market, this new oil trading situation makes single country embargoes, which could never be airtight even in the past, still less of a threat.

Increased Availability of Natural Gas: The widespread concern in the 1970s about scarcity of natural gas resources has given way to aggressive increases in natural gas use, especially in industry, commercial space heating, and electric power generation.

International Agreements on Oil Sharing: The International Energy Agency (IEA) was created in the 1970s in part to coordinate maintenance of strategic stocks of petroleum as well as plans for demand reduction for use during an emergency. In early 1991, the IEA governing board voted to draw on 2 billion bards of crude oil reserves to avert any shortages caused by the Middle East war.

Changed Energy Regulation: United States oil prices are no longer controlled as they were during the 1970s. In the event of a new price increase, the market forces that act to reduce demand and increase supply will be felt in full. In addition, restrictions on the use of natural gas in electric utility boilers and other industrial applications are no longer in effect. These and other regulations, e.g., the national 55 miles-per-hour speed limit, could be reimposed m case of crisis, but the overall trend has been toward letting the market control the allocation of energy.

Changing Economic Structure: Over the last decade, the steady decline in energy intensity (energy consumed per unit of gross domestic product produced) accelerated in response not only to the influence of improving energy efficiency, as noted above, but also to changing patterns of consumer demand, a shifting balance of imports and exports of both energy and nonenergy goods, and the changing market basket of goods produced in the United States. These changes have, as a consequence, had an effect on the future oil replacement potential m the U.S. economy.

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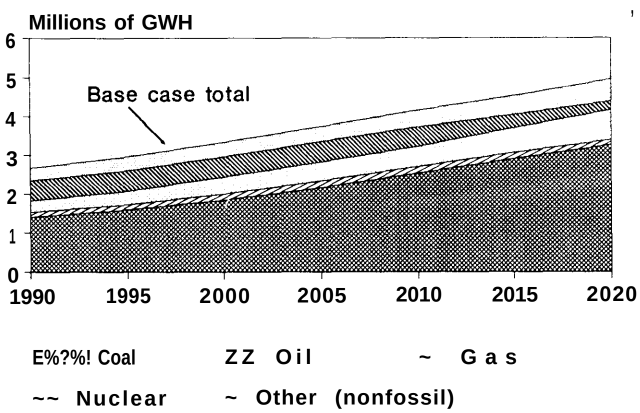
[1] See U.S.Congress, Office of Technology Assessment, *Technology and the American Economic Transition: Choices for the Future,* OTA-TET-283 (Washington, DC: U.S. *Government Printing Office, May* 1988).

[2] OTA is examining this in much more depth in its ongoing assessment *U.S. Energy Efficiency: Past* Trends and *Future Opportunities.*

[3] *Energy Information Administration, Monthly Energy Review, February 1991,* DOE/EIA-0035(91/02), Feb. 25, 1991, p. 41.

Figure 1-4--U.S. Electricity Consumption, 1989 Base Case to 2020



SOURCE: Gas Research Institute Baseline for 1989.

- the anticipated effects of the Clean Air Act Amendments of 1991; and
- the long-term implications of policies concerning global climate change.

These changes are certain to affect future technology choices, operating characteristics, and regulatory policy. Box 1-C summarizes these changes in more detail.

Changing Environmental Dimensions of Energy Policy

Much of the energy policy enacted in the last decade has actually been driven by environmental concerns. Moreover, the impetus for accelerated development of some new energy technologies has been spurred primarily by environmental concerns, e.g., clean coal technologies such as gasifiers and alternative transportation fuels such as methanol. The evolution of environmental regulation in air, water, nuclear waste, surface mining, oil exploration and development, and other areas will strongly influence the evolution of energy supply and demand technologies in the coming decades. These issues are discussed in chapters 2 and 3.

The Nuclear Dilemma

In much of the industrialized world, including the United States, nuclear power is playing an increasing role in electric power generation, while simultaneously encountering serious obstacles to further development, In the United States, nuclear power provides almost 20 percent of our electricity, but the last viable order for a new nuclear powerplant was made in 1974.

In 1984 OTA delivered its report *Nuclear Power in an Age of Uncertainty,* which addressed the issues involved in keeping nuclear as an option, and concluded: "Without significant changes in the technology, management, and level of public acceptance, nuclear power in the United States is unlikely to be expanded in this century beyond the reactors already under construction. " The conclusion is still valid today, but increasing concern over CO_2 emissions, which nuclear can help control, greatly increases the importance of resolving the issues.

Most of the major issues besetting the nuclear option are related to the technology:

- Are reactors sufficiently safe?
- Can they be built, operated and eventually decommissioned economically?
- Can nuclear waste be disposed of safely?
- Does nuclear power significantly increase the risk of the spread of nuclear weapons?

Several technological approaches to these issues, e.g., improved safety and economics, are discussed in chapters 3 and 4. Whether these efforts will be enough to improve public opinion is still uncertain.

Renewable Energy Technology

Some renewable energy technologies are already mature, e.g., hydropower, solar collectors, and passive solar design features. At the other extreme, solar power satellites would require decades of research and development (R&D). Some renewable technologies, e.g., photovoltaics and wind, are commercially available but are competitive with traditional fuels only for specific sites and can make only a limited contribution at present. Finally, other renewable technologies, e.g., solar thermal electric power and some advanced biomass technologies (including biomass-based synthetic liquid and gaseous fuels), have few commercial applications, but have great potential for improved cost and performance.

The technologies in the latter two categories—those with some commercial applications and those that are near-commercial, waiting for escalations in fossil fuel prices, continued technical development, and possible public policy changes--could potentially be in a position for significant commercial

Box 1-C-The Changing U.S. Electric Utility Industry

Uncertainty in Electricity Demand Growth: A crucial legacy of the 1970s and 1980s is the uncertainty in future electricity demand growth. The experience of the 1970s reveals that users of electricity are able to alter the quantity they use much more quickly than utilities can accommodate these changes with corresponding changes in generating capacity. The current range of published forecasts is about 1-to 4-percent average annual peak demand growth, This translates to a range of around a 30-gigawatt (GW) surplus of electric generating capacity **to** a 280-GW shortfall of capacity beyond currently planned additions and retirements by 2010. Even within individual forecasts, the range of uncertainty is typically very high. For example, the North American Electric Reliability Council projects that total electricity demand (summer peak demand) for 1999 with an 80-percent probability band will be 128,000 megawatts (MW)--amounting to a 1OO-GW shortfall or about a 28-GW surplus at the ends of the uncertainty range compared to currently planned additions and retirements. [1]

Shifting Electricity Markets: Compounding the demand uncertainty is the changing nature of demand. For example, in the residential sector there is saturation in some markets, e.g., many major appliances in homes, but there is also intense competition between natural-gas-fired space heating and electric heat pumps. The future of industrial demand is clouded as some large industrial users of electricity are experiencing declines in domestic production due to foreign competition while others, like steel, are improving. At the same time, rapid growth continues in other areas, e.g., space conditioning for commercial buildings and electronic office equipment. Predicting the net impact of these offsetting trends, along with continued movement toward increased efficiency, has greatly complicated the job of forecasting demand.

Increasing Costs of Electricity Generation: Increased attention to environment and safety issues over the last two decades has contributed to both extending leadtimes in the siting, permitting, and construction of new powerplants as well as to rapidly rising per kilowatt costs of these plants, especially coal and nuclear plants. In the ‘‘old’ days (1960s for the utility business) of steady demand growth, falling marginal costs (due largely to improving technology) and low interest rates, an excess of new capacity was not all that costly and demand growth would quickly erase the excess. Now, uncertainty about demand growth dominates. It is not only greater, but also more important, and overcommitting to new capacity can be very costly.

More Flexible Planning Strategies: Uncertainty has forced utilities to plan for contingencies. They now plan for a range of plausible future scenarios rather than committing to a fixed plan. When load growth exceeds expectations, as in New England and the Mid-Atlantic Regions in the 1980s, shorter leadtime resources such as demand-side management (DSM) and combustion turbines are called upon. Also, some utilities are performing pre-construction planning and site preparation to reduce the time required to construct new units, in case demand grows rapidly.

More Technology Options: Utilities now seek technology that comes in smaller unit sizes that can much more flexibly meet uncertain demand growth. The uncertainty in load growth provides the opportunity to dramatically expand the role of DSM and smaller-scale, shorter leadtime generating technologies (e.g., natural gas-fired combined cycle units) in utility resource plans. In addition, the prospects for advanced coal technologies renewable are expanding, although their commercial penetration is being slowed by low fuel prices.

Changing Regulatory Structure: In 1978, the Public Utility Regulatory Policies Act (PURPA) amended the 1935 Federal Power Act to require electric utilities to purchase electricity from nonutility generating facilities that met standards established by the Federal Energy Regulatory Commission, i.e., cogenerators and small power producers termed qualifying facilities (QFs). PURPA was the first major Federal move to open the electric utility market to nonutilities. Opening electricity markets to increased competition was the focus of the policy debates in the electric utility industry throughout most of the 1980s. Until the late 1980s, however, competition played a minor role in electricity markets, with the notable exception of facilities operated under PURPA.

In the last several years, as utilities resolved technical concerns and gained more experience with nonutility generation through PURPA, State regulators established mechanisms to foster competition for new generating facilities, e.g., competitive bidding by independent nonutility power producers. Also until recently, most State regulation of electric utilities has in effect linked utility profits with the amount of electricity sold, discouraging utilities from motivating their customers or undertaking themselves cost-effective energy conservation options. Some State utility commissions are establishing integrated resource planning programs that allow utilities to profit from investing in energy conservation programs or promoting such programs by their customers.

[1]North *American Electric Reliability Council, 1990 Electricity Supply & Demand for 1990-1999,* November 1990, p. 15.

application in the 1990s, but not at their current rate of technical development. For most renewable, the goal of research, development, and demonstration (RD&D) remains to reduce costs and increase performance so that these technologies can compete with the conventional energy sources under traditional terms.[5] Performance improvements, cost reduction, and resolution of uncertainties will all occur, but the rate at which these improvements occur will depend on sustained progress in RD&D and survival of an industry infrastructure. Moreover, as we gain experience with some renewable, we learn more about their own adverse environmental impacts, e.g., hydropower's aquatic ecosystems impact and wind energy's noise impacts.

Technology Research, Development, and Demonstration

Many technologies are available to supply energy or improve its use. Many more will be available as R&D programs are pursued. Some of these were noted above. A continued Federal presence in RD&D is essential to sustain energy technology development. OTA's 1985 report New *Electric Power Technologies: Problems and Prospects for the 1990s* identified a number of alternative policy options aimed at accelerating the commercial availability of technologies potentially useful in the electric power industry. These options apply in many respects to other new energy technologies as well since they focus on reducing cost, improving performance, and resolving uncertainty in both cost and performance. The major policy questions are on the level and direction of the Federal programs, and whether it should include commercialization initiatives.

The appropriate level and direction of RD&D depends on the perceived need for new technology. Economically, it is likely that a significantly larger RD&D program could be justified even under current, noncrisis conditions. New technology can save money, and the energy system is so large that even a small saving can pay back a large investment in R&D. If a major reduction of CO_2 emissions proves necessary, the RD&D program should be much larger. Every available efficiency, nuclear, and renewable energy option would be necessary, and most of these could be made available sooner with greater funding. These technologies are discussed in the following chapters.

Under less drastic conditions, the current level may be adequate, but shifts in emphasis among programs may be considered, depending on the results desired. The scenarios in chapter 4 assemble the technologies according to the conditions under which they would be most useful.

The current U.S. R&D strategy assumes that private industry will commercialize new energy technologies as they become viable. This strategy reflects the desire to avoid repeating premature commercialization failures, e.g., the Synthetic Fuels Corporation. However, it is legitimate to ask if this strategy may not be an overreaction to past failures, especially since the Federal Government may have a greater interest in promoting particular technologies than has private industry. In particular, private industry is not traditionally expected to include environmental concerns or nonmarket considerations of foreign policy and national security in corporate investment decisions. The Federal Government plays the principal role in encouraging and sponsoring technology development for such reasons. Of particular concern is assuring availability of liquid fuels as substitutes for oil and improving efficiency in the use of oil, on which virtually our entire transportation system relies. Another concern is finding more environmentally acceptable ways to provide energy services. The current period of low and stable world oil prices, which may well continue through the 1990s, provides a window of opportunity for developing supply substitutes and new, more efficient end-use technologies, to ensure commercial availability of these technologies in the 1990s.

CANDIDATE ENERGY POLICY GOALS TO REFLECT A NATIONAL ENERGY STRATEGY

Long-term energy policy goals must be responsive to the three long-term policy interests of *economic health, environmental quality, and national security* because energy's importance is

[5] Competition under traditional terms neglects to account adequately for the pollution and other externalities of energy production and use. For renewable to compete better in our current economic and regulatory system, further RD&D will be needed. Of course, if externalities such as environmental damage were captured in the price system, renewable technologies would at present be far more competitive with conventional fossil and nuclear sources.

mostly gauged by its ability to sustain such societal goals. The following prospective energy goals are aimed at this end.

Limit Oil Import Dependence and Diversify Supply Sources

Candidate goals to reflect a strategy of limiting oil import vulnerability are: 1) to limit overall oil imports to a fraction of total U.S. oil use (perhaps 50 percent); and 2) to diversify sources of world oil production and, therefore, U.S. sources of imports to regions of the world outside the Middle East, where such imports can be aligned with other U.S. policy interests. The latter includes the transfer of technology to the Soviet Union to improve oil production from depleted wells. Such transfers were discussed in 1981 in the OTA report *Technology & Soviet Energy Availability. Since these* decisions are primarily political not technological, this report focuses on the first goal.

Supply mechanisms to limit oil imports include sustaining or slowing the decline in domestic oil production, and developing and producing alternative transportation fuels. Demand and fuel-switching mechanisms include improved efficiency of use in all sectors and shifting industrial, residential, and commercial oil use to other sources, e.g., natural gas or electricity.

All of these options imply commercial development of new technologies. Some technology options, however, may lead to policy conflicts. For example, the current strategy for developing alternative transportation fuels is driven by the need to improve air quality in urban areas. Likely options include alcohol fuels (methanol and ethanol), compressed natural gas, and electricity. If methanol produced from natural gas proves to be the most practical and cost-effective option, most of the additional demand would have to be met with imports, because U.S. production is unlikely to increase sufficiently. The world natural gas market is more diversified than is oil, but the most inexpensive and plentiful supplies are, like oil, located in the Middle East.

Improve Energy Efficiency

OTA's studies over the past decade have consistently shown that energy efficiency is an essential cornerstone to a comprehensive energy policy framework. About two-thirds of the growing U.S. energy productivity of the last decade is attributable to improving energy efficiency. Efficiency gains have also affected electricity use, which historically has grown faster than the economy but, in the last decade, has fallen back to the same rate of change as GNP. Moreover, these efficiency gains generally have been realized with net cost savings and without sacrifice of comfort or dollars. Considerable future energy efficiency gains are still possible in all sectors of the economy using existing technology. Even greater cost savings and efficiency gains will be possible with technologies under current R&D. An efficiency goal of sustained improvement of 2 percent per year[6] is realistic for the United States. With more vigorous research on energy efficiency, coupled with investment and policy leadership, this goal can be met or exceeded-and with options that are no more costly than pursuing the supply-side path. Moreover, pursuing such a goal supports all three policy interests of economic health, environmental quality, and energy security.

Improve Environmental Quality

A responsible energy policy should complement as much as possible a responsible environmental policy. Clearly there are some activities that can spur our economy and enhance national security but run counter to environmental goals (e.g., aggressively pursuing a long-term strategy of alternative transportation fuels such as methanol, but allowing the feedstock for these fuels to be coal rather than biomass). But those activities should be seriously considered only if we have exhausted other options that more generally support all three goals (e.g., developing economical fuel cells that burn biomass-derived fuel efficiently and cleanly to power automobiles).

With a wealth of existing or in some cases near-commercial technology, we see no reason why

6 Energy efficiency is easy to measure for individual products or processes but difficult to define in the aggregate. Total energy use divided by GNP yields the energy intensity of the economy, but shifts in the energy intensity may signal changes in the mix of the economy or the goods and services involved that do not necessarily mean changes in efficiency. If the economy maintains its characteristics, then intensity and efficiency are identical. In that case, the goal could be met by, e.g., a 2-percent growth in GNPwith constant energy demand. If the economic trends of the past decade are maintained, i.e., energy-intensive industries such as steel declining while less intensive service industries grow, then energy intensity would have to decline by 3 percent to show a 2-percent gain in efficiency; see U.S. Congress, Office of Technology Assessment, Energy *Use and the U.S.* Economy, OTA-BP-E-57 (Washington, DC: U.S. Government Printing Office, June 1990).

existing environmental goals need to be significantly compromised to achieve energy goals. Energy and environmental goals are, of course, closely linked and, therefore, neither energy nor environmental policies should be developed, assessed, or changed in isolation.

Implications of Goals on U.S. Oil Import Dependence

In chapter 4 we consider several aggressive strategies in supply, efficiency, and fuel shifting for reducing U.S. oil import dependence. The options include improving efficiency of energy use in transportation, industry, and buildings; increasing domestic production of oil; and encouraging the use of alternative fuels.

It is clear that vigorous and sustained efforts would be required to stabilize oil import dependence over the next several decades-even at a level of 50 percent. The biggest opportunities for this lie on the demand side. Fortunately, these can provide important new economic activity and strength at home. To the extent that we improve efficiency cost-effectively, supplies will last longer, environmental problems will be eased, and international tensions lessened. But improved efficiency is unlikely to be enough. The opportunities on the supply side, e.g., enhanced domestic production in the lower 48 States, offshore, and in Alaska, are more modest than increased demand efficiency, but still potentially important. And, as noted earlier, there are opportunities for using alternative transportation fuels, e.g., methanol and electricity. These fuels have extensive long-term implications, however. The oil replacement potential must be weighed against the economic, energy, and environmental costs associated with producing and using these fuels. Last fall OTA released its report *Replacing Gasoline: Alternatives for Light-Duty Vehicles,* which addresses this subject in more depth.

The pacing and mix of all the efforts described above are very important. Much can be done to counterbalance the ominous projected growth of oil import dependence, but even with relatively heroic measures the United States is likely to face a future of high dependence on imports. We are *not as* optimistic here as the administration's position in the National Energy Strategy. In particular, the National Energy Strategy projects that the implementation of its domestic oil production policies along with assumed increases in the use of alternative fuels will lower net crude imports to just under 41 percent of domestic demand by 2010.[7] As this National Energy Strategy projection of slackening import dependence is largely based on assumptions about domestic production increases from enhanced oil recovery technologies and yet unverified Arctic National Wildlife Refuge reserves, OTA considers this drop in the level of oil imports improbable and optimistic. Coupled with aggressive efficiency efforts, however, this projection would appear more reasonable. In the following chapters we outline the technology dimensions inherent in alternative strategies for reducing import dependence.

Linking U.S. Energy Strategy to Global Climate Concerns

For decades we assumed that fossil fuels could supply our energy needs for several more centuries. Our only serious "bet-hedging" to fossil fuels has been nuclear power—fission and fusion. While the latter goal remains frustrating and elusive, the former now accounts for 20 percent of U.S. electricity, or about 8 percent of our total primary energy budget. Other nonfossil (mostly hydroelectric and biomass) fuels add another 8 percent, so our present nonfossil energy budget is about 16 percent. But the nuclear fission power enterprise, as noted earlier, is in deep trouble. Our long-term efforts to harness solar energy have been inadequate to produce options that could be widely deployed at reasonable cost.

The rising specter of air pollution and climate change creates added concerns for continued reliance on fossil fuels. This means that renewed efforts to develop solar and nuclear power (fission and fusion) must be considered. Developing and preserving nuclear and solar options are certainly possible, but they will require long-term commitments of research, development, and investment. The OTA report *Changing by Degrees: Steps To Reduce Greenhouse Gas Emissions* outlines the technical steps that would be necessary to reduce U.S. carbon dioxide emissions.

[7] In its integrated analysis of proposed policy options, the National Energy Strategy projects that total U.S. oil demand in 2010 will amount to 19.2 million barrels/day (MMB/D), while net imports in that year will be only 7.8 MMB/D. *National Energy Strategy,* op. cit., footnote 2, pp. C22-C23.

CONCLUSIONS

In addition to providing for contingencies and interruptions, a priority policy consideration is to decide whether it is wise to constrain the growing U.S. appetite for imported oil. Another key policy avenue is the need to make an explicit commitment to a smooth, multidecade transition to the postfossil fuel age as well as an era of constantly advancing energy productivity. If we want to accomplish such goals at minimum cost, it will take more than a decade from whenever we start to stabilize our dependence on imported oil, and it will take a half-century or more to get beyond fossil fuels. Our long-term economic, environmental, and national security future hangs on such transitions, and the specter of global warming could greatly foreshorten the time we once thought we could depend on coal and other carbon-rich fossil fuels. The relationships among the long-term goals of economy, environment, and security provide some important guiding principles-principles from which a systematic, integrated, and comprehensive energy strategy, which is responsive to all three goals, can logically follow. In the following chapters we examine the technology dimensions of affecting these transitions.