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BY THE COMPTROLLER GENERAL

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Report To The Congress

OF THE UNITED STATES

Questions On The Future Of Nuclear Power: Implications And Trade-Offs

Since 1972 nuclear energy has been the largest single growth factor in domestic energy supplies. However, recent events have raised questions about the desirability of continuing nuclear growth. Whatever decisions are made will be complex, involving many difficult trade-offs.

The trends GAO has projected indicate that, if actions are taken to limit or halt the growth of nuclear power, they must be accompanied by actions to severely limit electricity requirements or programs to expand coal supply or other non-nuclear fuels. Otherwise serious shortfalls of electricity supply are likely to occur in the 1980s.

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COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

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To the President of the Senate and the
Speaker of the House of Representatives

The recent events at Three Mile Island have brought the question of the future role of nuclear power into sharp focus. There is likely to be a strong debate in the coming months on this issue, the results of which could have a large impact on the U.S. energy future. Any decisions made will be complex, involving many trade-offs.

The purpose of this report is to provide a perspective within which these trade-offs can be made by assessing the implications of widely different nuclear growth rates on the U.S. energy system. We hope that this perspective will provide a common and useful basis on which any discussions of the future role of nuclear power can proceed. The objective is to shed some light on the degree of flexibility that we have to substitute other fuels for nuclear power or to reduce electricity consumption.

Our report demonstrates that, even with continued nuclear growth, the Nation will need to exert significant constraint on future growth in electricity consumption. With slower or no nuclear growth, substantially more stringent electricity constraints would be required, unless non-nuclear technologies (e.g., coal, solar, and geothermal) can increase their output beyond the levels assumed in this study. The alternative is to sharply curtail coal use outside the electrical sector.

We have not obtained the comments of any Federal agency since we do not make any specific recommendations for Government action, and the nature of this report is an analysis of policy trade-offs and implications rather than an audit of existing Government programs.

We are also sending copies of this report to the Director, Office of Management and Budget; the Secretary, Department of Energy; and the Chairman, Nuclear Regulatory Commission.

Comptroller General
of the United States

COMPTROLLER GENERAL'S
REPORT TO THE CONGRESS

QUESTIONS ON THE FUTURE OF NUCLEAR POWER: IMPLICATIONS AND TRADE-OFFS

D I G E S T

In this report GAO attempts to provide a perspective on the future role of American nuclear power by assessing the impacts of widely differing nuclear growth on the U.S. energy system. (See pp. 2 and 6.)

While nuclear reactors account for only 9 percent of U.S. installed capacity, nuclear power has been the major growth factor for U.S. electricity. Since 1972 nuclear facilities have accounted for over 20 percent of new capacity additions and over 50 percent of the increased electricity output. Nuclear power has also been the largest single growth factor in domestic energy supplies, exceeding coal by 25 percent.

If nuclear growth were to continue its current trends, it could increase U.S. domestic energy supply by the year 2000 by the equivalent of almost 10 million barrels of oil a day over 1978. However, increasingly the desirability of this trend has been questioned.

The discussions surrounding nuclear power have been heated and protracted. The recent accident at Three Mile Island has heightened the volume of debate and the emotion associated with nuclear power issues. This accident has called into question in stark terms the future role of nuclear power.

NUCLEAR ISSUES

Both the desirability and necessity of nuclear power have been questioned (see pp. 2 and 6) on issues such as:

--Waste disposal. Can the long-lived wastes resulting from normal operations of nuclear facilities be isolated from the environment until they decay to negligible levels?

--Nuclear proliferation. Can the weapons material generated in the course of the normal reactor operations be kept from being used to build nuclear weapons?

--Economics. With escalating nuclear construction costs and the need to include costs of waste disposal and plant decommissioning, can nuclear power remain cost effective?

--Safety. Can we adequately insure that the radioactive material contained in a nuclear reactor will not enter the outside environment?

--Electricity Demand. Will electricity demand grow fast enough to justify large-scale commitments to nuclear power?

While there are valid concerns about the use of nuclear power, there are three major reasons why nuclear power merits consideration for a continued and possibly expanded role in the U.S. energy system.

--It is a domestic energy source. The major goal of U.S. energy policy is to reduce U.S. dependence on foreign energy sources. Coal and nuclear are the only major existing domestic energy sources which can provide large amounts of additional energy production through the end of the century.

--It can provide additional electric capacity. In GAO's view prudent energy planning should be based on the assumption that new electricity capacity through the end of the century will largely utilize existing technologies and fuels (petroleum, natural gas, hydroelectric, geothermal, coal, and nuclear). While coal has great growth potential, it is expected to also be used for coal gasification, coal liquefaction, and direct burn in industry. To the extent that coal cannot meet all these demands, nuclear is the only developed domestic energy source able to provide large amounts of new electric capacity.

--It does not produce carbon dioxide. Increasing carbon dioxide levels in the earth's atmosphere might bring about curtailments in the use of fossil fuels by the turn of the century. Nuclear is a currently commercial energy source that does not emit carbon dioxide; some solar technologies are future ones.

NUCLEAR CAPACITY ASSUMPTIONS

GAO has estimated future nuclear capacity under three different sets of assumptions. (See pp. 7-10.)

--A moratorium on nuclear licensing is imposed almost immediately. Only plants which are more than 75-percent complete receive new operating licenses. This results in a maximum nuclear capacity of 64 gigawatts (GWe) in the early 1980s.

--Effective immediately, no new nuclear construction permits are issued, plants with construction permits are completed, and they become operational. This results in nuclear growth through the late 1980s, with a maximum capacity of 152 gigawatts through the early 1990s.

--Future nuclear capacity is estimated in the light of existing orders and recent Government expectations (pre Three Mile Island) of future orders on the assumption that the Three Mile Island accident does not significantly affect long-term nuclear growth prospects. Nuclear capacity grows steadily, reaching 340 gigawatts by 2000.

NON-NUCLEAR ASSUMPTIONS

In the last 2 years, nuclear power has been referred to as the energy source of "last resort." Recent events have tended to focus more attention on this description of nuclear power. Implicit in this description is that there are other options which would allow the minimization of the nuclear role while still increasing domestic energy supply, reducing imports, and meeting electricity demand. The two major options currently available to minimize the nuclear role are conservation to reduce the demand for electricity and coal to substitute for nuclear power.

Electricity demand

Estimates of future electricity demand growth by a cross-section of institutions (industry, Government research organizations) indicate that electricity demand growth rates are expected to decrease through at least 1985. From 1977 to 1990 the studies estimate that growth will range between 3.9 percent a year and 4.8 percent a year. The estimated average growth through 1990 is 4.5 percent a year.

There are very few estimates beyond 1990. While it is reasonable to expect that conservation and slowing population growth could combine to further reduce electricity growth rates, at the same time world oil supplies might cease to grow and perhaps begin to decline in the 1990s. If electricity is substituted for oil and gas, this could halt the decline in electricity growth rates despite increasingly effective conservation. It appears that unless the outlook for world oil supplies in the 1990s changes, or there are periods of recession, it is not prudent to expect that electricity growth rates should slow significantly in the 1990s. As a result, GAO assumes that electricity growth rates continue to decline slowly after 1990, averaging 3.75 percent a year through 2000. (See pp. 11-14.)

Supplies from other fuels

This analysis of the effects of different levels of nuclear energy on electric supply and the availability of coal for non-electrical uses is based on the following assumptions regarding supplies from other fuels: (See pp. 15-23.)

--U.S. coal production reaches 2 billion tons by 2000. This is toward the high end of the range of coal production estimates made in recent studies.

--Oil and gas generation of electricity remains at 1976 levels through 1985, and decreases one-third every 5 years until phased out in 2000. Legislation mandates the phase-out of natural gas to generate electricity after 1990. World oil production may begin to decline as early as the mid-1980s. It is doubtful that substantial petroleum generation of electricity could be sustained past the end of the century, particularly in the face of demands for petroleum from sectors such as transportation, for which there are almost no fuel alternatives.

--Hydroelectric output grows 2 percent a year, reaching 463.8 billion kilowatt hours by 2000. This is more than 90 percent of total U.S. hydroelectric potential outside of Alaska and Hawaii.

--Other sources double from 1977 to 1980, doubling every 5 years thereafter. This is 32 times the 1977 output. These sources include geothermal, wood, waste, solar electric, etc. While there are other larger estimates for electricity from these technologies, most of these technologies are still in research and development or demonstration stages. In general, it is our view that prudent planning must be relatively conservative, and should not count on energy supplies or savings from new technologies or sources until they have been proven available, effective, and economically competitive in actual demonstrations rather than only on paper or in the laboratory.

CONCLUSIONS

The trends GAO has projected indicate that, if actions are taken to limit or halt the growth of nuclear power, they must be accompanied by actions to severely limit electricity requirements or programs to expand coal supply or other non-nuclear fuels. Otherwise, serious shortfalls of electricity supply are likely to occur within the next 5-10 years.

Even with continued nuclear growth, the Nation will need to exert significant constraint on future growth in electricity consumption. With slower or no nuclear growth, substantially more stringent electricity conservation would be required, unless non-nuclear technologies (e.g., coal, solar, and geothermal) can increase their output beyond the levels assumed in this study. The alternative is to sharply curtail coal use outside the electrical sector.

GAO's analysis indicates that in order to maintain a steady growth in coal availability for non-electrical uses through 2000:

If nuclear power peaks at	Then annual electricity growth must be held below
340 GWe	4.25%
152 GWe	3.0%
64 GWe	2.5%

Even if the extreme assumption were made that <u>all</u> of a 2 billion ton per year coal production in 2000 is used to generate electricity:

Tear Sheet

If nuclear power peaks at	Then annual electricity growth must be held below
340 GWe	5.5%
152 GWe	4.5%
64 GWe	3.5%

It appears very likely that, short of very optimistic conditions, coal availability outside of electricity generation will cease to grow in the mid- to late 1980s, the earliest time when synfuels from coal could begin to make a significant contribution. This loss of growth in coal availability is largely the result of the phasing out of petroleum and natural gas power facilities. The extent to which nuclear is phased out without compensating increases in non-nuclear electricity sources or reduced electricity demand will reduce coal availability even further. (See pp. 26-27.)

OBSERVATIONS

The above conclusions have been based on relatively optimistic assumptions for the future growth of existing electricity sources, and conservative assumptions for the prospects of supplies from technologies and sources which are now in research and development stages. The history of development and deployment of new energy technologies argues for caution in developing policies and plans on the basis of anticipated breakthroughs in technologies still in the research and development or demonstration stages. If, in the coming years, there is substantial progress in development efforts for these new technologies and sources, then our conclusions would be modified to allow for less need for electricity, for more growth in electricity supply, or for substitution of the new sources for nuclear or coal energy. (See pp. 24-26.)

Tear Sheet

Contents

ABBREVIATIONS

BPA	Bonneville Power Administration
Btu	British thermal unit
DOE	Department of Energy
GWe	gigawatts of electricity
kWh	kilowatt-hour
LMFBR	liquid metal fast breeder reactor
MWe	megawatts of electricity

CHAPTER 1

INTRODUCTION

Nuclear energy has become increasingly controversial in the past few years. Recent events have heightened this controversy, calling into question the necessity and desirability of nuclear energy. As a result, the Nation is today re-assessing the future of nuclear energy. This re-assessment requires an understanding of the current and possible future roles of nuclear power in the Nation's total energy system as well as the trade-offs in and timing of new policy initiatives which might change that role. The purpose of this report is to provide a perspective on such policy initiatives by assessing the implications of widely different nuclear growth rates on the U.S. energy system.

As of January 1, 1979, the United States had 70 nuclear reactors in commercial operation with a total capacity of 51,822 MWe. 1/ While this is only 9 percent of installed electrical capacity in the United States, nuclear power has been a major or even the dominant growth factor for U.S. electricity. Since 1972 nuclear facilities have accounted for over 20 percent of new capacity additions and over 50 percent of increased electricity output. From 1979 through 1985 the electric utilities expect nuclear facilities to account for over 40 percent of the new capacity additions.

Despite nuclear's recent prominent role and expected contributions to electricity growth through 1985, its projected role after 1985 has entered into an era of diminishing expectations. In less than 4 years, nuclear power has gone from an energy source whose growth could not be allowed to falter to one which should only be used as a "last resort."

1/This total does not include Indian Point 1 and Humboldt Bay which are shut down indefinitely. It does, however, still include Three Mile Island 2.

Two factors have been largely responsible for this change. First, the desirability of nuclear power has been severely questioned on issues such as:

--Waste disposal. Can the long-lived wastes resulting from normal operations of nuclear facilities be isolated from the environment until they decay to negligible levels?

--Nuclear proliferation. Can the fissionable material generated in the course of the normal reactor operations be kept from being used to build nuclear weapons?

--Economics. With escalating construction costs and the need to include costs of waste disposal and plant decommissioning, can nuclear power remain cost effective?

--Safety. Can we adequately insure that the radioactive materials contained within a nuclear power plant can be prevented from entering the environment?

A second factor is that, as estimates for electricity have been reduced, the necessity for nuclear power has been questioned.

The discussions surrounding these issues have been heated and protracted. The recent accident at Three Mile Island has especially heightened the volume of debate and the emotion associated with nuclear power issues. This accident has called into question in very stark terms the future role of nuclear power.

The purpose of this report is to provide a perspective within which the debate on the future role of nuclear power can be carried out. It is not meant to either defend or attack nuclear power. Rather it is to provide a basis for understanding how particular decisions, whether pro- or anti-nuclear, would affect the U.S. energy system. It has been often said in energy discussions, "There is no such thing as a free lunch." This report hopes to describe the energy menu and some of the prices on it.

POTENTIAL NUCLEAR ROLES

While there are valid concerns about the use of nuclear power, there are three major reasons why nuclear power merits consideration for a continued and possibly expanded role in the U.S. energy system.

--It is a domestic energy source.

--It can provide additional electric capacity.

--It does not emit carbon dioxide.

Domestic energy source

The major goal of U.S. energy policy is to reduce dependence on insecure foreign energy sources. In 1978, 22.2 percent of U.S. energy consumption came from imported oil and natural gas. It is very likely that U.S. petroleum and natural gas production will continue to decline. As a result, even if there were no growth in U.S. petroleum and natural gas consumption, U.S. imports of petroleum and natural gas would still need to increase.

In order to reduce U.S. petroleum and natural gas imports, domestic energy production must increase for two reasons,

--to counteract declining U.S. petroleum and natural gas production and

--to provide for future growth in U.S. energy consumption.

Otherwise oil imports would continue to increase, at least until the world's petroleum and natural gas production no longer grows.

Coal and nuclear are the only major existing domestic energy sources which can provide large amounts of additional domestic energy production through the end of the century. However, these sources have not been capable of counteracting the recent declines in domestic oil and gas production.

Electricity capacity

For decades electricity has been and still continues to be the fastest-growing element in the U.S. energy system. Even though many analysts have pointed out that increased electrification results in greater increases in fuel use than other technologies, electricity's convenience has sustained this growth and indications are that relatively strong growth could continue. Some analysts, in fact, expect that electricity could account for a major share of increased domestic U.S. energy use.

Given the status of new electricity generating technologies, their current paces of development, and historical experience in the development of many sorts of new technologies, we believe prospects for large-scale sustained electricity capacity additions (on the order of 10,000 MWe or more per year) from new technologies before the year 2000 are very uncertain. As a result, at this time prudent planning would indicate that new electricity capacity through the end of the century will be largely based on existing technologies (petroleum, natural gas, hydroelectric, geothermal, coal, and nuclear). Of course, the extent to which new technologies could contribute before 2000 would reduce the demands on existing technologies.

In 1977 petroleum and natural gas generated 31.2 percent of all electricity in the United States. Industry and Government analyses expect that petroleum and natural gas generation of electricity will fall to about 60 percent of 1976 levels by 1990. Existing legislation mandates that natural gas generation of electricity be phased out, with few, if any exceptions, by the 1990s.

World oil production is expected to decline as early as the mid-to-late 1980s. If such declines occur, serious problems could arise in petroleum-consuming sectors, such as transportation, for which there are almost no fuel alternatives. Under such circumstances it would probably not be prudent to continue substantial petroleum generation of electricity into the next century. As a result, unless prospects for world oil production change and existing legislation is repealed, it is reasonable to expect that little or no electricity will be generated from petroleum and natural gas by the end of the century.

This means the other technologies must expand for two reasons,

--to meet increased electricity demand and

--to replace the lost petroleum and natural gas capacity.

To replace the lost petroleum and natural gas generated electricity, the existing technologies would have to increase their output up to 44 percent, even if there were no growth in electricity demand.

Under very optimistic circumstances hydroelectric and geothermal capacity might replace about one-half of the lost petroleum and natural gas generated electricity. Almost all the remaining lost electricity and future electricity growth would have to be generated by coal and nuclear power plants.

Coal has great growth potential, but it is also expected to be used for coal gasification, coal liquefaction, and direct burn in industry. Current Government policy is directed towards mandating significant increases in coal consumption in the industrial sector. This would mean serious competition for the electricity sector in its attempts to obtain coal. To the extent that coal could not meet all these demands, nuclear power is the only developed domestic energy source that could be called upon to provide the needed large increases in electricity production.

Carbon dioxide emission

Since 1850 the concentration of carbon dioxide in the atmosphere has increased by about 14 percent. However, over one-third of the increase has come since 1958. A significant part of this growth is a result of the recent exponential growth in the use of fossil fuels, namely petroleum, natural gas, and coal.

There is no agreement on the levels of carbon dioxide which could cause significant changes in the world's climate, nor on the nature of those changes (e.g., melting the ice caps, a new ice age, significant alterations of weather in world agricultural areas). However, whatever changes might occur would not be quickly reversible, if at all.

Some analysts warn that increasing carbon dioxide levels in the earth's atmosphere might require curtailments in the use of fossil fuels by the turn of the century. If that were to occur, it would be necessary to have significant new technologies available which did not emit carbon dioxide. Of course, the earlier such technologies could be introduced, the better. Nuclear power is a currently commercial energy source which does not emit carbon dioxide; some solar technologies are future ones.

REPORT SCOPE

Although nuclear power can play three major roles in the future U.S. energy system, expectations for its future continue to diminish, and its basic existence has been called into question. The Three Mile Island accident has brought this debate into sharp focus.

To provide a perspective within which the future role of nuclear power can be assessed, this report seeks answers to the following questions:

--How much nuclear capacity can be reasonably expected? This question will be addressed in the light of a continuation of current trends as well as a reasonable representation of the recent nuclear moratorium proposals.

--What are the implications of this capacity for the Nation's energy system? We will assess the levels of electricity demand which can be supported by the U.S. energy system. We will also assess the impacts of these nuclear supply levels on the availability of coal for uses other than electricity generation (e.g., industrial boilers and in synfuel plants).

CHAPTER 2

HOW MUCH NUCLEAR CAPACITY

CAN THE UNITED STATES EXPECT?

The levels of nuclear capacity expected by the end of the century have decreased significantly in the past few years. In 1974 the Atomic Energy Commission estimated there would be 1,090 GWe 1/ in commercial operation by 2000. In 1976 the Energy Research and Development Administration reduced this estimate to between 450 GWe and 800 GWe. Today the Energy Information Administration of the Department of Energy (DOE) expects that only 300 GWe to 380 GWe will be in commercial operation by 2000. The recent accident at Three Mile Island may result in even further reductions in expected nuclear capacity.

This chapter estimates future nuclear capacity under three different sets of assumptions.

--A moratorium on nuclear licensing is imposed almost immediately. Only plants which are more than 75 percent complete receive new operating licenses. This results in a maximum nuclear capacity of 64 GWe.

--Effective immediately, no new nuclear construction permits are issued; plants with construction permits are completed and become operational. This results in nuclear growth through the late 1980s with a maximum capacity of 152 GWe.

--Future nuclear capacity is estimated in the light of existing orders and Government expectations of future orders on the assumption that the Three Mile Island accident does not significantly affect long-term nuclear growth prospects. This results in a nuclear capacity of 340 GWe in 2000.

These estimates of nuclear capacity should not be seen as definitive forecasts. They are reference cases

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1/1 GWe = 1,000 MWe.

against which we will assess the future role of nuclear power in the U.S. energy system. However, given the current situation affecting U.S. attitudes towards nuclear power, we believe these reference cases effectively describe the reasonably achievable maximum and minimum nuclear growth rates.

NO OPERATING LICENSES AFTER 1980

This case is an almost immediate nuclear moratorium. It allows those facilities which are more than about three-fourths complete to be completed and licensed for operation. All other facilities would not be completed. This, of course, could entail significant financial losses to the utilities and investors involved.

Under this scenario, nuclear capacity would peak at 64.3 GWe in 1980, 12.5 GWe more than 1978 capacity. Capacity would begin to decline in the 1990s as the 30-year operating licenses of these plants begin to expire. By 2000 nuclear capacity would fall to 59.1 GWe, an 8.1 percent decline from its peak value. By 2010 all nuclear capacity would be gone. A detailed profile of this nuclear scenario is shown below.

	Capacity (GWe)
1978 (actual)	51.8
1980	64.3
1985	64.3
1990	64.1
1995	63.9
2000	59.1

NO NEW CONSTRUCTION PERMITS

As of January 1, 1979, the Nuclear Regulatory Commission had given construction permits to 91 reactors (100.4 GWe). Utility schedules indicate that 89 percent of this capacity is expected to be in commercial operation by 1985, for a total installed capacity of 141 GWe. However, given current construction rates, many of these reactors will probably not be completed until after 1985.

Our analysis indicates that only 53 of the 91 reactors scheduled to be in commercial operation by 1985 are likely to meet that schedule. This will result in a nuclear capacity of 109.7 GWe by the end of 1985. This is comparable to the most recent DOE reference case estimate of 111 GWe.

All plants with construction permits should be in commercial operation by 1990. This would result in a capacity of 152 GWe. This is slightly lower than the most recent DOE forecast.

As in the previous case, nuclear capacity would begin to decline in the 1990s as nuclear operating licenses begin to expire. By about 2020, all nuclear power facilities would have disappeared. A detailed profile of this scenario's nuclear capacity is shown below.

	Capacity (GWe)
1978 (actual)	51.8
1980	64.3
1985	109.7
1990	152.0
1995	151.8
2000	147.0

CURRENT TRENDS

If previous trends in nuclear construction were to continue, with new plants beginning construction at a steady pace, then the amount of nuclear capacity in commercial operation would increase beyond that shown in the previous two cases. Prior to Three Mile Island, DOE was estimating a nuclear capacity of from 300 GWe to 380 GWe by 2000. We believe a reasonable planning estimate at this point is 340 GWe, the midpoint of the range. A detailed profile of this growth scenario is shown below.

	Capacity (GWe)
1978 (actual)	51.8
1980	64.3
1985	109.7
1990	172.0
1995	254.8
2000	340.0

This listing shows that the expected rate of nuclear additions will begin to increase after 1985.

We have developed three possible scenarios for future nuclear growth: (1) the maximum capacity peaks in the early 1980s at 64 GWe, (2) the maximum capacity peaks in the late 1980s at 152 GWe, (3) a continuation of current trends in which capacity grows steadily to 340 GWe by the end of the century. The next chapter will discuss the implications of these different nuclear capacities on the U.S. energy system.

CHAPTER 3

WHAT ARE THE IMPLICATIONS

OF THESE NUCLEAR CAPACITIES

FOR THE U.S. ENERGY SYSTEM?

In the last 2 years nuclear power has been referred to as the energy source of "last resort." Recent events have tended to focus more attention on this description of nuclear power. Implicit in this description is that there are other options which would allow minimizing of the nuclear role while still increasing domestic energy supply, reducing imports, and meeting electricity demand. The two major options currently available to minimize the nuclear role are conservation to reduce the demand for electricity and coal to substitute for nuclear power.

This chapter discusses both options in relation to the nuclear growth cases developed in chapter 2. It assesses

--the future trends in electricity demand and

--the ability of coal to substitute for nuclear electricity.

ELECTRICITY DEMAND TRENDS

From 1960 to 1973 electricity demand grew 7.2 percent a year. Since 1973 it has been very difficult to discern any definitive trends which would allow a reasonably precise estimate of future trends in electricity demand. From 1973 to 1975 electricity demand grew less than 1 percent due primarily to the recession and the large increases in electricity prices. In 1976, however, electricity demand grew 6.1 percent as the economy recovered from its deepest recession since World War II.

In 1977 growth slackened to 5.1 percent despite a generally healthy economy, but during 1977 there was a severe Western drought which cut hydroelectric output more than 22 percent. This drop in electricity availability forced drastic cutbacks to interruptible users such as the aluminum industry in the Pacific Northwest. The Bonneville Power Administration (BPA), which accounted for a major share of the reduction in hydroelectric output, cut interruptible sales by over 96 percent (20.6 billion kilowatt-hours (KWhs)) and total deliveries by 20 percent (30.2 billion kWhs). If BPA deliveries had remained at their 1976 levels, U.S. electricity demand would have grown 6.7 percent in 1977.

For the first 8 months of 1978, electricity demand grew only 3.0 percent. However, for the last 4 months of 1978, electricity production averaged more than 5.0 percent over 1977 production. A significant part of the low growth in electricity in the first 8 months was due to the coal strike in early 1978. During the height of the strike, industrial use of electricity was down 10 to 20 percent over the same month the year before in the heavily industrialized East North Central and East South Central regions, and outside lighting and commercial use of electricity were cut back. Had there been no coal strike, it appears the electricity demand might have grown significantly more than the 3.0 percent through the first 8 months of 1978, probably on the order of at least 5 percent, comparable to the growth in electricity production over the last 4 months.

While events since 1973 suggest that electricity growth will probably not return to its pre-1973 rates of 7.2 percent a year, the precise trends are still very uncertain, particularly as U.S. oil and gas supplies become constricted and increasingly expensive. In the future, electricity growth will come from two major markets:

--The existing electricity markets which grew 7.2 percent a year from 1960 to 1973.

--The substitution of electricity for oil in additional markets to compensate for decreasing domestic supplies and ultimately decreasing world supplies.

The growth in the existing electricity markets appears to be slowing as conservation and slower population growth take effect. It would not be unreasonable to expect that this growth, in the long term, would be reduced even more. However, in the long term world oil supplies will cease to grow and, perhaps, even contract. If electricity is substituted for oil or gas, this would tend to sustain high electricity growth rates. For example, if electricity were substituted for 150,000 barrels of oil per day, this would result in an increase of 2.9 percent over the 1977 U.S. electricity demand. United States crude oil production in the Lower 48 States in 1977 was 230,000 barrels a day less than in 1976. These figures suggest that, despite extensive conservation efforts in both electricity and petroleum consumption, electricity demand could continue to grow substantially through the end of the century.

While there are very few studies which estimate electricity demand through the end of the century, many estimate growth through 1990. (Estimates of future electricity demand growth by a cross-section of institutions--industry, Government, research organizations--are shown in table 1). There is a general consensus among these studies that electricity demand growth rates will decrease through at least 1985. The only exception to this is the Electric World study, which assumes a recession in 1979-80. Once the economy recovers, its growth rates are consistent with the other studies. From 1977 to 1990 the studies project growth ranging between 3.9 percent a year and 4.8 percent a year. The average growth through 1990 according to these studies is 4.5 percent a year.

There are very few estimates beyond 1990. While it is reasonable to expect that conservation and slowing population growth could combine to further reduce electricity growth rates, at the same time world oil supplies may begin to decline in the 1990s, thus pushing electricity growth up. It appears that, unless the outlook for world oil supplies in the 1990s changes, or there are some periods of recession, it is not prudent to expect that electricity growth rates should slow significantly in the 1990s. As a result, we assume that electricity growth rates continue to decline slowly after 1990, averaging no more than 3.75 percent a year from 1990 to 2000.

TABLE 1

Average Annual Growth Rates for Electricity Use (percent)

Study	Date Issued	Period	Annual Growth
Exxon	1/77	1977 - 1990	4.8
Electric World	9/78	1977 - 1980	3.6
		1980 - 1985	4.3
		1985 - 1990	3.7
		1990 - 1995	3.8
Petroleum Industry Research Foundation (PIRF)	10/77	1976 - 1980	5.3
		1980 - 1985	4.9
		1985 - 1990	4.0
Shell	7/78	1976 - 1980	6.1
		1980 - 1985	4.2
		1985 - 1990	3.7
Congressional Research Service (CRS)	11/77	1976 - 1980	6.3 - 6.4
		1980 - 1985	4.5 - 4.6
		1985 - 1990	3.8 - 4.2
Energy Information Administration (EIA)	4/78	1976 - 1979	5.6
		1979 - 1985	3.6 - 4.4
		1985 - 1990	3.2 - 4.2

ELECTRICITY DEMAND AND COAL CONSUMPTION

To the end of the century, and possibly beyond, electricity will be generated principally from hydroelectric systems, geothermal, petroleum, natural gas, coal, and nuclear. Petroleum and natural gas generating plants will probably almost totally disappear by 2000, hydroelectric is severely limited with regard to additional growth, and geothermal, although having great potential, will probably be limited to particular regions such as the immediate area of the Salton Sea in Southern California. This leaves only nuclear energy and coal available for large electrical growth on a national basis. Of course, if other sources (e.g., solar, biomass) could achieve large-scale commercialization, this picture could change. However, at this point, we do not believe it prudent to plan on this happening by the end of the century.

There are, however, significant demands for coal outside of the electrical generation sector. Current Government policies are intended to increase the use of coal outside of the electric utilities. The development of an industry to produce synthetic gas and oil from coal is expected to have an effect on counteracting declining domestic oil and gas production and controlling the growth in imports. One of the critical factors affecting the availability of coal for non-electricity uses will be the extent to which coal electric generation can be displaced by other fuel sources such as nuclear or geothermal or by the reduction in electricity demand.

In our assessment of U.S. Coal Development 1/ we concluded that it would be very difficult to achieve 1 billion tons of annual coal production by 1985. Relative to 1976 this is a 4.4-percent annual growth rate. Extrapolating this growth through 2000 would result in coal production of 1.9 billion tons per year.

There are few analyses of coal production through 2000. Most are through 1990 and indicate that production would grow at annual rates ranging from 3.6 to 5.7 percent, with an average of 4.6 percent. The few studies through 2000 indicate production relative to 1976 will grow at an average annual rate of from 3.7

1/ "U.S. Coal Development--Promises, Uncertainties" (EMD-77-43, Sept. 22, 1977).

to 5 percent, resulting in coal production ranging from 1.4 to 2.2 billion tons by 2000. We will assume that coal production will reach 1 billion tons in 1985 and 2 billion tons in 2000.

We recognize that coal mining is a known technology and as such does not suffer from the growing pains that can be expected to accompany the introduction and growth of a new technology. As a result, a major national commitment to expand coal output and accept a number of social and environmental costs might expand coal production substantially beyond 2 billion tons in 2000. We think, however, in the absence of such major policy changes, 2 billion tons is a prudent planning estimate for coal production in 2000.

In 1978 almost 75 percent of all coal energy was consumed to generate electricity. Figure 1 on the following page compares the expected range of electricity demand with the electricity supplies achievable under the following assumptions:

--The electricity demand grows from 3.9 percent a year to 4.8 percent a year from 1977 to 1990, and 3.75 percent a year thereafter. (The demand range in figure 1 is the shaded area).

--Seventy-five percent of available coal energy is used to generate electricity.

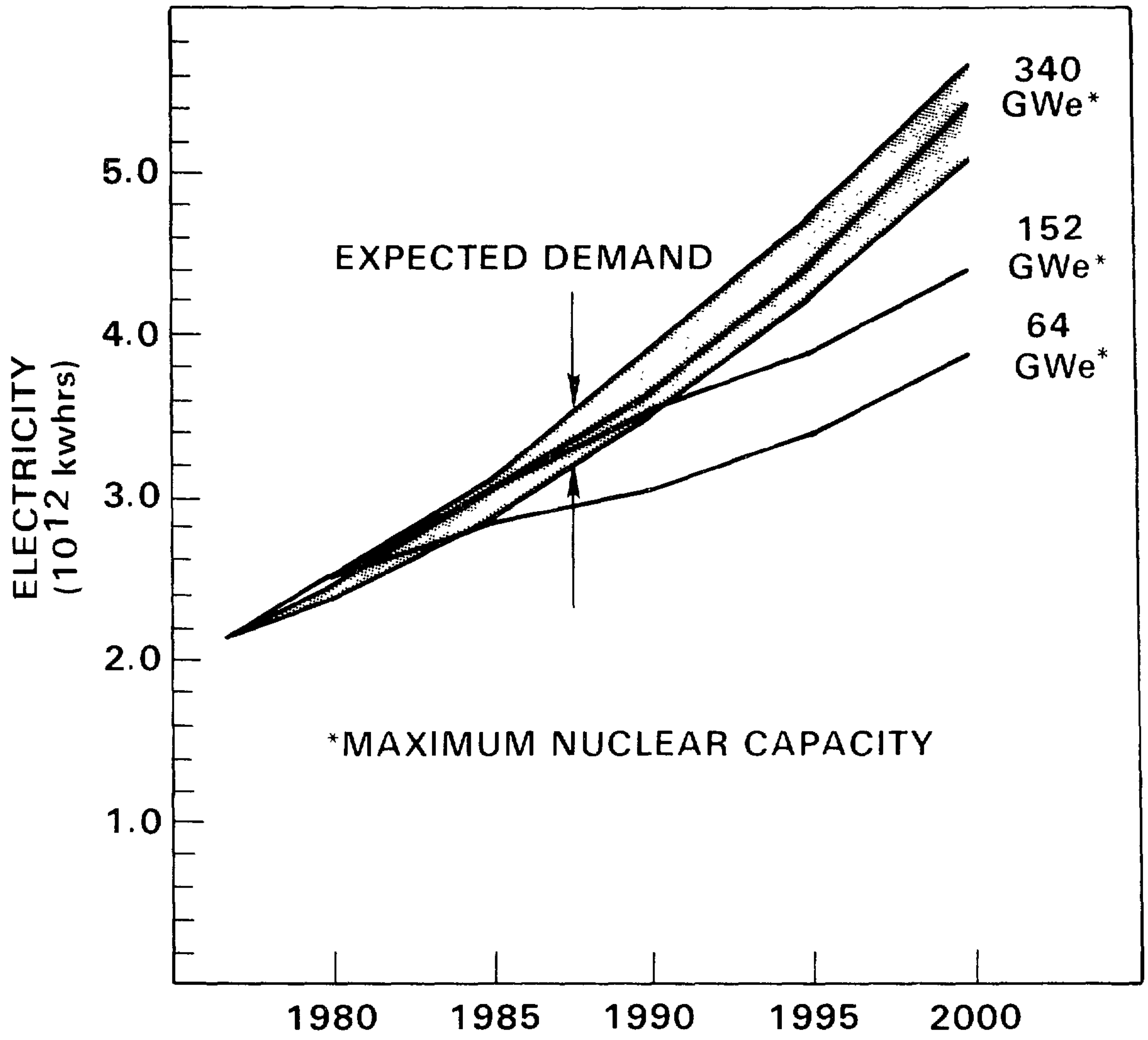
--Because of existing legislation 1/ and expected declines in world oil production, oil and gas generation of electricity remains at 1976 levels through 1985, and decreases one-third every 5 years until phased out in 2000.

--Hydroelectric output grows 2 percent a year, reaching 463.8 billion kWhs by 2000. This is more than 90 percent of total U.S. hydroelectric potential outside of Alaska and Hawaii.

--Other sources double from 1977 to 1980, and double every 5 years thereafter. These sources include geothermal, wood, waste, solar electric, etc. This amounts to 1.4 quads (quadrillion Btu's) of equivalent fuel input in 2000.

1/The Power Plant and Industrial Fuel Use Act (Public Law 95-620).

FIGURE 1. ACHIEVABLE ELECTRICITY SUPPLY LEVELS. COMPARED TO EXPECTED ELECTRICITY DEMAND.



--Nuclear capacity in 2000 ranges from 60 GWe, to 150 GWe, to 340 GWe.

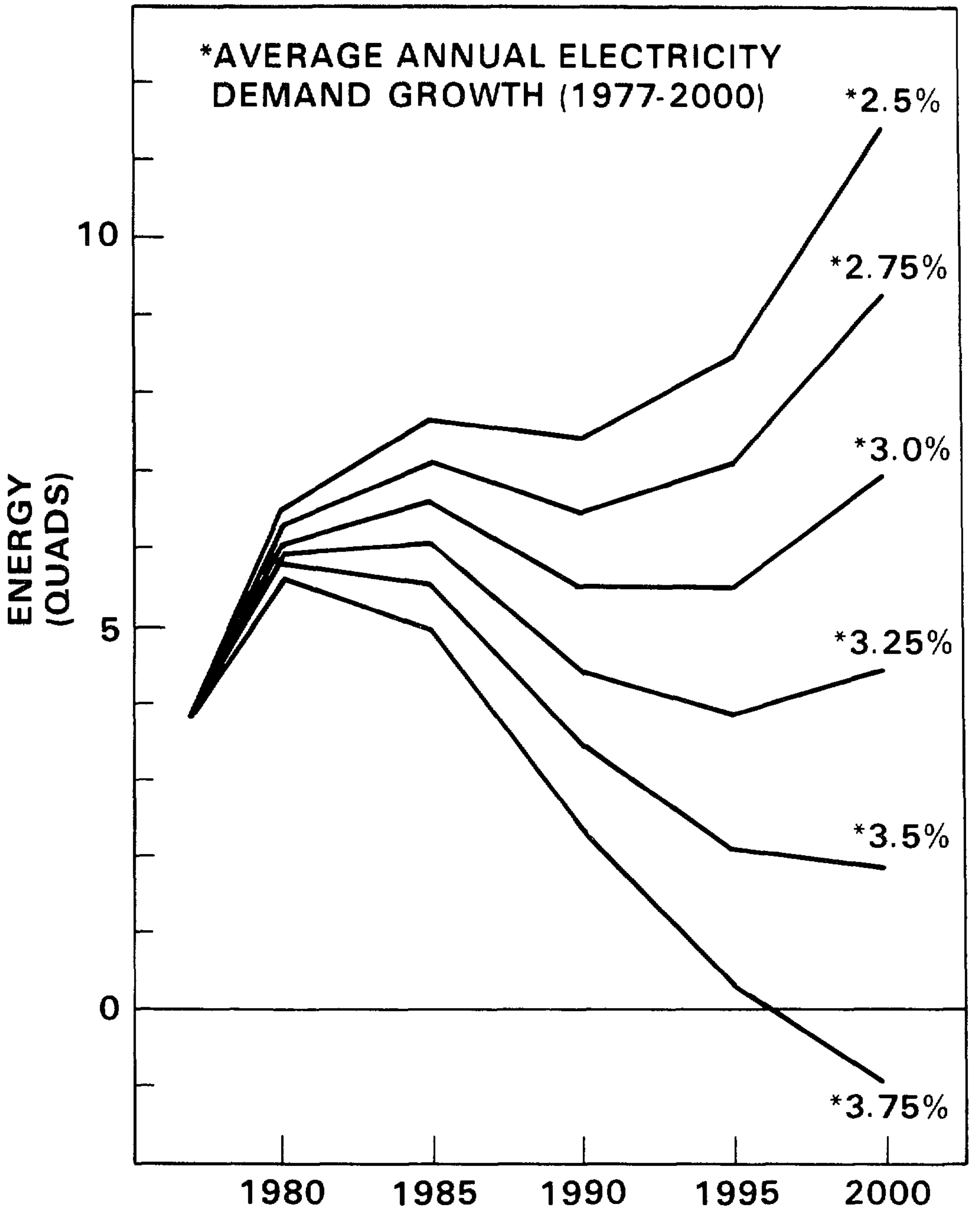
Figure 1 shows that if nuclear capacity grows to 340 GWe, growth in U.S. electricity demand can be met. However, the supply could not keep pace with growth above about 4.5 percent a year. The 152-GWe nuclear capacity case would be unable to meet even the lowest growth rate, 3.9 percent a year by about 1990, and the 64-GWe capacity case would be unable to meet the lowest growth rate before 1985. As a result, it is possible, even in the 340-Gwe case, that more than 75 percent of the available coal energy would have to be used for electricity generation. This could limit the amount of coal available for other uses such as industrial consumption or coal gasification or liquefaction.

Whether directly in industry, or indirectly, via synthetic fluids or electricity in all consuming sectors, coal is expected to take an increased role in meeting all forms of U.S. energy demands. Current Government policy mandates or encourages, consistent with environmental standards, the conversion of large boilers from burning oil and gas to burning coal. As noted earlier, coal is the only domestic fuel except nuclear energy which is currently capable of adding substantially to electricity generation. Furthermore, coal is expected to be a major source for substantial increments of synthetic gas and oil to substitute for declining and/or increasingly expensive supplies of domestic or imported oil and gas.

Because coal is expected to be the "swing" fuel in the U.S. energy system, we have presented the balance of our analytic results in terms of coal. The following three figures will show the amount of coal which would be left available for non-electric uses under the three previously stated alternate assumptions for nuclear power growth, and will illustrate the effects of different rates of growth in electricity consumption.

Figure 2 on the following page shows the availability of coal for non-electric uses as a result of an almost immediate moratorium in which nuclear capacity does not exceed 64 GWe. In this case electricity demand growth of 3.75 percent a year could not

FIGURE 2. NON-ELECTRIC COAL AVAILABILITY FOR 64 GWe MAXIMUM NUCLEAR CAPACITY.

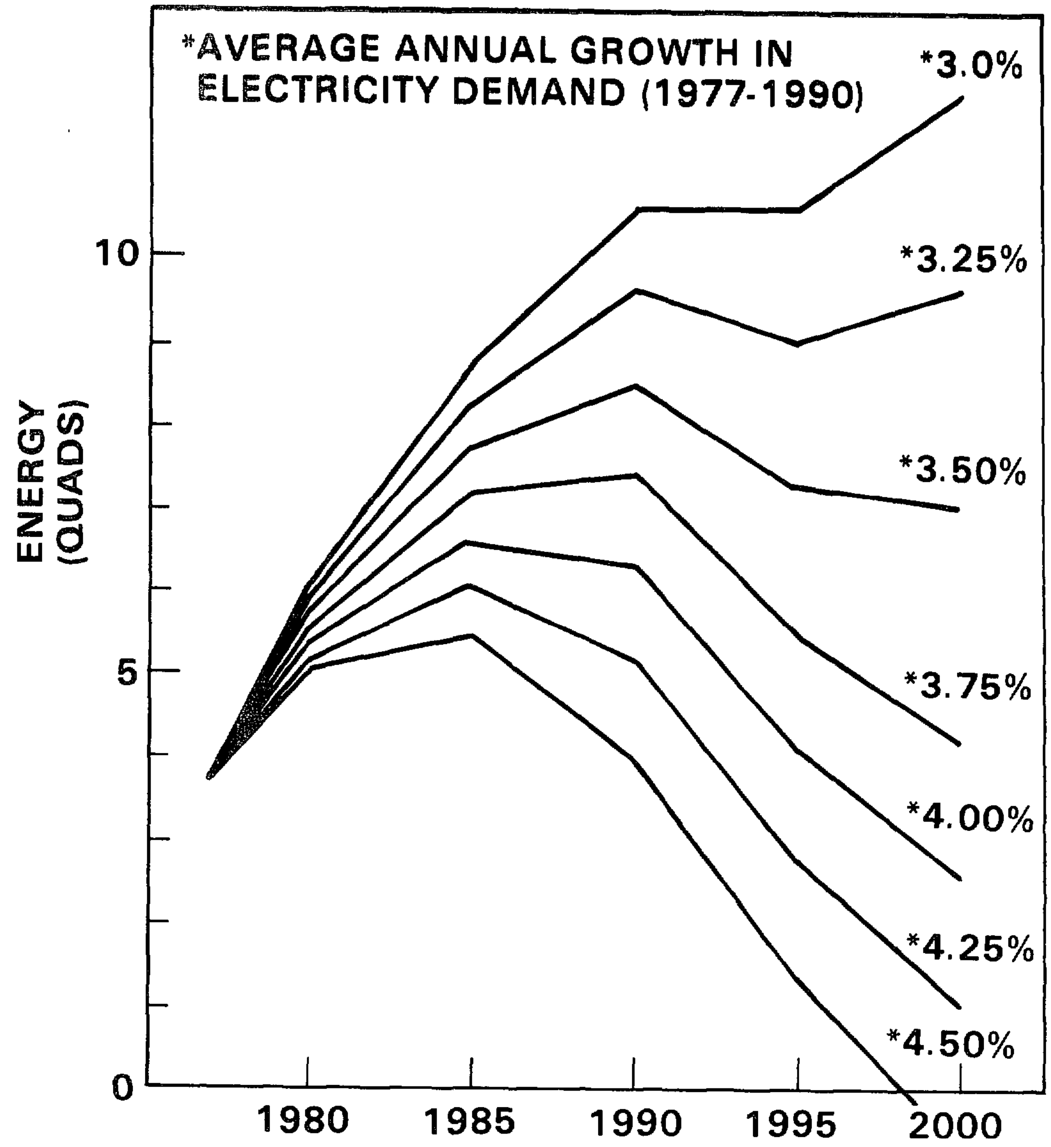


be met in 2000 even by using all of a 2-billion-ton annual coal output. At a lower annual growth rate, 3.25 percent, the amount of coal available for non-electric uses in the 1990s would be limited to about that used in 1977. Only if electricity grew at an annual rate of 2.75 percent or less could non-electric coal use expand comfortably through the end of the century; and electricity growth would have to be held to 2.5 percent a year to allow the United States to keep a full 25 percent of its coal available for non-electric uses through the end of the century.

The downward dip starting in about 1985, in all the curves in this and succeeding figures, shows a drop in coal availability which would occur because more coal would be needed to replace oil and gas which we have assumed will be phased out of electricity generation between 1985 and 2000. This dip illustrates the most serious problem which this study has identified. In all three nuclear cases examined, the assumed growth in total coal supply could meet relatively high electricity demand growth until 1985 and, if sustained, could again begin to improve electricity supply prospects in the next century. However, over the mid-term, about 1985 to 2000, the combined demands on coal to displace oil and gas from electricity generation and to meet additional electricity demand growth appears likely to constrain the ability to expand non-electric coal use. Yet this is the very interval during which a domestic oil decline and an end to the growth of world oil supplies are expected to combine to make it necessary that a coal-based synthetic fuel industry begin to contribute significantly to the Nation's supply of fluid fuels.

If nuclear generating capacity is allowed to continue to grow, up to the 152-GWe maximum level which would be reached by completing construction of all plants now holding construction permits, the limits on electricity demand growth would be less severe by about one-half to three-fourths of 1 percent per year. This is illustrated in figure 3 on the following page, which shows that commitment of the entire 2 billion ton per year coal supply assumed for 2000 could meet electricity consumption which grew at up to 4.25 percent per year. A growth in electricity demand of 3.75 percent per year or less

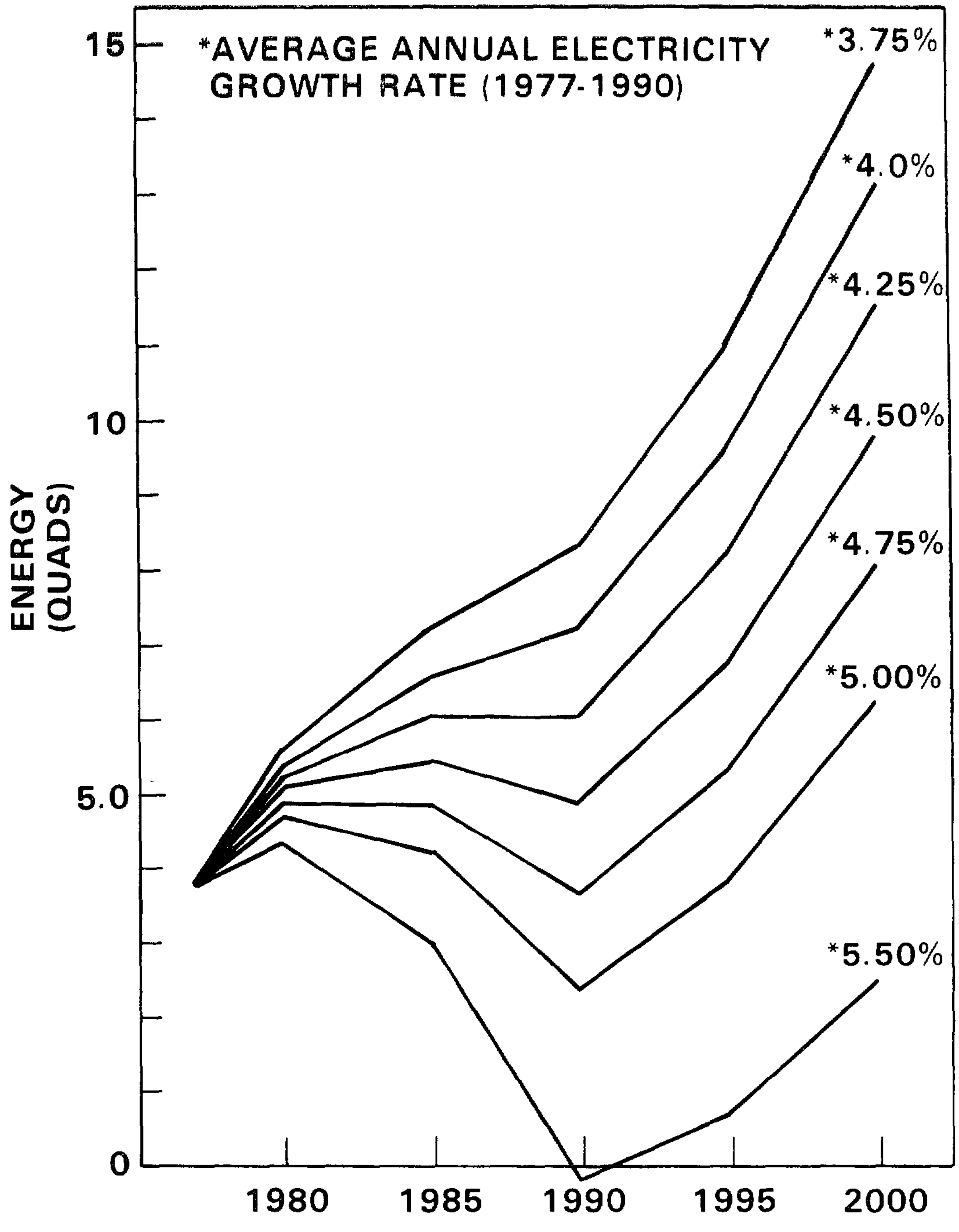
FIGURE 3. NON-ELECTRIC COAL AVAILABILITY FOR 152 GWe MAXIMUM NUCLEAR CAPACITY



would leave about as much coal available for non-electric use in 2000 as was used outside of the electrical sector in 1977. To allow relatively constant or increasing non-electric use of coal through the 1980s and 1990s, the growth of electricity consumption would have to be held to about 3.25 percent per year and, if 25 percent or more of the coal supply were to be kept available for non-electric uses, the electricity consumption would have to be limited to about a 3-percent annual growth.

The results for the third case which we have analyzed, in which nuclear generating capacity is allowed to continue to grow to 340 GWe by the end of the century, are presented in figure 4. This case would support substantially higher electricity consumption through the end of the century: it would allow electricity demand growth of fully 5.5 percent per year before the entire coal supply was consumed by the electrical sector. Electric demand growth of about 4.75 percent per year would still leave about as much coal available for non-electric uses in the tightest year, 1990, as was used outside of the electric sector in 1977. Even at somewhat higher electric growth rates, the coal supply could resume increasing after 1990. Finally, at electricity growth rates at or below 4.25 percent per year, non-electric coal supply would increase or at least remain constant throughout the period we have examined, and would also remain at or greater than 25 percent of total coal supply.

FIGURE 4. NON-ELECTRIC COAL AVAILABILITY FOR 340 GWe MAXIMUM NUCLEAR CAPACITY



CHAPTER 4

OBSERVATIONS AND CONCLUSIONS

We have described the limits of growth in electricity consumption in the United States which would have to be met under three different possible policies regarding future nuclear power use. These limits were determined in large part by the assumptions made about the prospects for other energy sources. Our overall approach has been to take what we regard as optimistic assumptions for the future growth of existing sources, and conservative assumptions for the prospects of supplies from technologies and sources which are now in research or development stages. Obviously, if different assumptions had been chosen, different conclusions would have been reached. Therefore, the most important questions to examine are:

1. Are these assumptions reasonable, at least at this time?

2. What events or developments could change these assumptions?

OBSERVATIONS

One major school of thought in the energy debate has claimed that greater commitments to develop and use decentralized and/or renewable technologies, the so-called "soft energy paths," would obviate the need for further expansion of centralized electricity generation and, in fact, could substantially slow and eventually halt further growth in overall energy use. While we of course recognize that this is possible, the history of development and deployment of new energy technologies argues for caution in developing policies and plans on the basis of anticipated breakthroughs in technologies still in the research and development or demonstration stages. For example, our 1976 research on the prospects for the liquid metal fast breeder reactor (LMFBR) development, 1/ concluded that substantial LMFBR deployment was at least 7 years, and quite possibly 11 or more years,

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1/ "Consideration for Commercializing the Liquid Metal Fast Breeder Reactor," EMD-77-5; Nov. 29, 1976.

further away than its developer, the Energy Research and Development Administration, was estimating.

In general, it is our view that prudent planning must be relatively conservative, and should not count on energy supplies or savings from new technologies or sources until they have been proven available, effective, and economically competitive in actual demonstration rather than only on paper or in the laboratory. This explains why we have assumed only relatively modest contributions to electricity supplies from geothermal and new technologies--a total of about 131 billion kwhrs by the end of the century. However, even this is 32 times current output. Approximately 1.4 quads of fuel would be required to generate this amount of electricity.

If, in the coming years, there is substantial progress in development efforts on these fronts, then our conclusions should be modified to allow for less need for electricity, for more growth in electricity supply, or for substitution of the new sources for nuclear or coal energy at the same growth rate. Such modifications will be appropriate, for example, if there is early success in developing technology for exploiting western shales or tar sands as oil sources, or devonian shale, tight sands, or geopressurized zone sources of natural gas, and also if major new sources of domestic oil or gas are found, for example from new Outer Continental Shelf exploration. Successful negotiations to obtain firm long-term commitments for oil and/or gas supply from the newly found deposits in Mexico or significant development of the Venezuelan and U.S. heavy oil deposits could also relax the limits found in our analysis, most likely by allowing delay of the phase-out of oil and gas from electricity generation which was assumed to begin in 1985 and be completed by 2000. Lastly, our conclusions could be modified if the assumptions for geothermal electric power, low-head hydroelectric or waste and biomass sources of electricity prove to be too conservative as research, development, and demonstration efforts proceed in these fields.

On the other hand, if experience in the near future shows that the assumptions for hydroelectric and coal growth are too optimistic, then the need to limit electricity demand growth and/or to continue expansion of nuclear power would become more pressing. This would also be the case if pressure on our oil supply, from further decline of domestic sources or increased difficulty with imports, made it imperative to accelerate the phasing out of oil from electricity generation, which was assumed to begin only in 1985.

CONCLUSIONS

The trends we have projected indicate that if actions are taken to limit or halt the growth of nuclear power, they must be accompanied by actions to severely limit electricity requirements or programs to expand coal supply or other non-nuclear fuels. Otherwise serious shortfalls of electricity supply are likely to occur in the 1980s.

--If electricity growth exceeds 5.5 percent a year, 340 GWe of nuclear plus 2 billion tons of coal will not provide adequate electricity.

--If electricity growth is kept below 4.5 percent, then nuclear growth could be held to 150 GWe.

--If electricity growth is kept significantly below 4 percent, then there could be a nuclear moratorium.

However, in all of these cases there would be little or no coal available for non-electricity uses. If coal is to be required for direct burn in industry and as a source of synthetic fuels, then the following conclusions are drawn:

--Even if nuclear capacity grows to 340 GWe by 2000, electricity growth would have to be limited to 4.25 percent a year to provide increased coal availability outside of the electricity generation sector beginning in the early 1980s.

--If no new nuclear construction permits are issued, electricity growth through 2000 would have to be held to about 3 percent a year or less to hold the percentage of coal used for non-electric purposes at its 1977 level of 25 percent.

--For a nuclear moratorium, annual electricity growth through 2000 must be less than 2.5 percent to allow non-electric coal use to remain at 25 percent of of U.S. coal use.

Of a more general nature:

--It appears very likely that, short of very optimistic conditions, significant growth in coal availability outside of electricity generation might not occur in the mid- to late 1980s, the earliest time when synfuels from coal could begin to make a significant contribution.

--The phasing out of petroleum and natural gas power facilities will place serious strains on the remaining electricity generating technologies. Of course if oil and gas generation of electricity could be held at 1990s level through 2000, electricity demand could grow about 0.5 percent a year faster then previously estimated or an additional 4.4 quads of coal would be available for use outside of electricity generation.

--Non-coal electricity generation technologies (e.g., nuclear, hydro) must provide additional capacity for three reasons: (1) to displace existing oil and gas generating capacity, (2) to provide for some new growth in electricity demand, and (3) to reduce the electricity demand on coal and thereby free coal for use in other sectors (e.g., synfuels, direct burn) unless coal production can grow much faster than assumed in this analysis.

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