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BNL NORTHEAST ENERGY PERSPECTIVES STUDY

A PERSPECTIVE ON THE ENERGY FUTURE OF THE NORTHEAST UNITED STATES

Joel Brainard, Harry Davitian,
Richard Goettle IV, and Philip F. Palmedo

June 1976

MASTER

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A PERSPECTIVE ON THE ENERGY FUTURE OF THE NORTHEAST UNITED STATES

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ABSTRACT

This study was undertaken to examine the implications of alternative energy futures for the Northeastern United States. First, the past and present energy supply and demand patterns for the United States and the Northeast region are reviewed. Then, on the basis of detailed analyses of present and possible future supply and demand activities, scenarios for the years 1985 and 2000 are constructed and compared to examine the implications of various policies that will affect future supply and demand activities. Economic and environmental consequences are also discussed.

The principal findings of the study are these: 1) Conservation measures can reduce fuel and resource requirements in the Northeast by over 30%. 2) Oil imports are likely to continue to be a major energy resource for the Northeast since only if strong conservation measures are combined with large increases in U.S. energy supplies is there apt to be a substantial decline in oil imports to the region. 3) A shift to coal and other alternate energy supplies, coupled with increased conservation, could compensate for a curtailment in the use of nuclear power in the region. 4) New resource technologies are capable of supplying up to 20% of the region's energy requirements in 2000. 5) No single supply technology or single conservation strategy taken alone can reduce the region's increasing dependence on foreign oil. Rather, the creation of an acceptable energy system for the region will require efforts in many directions in terms both of reducing demand and developing reliable, diversified supplies.

FOREWORD

This report presents a perspective on the energy supply and demand alternatives confronting the states of the Northeast United States. In support of this integrated analysis a number of issue papers were prepared by Brookhaven National Laboratory staff and collaborators from other institutions. Drafts of these issue papers, which address specific energy supply or demand topics, and a draft of this report served as a basis for discussion at the Northeast Energy Perspectives Meeting held at Brookhaven on March 16 and 17, 1976. Since that time both this report and the issue papers have undergone major revisions, in part as a result of helpful criticisms and comments received from participants at the meeting and others who have critically reviewed the draft report and issue papers. We are greatly indebted to all those who have provided us with wise council, information and advice.

Robert Brown and his staff in the BNL Graphic Arts Department and Robert Stern were essential collaborators in the preparation of this report and its back-up documents. Ernest Silver of the Institute for Energy Analysis, Oak Ridge, Tennessee, provided a computer program that served as a starting point for our analytical framework. Georgia Irving bore the burden of coordinating the typing of sequential versions of this report with the skilled typing assistance of Donna Visone, Frances Ligon, and Adele Hough. We were aided greatly in the technical editing of this report, and the ten supporting volumes, by Margaret Dienes and Alice Perez, technical editors at Brookhaven National Laboratory.

The issue papers prepared for the Northeast Energy Perspectives Study and this report are available from:

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The individual issue papers are listed below:

H. Bronheim, "Future Oil Supply to the Northeast United States," BNL 50557 (June 1976).

R. J. Goettle, IV, "Alternative Patterns of Industrial Energy Consumption in the Northeast," BNL 50555 (March 1976).

R. N. Langlois, "Future Natural Gas Supply to the Northeast," BNL 50558 (April 1976).

J. Lee, "Future Residential and Commercial Energy Demand in the Northeast," BNL 50552 (March 1976).

P. M. Meier and T. H. McCoy, "Solid Waste as an Energy Source for the Northeast," BNL 50559 (June 1976).

P. M. Meier, T. H. McCoy, and S. Rahman, "Issues in the Future Supply of Electricity to the Northeast," BNL 50553 (June 1976).

B. S. Edelston and E. S. Rubin, "Current and Future Use of Coal in the Northeast," BNL 50560 (May 1976), Environmental Studies Institute, Carnegie-Mellon University, Pittsburgh, Penn.

V. L. Sailor and F. J. Shore, "The Future of Nuclear Power in the Northeast," BNL 50551 (March 1976).

G. R. Bray, S. K. Julin and J. A. Simmons, "Supply of Liquefied Natural Gas to the Northeast," BNL 50556 (April 1976), Science Applications, Inc., 1651 Old Meadow Road, McLean, Va.

System Design Concepts, Inc., "Transportation Energy Consumption and Conservation Policy Options in the Northeast," BNL 50554 (April 1976), System Design Concepts, Inc., 9 Rector Street, New York, N.Y. 10006.

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I. EXECUTIVE SUMMARY

A. Aims and Approach of the Study

This study represents a first step in analyzing the implications of alternative energy futures for the Northeastern United States. It was carried out as part of the Brookhaven National Laboratory Regional Energy Studies Program with support from the U.S. Energy Research and Development Administration. That Regional Program is based on the concept that a regional scale of analysis, intermediate between the scale of the State and that of the Nation, can be useful to both State and Federal energy planning.

Regional analysis can be used by states within a region to identify their common interests, which in turn can influence Federal energy decisions as well as those taken by other sections of the country. It can demonstrate the interdependence of the energy supply, distribution, and consumption problems within a region and suggest solutions which, while not possible for individual states, might be feasible on a regional basis. The region considered in this study includes the New England States, New York, New Jersey, Pennsylvania, Maryland, Delaware, and the District of Columbia.

The Northeast now obtains more than 90% of its energy supplies from outside the region, and over 40% of these from foreign countries. This makes the Northeast highly sensitive to decisions now being made, with increasing awareness and skill, by energy-exporting regions of the country and the world. To a greater extent than ever before, these states and countries are attempting to exploit their resources in the manner most beneficial to their own economies and environments. Such efforts can significantly affect

the flow of energy between regions of the country (energy both in its raw-material and processed forms and also embodied in materials and goods) and thereby alter the competitive position of industries in energy-importing regions.

1. Study Approach

We have used a scenario approach to examine the implications of future energy supply and demand situations in the Northeast. Separate studies were carried out of all pertinent supply sectors: coal, oil, natural gas, liquefied natural gas, nuclear power, municipal waste, solar energy, and wind power. In each case a range of estimates of supplies to the Northeast was constructed, reflecting possible policy and technological developments and also the basic uncertainties of all such projections. Similarly, on the demand side, ranges of future regional energy demands were constructed representing, among other things, various levels of energy conservation practices in specific uses of energy.

We then constructed scenarios which matched possible regional demands for various fuels with their supplies. It was assumed that a shortage of liquid supplies from the U.S. would be made up by imports. A set of environmental coefficients (e.g., emissions into air and water) was assigned to each fuel-specific energy use so that an indication of environmental impacts could be derived for each supply-demand scenario. A number of scenarios based on alternative supply and demand assumptions could then be used to examine particular issues such as oil import reduction, offshore oil development, or nuclear power curtailment. It should be emphasized that the study did not deal with short-term energy supply problems, nor did it deal directly with the complex feedback relationships between energy prices, industrial activity, consumer demand, and employment.

The results of the scenario analysis can be briefly summarized as follows.

B. Principal Findings

1. Reference Scenario

Current energy consumption in the Northeast (as fuels, including electricity) is about 12.3 quads (quadrillion or 10^{15} Btu). This requires the use of some 15.8 quads of basic energy resources.

A continuation of current trends in population, economic growth, and energy use patterns and of current policies related to energy resource development and usage would lead to an 80% increase in the demand for fuels in the Northeast and a 100% increase in energy resource requirements between 1972 and 2000. The need for imported oil would increase by 85%. Coal and nuclear power would each supply roughly 20 to 25% of the total resources used by the Northeast in 2000. (See Figure 1.)

2. Energy Conservation

Conservation can play a major role in reducing the fuel and resource requirements of the Northeast: The moderate-conservation actions considered in this report can reduce fuel demands by 11% in 1985 and 18% in 2000 from the levels in the reference scenario, and the strong-conservation actions can reduce them by 19% in 1985 and 32% in 2000. Most of the measures that comprise the conservation strategies can be enacted or implemented at the State or local level.

The reduction in energy requirements resulting from conservation would have four broad effects in the Northeast: (1) It would make the Northeast less vulnerable to supply constraints and production bottlenecks and provide more options for dealing with them.

Figure 1. Resource requirements, reference scenario (Scenario 1).

(2) The substitution of devices and procedures consuming less energy would result in net long-run monetary savings. (3) Conservation strategies have a potential for creating more jobs within the region than corresponding supply strategies. (4) Environmental and health benefits would be derived from the lower levels of resource extraction and energy use both within the region and outside it.

3. Imported Oil

Imported oil is likely to continue to play a major role as an energy resource for the Northeast. The reference scenario, based on the assumption that no new policy initiatives are undertaken to affect supply or demand, projects an increase in imported oil requirements from the 1972 level of 6.5 quads to 12 quads in 2000. This corresponds to a change in the fraction of oil that is imported from 61% to 77%.

If a vigorous U.S. effort were mounted to produce synthetic liquids from coal and to develop oil shale resources and enhanced recovery techniques for conventional crude oil, and if this were coupled with higher than expected crude oil discoveries, the need for imported oil in the region could be reduced by nearly 4 quads. For a variety of reasons, a liquid fuel supply augmentation of this magnitude appears problematic.

On the demand side, moderate conservation could reduce the need for imports by about 2 quads and strong conservation by about 4 quads from the reference level (assuming constant supplies of other liquid fuels to the region).

If an effort is made to shift some of the demand from oil to electricity and low-Btu gas (produced from coal) and moderate conservation is invoked, import requirements for 1985 and 2000

could be maintained at approximately the 1972 level. Trends in oil imports implied by a number of the scenarios considered in this report are shown in Figure 2. It is clear that a significant reduction in the level of imports, if it is deemed desirable and if it is to be achieved voluntarily and gradually, can be brought about only through early, concerted action at both the Federal and the local level.

4. Offshore Oil and Gas

Estimates of the quantities of crude oil and natural gas recoverable from fields in the Atlantic Outer Continental Shelf are highly speculative and uncertain because of the lack of exploratory drilling to date. Current resource estimates suggest that in 2000 the maximum likely production rates would be 0.86 quads/year of oil and 0.56 quads/year of gas. The sum of these, 1.4 quads/year, amounts to 6% of the total fuels required for the region in the year 2000 in the reference scenario. Gas production of 0.56 quads/year, however, amounts to 20% of the reference case gas demand in 2000 so that, if this production rate were achieved and the gas were consumed totally in the Northeast, the offshore resources could provide a substantial fraction of the region's gas needs for two to three decades.

5. Nuclear Curtailment

In the reference scenario nuclear power is projected to supply 6.5 quads of energy input to electricity production in 2000. In the low nuclear supply case, which would reflect a public decision to curtail the use of nuclear power, we assumed that no new construction is initiated after 1977 but that plants in operation or under construction at that time are unaffected. This would freeze the energy supplied by nuclear power at a level of 2.2 quads/year. If coal alone were employed to make up for the reduction in use of nuclear resources, the increased coal

Figure 2. Oil imports to the Northeast (intermediate liquid supplies assumed except as indicated).

requirements would be 60% above the intermediate regional coal supply projection for 2000. Unless strict emission standards were met, such high coal use could result in a large number of deaths attributable to an increase in air pollution.

With moderate-conservation demand levels, nuclear power would provide 4.5 quads/year in 2000 without curtailment. The decrease to the 2.2 quad level under curtailment could be made up by the substitution of coal, raising the required regional coal supply level to less than 20% above the intermediate level. Alternatively, moderate conservation coupled with vigorous implementation of the use of wind power and solid waste for generating electricity could completely compensate for the decreased nuclear

output. We have not considered all the possible substitutes for nuclear power. In particular, oil, either imported or produced synthetically, could be used to compensate at least in part for a reduction in nuclear power. However, such a shift to oil would raise the level of imports or production levels of synthetics above the already high levels in the reference scenario. Also, if the substitutes for nuclear power are higher in cost, the total cost to the region could be very high (in terms of both electricity prices and reduced economic growth).

6. New Resource Technologies

Three new energy resource technologies can play a role in the Northeast by 2000: solar energy for heating and cooling; wind power; and the conversion of solid waste to electricity and gas. None of these technologies is impeded by significant technological barriers, but all are affected by institutional constraints. Waste conversion is economically competitive today under some circumstances, but this resource is limited to a relatively minor role (approximately 0.2 quads of electricity and 0.02 quads of gas) because of limitations on the availability and collection of wastes and refuse. The most rapid rate of introduction of solar energy systems considered in this study assumes that solar systems would supply 25% of the energy required for space heating and 70% of that for water heating in buildings constructed after 1985. Such use of solar systems would result in a 20% reduction in conventional fuel requirements in the residential and commercial sector by 2000, which is equivalent to 6% of the total fuels projected to be required in that year.

Wind power could also contribute materially to the fuel supply of the Northeast by 2000. Wind is abundant and the technology for its utilization is highly advanced. Although some cost estimates are encouraging, the economic viability of wind power as a major component of utility systems is still uncertain. The eventual level of implementation will depend also on public reaction to the visual impact of large windmills. In the intermediate wind power projection constructed for this study, it was assumed that wind power would provide 0.13 quads of electricity in 2000, about 4 to 5% of the electricity demand in that year, corresponding to about 1.5% of the resource requirement in the reference scenario. This would require approximately 6500 windmills of 1.5-MW rated capacity each.

Although the production of low-Btu gas in the region from coal was not projected to supply more than one quad of energy by 2000, it is a technology with a number of potentially beneficial features to the Northeast and deserves more serious study.

7. The Possibility of Lower U.S. Supplies

Constraints on the supplies of U.S. oil and natural gas to the Northeast, reflecting a combination of lower than expected discoveries and a lower fractional allocation of the total U.S. production to the Northeast would, under the assumptions of this analysis, reduce the total supplies of these resources to the region in 2000 to approximately half the levels projected in the reference case. What the future supply of natural gas will be is particularly unclear because of regulatory uncertainties that will

affect future prices, the production levels at those prices, and regional allocations. In the low-supply case, natural gas supply to the region drops from the current 2.3 quads to 0.3 quads in 2000.

These reductions in availability of resources could be compensated for only by significantly higher use of coal (by a factor of 2) or by strong conservation and fuel shifts on the demand side. The region clearly has a vital interest in assuring the adequate development of U.S. resources.

C. Final Conclusion

Unless concerted action is taken at both the Federal and State levels, the energy future of the Northeast will remain precarious. There are no panaceas; no single new supply technology or single conservation strategy goes very far toward reducing the region's dependence on foreign oil. The creation of an acceptable energy system for the region will require efforts in many directions in terms both of reducing demand and of developing reliable diversified supplies. Collaboration among states in the region could contribute to the effectiveness of individual actions and to the success of the whole.

D. Future Analysis

The study summarized in this report should be considered as the first stage of a continuing, increasingly sophisticated analysis of the energy problems of the Northeast. In current work at BNL emphasis is on the development of methods for incorporating economic considerations, including employment effects, into the analysis. Also, the regional data base is being augmented on a state by state basis. In the broader Regional Energy Studies Program, major emphasis in 1976 is on clarifying the ramifications of the future use of coal in the region and on the problems of offshore development.

II. INTRODUCTION

A. Aims of the Study

Over the past two years, the world has become increasingly aware of the critical role of energy in developing and maintaining advanced industrial economies. We in the United States have become aware of the complexity of our own energy system, its interconnectedness with virtually all aspects of modern life, and the great difficulty of changing it in response to new economic and political realities. The oil embargo of 1973 and the subsequent energy crisis helped focus attention on our energy system and our heavy dependence on imported petroleum products. The Nation's heightened interest in energy issues led to the creation of agencies at all levels of government that were charged with the responsibility of formulating coherent energy policies.

At the Federal level, significant changes have been made in the structure of energy institutions. Three new agencies have been created: the Energy Research and Development Administration (ERDA) and the Nuclear Regulatory Commission (NRC), each assuming some functions of the former Atomic Energy Commission, and the Federal Energy Administration (FEA). Significant changes were made in the Federal research and development program, particularly with regard to new programs on renewable resources and conservation technologies. Both FEA and ERDA initiated significant programs to develop the information and analytical framework needed for understanding the Nation's future energy alternatives and evaluating future policy choices. Thus, although a coherent national energy policy is yet to emerge from Congress, the Federal Government has begun to move in response to the new energy imperatives.

State governments also are faced with important energy choices and have likewise become aware that future economic growth, employment, and environmental quality within their boundaries will be critically affected by their decisions. An additional complication is that Federal policy decisions yet to be made will have a strong influence in defining the limits of State actions. This suggests that a new multistate approach may be needed as a basis for analyzing State energy problems. Analysis on a regional scale, intermediate between that of the State and that of the Nation, has a number of advantages. It can be used by states within a region to identify common interests relevant to energy decisions by the Federal Government and by other sections of the country.* It can show the interdependence of the energy supply, distribution, and consumption systems within the region and suggest actions whose implementation, in some cases, may be feasible only on a regional basis.

Other, energy-exporting, sections of the country have already perceived these advantages and have taken the initiative in analyzing their energy-related problems on such a scale. The significance of this should not be underestimated by the energy-importing Northeast. Two trends are particularly important: (1) the rising difference in price per unit of utilizable energy (averaged over the region and over all energy forms) between the Northeast and other areas of the country, and (2) the increasing significance of energy prices and fuel availability as factors in the locational decisions of major manufacturers. These energy-related trends occur at a time when other societal and economic factors are contributing to uncertainties regarding the future economic strength of the region.

*One area of Federal decision making in which the region should seek to exert some influence is energy R&D policy. See Appendix B.

The energy-importing character of the Northeast makes it highly sensitive to decisions now being made, with increasing awareness and skill, by energy-exporting regions of the country. To a greater extent than ever before, those regions are seeking to exploit their resources in the manner most beneficial to their own economies and environments. Such efforts can significantly influence the flow of energy (both in its raw-material and processed forms and also embodied in materials and goods) between regions of the country and thereby alter the composition of the industrial base in energy-importing regions. The situation is similar with regard to some of the Northeast's major foreign sources of oil. Although the Federal Government can seek to mediate the more severe effects to the region, it behooves the Northeast to identify and assess the probable effects of such actions taken by the other regions in the U.S. or by other nations in order to plan its own response.

The Northeast Energy Perspectives Study represents the first step in an effort by the Regional Energy Studies Program at Brookhaven National Laboratory to provide an analytical framework and data base for discussing the energy problems that will confront the Northeast over the next 25 years. In this study the Northeast includes 11 states and the District of Columbia, grouped into the following three subregions: New England; New York; and the New Jersey, Pennsylvania, Maryland, Delaware, and D.C. subregion. Some of the specific questions being addressed include the following:

What are the ranges of likely fuel supplies to the Northeast, assuming no major departures from current international, national, and regional energy-related policies?

What energy supply and conversion technologies are likely to be employed in meeting projected demands under such business-as-usual conditions?

To what extent can the projected regional energy supply-demand balance be altered as a result of supply enhancement and conservation measures adopted within the Northeast region, by the Federal Government, and elsewhere within the country and overseas?

What would be the consequences of environmental or safety actions curtailing the use of high-sulfur coal or of nuclear power?

How can reliance on imports of foreign petroleum be reduced?

How significant is the role of offshore oil and gas in the Northeast's future energy supply?

What effect can new technologies, such as those involving the use of solar energy or municipal waste, have on energy supply to the region by the year 2000?

Note that many aspects of the energy problems of the Northeast are not dealt with in this analysis. We do not consider short-term problems and the dislocations that they may cause; these must be addressed at the State level. Our time horizon is designed to reveal the problems implicit in long-term trends, the trends that will create the short-term crises 5 to 25 years from now. We do not deal in a fully integrated fashion with the economics of energy supply and demand or with the complex feedback relationship between energy prices, regional industrial activity, and their effects on jobs, income, and residential energy demand. Consistent assumptions are implied, however, concerning energy prices and their influence on both supply and demand.

It is not the intention of the study to come up with specific recommendations related either to particular energy supplies or technologies or to the adoption of specific energy conservation policies. Nor is it intended to suggest that the adoption of a regional perspective obviates or supersedes the need for State

energy planning efforts. The goal is rather to provide the individual states in the Northeast, and the Federal Government, with a basis for considering the regional interests of the Northeast in relation to their respective interests.

This study is part of an extensive energy analysis program centered at Brookhaven National Laboratory and supported by the U.S. Energy Research and Development Administration to address key energy and environmental issues of the Northeast.¹ The overall program includes elements aimed at improving methods for analyzing impacts of specific actions such as implementing energy conservation practices or increasing the use of coal in the region, as well as the development of integrated energy, economic, and environmental models for the region.

B. Study Approach

Analytical work on the types of questions listed above can employ a variety of approaches. Given the intended purpose and audience of this study, we wanted to present our results in terms of alternative future supply-demand balances in the region. We also wanted to show how technological changes and policies can affect specific energy supplies and demands (for example, how development of offshore oil deposits would affect supplies, and how changes in air-conditioner and automobile efficiencies would affect demands). We therefore required detailed information both on the energy supply to the region and on the energy consumption in the region. This was built up through detailed studies (separately reported) of all the major supply sectors--coal, oil, natural gas, liquified natural gas, nuclear power, municipal waste, solar energy, and windpower--and all the major demand sectors--residential, commercial, transportation, and industrial.*

*These reports are listed in the Foreword.

At the same time, we wanted to take into account the very large uncertainties associated with the energy and economic future of the region, and indeed the country as a whole. In formulating public policy, it would be irresponsible to base decisions on a single view of the future even if that view were the most likely. The cloudiness of the crystal ball must be explicitly considered in policy choices. A range of possibilities was therefore specified for all of the future supply and demand projections. On the supply side, high and low cases were constructed in addition to a base case. In some instances this was done in terms of both national supply and allocation to the region. On the demand side, in addition to a base case, actions producing various levels of energy conservation were assembled into a moderate-conservation case and a strong-conservation case. Thus the projections for individual sectors span the range of supply and demand possibilities that can reasonably be expected given the varied assumptions considered in this study.

The supply and demand projections were prepared independently. However, the supply and demand for specific fuel forms--liquids, gases, coal, and electricity--must balance within the region to define a feasible future condition.* Such a balance is reached by iteratively constructing possible future energy scenarios for the region, each incorporating the assumptions associated with the specific supply and demand projections used. The process is indicated in Figure 3 and is described in more detail in Section VI. The general approach is to focus on the fuels that are required to satisfy regional demands and which must be supplied by the various resources considered.

*Solar energy used for heating and cooling is considered in the demand analysis in determining the requirements for these energy forms.

Figure 3. Analytical framework for construction of scenarios.

Scenarios were constructed in which the demands for the four fuels were matched with their supplies. It was assumed that a shortfall of liquid supplies from the U.S. would be made up by imports. A set of environmental coefficients for air and water emissions was assigned to each fuel-specific energy use so that an indication of environmental impacts could be derived for each supply-demand scenario. A number of scenarios based on alternative supply and demand assumptions were then used to examine the effects of particular actions such as reducing oil imports, developing offshore oil fields, or curtailing the use of nuclear power. The results of the scenario analysis and the conclusions derived from the supporting detailed studies of the supply and demand sectors are discussed in Section VI.

In Section III, the current energy supply-demand situation is described, with a brief review of the pertinent features of the national energy scene. In Sections IV and V, the analyses of the supply and demand sectors are summarized. The uses to which this analysis can be put are indicated below.

C. Energy Policy Goals and the Role of Analysis

Major energy choices invariably involve trade-offs between conflicting societal goals. Some of the energy policy issues that must be considered by governments in setting these goals include the impacts on human health, environmental quality, economic activity, reliability of supply, energy costs to the consumer, and the equity of the distribution of these costs.

A number of policies that decrease the cost of energy (increased burning of high-sulfur coal, for example) damage environmental quality. Taxes on fuels to reduce energy consumption might produce environmental benefits but might also cause employment dislocations and distributional inequities. The relative importance of these goals is perceived differently by different people and is also influenced by the geographical scale of interest. Foreign policy considerations, for example, may be more significant at the national level than at the state level.

There is no single correct method of deciding how much weight to give the various goals involved in an energy policy decision. That depends on the values held by those affected by the decision. Thus, the important choices must be made through the political system. It follows that the role of the analyst

is not to determine what is best but rather to clarify and, if possible, to quantify the implications of alternative actions. Such actions may require collective as well as individual initiatives on the part of the states included in this analysis. The current lack of mechanisms for considering such actions jointly may seriously inhibit the achievement of regional energy goals.

In presenting this study, we want to emphasize its preliminary nature. It is presented not as a complete or final statement but rather as an initial contribution to a dialogue between those at the local level who are responsible for making decisions affecting energy supply and demand and those in the technical community who would like to contribute whatever insights and information they can to those faced with making the decisions. We hope that this will provide a useful perspective on some of the energy problems that the Northeast will face through the year 2000 and that a dialogue with the states will ensue that will indicate the directions in which our analysis should proceed in order to make it most useful to the decision makers and, ultimately, to the citizens of the Northeast.

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III. HISTORICAL TRENDS AND THE CURRENT ENERGY SITUATION

The Northeast, in its energy characteristics and choices, is strongly dependent on the rest of the Nation perhaps to a greater degree than any other region. The nature of this relationship and its future prospects are analyzed in Section VI. Here, some of the historical features of the national energy picture germane to understanding the future are surveyed, and the current energy supply-demand situation in the Northeast is summarized.

A. The National Energy Scene

Over the past century, energy use patterns have shifted dramatically. A hundred years ago, wood supplied the bulk of space and process heat, and animals supplied most of the motive power for heavy farm work and much of the power used for transportation. Limited use was made of wind and water power, and some bulk cargo was still transported in sailing ships.

Around 1890, coal, a more concentrated source of energy, replaced wood as the predominate fuel for heat and transportation. It was not until 1950 that petroleum displaced coal as the Nation's primary source of energy. Natural gas, initially treated as a useless by-product of oil exploration, passed coal as a national source of energy in the late 1950's (mainly because of construction of a nationwide system for its efficient distribution). These trends are shown in Figures 4 and 5. Clearly, major shifts in energy supply can occur even in time periods as short as those covered in this study (25 years).

The massive shift to forms of fuel that are easier to transport and more adaptable to a variety of end uses was of the utmost importance in permitting both the geographic diversification of

Figure 4. U.S. gross energy use, 1850-1970.²

Figure 5. Trends in national energy supply.²

energy-consuming industries and an increase in energy-expending consumer activities, the most significant of which was the increase in the use of the automobile.

With the advent of efficient long-distance distribution systems, it became easy to transport fuels from energy-rich to energy-deficient areas of the country--Texas oil to the Northeast and Louisiana natural gas to the Midwest. Until the last two years industrial users of energy (with the possible exception of the most energy intensive) could locate anywhere in the country and be guaranteed a plentiful and relatively cheap supply of energy. Regional energy self-sufficiency was not even considered a topic worthy of analysis.

Over much of this transitional period, the U.S. had energy resources sufficiently diverse and abundant to supply its own growing demands and those of other countries. Only within the last decade or so has the price differential between foreign and domestic oil initiated a dependence on imported oil. This dependence, which now rests on a real shortage of domestic fuels, has grown to represent a significant portion of total annual U.S. usage.

During this period, characterized by a radical shift in the mix of primary fuels, energy demand rose steadily, largely because of population growth. As seen in Table 1, the U.S. population increased by a factor of 4.7 over the past century and the total energy consumption by a factor of about 10.4 so that the increase in per capita consumption was by a factor of only about 2.2. Note, however, that a large part of the increase occurred within the past 25 years.

Table 1

CHANGES IN U.S. POPULATION, ENERGY CONSUMPTION,
AND PER CAPITA ENERGY CONSUMPTION OVER THE PAST CENTURY

<u>Year</u>	<u>U.S. population (millions)</u>	<u>Gross energy consumption* (10¹⁵ Btu)</u>	<u>Per capita energy consumption (10⁶ Btu)</u>
1875	45.1	6.9	153
1900	76.1	11.7	154
1925	115.8	23.5	203
1950	150.0	31.8	212
1975	212.1	71.5	337

*Includes energy equivalent of feed for work animals.

1. The Correlation Between Energy Consumption and Economic Welfare

Historically the connection between economic activity and energy consumption has understandably been strong. In times of depressed economic activity, manufacturing diminishes and less money is spent on energy-consuming amenities. The peaks and valleys seen in Figure 4 reflect the general economic health of the Nation. The effect of the great depression of the 1930's is clear. Business cycles before 1890 are less apparent, partly because a large fraction of the major fuel, wood, was outside the commercial market, being free for the taking. With the shift from wood to coal and other commercial fuels, the panic of 1894, the rich man's panic of 1914, the primary postwar depression of 1921, and the 1949 recession all show up clearly.

Although the general impact of an economic recession on energy consumption is clear, the economic consequences of a restricted supply of energy or of rising energy prices have not been adequately analyzed. The real price of energy has been declining over a long period and the energy consumed per unit of gross national product (GNP) has also shown a long-term decrease. The response of the economy to a reversal of this price trend remains largely unknown, but it is reasonable to expect that rising energy costs would reinforce the long-term decline in the energy/GNP ratio.

One of the principal findings of this study is that substantial quantities of energy can be saved by implementing conservation measures. Some energy policy makers are concerned that conservation is harmful to the economy. Whether energy conservation is in conflict with economic growth can be better understood by examining the long-term trends of energy consumption and GNP.

From 1880 to 1910 the use of energy from fossil fuels, hydro-power, and wood fuel per unit of GNP rose by an average of about 0.4%/year. The ratio of energy use to GNP has declined since 1920 (Figure 6) although the rate was less than 1%/year from 1930 to 1970. Some of the interrelated factors responsible for this decline include improvements in the efficiency of energy utilization, changes in the mix of national output, and changes in technology that have raised overall productive efficiency.³

Recent energy use and GNP statistics suggest not only that a long-term decline in the energy/GNP ratio is occurring but also that such a decline is quite compatible with economic growth. For example, from 1970 to 1973, when the rate of economic growth was substantially above the long-term average, the energy/GNP ratio fell by about 1.2%/year.

Figure 6. The ratio of U.S. gross energy use to GNP.

Energy use and economic growth are certainly interdependent, but their relationship is not so rigid as to preclude a substantial reduction in the growth rate of energy use while maintaining a healthy economy. A continuing decline in the growth rate of energy use not only is compatible with continued economic growth but may in fact be a prerequisite for it during a period of rising energy costs.

2. Energy Prices

The stability of the energy/GNP ratio over the past 30 years is remarkable considering that energy costs decreased significantly compared with other production costs. Between 1947 and 1967, for example, the price of electricity went up only 12% while the overall price level increased 50%. Recently energy prices have jumped in response to the abrupt change in world oil prices in

late 1973. Figure 7 shows recent price trends for selected energy products and Figure 8, for the resources on which they are based.⁴ These figures reveal the large differences between the costs of various forms of energy when viewed on a common scale.

3. The Driving Forces for Change

Historically, changes in fuel mix have resulted from technological innovations which made first one fuel and then another economically attractive. For example, the development of locomotive and ship boilers that used bituminous coal reduced the competitive position of wood as a fuel for transportation. Later the development of the gasoline and diesel engines became the major factor in shaping modern energy consumption patterns and lifestyles. Throughout this century of evolution, at no time was resource limitation a dominant factor.

This situation has recently undergone a dramatic change: domestic production of the primary fuels, crude oil and natural gas, can no longer satisfy demand. The decrease in natural gas production is particularly noteworthy. New discoveries have declined each year since 1973, and (as discussed later) probably almost half the natural gas ever to be drawn from domestic deposits has already been consumed. For petroleum, the domestic production level passed its maximum in 1970. Since then all the increase in demand and decrease in domestic production have been made up by imports, which have risen from 23% of oil consumption in 1970 to 38% in 1975 with a further substantial rise projected for 1976. In spite of an increased awareness of what this may imply, the U.S. is considerably more dependent on members of the Organization of Petroleum Exporting Countries in 1976 than it was at the time of the oil embargo in 1973.

All the above developments indicate that fuel scarcities and rising energy prices will play an increasingly important role in determining changes in patterns and levels of energy use.

- a. RETAIL PRICE OF REGULAR GRADE GASOLINE EXCLUDING TAXES.
- b. RESIDUAL OIL PURCHASES BY UTILITIES.
- c. AVERAGE UTILITY PRICES.
- d. COST PER UNIT OF ELECTRICAL ENERGY EXPRESSED IN Btu.

Figure 7. Prices of energy products
(not adjusted for inflation).⁴

B. Energy Patterns in the Northeast

The Northeast has a population of 55 million, slightly more than one quarter of the U.S. population, living in a land area less than one twentieth of the total (Table 2). It consumes about one fifth (22%) of the Nation's energy, but because of its special geographical and economic characteristics, its average per capita consumption is only about four fifths as large as the national average.

Figure 8. Prices of energy resources (not adjusted for inflation).⁴

The population of the Northeast is highly concentrated in the coastal regions, particularly in the megalopolitan corridor between Boston and Washington. Since World War II, most of the development has been in large areas surrounding major cities. This growth pattern has had a significant effect on energy consumption. It has increased the fraction of single-family dwellings and has made the private automobile indispensable. While highway networks have expanded (and become instantly congested), public transportation has deteriorated.

Table 2

CHARACTERISTICS OF THE NORTHEAST COMPARED
WITH NATIONAL AVERAGES, 1972

	<u>Northeast</u>	<u>Total U.S.</u>	<u>Ratio Northeast/ U.S.</u>
Population (10^6)	55.1	208.2	0.265
Land area (10^3 square miles)	175.0	3537.0	0.05
Gross energy consumption (10^{15} Btu)	15.38	72.24	0.216
Energy use per capita (10^6 Btu)	283.0	347.0	0.82

Estimates of population levels (Table 3) indicate that between 1970 and 1974 the Northeast was growing more slowly than other regions. Interregional migration data (Table 4) show a net migration out of the region of nearly 240,000 annually during this period. Many of the most densely settled states in the region grew less rapidly than they had in the past. If the growth rates shown in Table 3 were to persist, the population in the Northeast in the year 2000 would be about 15% less than projected by the U.S. Departments of Commerce and Agriculture.⁵

The decline of the railroads and other forms of mass transit has been particularly marked. Rail service to many areas has been

Table 3

ESTIMATED POPULATION (In Thousands) IN THE NORTHEAST
REGION, April 1, 1970, and July 1, 1974⁶

	<u>7/1/74</u>	<u>4/1/70</u>	<u>Change, 1970 to 1974</u>	
			<u>Number</u>	<u>Percent</u>
United States	211,390	203,212	8,178	4.0
<u>Regions</u>				
Northeast	54,816	54,278	538	1.1
North Central	57,544	56,577	967	1.7
South	61,787	57,571	4,216	7.3
West	37,244	34,809	2,434	7.0
<u>Northeast</u>				
New England				
Maine	1,047	994	53	5.3
New Hampshire	808	738	70	9.5
Vermont	470	445	25	5.7
Massachusetts	5,800	5,689	111	1.9
Rhode Island	937	950	-13	-1.3
Connecticut	3,088	3,032	56	1.9
Middle Atlantic				
New York	18,111	18,241	-130	-0.7
New Jersey	7,330	7,168	162	2.3
Pennsylvania	11,835	11,794	41	0.4
South Atlantic				
Delaware	573	548	25	4.5
Maryland	4,094	3,922	171	4.4
District of Columbia	723	757	-34	-4.5

Table 4

INTERREGIONAL MIGRATION⁶
(in thousands)

March 1970 to March 1974

	<u>Northeast</u>	<u>North Central</u>	<u>South</u>	<u>West</u>
Immigrants	1035	1800	3377	2141
Outmigrants	1993	2512	2312	1536
Net migration	-958	-712	1065	605

discontinued (partly because of a shift away from coal use), and most of the remaining trackage is in need of substantial renovation. The condition of the railroad network in the Northeast will be an important factor in determining the feasibility of future shifts to heavier use of coal.

Historically, water power was used by much of the industry in the Northeast. This required industries to locate close to sources of water power. Replacement of water power with steam power and later with electricity (both with coal as the primary energy source) permitted greater diversification both of industrial location in the region and of types of goods manufactured. Aided by its supply of skilled labor and capital base, industry in the Northeast grew rapidly during the last quarter of the past century and the first quarter of this one. The rise in industrial energy consumption was accompanied by a commensurate increase in consumer energy demand, abetted by the increases in automobile ownership and in central heating in residences. The character of the industrial base that developed is particularly noteworthy from an energy perspective: the industries in the Northeast have, on the average, a higher value added per unit of energy input than do industries in the country as a whole.

Recent economic trends in the Northeast have been strongly affected by the outflow of capital and skilled labor. As the region has lost some manufacturing activities, it has tended to specialize in activities providing a variety of services to the whole country, which have a high value added per unit of energy input. Lately, however, competition from other parts of the country has been increasing for service as well as manufacturing activities, and it is not yet clear how this will be affected by recent changes in the price and availability of fuel, but the impact on the Northeast is not apt to be beneficial.

A number of other factors have contributed to the current energy situation in the Northeast. The most prominent is the lack of major indigenous sources of energy. The region has some coal (in western Pennsylvania) and very limited reserves of oil, natural gas, and hydropower, but there appears to be no possibility of major new discoveries of conventional energy sources.* In addition the presence of a large number of areas with high population density in the region has led, in part, to the imposition of air pollution controls, which has discouraged the use of coal and brought about an increasing dependence on low-sulfur oil and natural gas. In 1972, for example, only 1.4% of the energy used in New England was derived from coal.⁷

Another factor that affects energy demand is climate. The cold winters in the Northeast result in a higher than national demand per household for space heat. While this might suggest that there is a large potential for the use of solar heating devices, the high average cloud cover and atmospheric turbidity reduces insolation in the region substantially below that in corresponding latitudes in other parts of the country (the midwinter insolation in New York, for example, is lower than in most parts of Minnesota). On the other hand, because of the region's high energy prices and

* A possible exception is Outer Continental Shelf oil and gas. This is discussed in Section V.

heavy dependence on petroleum imports, the use of solar energy in the Northeast could be more valuable than in any other region.

As a result of the various factors mentioned above, the Northeast is now almost wholly dependent on fuel resources obtained from outside the region. In 1972, the sources of fossil fuels consumed were as follows:⁷

<u>Source</u>	<u>%</u>
Indigenous	12.8
Other regions of U.S.	47.5
Foreign import	39.7

The foreign import fraction has continued to increase since then. Most of the indigenous supply was Pennsylvania coal, consumed in Pennsylvania.

The fuel mix in the Northeast is also somewhat different from the national average, as shown below and in Figure 9.

Energy Fuel Mix (%), 1972

	<u>Northeast</u>	<u>Nation average</u>
Oil and refined products	63	45
Natural gas	18	32
Coal	17	18
Hydro	1	4
Nuclear	1	1

The predominant characteristic of the fuel mix is the heavy dependence on oil, most of which is of foreign origin. The region would consume more natural gas if it could be obtained, but allocations to the Northeast of existing supplies have been decreasing since 1973. The dependence on foreign oil is particularly noteworthy in the production of electricity. Almost 100% of the residual fuel oil burned in base-loaded oil-fired steam generating plants is of foreign origin. Input fuels for electricity production are listed below:

Figure 9. Comparison of fuel mix, 1972.^{8,9}

Input Energy for Electricity Production (%), 1972

	<u>Northeast</u>	<u>National average</u>
Oil	51	17
Natural gas	3	22
Coal	35	42
Hydro	5	16
Nuclear	6	3

These data reveal that the Northeast is critically dependent on foreign oil for electricity and that for all practical purposes natural gas is no longer available for generating electricity.

The utilities of the Northeast (outside the Pennsylvania coal belt) have recently strongly emphasized nuclear units for new capacity. By 1975, the nuclear share had increased to about 18% in the region and 27% in New England.¹⁰

The energy supply-demand situation in the Northeast in 1972 is presented in network form in Figure 10.⁷ Each arrow represents an energy-related activity, and the number above it gives the energy flow (in 10^{12} Btu) through that activity. The numbers in parentheses are the efficiencies of the processes.

The picture that emerges from this brief overview of the national and regional energy situation is not encouraging. While energy demand continues to rise, national energy supply trends have led to a dependence on domestic resources that are limited and foreign resources that are unreliable and expensive. These unfortunate trends and their economic implications are magnified in the Northeast. More precise information that can be used in considering choices that will affect the future of the Northeast is presented in Sections IV and V.

Figure 10. Northeast reference energy system, 1972.⁷

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IV. ENERGY DEMAND AND CONSERVATION ANALYSIS

A. Introduction

One of the important objectives of this study is to estimate a range of future energy demands associated with changes in technology and end-use patterns. In designing our approach to projecting future energy demand in the region we established two primary criteria. First, the projections should reflect the very large uncertainty that dominates any realistic appraisal of future energy demand. Second, the projections should include detailed consideration of the activities for which energy will be demanded and be explicit about the ways in which those demands are to be satisfied in the future. If this is done, the analysis of energy conservation, through improvements in the efficiency of energy use or changing usage patterns, can be made an integral part of the demand analysis.

We first established a detailed picture of energy use in the historical reference year, 1972. On the basis of population and income growth projections for each state in the region, we proceeded to analyze the demand for energy in three major sectors: residential and commercial, transportation, and industrial. The population, income, and earnings assumptions for the Northeast are summarized in Table 5.

Table 5

BASIC ASSUMPTIONS OF DEMAND PROJECTIONS⁵

	<u>1972</u>	<u>1985</u>	<u>2000</u>
Population (10^6)	55.1	61.5	68.8
Total personal income (10^9 1967\$)	225.9	370.4	615.6
Total earnings (10^9 1967\$)	175.6	288.7	478.6

For each sector the first step was to extrapolate a set of determinants of energy demand (automobile ownership, vehicle miles traveled, housing stock of various types, appliance ownership, etc.) to the two future reference years, 1985 and 2000. Then, on the basis of these extrapolations and assumptions concerning technological innovation and implementation rates, projections for each sector were constructed to indicate what the level of future energy demand might be provided no new initiatives are taken to conserve energy. These base-case projections did, however, include the most significant actions already being taken in the various sectors in response to recent energy price increases and Federal legislation. Next, a number of moderate-conservation and strong-conservation projections were constructed under explicit assumptions as to the actions taken to reduce energy consumption.* Additional projections were made to explore the possibilities of shifts between fuels, which can reduce the demand for specific fuels without significantly changing total energy resource requirements.

For each of the three demand sectors, demand was specified in terms of a mix of the following fuels: liquids, which comprise refined crude oil products and synthetic liquids from coal and shale; gases, which include natural gas and high- and low-Btu synthetics; coal, used directly and in coal-to-coke conversion processes; and electricity. Electricity, not usually considered a fuel, is included, for convenience, in our usage of the term. The demand analysis for the residential and commercial sector included consideration of the use of solar energy for water heating and space heating and cooling.

For each of the demand sectors a separate report has been prepared which describes in detail the assumptions underlying the

*The conservation cases constructed for the industrial sector are not as detailed as those for the other sectors because of limitations on the available data.

alternative projections.^{7,11-13} For the residential and commercial and the industrial sectors the demand analysis is also disaggregated by subregion within the Northeast. In the brief summary given here, we emphasize the characteristics of the aggregate demands for the fuels considered in our scenario analysis and describe some of the actions and policies that account for the major differences between the base case and the conservation cases. A thorough understanding of the conservation strategies, however, can be obtained only by reference to the detailed reports.

B. Residential and Commercial Energy Demand

The 1972 residential energy demand by energy fuel type was estimated for space heating, air-conditioning, water heating, cooking, and lighting plus miscellaneous appliances for each of four housing types: single-family detached, single-family attached, lowrise, and highrise. These estimates were broken down for each subregion in the Northeast.

The estimation procedure required the use of saturation factors and unit energy demand values that were themselves important parts of the reference-year data base used for demand projections.* The procedure used to develop this data base and the detailed results of this work are given by Lee.⁷ The results are summarized in Table 6.

The commercial sector is defined in this study as comprising activities not classified as resource extraction, manufacturing, transportation, and residential; it thus covers a diverse agglomeration of activities associated with wholesale and retail trade,

*The saturation factor is the fraction of the potential demand for a particular energy use actually being fulfilled at a given time. For example, if 95% of all households have a refrigerator and it is assumed that each household could have a maximum of one refrigerator, then the saturation factor would be 0.95. The unit energy demand is the energy demanded per unit (e.g., per household) measured after all conversion and transmission has taken place.

Table 6

SUMMARY OF RESIDENTIAL END USE OF ENERGY IN THE NORTHEAST,
1972

<u>End use</u>	<u>Consumption (10¹² Btu)</u>	<u>% of Total</u>
Space heating	2345	71
Air-conditioning	36	1
Water heating	556	17
Cooking	122	4
Lighting plus miscellaneous appliances	242	7
TOTAL	3300	100

finance and insurance, services, schools, hospitals, cultural and recreational establishments, and government institutions. Because of this diversity, virtually no composite information on commercial end use of energy is available at the regional level. The basic approach used to make estimates of the disaggregated consumption in 1972 for this sector was similar to that used for the residential sector. For space heating, air-conditioning, and lighting plus miscellaneous appliances, consumption was calculated on the basis of estimated commercial floor space and energy demand per unit of floor space for each subregion in the Northeast. Since estimation of energy consumption for water heating was not amenable to this approach, it was made from national data broken down by region, under the assumption that hot water consumption is proportional to commercial floor space. Commercial energy use in 1972 is summarized in Table 7.

Energy use in the combined residential and commercial sector is shown in Figure 11.

The 1972 fuel demands in the residential and commercial sector are shown in Table 8.

Table 7

SUMMARY OF COMMERCIAL END USE OF ENERGY IN
THE NORTHEAST, 1972

<u>End use</u>	<u>Consumption (10¹² Btu)</u>	<u>% of Total</u>
Space heating	1305	76
Air-conditioning	47	3
Water heating	142	8
Lighting plus miscellaneous	<u>223</u>	<u>13</u>
TOTAL	1716	100

Table 8

RESIDENTIAL AND COMMERCIAL FUEL DEMANDS (10¹² Btu),
1972

<u>Sector</u>	<u>Natural gas</u>	<u>Oil</u>	<u>Coal & some misc.</u>	<u>Electric</u>
Residential	1186	1647	98	370
Commercial	<u>372</u>	<u>1041</u>	<u>7</u>	<u>296</u>
Total	1558	2687	105	666
% of total demand	31	54	2	13

Figure 11. Residential and commercial energy use in the Northeast, 1972.⁷

The projections and the methodology for the residential and commercial sector are described in detail by Lee¹¹ and summarized here. For the residential sector, the number of housing units was projected on the basis of historical trends. Housing mix was projected on the basis of Project Independence estimates.¹⁴

These figures were combined with projected unit demands (Btu per housing unit) and the saturation levels of various devices (such as air-conditioners) to derive total energy requirements. Final demand fuel requirements were determined for each projection as a function of (1) an assumed distribution of fuel purchases and (2) a set of conversion efficiencies, both of which varied according to the underlying assumptions of a specific projection. For the commercial sector the same basic procedure was followed. Floor space was estimated from Project Independence projections.¹⁴ This was combined with unit demand estimates (Btu per square foot of floor space), saturation factors, fuel distribution, and efficiencies to derive the final demand for fuels.

Eleven different projections of residential and commercial energy demand were made for the years 1985 and 2000, but all are related to the three general cases: the base-case, the moderate-conservation case, and the strong-conservation case. Even in the base-case projection, some energy conservation in 1985 and 2000 is assumed to occur relative to recent energy use practices. The more important projections are briefly described below.

1. Base Case

The base-case energy demands were calculated under the assumption of no major change in technology, price, or government policy. Some conservation measures were included to the extent that current market forces alone are expected to bring about their implementation. This means that a gradual improvement in efficiency is expected for most elements of the energy system in new construction, plus some reduction in unit energy demand for existing structures. It is assumed that new structures will have better insulation and more efficient heating and cooling units than existing ones, and that some existing structures will have

their insulation increased and their heating units better maintained. All buildings are assumed to be operated in a less energy-intensive fashion (for example, a setback of residential thermostats of 2°F is assumed).

For the residential sector the fuel mix was estimated under the assumption that in existing housing units it will remain unchanged, and in new housing units it will change as follows:

(a) The total number of gas-heated homes will remain constant, the number of new ones being equal to the number of removals from existing stock. (b) Of the new structures built between 1972 and 1985, 30% will be electrically heated; thereafter 50%. (c) The remaining new housing units will be heated by oil.

For the commercial sector, the amount of natural gas used and the relative market share of oil were kept constant at the 1972 levels, with the remaining demand being met by electricity. The use of other fuels and solar energy was assumed to be negligible.

2. Moderate Conservation Case

The energy demands for this case were projected under the assumption that the conservation measures considered in the base case would be implemented at a higher level, and that government policies that would improve the operation of the market system would be implemented. In this case, the public is not generally asked to sacrifice convenience or to change life style. The fuel mix is altered from that in the base case by the assumption that, in structures built between 1985 and 2000, solar devices will provide 35% of the demand for water heating and also, in 25% of them, 50% of the space-heat demand. The amount of solar energy used (0.37 quads) reduces the demand that has to be met by oil, gas, and electricity.

3. Strong-Conservation Case

For this case, it is assumed that conservation measures are strongly affected by government policies through direct regulation and alteration of prices. Some public sacrifice of convenience and changes in life style are expected. In the residential sector, all new oil- and gas-heated homes are assumed to be built in accordance with ASHRAE-90 standards.* Of the new electric homes built between 1972 and 1985, 40% are assumed to use heat pumps; thereafter, 100%. Of existing homes, 5% are assumed to be retrofitted per year to 1985, compared with 2% in the moderate-conservation case and 1% in the base case. Existing commercial buildings are expected to lower their current unit energy demands by 25 to 35% through advances in technology and changes in operating procedures. For new commercial buildings this savings is expected to reach 50%.

The conservation measures under which demands were projected for these three general cases are listed in Table 9. The measures for the base case include very slight changes from current practices and trends, and even the strong-conservation case requires only minor changes in life-style. The conservation measures specified for all these cases rely heavily on technological improvements coupled with enlightened consumer responses to rising energy costs.

Table 10 summarizes the energy demands of the residential and commercial sectors by fuel and degree of conservation for 1985 and 2000.

Certain of the conservation measures in Table 9 and assumptions in the projection methodology are more important than others in accounting for the differences in energy consumption between the

*ASHRAE = American Society of Heating, Refrigerating and Air-conditioning Engineers.

Table 9
SUMMARY OF CONSERVATION SCENARIOS¹¹

<u>CONSERVATION MEASURES</u>	<u>LEVEL OF IMPLEMENTATION</u>		
	<u>BASE</u>	<u>MODERATE</u>	<u>STRONG</u>
<u>RESIDENTIAL - Space Heating</u>			
1. Improved insulation in existing homes - retrofits of insulation, storm windows, storm doors, etc. in existing single-family homes.	12% to 15% savings per unit (depending on housing type) implemented at 1% of housing stock per year to 1985.	Same as base case but implemented at 2% per year to 1985.	Same as base case except implemented at 5% per year to 1985.
2. Improved insulation in new homes - adoption of energy conservation building codes.	ASHRAE 90-standards on 10% of fossil fuel heated homes beginning in 1977. All electric homes built to standards that result in 40% savings over existing units.	ASHRAE 90-standards on 50% of fossil fuel homes beginning in 1977. Electric homes same as base case.	ASHRAE 90-standards on 100% of fossil fuel homes beginning in 1977. Electric homes same as base case.
3. Improved maintenance of existing oil and gas furnaces.	Average efficiency up 5% implemented at 1% of housing stock per year to 1985.	Average efficiency up 5% implemented at 2% per year to 1985.	Average efficiency up 5% implemented at 5% per year to 1985.
4. Improved design of new gas and oil heating systems.	New unit efficiencies up 10% over existing 1972 units.	Same as base case.	Same as base case.
5. Use of electric heat pumps instead of resistance heating.	50% of electric homes built between 1985 and 2000 heated by heat pumps.	70% of electric homes built between 1972 and 1985 heated by heat pumps and 70% of new electric homes from 1985 to 2000.	40% of electric homes built between 1972 and 1985 heated by heat pumps and 100% from 1985 to 2000.
6. Solar space heating in new homes	NONE	25% of homes built between 1985 and 2000 receive 50% of space heat demand from solar devices.	Percentage of homes increased over moderate case to 50%.
7. Lowered thermostats	70°F day and night.	70°F day/68°F night.	68°F day/55°F night.
<u>Air Conditioning</u>			
1. Improved insulation			
2. Improved efficiency - new air conditioners	All factors result in 46% savings for 1985 and 2000.	Savings increase to 56% for 1985 and 61% for 2000.	Savings increase to 61% for 1985 and 71% for 2000.
3. Higher thermostat levels			
<u>Water Heating</u>			
1. Improved efficiency and insulation of new water heaters.	NONE	5% more efficient in 1985 and 10% in 2000 for gas and oil heaters. 5% improvement in electric heaters in 2000.	10% more efficient in 1985 and 15% in 2000 for gas and oil heaters. Electric heaters same as moderate case.
2. Use of solar energy for water heating	NONE	Supplies 35% of hot water demand for housing built between 1985 and 2000.	Supplies 20% of demand for housing built between 1972 and 1985 and 70% for housing built between 1985 and 2000.
<u>Cooking</u>			
1. Improved efficiency of ovens - microwave ovens, etc.	NONE	10% savings in 1985 and 2000.	25% savings in 1985 and 2000.
<u>Lighting and Miscellaneous Electric</u>			
1. Improved efficiency - fluorescent lights, etc.	NONE	5% for 1985 and 2000.	10% for 1985 and 2000.
<u>COMMERCIAL - Space Heating, Cooling and Lighting</u>			
1. Reduced demand in existing buildings - lowered thermostats, improved operating procedures, reduced lighting levels.	15% reduction in average demand of all existing buildings for 1985 and 2000 for heating and 10% for cooling.	20% reduction in demand for 1985 and 2000.	25% reduction in demand for 1985 and 35% reduction for 2000.
2. Improved efficiencies in new buildings - air conditioning, total energy systems, lighting levels, etc.	Same as for existing buildings above.	35% reduction in demand for 1985 and 2000.	50% reduction in demand for 1985 and 2000.
3. Space heating and water heating from solar energy.	NONE	Same criteria as for residential sector	None prior to 1985. After 1985, same criteria as for residential sector.

various projections. Table 11 lists the conservation measures most important in terms of impact on residential energy consumption for the year 2000.

Table 10

SUMMARY OF RESIDENTIAL AND COMMERCIAL ENERGY DEMAND (10^{15} Btu)

	FOR THE NORTHEAST					
	1985			2000		
	Base	Mod.cons.	Strong cons.	Base	Mod cons.	Strong cons.
Fuel oil	3.1	2.74	2.24	4.31	3.37	2.42
Natural gas	1.44	1.30	1.07	1.34	1.11	0.82
Electricity	1.27	1.13	1.0	2.44	1.93	1.49
Solar energy*	-	-	0.025	-	0.37	0.631
TOTAL	5.8	5.2	4.3	8.1	6.8	5.4

*These numbers refer to the solar energy used, not the thermal input to a solar array.

Table 11

IMPACT OF SELECTED CONSERVATION MEASURES IN THE RESIDENTIAL SECTOR, 2000

(Percentage change in total residential energy demand)*

	<u>Base</u>	<u>Mod.cons.</u>	<u>Strong cons.</u>
Use of heat pumps	2	2	4
Improved insulation in existing homes	1	2	9
Lower thermostat setting	7	10	13
Use of solar energy**	-	7	17
Improved insulation and furnaces in new homes	15	17	26

* Percentages refer to the increase in residential energy demand that would occur if the conservation measure were not taken. Figures are approximate and not additive.

** Calculated in terms of additional fuel requirements.

Three other sets of cases were constructed to explore the effects of variations in the fuel mix, but only the cases that figure prominently in our scenario analysis are discussed here. The other cases are described by Lee in his report on residential and commercial energy demand.¹¹

4. Fuel-Mix Shift to Electricity and Gas

These cases were constructed in order to see to what extent a shift to electricity and gas, supported by production of low-Btu gas, could reduce the need for oil. For each of the three cases discussed above (base, moderate, conservation, and strong conservation), a corresponding case was constructed with a fuel-mix shift to electricity and gas.

In each of these alternative cases, gas is assumed to continue to heat the same fraction of households and commercial floor space as in 1972. The use of electricity is assumed to increase as follows: 50% of the homes built between 1972 and 1985, and 75% thereafter, will be electrically heated; half of the existing stock of warm-air furnaces needing replacement within the projected period will be replaced with electric units; and, in the commercial sector, electricity will be used for heating in twice as many units as in the case without the fuel shift. Solar energy use will be the same as if there were no fuel shift. Oil will be used for the remaining demand.

The fuel usages for the base, moderate-conservation, and strong-conservation cases with a shift to electricity and gas are shown in Table 12.

5. High Residential Demand Case

This case was developed to show the impact of a diminishing interest in conservation and a failure of institutions to bring about a shift toward minimizing lifetime costs of structures.

Table 12

RESIDENTIAL AND COMMERCIAL ENERGY DEMAND (10^{15} Btu) FOR THE NORTHEAST
WITH FUEL SHIFT TO ELECTRICITY AND GAS

	1985			2000		
	<u>Base</u>	<u>Mod.cons.</u>	<u>Strong cons.</u>	<u>Base</u>	<u>Mod.cons.</u>	<u>Strong cons.</u>
Fuel oil	2.52	2.25	1.85	2.95	2.18	1.56
Natural gas	1.74	1.55	1.29	2.15	1.74	1.29
Electricity	1.4	1.23	1.07	2.8	2.19	1.67
Solar energy	<u>-</u>	<u>-</u>	<u>0.025</u>	<u>-</u>	<u>0.37</u>	<u>0.63</u>
TOTAL	5.7	5.0	4.2	7.9	6.5	5.2

In this case, the residential energy demand is extrapolated from 1972 consumption on the basis of the number of projected households, assuming no implementation of the conservation measures listed in Table 9 for the reference case and no significant change in housing mix. The commercial energy demand and fuel mix are the same as in the base case. The energy demand in the residential and commercial sector in the year 2000 for this case is approximately 15% higher than in the base case.

C. Transportation Energy Demand

The transportation sector is of central importance in dealing with the energy problems of the Northeast because of its almost complete dependence on petroleum. In 1972, 38% of the oil consumed in the region was used to transport people and goods. Figure 12 shows the distribution of energy consumption within the transportation sector. The dominant role of the automobile is obvious. In 1972 the automobile alone used more than 65% of the total transportation energy demand, and under the base case assumptions, it is

Figure 12. Transportation energy consumption in the Northeast by mode, 1972.¹³

expected to use about 50% of the total in the year 2000. The detailed analysis used to project alternatives for the transportation sector in the Northeast and their energy implications is described elsewhere.¹³ Only the most critical assumptions and the basic results are summarized here.

1. Automobile Energy Demand

Historical data for 1967, 1970, and 1972 were compiled for the U.S. and the region on automobile vehicle miles traveled (VMT), auto registrations, and licensed drivers. Projections to 1985 and 2000 were made as follows:

a. The percentage of the population in 1985 and 2000 with driver's licenses was estimated as a function of the percentage of the population employed.

b. The number of personal-use vehicles per licensed driver was estimated graphically as a function of income and time.

c. The total number of vehicles was calculated as a product of the estimates made in steps a and b and the OBERS⁵ estimated population levels.

d. The total number of personal-use vehicles was separated into automobiles and personal-use trucks.

e. VMT were calculated for these two types of vehicles as the product of the number of vehicles estimated for a particular year, VMT/vehicle in 1972, and the estimated ratio of income per capita in either 1985 or 2000 to the income in 1972 raised to the 0.3 power. This last factor takes into account the income effect on VMT. The short-term elasticity of 0.3 was used because some of the long-term income effects on VMT are already taken into account in the estimates of the numbers of vehicles for the future years.

f. Energy demand was calculated on the basis of the following fuel efficiencies:

	<u>Fuel Efficiency (mpg)</u>		
	<u>1972</u>	<u>1985</u>	<u>2000</u>
Automobile	13.5	19.6	19.6
Personal-use truck	11.56	16.18	16.18

If the recently mandated Federal automobile mileage standards are met, they will produce an improvement in the automobile fleet fuel efficiency over the 1972 value of approximately 48% by 1985,* whereas our figures imply an improvement of approximately 45%. Thus the calculations above tend to give slightly conservative results for 1985. Furthermore, if no further improvements are made in model-year fuel efficiencies after 1985, the Federal standards would result in a fleet average approximately 83% better in 2000 than in 1972. Compared with our base-case projections, this could produce an additional savings of 0.68 quads in 2000 or 10% of the total base-case transportation energy demand in that year. We therefore consider our base-case automobile energy demand estimates to be slightly higher than the consumption levels likely to occur even if no further incentives develop for improving auto efficiency or reducing auto VMT.

2. Truck Energy Demand

The 1972 energy and ton-mile estimates are based on VMT, ton-mile/VMT, and fuel efficiency estimates derived in detail by System Design Concepts (SDC).¹³

The 1985 and 2000 ton-mile projections were made by extrapolating the 1967 to 1972 trends of ton-miles per dollar earnings for major commodity groups. Energy projections were then made, based on OBERS⁵ earnings estimates, with the assumption that the fuel efficiency of trucks, in terms of ton-miles per gallon, would remain at the 1972 level.

*This assumes that fuel efficiency will be about 10% lower than predicted by the EPA composite mileage index.

3. Maritime-Transport Energy Demand

For both maritime and air transport, the amount of fuel purchased by the industry in the Northeast may differ from the amount consumed in transporting passengers and cargo in the region. Our general procedure for handling this problem was first to obtain base-year data on the ratio of energy purchased in the region to some particular travel index for the region (such as ton-miles) and then to assume that this ratio would remain fixed or follow the historical trend over the time spanned by the projections.

For maritime transport, the 1972 ton-mile estimates were based on state and national statistics from the U.S. Army Corps of Engineers. Fuel consumption was estimated on the basis of actual fuel sales in the region. Ton-miles of foreign trade were estimated on the basis of origin and destination data from the Census Bureau. Fuel consumed in foreign trade was estimated from Census data on fuel taken on by vessels clearing U.S. ports.

For the 1985 and 2000 projections it was assumed that the ratios of ton-miles and Btu consumed to dollar earnings would remain constant for domestic maritime transport. Energy projections were made using OBERS⁵ regional earnings projections. Foreign maritime transport was assumed to grow 1% per year faster than domestic transport, reflecting the historical difference in growth rates. Energy used for water recreation was projected using OBERS personal income figures.

4. Air-Transport Energy Demand

For air transport, estimates of fuel purchased, by state, in the Northeast region in 1972 for both domestic and international air operations were obtained from ATA.¹⁵ These fuel purchases were attributed to either cargo or passenger operations on the basis of revenue ton-miles. These involved derivations are

given in detail by SDC¹³ and summarized below.

It was assumed that the percentage of U.S. passenger ton-miles accounted for by passenger ton-miles in the Northeast is the same as the percentage of U.S. passenger-miles accounted for by passenger-miles in the Northeast. Revenue ton-miles for domestic cargo for the Northeast were calculated as a percentage of U.S. revenue ton-miles. This percentage was obtained by estimating an average air-freight trip length for the Northeast and for the U.S., and multiplying these estimates by the number of enplaned tons of manufactured goods in the Northeast and in the U.S. respectively. This may produce a biased estimate of ton-miles for all types of cargo, but the percentage estimate obtained was thought to be reasonably accurate.

For international flights the ratio of passenger to cargo operations were assumed to be the same for the Northeast as for the U.S.; therefore, the U.S. ratio was simply applied to the Northeast fuel purchase figures for international travel in order to get estimates of the energy demands for international passenger and cargo operations in 1972.

On the basis of published estimates of growth rates for the airline industry and unpublished operating data since 1972, growth rates of energy consumption for air transport were estimated (Table 13), with the assumption that load factors would increase until 1985. The rates projected for domestic air operations between 1985 and 2000 are approximately the same as those being forecast by the Federal Aviation Agency.

5. Summary of Demands

Table 14 summarizes fuel consumption in the transportation sector in our base-case projection. The modes of transportation specified account for over 94% of the transportation energy demand in 1972 and nearly as much in the base projections for 1985 and 2000.

Table 13

GROWTH RATES (%/year) IN AIR-TRANSPORT ENERGY CONSUMPTION

	<u>Domestic</u>		<u>International</u>
	<u>Passenger</u>	<u>Cargo</u>	<u>Passenger and cargo</u>
1972-1974	1.5	2.9	0.0
1974-1975	3.1	6.0	0.0
1975-1985	3.1	6.0	4.1
1985-2000	6.0	9.0	5.5

Table 14

TRANSPORTATION ENERGY CONSUMPTION (10^{15} Btu) IN THE NORTHEAST
BY FUEL TYPE AND MODE: 1985-2000 BASE-CASE PROJECTIONS

<u>Fuel type</u>	<u>Mode*</u>	<u>1972</u>	<u>1985</u>	<u>2000</u>
Gasoline		2.66	3.0	4.0
	Automobile	2.3	2.47	3.25
	Truck (freight)	0.237	0.353	0.504
Distillate & residual		0.86	1.33	2.62
	Truck (freight)	0.20	0.307	0.438
	Water (freight)	0.117	0.171	0.249
	Air (freight)	0.073	0.147	0.535
	Air (intercity)	0.149	0.215	0.518
	International			
	Air (passenger)	0.079	0.118	0.263
	Air (freight)	0.032	0.047	0.106
	Water (freight)	<u>0.117</u>	<u>0.187</u>	<u>0.282</u>
	TOTAL (including omitted modes*)	3.537	4.352	6.644

*Certain modes, which in aggregate account for less than 8% of the total demand, are not listed.

Table 15

ESTIMATED ANNUAL ENERGY SAVINGS (10^{12} Btu) BY FUEL TYPE, 1985-2000.¹³

Action	1985			2000		
	Gasoline	Diesel	Total	Gasoline	Diesel	Total
SPEED REDUCTION						
Enforce 55-MPH limit for autos	73.1	-	73.1	96.4	-	96.4
Enforce 55-MPH limit for trucks	.9	14.9	15.8	1.4	21.1	22.5
Optimum cruising speed for airlines	-	19.1	19.1	-	54.0	54.0
Reduce speed of mari- time vessels	-	128.0	128.0	-	3.4	3.4
MODIFY REGULATIONS						
Increase airline load factors	-	114.1	114.1	-	305.3	305.3
Relax truck weight length limits	-	23.0	23.0	-	67.0	67.0
COMMUTER CAR-POOLING						
Achieve 50% partici- pation	130.0	-	130.0	160.0	-	160.0
PROMOTE PIGGYBACKING						
Economic incentives for trailer-on-flatcar	3.0	23.1	26.1	3.6	45.5	49.1
PROMOTE PUBLIC TRANSIT*						
No fare or reduced fare transit	44.3	-	44.3	59.5	-	59.5
Double transit fleet VMT	19.1	-	19.1	24.3	-	24.3
Commuter parking tax	46.7	-	46.7	62.3	-	62.3
FUEL TAXES						
50% increase in price of gasoline	300.0	-	300.0	390.0	-	390.0
NEW TECHNOLOGY						
High-speed surface transportation	-	-	-	-	170.0	170.0
Maximum refinement of gasoline engine	-	-	-	1214.0	-	1214.0
Railroad electrification	-	-	-	-	30.0	30.0
Electric cars	-	-	-	400.0	-	400.0
LAND USE*						
Energy efficient patterns for new development	-	-	-	193.0	-	193.0
Transit to industrial & commercial concentrations-	-	-	-	90.0	-	90.0

*Estimated savings do not reflect increases in transit energy consumption.

6. Conservation Options in Transportation

The list of conservation actions considered for the transportation sector and the associated gross energy savings are shown in Table 15. The actions are grouped according to criteria such as ease of implementation, likely impact, and suitability for implementation in the short run or the long run. Table 16 lists the actions considered for the moderate-conservation and strong-conservation cases, the estimated energy savings potential, and the level of energy savings assumed in our demand projections.

Table 16

CONSERVATION CASES FOR TRANSPORTATION

<u>Moderate</u>	<u>Potential savings (%)</u>		<u>Level used in projections (%)</u>	
	<u>1985</u>	<u>2000</u>	<u>1985</u>	<u>2000</u>
1. Reduce speeds	9-13	12-20	12	12
2. Modify regulations				
3. Promote piggybacking				
4. Promote car-pooling				
5. Promote public transit				
6. Tax fuels				
<u>Strong</u>				
1. All actions listed above	17-20	>30	18	34
2. Refine gasoline engine				
3. Alter land-use patterns				

7. Fuel-Mix Shifts in the Transportation Sector

We have estimated that, given appropriate advances in battery technology, a substitution of electric cars for gasoline-powered cars would be possible that would reduce gasoline consumption in the year 2000 by about 12% compared with the base case. For the base and moderate-conservation cases we assumed that electric cars would be 4.3 times as efficient in terms of final use of energy than the gasoline cars they would replace (this excludes any consideration of the efficiency of electricity generation). In the strong-conservation case, since improved efficiency was assumed for gasoline-powered vehicles, electric cars were taken to be only 3 times as efficient. Table 17 shows the reduction in demand for gasoline and the corresponding increase in demand for electricity that would result from these shifts to electric cars.

Table 17

CHANGE IN ENERGY DEMAND (10^{15} Btu) IN 2000 DUE TO
SHIFT TO ELECTRIC CARS

	<u>Gasoline savings</u>	<u>Increase in electricity use</u>
Base case	0.489	0.114
Moderate conservation	0.443	0.103
Strong conservation	0.237	0.079

D. Industrial Energy Demand

For the industrial sector, we made high and low projections of total energy demand for 1985 and 2000. A number of specific projections were then constructed under different sets of assumptions concerning the relative growth of various segments of the industrial sector and the ease of interfuel substitution. The projections developed and used in our scenario analysis are summarized here. A detailed analysis of the industrial sector and a description of all the projections are given by Goettle.¹²

1. Case I: High Demand With Historical Mix of Industries

For this case the 1972 consumption per constant dollar of economic activity was computed for each subregion, appropriate Standard Industrial Classification (SIC) grouping, and fuel. These values were assumed to hold for 1985 and 2000, and the fuel demands for those years were determined by multiplying the forecasted values of economic activity (from the OBERS⁵) by the 1972 energy coefficients. Such a calculation implies that energy, either in aggregate or by fuel type, is not substitutable in the production process and that its future demands will be determined by sectoral and subregional indices of manufacturing activity. It is as if all factor prices were inflating at the same rate along the projected growth path of economic activity. The data for coal converted to coke, petrochemical feedstocks, and other nonfuel petroleum products determined in this calculation were utilized in all subsequent cases.

2. Case II: Moderate Conservation (Low Demand) With Fuel Shift to Electricity

The industrial sector has strong incentives for energy conservation; therefore, for Case II, the 1972 energy-intensity values computed for Case I were assumed to change in the future reference

years. The changes result in reductions of all fuel demands and also include a shift to purchased electricity from fossil fuels. The energy-intensity reductions were developed from a Project Independence report¹⁶ which evaluated the conservation potential for several energy-intensive industries. In that report the intensity reductions are attributed to a number of important economic, technological, and environmental considerations relating to the markets both for industrial output and for the factors of production required to generate that output. After the energy-intensity coefficients for 1985 and 2000 were reformulated, fuel demands were calculated as for Case I.

3. Case III: High Demand With Fuel Shift to Electricity

In Case III the fuel distribution (i.e., the percentages of total energy demand satisfied by particular fuels, excluding non-fuel and power usages) of Case II was applied to the total energy demand from Case I. In doing this, we assume that the aggregate energy intensities of the various industries remain constant over the reference period (allowing for changes in the industrial composition of output), but that the same factors leading to the fuel shift of Case II result in the interfuel substitution of purchased electricity for fossil fuels. Thus, while aggregate energy is assumed to be employed according to fixed proportions, fuel consumption patterns change in response to certain price, scarcity, technology, or environmental conditions.

4. Case VI: Moderate Conservation With Fuel-Mix Shift to Electricity and Gas

In this alternative, the total energy consumption value and the total coal and electricity demands of Case II were used. The gas consumption values were taken from Case I. Liquid demands were derived from those of Case II by reallocating the difference

between Case I and Case II gas demands (in Btu). Fifty percent of this difference was applied to reducing feedstock demands and 50% to reducing the industrial demands of liquids for process heat and power. The rationale for this alternative is that the generation of intermediate- and low-Btu gas from coal provides an attractive alternative for meeting the future feedstock and fuel plus power requirements currently derived from petroleum products.

5. Case VII: High Demand With Fuel-Mix Shift to Electricity and Gas

This alternative represents the high-demand version of Case VI, and it is explicitly assumed that additional gas demands may be satisfied by low- and intermediate-Btu gases derived from coal. These new and potentially competitive resources may reduce the region's dependence on feedstocks and fuels for process heat and power that are currently petroleum based. The electricity, coal, and total energy values for this case were taken from Case III, and the adjustments to the liquid and gas demands were applied to the data of Case III. The gas consumption values were determined by summing those of Case III and the difference between the Case I and Case II gas demands. Liquid demands for this alternative were derived and allocated according to the procedure adopted for Case VI.

6. Summary of Cases

The various cases are summarized in Table 18 in terms of relative fuel demands. The absolute demand levels are presented in Figure 13.

E. Summary of Demand Projections

Table 19 summarizes the total Northeast energy demand by sector for 1972 and the projected energy demand by sector for 1985 and 2000 for our base case. Annual growth rates are shown in Table 20.

Table 18

SUMMARY OF INDUSTRIAL USAGE¹²

Fuel ^a	Case No. ^b	Annual growth rate (%)		Index ^c	
		1972-85	1985-2000	1985	2000
<u>Electricity</u>	I	2.84	2.46	100	100
(414.717)	II,V,VI	2.77	2.23	99	96
	IV	1.41	1.60	83	74
	III,VII	4.22	3.09	119	130
<u>Coal</u>					
All uses	I,V	1.93	1.70	100	100
(1111.538)	II,VI	1.36	1.29	93	88
	III,VII	1.77	1.58	98	96
	IV	1.50	1.38	95	90
Fuel & power	I,V	3.15	2.68	100	100
uses	II,VI	1.16	1.54	78	66
(298.216)	III,VII	2.64	2.38	94	90
	IV	1.67	1.83	83	73
<u>Liquids</u>	I	3.36	3.03	100	100
All uses	II	2.54	2.75	90	86
(1494.547)	III	3.18	3.03	98	98
	IV	2.70	2.74	92	88
	V	2.36	2.65	88	83
	VI	1.72	2.35	81	73
	VII	2.42	2.71	89	85
Distillate	I	2.90	2.50	100	100
and residual	II	1.13	1.62	80	70
fuel oils used	III	2.53	2.47	95	95
for fuel and	IV	1.50	1.65	84	74
power	V	0.73	1.28	76	63
(778.012)	VI	0.20	0.90	71	56
	VII	1.74	2.05	86	81
<u>Gases</u>	I,VI	2.56	2.23	100	100
(746.005)	II	0.83	1.08	80	68
	III	2.30	1.91	97	92
	IV	1.09	1.40	83	73
	V	0.21	0.75	74	59
	VII	3.78	2.69	117	125
<u>TOTAL</u>					
All uses	I,III,VII	2.74	2.48	100	100
(3766.807)	II,IV,V,VI	1.91	2.03	90	84
Fuel &	I,III,VII	2.81	2.43	100	100
power uses	II,IV,V,VI	1.37	1.59	83	73
(2236.950)					

^aNumbers in parentheses are 1972 demands in 10¹² Btu.

^bSee Goettle¹² for discussion of Cases IV and V.

^cAll index comparisons are made relative to the Case I value for the same fuel class in the same time period (Case I index = 100).

Figure 13. Demand alternatives for industry in the Northeast.¹²

Table 19

NORTHEAST ENERGY DEMANDS (10^{15} Btu), BASE CASE

<u>Sector</u>	<u>1972</u>	<u>1985</u>	<u>2000</u>
Residential and commercial	5.02	5.8	8.1
Industrial	3.77	5.36	7.73
Transportation	<u>3.54</u>	<u>4.35</u>	<u>6.64</u>
TOTAL	12.32	15.51	22.47

Table 20

NORTHEAST BASE-CASE GROWTH RATES (%/year)

<u>Sector</u>	<u>1972-1985</u>	<u>1985-2000</u>	<u>1972-2000</u>
Residential and Commercial	1.1	2.25	1.7
Industrial	2.75	2.5	2.6
Transportation	1.6	2.86	2.3
All Sectors	1.8	2.5	2.2

Table 21

NET ENERGY CONSUMPTION AVERAGE ANNUAL
GROWTH RATES (%),
1968 - 1972

	<u>FEA</u> ¹⁷	<u>Bur. of Mines</u> ^{18,19}
Northeast	1.9	2.1
Subregion I	3.6	3.9
Subregion II	1.2	0.7
Subregion III	1.6	2.2

Data from the FEA¹⁷ indicate that net energy consumption in the Northeast grew at an average annual rate of 1.9% from 1968 to 1972, and Bureau of Mines data^{18,19} indicate that it grew at 2.1%. Table 20 shows that our base-case projections imply a long-term growth rate not substantially different from these estimates of recent historical growth. The growth rates implied by the FEA and the Bureau of Mines data for the Northeast and each subregion are shown in Table 21. (The rate for net energy consumption in the whole U.S. averaged 3.2% over the same time period).

Tables 22 to 24 and Figures 14 to 16 summarize the 1972 and projected 1985 and 2000 energy demands by sector for the base and conservation cases. The total energy demand for all sectors is shown in Table 25 and Figure 17.

Table 22

NORTHEAST RESIDENTIAL AND COMMERCIAL ENERGY DEMAND
(10¹⁵ Btu)

	<u>Base</u>	<u>Mod.cons.</u>	<u>Strong cons.</u>
1972	5.02	-	-
1985	5.81	5.16	4.33
2000	8.09	6.78	5.36

Table 23

INDUSTRIAL ENERGY DEMAND (10¹⁵ Btu)

	<u>Base</u>	<u>Mod. cons.</u>
1972	3.77	-
1985	5.36	4.81
2000	7.73	6.51

Figure 14. Residential and commercial fuel consumption in the Northeast.

Figure 15. Industrial fuel usage in Northeast.

Figure 16. Transportation fuel consumption in the Northeast.

Figure 17. Total fuel consumption in the Northeast.

Table 24

TRANSPORTATION ENERGY DEMAND (10^{15} Btu)

	<u>Base</u>	<u>Mod. cons.</u>	<u>Strong cons.</u>
1972	3.54	-	-
1985	4.35	3.82	3.57
2000	6.64	5.88	4.39

Table 25

TOTAL NORTHEAST ENERGY DEMANDS (10^{15} Btu)

	<u>Base</u>	<u>Mod. cons.</u>	<u>Strong cons.</u> *
1972	12.32	-	-
1985	15.51	13.79	12.71
2000	22.47	19.18	16.26

*Assumes moderate conservation in industrial sector.

Note that in some cases these figures on energy demand include a contribution from solar energy. For example, in our strong-conservation case approximately 12% of the total residential and commercial energy demand in 2000 is supplied by solar energy.

For the three cases shown in Table 25 the ratios of energy use per capita and energy use per dollar of personal income were computed (Table 26).

It is interesting that in 2000, per capita energy consumption, even in the strong-conservation case, is higher than in 1972. The substantial decline in energy per dollar of income, however, implies a striking change in the energy intensiveness of certain activities by 2000 even for the base-case levels of energy demand.

Table 26

RATIOS OF ENERGY PER CAPITA AND ENERGY PER DOLLAR INCOME

	<u>1972</u>	<u>1985</u>			<u>2000</u>		
		<u>Base</u>	<u>Mod.cons.</u>	<u>Strong cons.</u>	<u>Base</u>	<u>Mod.cons.</u>	<u>Strong cons.</u>
Net energy use ¹⁵ (10 ¹⁵ Btu)	12.32	15.51	13.79	12.7	22.47	19.18	16.26
Energy use per capita (10 ⁹ Btu/person)	0.22	0.25	0.22	0.21	0.33	0.28	0.24
Energy use/\$ income (10 ⁶ Btu/\$)	0.055	0.042	0.037	0.034	0.037	0.031	0.026

(The ratio of resource consumption to dollar income would show a more modest decline over time than the ratios given in Table 26 because the share of final demand met by electricity is projected to increase over time.) A detailed analysis of the industrial sector reveals a shift to less energy-intensive industries in the Northeast, and this shift is taken into account in our industrial demand projections. Corresponding shifts in housing mix and modes of travel are incorporated in the residential and in some of the transportation sector projections.

Historically, energy use and real gross national product (GNP) have risen at slightly different rates. For example, between 1947 and 1966 and also between 1970 and 1973 the ratio of energy use to GNP fell by an average of 1.2% per year. A projection based on continuation of this rate of decline yields an energy to GNP ratio between those implied by our base case and by our moderate-conservation case.

If the price of energy relative to other goods continues to rise as it has in the past few years, then a decline in the energy to GNP ratio of substantially more than 1.2% per year would not be surprising. Our strong-conservation case implies an average drop in the energy to earnings ratio of less than 2.4% per year from 1972 to 2000.*

Figures 18 to 20 show specific fuel demands for certain of the more interesting combinations of the demand projections. All show the continued heavy dependence of the region on liquid energy sources. Only in Figure 20 (strong conservation coupled with a fuel-mix shift to electricity and gas) does the level of liquid demand remain fairly constant over time. Figures 18 and 19 (base case and moderate-conservation projections with and without fuel-mix shifts to electricity and gas) indicate a fairly large potential for shifts between fuels. Table 27 summarizes the shifts in fuel demands shown in Figures 18 and 19.

Table 27			
CHANGE IN FUEL DEMAND RESULTING FROM SHIFT TO ELECTRICITY AND GAS			
<u>Case</u>	<u>% Change in demands by 2000</u>		
	<u>Liquids</u>	<u>Gases</u>	<u>Electricity</u>
Base case with fuel-mix shift vs. base case	-17%	+44%	+23%
Moderate-conservation case with fuel-mix shift vs. moderate-conservation case	-17%	+47%	+21%

*GNP and earnings have moved together in the past and can be expected to continue to do so in the future.

Figure 18.

Figure 19.

Figure 20.

V. ENERGY SUPPLY

A. Introduction

The range of future demand for energy in the Northeast was charted in Section IV; here, the possible range of energy supplies is examined. In particular in this section we establish the amounts of coal, oil, natural gas, and nuclear energy that the Northeast can expect to obtain from domestic sources under several alternative sets of assumptions. Also described are the amounts of synthetic oil and gas that might be produced from coal elsewhere in the country and transported to the Northeast; the amounts of hydropower, wind power, and energy from municipal wastes that could contribute to the region's future energy requirements; and possible levels of imported natural gas. In general we present a range of supply cases (low, intermediate, and high) for each fuel or energy source. The differences between the cases result from different assumptions regarding total domestic production levels or regional allocations; they reflect, in part, the results of pursuing alternative national and regional policies. Electricity generation is discussed below, but issues such as capacity forecasting (and the related issues of reserve margins, outage rates, and system reliability), siting problems (in particular environmental and resource constraints and trade-offs between inland, estuary, and coastal siting), and some special topics (such as offshore nuclear plants and energy centers) are presented in more detail by Meier et al.²⁰

In Section VI, in the discussion of our scenario analysis, it will be shown how the projections of alternative supply and demand levels can be combined to provide a better understanding of the key energy issues facing the Northeast.

B. Coal Supply*

Earlier in this century, coal was a primary energy source in the Northeast. After World War II, natural gas and oil began to replace coal as fuel for electric power generation and industrial applications. In the late 1960's this trend accelerated as a result of growing environmental concerns coupled with the availability of low-cost imported oil. In 1961, 78% of the region's electricity was generated from coal; by 1973, only 40%. With Pennsylvania excluded, the shift is even greater: from 70% to only 17%.

Over the last two years, the outlook for coal has changed dramatically. Rapid oil price rises have improved the competitive situation of coal; the development of emission-control technology has made a large fraction of domestic coal environmentally acceptable for power generation; increasing costs and public opposition have raised questions about the viability of nuclear power; and, what is more fundamental, coal is relatively inexpensive, can be used with current technology, and is extremely plentiful.

Two basic ways of using coal to meet the energy needs of the Northeast are examined here: (1) through the production of electricity within the region and (2) through conversion to synthetic oil and gas (primarily outside the region). Before estimation of the levels of supply and constraints on the use of these energy forms, the basic question of what the future possible levels of national coal production will be must be answered.

1. National Supply Estimates

The national production of coal has remained relatively constant since 1970 following a period of substantial growth (about 5%/year) during the 1960's. The leveling is due to a

*This section is based primarily on a report prepared for this study by Edelston and Rubin.²¹

number of factors that will continue to influence production, such as manpower shortages, reduced output per laborer (due in part to the 1969 Coal Mine Health and Safety Act), shortages and increased costs of coal-mining equipment, and the environmental impacts of coal usage.

Total recoverable coal reserves in the United States are estimated at 427 billion tons, which would last over 330 years at 1974 production rates, assuming about 50% recovery of reserves (which corresponds to using present mining techniques). Even under the most optimistic estimates of future coal production, therefore, a resource constraint within the time frame of this study is highly unlikely.

Many projections of future coal production have been made over the past few years. Some of the better known are summarized in Figure 21, which demonstrates the wide range of estimates from which an analyst may choose.

One of the most comprehensive efforts to forecast future national coal production is the Project Independence (PI) study,⁸ which includes coal production estimates by U.S. Bureau of Mines district and type of mining through 1990. The two PI scenarios developed for coal supply are business-as-usual (BAU) and accelerated supply (ACC) scenarios. In the BAU scenario it was assumed that no significant immediate expansion in production capability would occur because of the long lead times required for mine development and equipment deliveries, but for the longer term capital would be available for new mines already planned or under development. It was also assumed that the supply of labor and the transportation system would both be adequate.

We used the PI-BAU scenario for the base-case coal supply projection for 1985 and obtained the projection for 2000 by extrapolation.

Figure 21. Selected national coal supply projections.²¹

ERDA Energy Research and Development Administration (1975)²

NPC National Petroleum Council (1973)²⁴

PI-ACC Project Independence Accelerated Supply Case (1974)⁸

PI-BAU Project Independence Business as Usual Case

SRI Standard Research Institute for the Synfuels Interagency Task Force (1975)²³

For our high case, the ACC scenario was used, although events since the time of the PI analysis suggest that the production levels projected for 1985 may not be attainable before 1987. We considered the growth rates assumed in the ACC case not to be sustainable beyond 1985, and therefore used a growth rate of 3%/year between 1985 and 2000 to reach the 2000 production level.

The NPC²⁴ 3%/year growth-rate case (developed before the oil embargo) was chosen for our low case. This case, in which an absence of new economic incentives for coal production is assumed, reflects a low rate of expansion (1%/year) of industrial and utility use of coal.

2. Northeast Regional Coal Supply

To forecast the coal supply specifically for the Northeast, assumptions are required regarding the regional distribution of future national production. The assumption here is that the Northeast would receive the same share of production from each national district in the future as at present (1974). Future production by district was taken from the same sources as national production and corrected for exports. Note that this does not imply a constant percentage of total national production since each district's production changes in the future. In the high-supply case, for example, national coal production increases predominantly in western districts, which now send a very small percentage of their production to the Northeast. Hence, the region's fraction of total U.S. supply would be less than at present.

The actual future coal supply will be determined by technical constraints, public policies, and market forces. At present, these factors are such that the Northeast generally pays the highest prices in the country for fuel. Presumably, however, the region

could capture an even larger market share of future eastern low-sulfur coal production or coal-derived energy were it willing to pay a premium for these fuels.

Although several electric utilities in the Northeast have recently purchased coal from Europe, we have assumed that, for various reasons, the use of imported coal will not be significant in the future. A more promising option is the use of regionally available anthracite coal. This high-quality, low-sulfur coal exists in both Northeastern Pennsylvania and the Naragansett basin of Massachusetts and Rhode Island. Conceivably these sources could increase the regional coal supply by a few percent in 1990-2000.²¹

3. Transportation Considerations

Increasing the future supply of coal to the Northeast may depend critically on the availability of transportation from mine to user. In the short term, any increase in coal utilization in the Northeast will have to rely on the existing transportation network, and the present situation can be described as grim. At one time as much as 52 million tons of coal moved to markets in New England and the Atlantic Coast per year, whereas present markets require only 15 to 20 million tons. This dramatic decrease has hit the railroad industry particularly hard and has contributed to their financial insolvency and to the physical deterioration of roadbeds and trackage. For example, in 1974, 23% of national coal production distributed by rail was carried by bankrupt railroad companies, almost all of which serve the Northeast. Thus, the present situation of the railroads must be considered an important potential constraint to any substantial increase in coal usage in the Northeast.

An overriding need of the regional rail system, if it is not to become a bottleneck to future coal utilization, is the rehabilitation of tracks and roadbeds to allow for future expansion. Hopper car and rolling stock shortages may also be a short-term problem but are not expected to be a major constraint. The Regional Rail Reorganization Act of 1973 provides \$2 billion in financial assistance for rail rehabilitation, but further investment in the regional rail system, both public and private, is vital in the short term for successful implementation of an energy policy committed to the use of more coal.

Both coal-slurry pipelines and long-distance electrical transmission lines can be used to transport the energy in coal to the Northeast. However, both have inherent technological and institutional problems which will most likely prevent their widespread future use in the region although limited use might be feasible in specific instances.

4. Coal Use by Electric Utility

Besides availability and relative cost, other major factors determining the amount of coal used to generate electricity in the Northeast are environmental restrictions and the availability and cost of related pollution control techniques, particularly for reducing sulfur oxide emissions where sufficiently low-sulfur coal is unavailable. The principal short term options are sulfur removal before combustion and flue-gas desulfurization (FGD) to remove SO_2 after combustion. These options are already available for commercial applications, but economic considerations and/or secondary waste disposal problems often make them unattractive.

Technologies currently under development include fluidized-bed and magnetohydrodynamic (MHD) combustion units, which remove sulfur at the time of combustion, and a variety of processes for converting coal into a gas or liquid.

In estimating the possible use of coal by regional electric utilities for 1985, two categories of plants were considered, existing fossil-fuel plants and new plants that will begin operation before 1985. Estimates of the potential for converting existing fossil-fuel plants to coal were made on a plant-by-plant basis in the region from available studies that include consideration of environmental restrictions, coal supply, and transportation availability.

Two conversion cases were used in the scenarios. The first includes plants using coal that would not require large expenditures to comply with environmental regulations; these plants might be converted in a very short time (perhaps a year) and have an aggregate capacity of 3527 Mwe. The second case includes all plants in the first case plus those for which FGD is considered feasible. These plants could be converted to coal in the time required to plan and install the necessary environmental control equipment, certainly by 1985. In addition, fossil-fuel plants that might be convertible to coal if local emission standards were relaxed to levels commensurate with ambient air quality standards were included.* Plants included in the second case have a total capacity of 9200 MWe.

The range of possible coal use in new electric generating plants built between now and 1985 was determined on the basis of utility projections. Three cases were constructed. For the high case, all new fossil capacity was assumed to be coal-fired. For the intermediate case, the fuel mix currently projected by the utilities was assumed. For the low case, it was assumed that no new coal-fired stations would be completed by 1985. The current, converted, and new plant capacities selected to represent the low, intermediate, and high cases, are given in Table 28.

*Edelston and Rubin²¹ also constructed an intermediate case in which such plants were excluded, but that case was not used in our supply-demand scenarios.

Table 28

SUMMARY OF 1985 ELECTRIC UTILITY COAL USE CASES
(10¹⁵ Btu)

<u>Type of plant</u>	<u>Low</u>	<u>Intermediate</u>	<u>High</u>
Current capacity	1.23	1.23	1.23
Conversion from oil	0.0	0.18	0.49
New capacity	<u>0.0</u>	<u>0.56</u>	<u>0.69</u>
TOTAL	1.23	1.97	2.41

Feasible levels of utility coal use in 2000 were projected by extrapolating power-pool estimates of total additions to capacity. The net addition to regional generation capacity between 1985 and 2000 was taken as 655.2 million MWh. For the low case, it was assumed that none of the net additions was coal-fired. The intermediate case is based on the fuel mix in 2000 being the same as that planned for 1985. In the high case, all new capacity is assumed to be coal-fired. The resulting fuel use is summarized in Table 29.

Table 29

SUMMARY OF REGIONAL COAL SUPPLY AND DEMAND CASES
(10¹⁵ Btu)

	<u>1985</u>			<u>2000</u>		
	<u>Low</u>	<u>Inter.</u>	<u>High</u>	<u>Low</u>	<u>Inter.</u>	<u>High</u>
Domestically available coal supply	2.6	3.2	6.7	3.3	5.1	10.2
Electric utility coal demand	1.2	2.0	2.4	2.0	3.9	9.0
"Effective" supply of synthetic oil and gas	0.0	0.2	0.9	0.9	2.7	5.4

5. Synthetic Fuels From Coal

Coal conversion processes producing gaseous and liquid fuels are receiving increasing attention in both the public and private sectors as an alternative way of utilizing coal. Currently, the only commercially available technologies are the Lurgi and Koppers-Totzek low-Btu gasification processes.* A variety of advanced processes for producing synthetic fuels from coal are undergoing development, however. All are technically feasible on a small scale but none is yet commercially available. The costs of synthetic fuels are still estimated to be well above current world energy market prices, which is further retarding rapid commercialization, but as energy prices rise and other sources are depleted, synthetic fuels are expected to play an increasingly important role in the domestic energy market.

Many factors will affect the future U.S. supply of synthetic fuels from coal, the main ones being capital availability, process economics, environmental impact, and socio-economic impact. All are today largely uncertain, and realistic projections must await a clearer understanding of the various constraints within which the synthetic fuels industry will operate.

It is not surprising that estimates for future industry production vary widely. Figures 22 to 24 present comparisons of recent estimates of national supplies of high-Btu gas, low-Btu gas, and synthetic liquids from coal for 1985 and 2000. A key to the sources precedes these figures. High, medium, and low national supply cases for each synthetic fuel type were defined so as to include the range of these estimates except for the highest 10%. In this way, the national synthetic fuel supply cases shown in Table 30 were formulated.

* Low-Btu gas is synthetic gas with a heating value of approximately 100 to 150 Btu/cubic foot. High-Btu gas is synthetic gas with a heating value of approximately 1000 Btu/cubic foot.

Table 30

SUPPLY CASES FOR U.S. SYNTHETIC FUELS FROM COAL
(10¹⁵ Btu/year), 1985 and 2000

<u>Supply case</u>	<u>1985</u>			<u>2000</u>		
	<u>High-Btu</u> <u>gas</u>	<u>Low-Btu</u> <u>gas</u>	<u>Liquids</u>	<u>High-Btu</u> <u>gas</u>	<u>Low-Btu</u> <u>gas</u>	<u>Liquids</u>
Low	- - - - -	negligible	- - -	3.0	1.8	0.4
Intermediate	0.6	0.5	0.2	6.0	4.0	4.0
High	2.0	1.5	1.5	10.0	6.0	10.0

Most of this synthetic fuel production goes into the total U.S. supply of gases and liquids and thus contributes to the Northeast supply only indirectly. To estimate an "effective" supply to the Northeast, estimates for regional consumption of liquid and gaseous fuel developed by Stanford Research Institute²⁵ for 1986 and 2001 were utilized. These indicated that New England, New York, New Jersey, and Pennsylvania would account for approximately 15% of the future gaseous fuel use and 25% of liquid fuel consumption. On the basis of current distribution patterns, consumption in Maryland, Delaware, and D.C. would raise these percentages to about 16% (gaseous) and 28% (liquids) for the region as a whole. Applying these percentages to the national supply estimates yields the "effective" regional supply estimates in Table 29.

KEY TO SCENARIO ABBREVIATIONS

ERDA	Energy Research and Development Administration (Scenarios II, IV, and V)
FPC	Federal Power Commission National Gas Survey
IGT(PRE)	Institute of Gas Technology (Pre-1973 Scenario)
IGT(POST)	Institute of Gas Technology (Post-1973 Scenario)
NAE	National Academy of Engineering
NPC(I)	National Petroleum Council (Case I)
NPC(II,III)	National Petroleum Council (Cases II and III)
NPC(IV)	National Petroleum Council (Case IV)
PI(ACC)	Project Independence (Accelerated Production)
PI(BAU)	Project Independence (Business-As Usual)
PI(UNR)	Project Independence (Unrestricted Production)
SPCP(INFO)	Synthetic Fuels Commercialization Program (Information Option)
SPCP(NOM)	Synthetic Fuels Commercialization Program (Nominal Program Option)
SPCP(MAX)	Synthetic Fuels Commercialization Program (Maximum Program Option)
SRI(NOM)	Stanford Research Institute Model (Nominal Scenario)
SRI(5YR)	Stanford Research Institute Model (5 Year Delay in Synfuels)
SRI(LGO)	Stanford Research Institute Model (Low Domestic Gas and Oil Availability)
SRI(LGOI)	Stanford Research Institute Model (Low Gas and Oil w/High Import Prices)
SRI(HI\$)	Stanford Research Institute Model (High Synfuels Price)

Figure 22. Comparisons of supply estimates for high-Btu gas from coal in 1985 and 2000.²¹

Figure 23. Comparisons of supply estimates for low- and medium-Btu gas from coal in 1985 and 2000.²¹

Figure 24. Comparisons of supply estimates for synthetic liquids from coal in 1985 and 2000.²¹

C. Oil Supply*

Oil is clearly at the heart of the current U.S. energy problem. This is due not only to the conflict between rapidly increasing demand for petroleum products and decreasing domestic production, but also to the lack of a current substitute for petroleum in the largest demand sector--automotive transport. Also, oil is the primary substitute for the other scarce fuel, natural gas. Because of relatively low prices for oil and an increasing concern over air pollution from coal fired plants, oil was even heavily substituted for coal in electricity production in the late 1960's. For all these reasons, oil is a central concern in energy planning for the Northeast and for the Nation as a whole.

1. Domestic Supply

As mentioned in Section III, domestic oil production has declined since a peak in 1970. Table 31 summarizes recent trends in the national supply situation. The combination of declining production and increasing demand has led to an increase in the imported fraction from 23% to 38% in the last 5 years.

A number of estimates have recently been made of future national oil production. Some of the most prominent are shown in Figure 25, which shows how widely they range. The projection methods ran the gamut from the use of simple resource production curves to the use of econometric models, and each incorporated various assumptions about future prices and Federal policies.

Of the projections in Figure 25 we chose the Project Independence business-as-usual (BAU) case as our high supply case for 1985, because (a) it is one of the highest estimates that is qualitatively reasonable with respect to the likely available resource

*This section is based primarily on a report prepared for this study by Bronheim.⁹

Table 31

NATIONAL OIL SUPPLY⁹
(10⁶ bbl/day)

<u>Year</u>	<u>Domestic production inc.natural gas liquids)</u>	<u>Foreign imports</u>	<u>Total</u>	<u>Foreign as % of total</u>
1968	10.6	2.8	13.4	21
1969	10.8	3.1	13.9	22
1970	11.3	3.4	14.7	23
1971	11.2	3.9	15.1	26
1972	11.2	4.7	15.9	30
1973	10.9	6.2	17.1	36
1974	10.5	6.3	16.8	37
1975	10.0	6.1	16.1	38
1976*	9.7	7.0	16.7	42

*Oil and Gas Journal projections.

base, (b) it accurately predicts the 1975 situation and the near-term declines in production currently being observed, and (c) it is a fairly recent estimate utilizing 1973 and 1974 data. The method used to make the BAU projection was to assume a future price of oil, \$11 a barrel (in 1974 dollars), and to calculate the expected drilling rates, finding rates (based on historical trends), and resulting national production.

For the low case in 1985, we chose the production estimates used by ERDA in their recent report on national energy supply.² These give a projected production curve almost identical to the one estimated by Hubbert,²⁶ shown in Figure 25. For the intermediate scenario, we used ERDA projections of the effects on oil production of enhanced-recovery techniques.

Figure 25. Various estimates of domestic oil production (10^6 bbl/day).⁹

Key:

FEA (B): Business as Usual (1976)

FEA (P): Pessimistic (1976)

FORD: Ford Foundation Energy Policy Project (1974)

Hubbert: (1971)

Hudson & Jorgenson: (1974)

NPC: National Petroleum Council (1972)

SHELL: Shell Oil Co. (1974)

SNOW: David G. Snow (1974)

SRI: Standard Research Institute (1972)

Although in the short term increasing domestic production may depend on increasing the economic incentives to producers to explore for additional petroleum reserves and develop them, in the longer term, the prime determinant of supply will be the petroleum resource base. Because of this and other reasons, econometric models are not appropriate for estimating supplies over the long term. Therefore, to extend the 1985 projections to 2000, we used Hubbert's depletion analysis,²⁶ in which historical resource production data and 1985 projections are combined with an estimate of the total resource base in an analytical expression for the depletion of a resource over time. For the high case, we assumed a resource base of 250 billion barrels,* the latest estimate of the U.S. Geological Survey²⁷ (other estimates are as high as 450 and as low as 172 billion barrels). For the low case, we took a resource base of 220 billion barrels, and for the intermediate case, we assumed that enhanced recovery would increase the effective base to 250 billion barrels. The three cases are shown in Figure 26. All projections include production from Alaska and the offshore regions.

2. Supply to the Northeast

The portion of the future national oil supply that the Northeast can expect to get will depend on a number of economic and political factors; we therefore included a range of possibilities in the three supply cases. We first distinguish between three sources of domestic production: (1) the lower 48 states excluding the Atlantic Outer Continental Shelf (OCS), (2) the Atlantic OCS, and (3) Alaska. For the first category, we assume in all cases that the Northeast will get 20%, its current share.

For Alaskan production, we assume in the low case that it will be absorbed by western and midwestern states, offsetting foreign

*122 billion barrels of which were extracted through 1975.

imports to those regions; and in the intermediate and high cases that the Northeast will be 20% of it (as of other domestic production).

Figure 26. Projected domestic crude oil production.⁹

- A - Historical Production
- B - Project Independence - BAU
- C - ERDA - Enhanced Recovery
- D - ERDA - BAU

There is a great deal of uncertainty concerning the amount of petroleum recoverable from the OCS. Serious exploratory drilling is just beginning in the Baltimore Canyon and in the George's Bank area. Although estimates have been made of the recoverable resource bases, which vary from none to several billion barrels, we based our estimates of possible OCS oil production on the range of recoverable resources reported by the USGS.²⁷ In our high case, production is assumed to start in 1981 and reach a level of 75 million bbl/year in 1985. After a peak in the early 1990's, the production would decline to about 150 million bbl/year by 2000. In the intermediate case, which is based on the medium USGS recoverable resource estimate, production is set at 60% of our high case values. Since there is some chance that no significant quantities of oil will be discovered and recovered, we assumed the OCS supply to be zero for our low case.

Our estimates of oil supplies available to the Northeast from the lower 48 states, the Atlantic OCS, and Alaska are given in Table 32, along with our estimates of the levels of synthetic liquids from coal and shale that could be allocated to the Northeast (from Section V.B.5.).

Even if large quantities of oil are recovered from the OCS, recent efforts to site additional refineries in the region have not succeeded, and the Northeast is expected to continue to be increasingly dependent on other parts of the Nation and the world for refining its gasoline and fuel oil.*

In 1972, 90% of the crude oil entering the region arrived over a water route. Although it is beyond the scope of this summary to discuss the pros and cons of modern large tankers

*Some implications of this dependency are discussed by Bronheim.⁹

(which carry up to 500,000 tons rather than the 30,000 to 35,000 tons common for tankers now supplying the Northeast) or of alternative transport, it is clear that the physical means of importing oil is an important regional issue.

Table 32

SUMMARY OF CASES OF DOMESTIC OIL SUPPLY (10^6 bbl/day)
TO THE NORTHEAST^a

Source	1985			2000		
	Low	Intermediate	High	Low	Intermediate	High
Lower 48 states ^b	1.63	1.72	1.84	0.61	1.35	1.43
Alaska ^c	0.00	0.20	0.40	0.00	0.10	0.20
Atlantic OCS ^d	0.00	0.12	0.20	0.00	0.26	0.43
SUBTOTAL	1.63	2.04	2.44	0.61	1.69	2.03
Coal liquids ^e	0.00	0.03	0.20	0.05	0.55	1.40
Oil shale ^e	0.00	<u>0.00</u>	0.03	0.00	<u>0.00</u>	0.61
TOTAL		2.07			2.24	

^aIn 1972, domestic supply to the Northeast was 1.79×10^6 bbl/day and foreign imports 2.82. (To convert number of bbl/day to quads/year, multiply by 2.)

^bExcluding Atlantic OCS and assuming that the Northeast gets 20% of national production, as at present.

^cIn low case, Alaskan production is assumed to replace imports in western states; in intermediate and high cases, 20% of it is assumed to go to Northeast.

^dAll Atlantic OCS production is assumed to go to the Northeast.

^eAllocation to the Northeast is taken as 28%.

D. Natural Gas Supply*

The basic problem of natural gas supply is the same as that of oil: annual domestic consumption has risen to a level that is large compared with the total remaining resource base. Yet the problem manifests itself quite differently. (1) Since natural gas prices are regulated, it can be argued that inadequate production results merely from prices being too low, and (2) unlike oil, domestic natural gas has no imported equivalent. For example, in 1972, 60% of the petroleum products consumed in the Northeast were derived from overseas imports but only 0.6% of the natural gas consumed was imported.

The Northeast's natural gas profile is significantly different from the national average in terms of both price and end uses. Because of higher transmission costs, natural gas prices in the Northeast are often double those paid in other nonproducing regions. As shown in Section III, almost half of the gas is consumed in the residential sector, mostly for space heat. The result has been that when supplies have been curtailed (in the 1974-75 winter, for example, supplies were short by 168 billion cubic feet) industrial consumers have been denied supplies and restrictions have been placed on new hook-ups of residential customers.

1. Domestic Supply

Since the current costs of synthetic gas from coal and imported liquefied natural gas are much higher than that of domestic gas, a central concern to the region is the possible future levels of domestic supply. As with domestic oil production, U.S. production of natural gas has fallen significantly if recent

*This section is based primarily on a report prepared for this study by Langlois.²⁸

years. Critics of price regulation maintain that a return to open market prices would stimulate production and new exploration, while limiting demand, so that a market equilibrium would be reestablished. (Intrastate wellhead prices are currently between \$1.25 and 2.00 per thousand cubic feet.)

Others maintain that supply shortages are a result of monopolistic practices of producing and transporting companies, artificially reducing supplies to drive intrastate prices higher and influence the debate over interstate deregulation. Still others maintain that the problem is geological--that reserves are nearing exhaustion and that deregulation would not appreciably increase supplies and would only result in inflated retail prices to consumers who could not afford to switch fuels.

It is clear, however, that regulation of the interstate market has resulted in a significant shift of new production from the interstate to intrastate markets, where prices are not regulated. New production additions dedicated to the interstate market in 1970-73 were about 11% of the total, compared with 67% in 1964-69.⁴² The dramatic shift to intrastate sales demonstrates one underlying cause of the Northeast's natural gas supply problems, a cause that can be remedied only by changes in the regulatory system.

Figure 27, which summarizes some of the recent projections of natural gas supply, shows that the future is not at all precisely defined. The first question to ask in selecting among the projections should be what general shape the supply curves can be expected to have over the next few years. If the current downturn is the result of regulation, then deregulation would cause production to rise; but if the shortage is not related to low prices, then the present downward trend would continue.

Figure 27. Some prominent recent national gas production projections in trillion cubic feet (Tcf).²⁸

Key

- Q_{∞} Hubbert curve (see text)
- M-P MacAvoy-Pindyck (1973)
- H-J Hudson-Jorgenson (1974)
- PI Project Independence (1974)
- IGT Institute of Gas Technology (1974)
- NGS National Gas Survey (1973)

Figure 28 shows the national supply projections adopted for this study. The high and intermediate-supply cases for 1985 were taken from the Project Independence accelerated (ACC) and business-as-usual (BAU) cases. The BAU case requires no government initiatives beyond deregulating wellhead natural gas prices. The ACC case includes also the assumption of an accelerated offshore leasing program by the Government and an escalated drilling program by producing companies. For the low-supply case, the case II projections of the FPC 1973 Nation Gas Survey (NGS) were adopted, which assumed low wellhead prices (58 ¢/thousand cubic feet) by 1990 and a delayed production schedule for the offshore fields.

The changes in the present trend implied by these projections can be seen in Figure 29, which shows the yearly additions to proved reserves that would be required to meet the projected production levels along with historic additions to reserves from production in the lower 48 states. Even the low (NGS) case requires some upturn from the average additions to reserves since 1968; however, in 1974 drilling was more active than it had been since 1956, and an average addition of at least 14.7 Tcf/year appears to be attainable.

The year 2000 projections shown in Figure 26 for oil production were developed by a method that takes into account the finite nature of the resource base. A similar method, based on Hubbert's depletion analysis, was used to estimate gas supplies.²⁸ The analysis was done separately for production from Alaska and from the lower 48 states (excluding the Atlantic OCS) with use of ultimate recoverable resource values shown in Table 33, which are based on estimates by the USGS²⁷ and by Hubbert.⁴¹

Figure 28. Summary of national gas production projections, 1985 and 2000.²⁸

Figure 29. Annual gas reserve additions, historic and implied by several projections.²⁸

Table 33

ULTIMATE RECOVERABLE NATURAL GAS RESOURCES (Tcf)

	<u>Low</u>	<u>Intermediate</u>	<u>High</u>
Alaska	77	124	180
Lower 48 states	1050	1158	1280

2. Supply to the Northeast

What share of future national gas production will go to the Northeast is difficult to predict. It will depend on national policies concerning intra- and interstate regulation, on the distribution of Alaskan North Slope resources, and on the existence, exploitation, and distribution of Atlantic OCS resources.

A high-supply case for domestic sources would be expected if interstate prices were deregulated, allowing the region's (interstate) suppliers to outbid intrastate markets and thus maintain the share of national production going to the Northeast. An intermediate-supply case results from assuming that the intra-state consumption is limited to 1972 levels and all other production (including Alaskan) is allocated by historical interstate market share. The low-supply case is the same except that production from Alaska is assumed to go entirely to Western states and only that from the lower 48 states to be allocated by historical market shares.

3. Offshore Production

As in the case of oil, there is great uncertainty about what the level of gas production from the Atlantic OCS will be; in fact, it is quite possible that no exploitable gas fields will be found off the Atlantic Coast. Recently the USGS revised its

previous estimates of probable undiscovered recoverable gas resources off the Atlantic Coast.²⁷ Their current estimates give a range of 5-14 trillion cubic feet (tcf) for the region. We constructed our supply cases on the basis of these estimates and of a reasonable production schedule resulting in a field life of 20 years.

Our high-supply case was based on the most optimistic resource estimates, with production expected to reach 350 billion cubic feet (Bcf) in 1985 and 700 Bcf in 2000. Although we assumed that gas was produced equally from the three supply areas (George's Bank, Baltimore Canyon, and the Georgia Embayment), we estimated that the Northeast region would receive as much as 80% of the total production.

The intermediate-supply case was based on the average of the resource estimates provided by the USGS, with production reaching 250 Bcf in 1985 and 500 Bcf in 2000. We assumed that the Northeast would receive two-thirds of the total amount, which would include all of the production from the George's Bank and Baltimore Canyon areas.

The low-supply case reflects the finite probability that no gas will be produced from the Atlantic OCS either because of a lack of economically exploitable resources or because of opposition to drilling.

The various cases are summarized in Table 34.

An analysis of the possibility of producing methane from solid waste generated in the region²⁹ indicated that possibly a nominal contribution of 20 Bcf could be produced by 2000.

Table 34

POTENTIAL NATURAL GAS SUPPLIES TO THE NORTHEAST (10^{15} Btu/year)

	<u>1972</u>	<u>1985</u>			<u>2000</u>		
		<u>Low</u>	<u>Int.</u>	<u>High</u>	<u>Low</u>	<u>Int.</u>	<u>High</u>
National*	2.33**	1.50	2.17	2.68	0.03	1.05	1.74
Atlantic OCS	-	0	0.17	0.28	0	0.34	0.56
LNG	-	0	0.80	1.10	0	1.00	2.00
Coal gasification	-	0	0.20	0.50	0.80	1.60	2.60

*Includes Alaskan and onshore regional production

**Includes 0.10×10^{15} Btu imported from Canada.

4. Liquified Natural Gas*

World reserves of natural gas are comparable (on an energy basis) to those of oil, but the high cost of transporting gas has limited its role in the world energy market. The rapid rise in world energy prices has increased the likelihood of worldwide shipments of natural gas. Receiving and exporting terminals to handle liquified natural gas (LNG) are currently under construction throughout the world. It now appears that imported LNG has a significant potential for contributing to regional natural gas supplies.

The importation of natural gas, like that of oil, is counter to the national policy of energy independence. This is somewhat mitigated by the possibility of obtaining gas and oil from different countries and thus diversifying the origins of imports. Obviously these imports will be very costly, perhaps more than $\$4/10^6$ Btu.

The only practical way to import natural gas from overseas sources is to liquefy it in the producing country, ship it

*This section is based on a report prepared for this study by Bray et al.³⁰

in cryogenic tankers, and regasify it at domestic receiving terminals for ultimate consumption. The liquifaction plant, the tanker fleet, and the receiving terminal are all extremely capital-intensive facilities, and their financing cost will be reflected in the ultimate price paid by the consumer.

Based on their known and potential reserves, domestic requirements, and geographical proximity to the Northeast region, the following countries are thought to be potential exporters of LNG to the region: Abu Dhabi, Algeria, Iran, Iraq, Kuwait, Libya, Nigeria, Saudi Arabia, Venezuela, and Western Russia. Of these countries, the Soviet Union has by far the largest reserves, possessing over 35% of global natural gas resources. The total amount of world liquifaction capacity now planned is 9.3 Tcf/day, but as more plants are being announced every month, this figure is a substantial understatement. Table 35 lists the operating and planned LNG receiving terminals in the Northeast.

Table 35

NORTHEAST LNG RECEIVING TERMINALS

<u>Company</u>	<u>Plant Site</u>	<u>Regasification capacity, 10⁶ cf/day</u>	<u>Storage capacity, 10⁶ cf/day</u>	<u>Year of operation</u>
Distrigas Corp.	Everett, Mass.	135	3250	1971
PSE&G Co., N.J.	Staten Island, N.Y.	360	6000	1973
Columbia LNG Co.	Cove Point, Md.	1200	5000	1976
Algonquin LNG Co.	Providence, R.I.	675	6000	1973
Transco Terminal Co.	Raccoon Island, N.J.	(850)	. . In planning	. .
Texas Eastern	West Deptford, N.J.	. .	. . In planning	. .

Considering the degree of uncertainty in the market and in regulatory attitudes, it is very difficult to estimate how much, if any, LNG will be imported to the Northeast in 1985 and 2000. On the basis of the capacity of receiving terminals expected to be operational in 1985, 0.8 Tcf/year was taken as the intermediate supply estimate, assuming an 80% load factor. Inclusion of the proposed plants raises this to 1.1 Tcf/year in 1985 for the high estimate. Finally, if acceptable resolutions of fuel-contract disputes cannot be made or if an LNG moratorium is declared, it is also possible that no LNG will be imported in 1985 or 2000, which defines our low-supply case.

Year 2000 supply can be estimated only in the crudest way. The FPC National Gas Survey gave estimates for total U.S. imports of LNG of 2.1 to 4.2 Tcf/year. Our estimate that the Northeast's share will be 50% of these imports yields intermediate-and high-supply estimates of 1 and 2 Tcf in 2000.

These estimates are shown in Table 34.

E. Nuclear Power*

The geographical relation of the Northeast, and particularly New England, to adequate fossil-fuel reserves has made nuclear power a particularly attractive option in the region. Nuclear power accounted for approximately 13% of the region's electrical generation during 1975. Production costs during the first half of 1975 averaged 12.7 mills/Kwh for nuclear, compared with 19.8 for coal and 19.3 for base-loaded oil-fired capacity. However, uncertainties exist regarding the future adequacy of various elements of the fuel cycle, particularly the capacity to enrich uranium and reprocess spent fuel. Regulatory uncertainties

*This section is based on a report prepared for this study by Sailor and Shore.¹⁰

include whether the Nuclear Regulatory Commission will authorize the recycling of plutonium (which has a significant effect on fuel cycle economics) and what the future requirements for high-level waste management will be. The possibility that a combination of difficulties arising from these factors or public opposition could slow or halt the growth of nuclear power in the region is explicitly considered in the scenarios discussed in Section VI.

1. Uranium Resource Availability

At present, only uranium from domestic sources can be used in U.S. power reactors. The U.S. uranium resources³¹ as of January 1, 1975 are shown in Figure 30. The bars show the cumulative tonnage of uranium (as U_3O_8) estimated to be available at the price per pound indicated. Note that the prices given are merely nominal figures based on the cost structure that existed prior to 1974, before major price escalation occurred for oil, coal, and uranium. During the past two years the market price for uranium has gone from about \$8/lb to \$25/lb for delivery in 1978, and it will probably escalate to \$50/lb for delivery in 1985. The amounts given for 1980 represent reserves, and those for 1996 include probable potential reserves.

The curve in Figure 30 is a projection of total U.S. demand which takes into account recent changes in utility plans and delay of plutonium recycling.³¹ It is clear that by the late 1990's significant quantities of the probable potential reserves must materialize. The exploration activity and investment in production facilities required to accomplish that are substantial but quite feasible. These issues as well as the requirements and economics of all parts of the nuclear fuel cycle as they pertain to the Northeast are discussed by Sailor and Shore.¹⁰

Figure 30. Domestic uranium reserves (as of Jan. 1, 1975) and projected demands.¹⁰

2. Nuclear Power in the Northeast

There is no reason why the Northeast should not get its share of national uranium production. For uranium, unlike other fuels, the cost of transportation is a relatively insignificant component of the cost of producing power. To construct scenarios for the future use of nuclear power in the region, therefore, we considered various possible levels of installed nuclear electric generating capacity additions. Three cases were constructed.

The base case reflects present (August 1975) plans of the region's utilities. Beyond 1985 the individual power pool projections were extrapolated to 2000 assuming the same fuel mix (gas, coal, oil, and nuclear) as for the preceding decade.* The regional distribution of capacity in the base-case scenario is indicated in Figure 31.

A high case was constructed by considering the rate at which the nuclear supply industry could expand production. This resulted in an installed capacity in 1985 about 10% higher than in the base case, and 43% higher in 2000.

A low (nuclear curtailment) case was constructed by assuming that because of public pressure or other factors new nuclear construction would be suspended for a period of 5 years starting on January 1, 1977, but that plants then under construction or operating would be unaffected by the curtailment. It was further assumed that such a suspension would make it impossible for the nuclear industry to recover by the end of the century, so that no new capacity would be added by 2000.

The three nuclear supply cases are summarized in Figure 32.

F. Other Electric Supply Technologies

In the preceding sections of this report a number of technologies, either new or not now widely used in the Northeast, were introduced into supply or demand cases. Solar space heating and cooling and solar water heating were included in the residential and commercial demand analysis as were heat pumps and improvements in efficiencies of various end-use devices. New technologies for producing synthetic oil and gas from coal were

*The nuclear share of new capacity is taken to be 76.4% in the New England Power Pool after 1985, 86.4% in the New York Power Pool after 1990, and 54.4% in the Mid-Atlantic region after 1985.

Figure 31. Base-case nuclear power scenario.¹⁰

Figure 32. Comparison of nuclear power scenarios for the Northeast.¹⁰

discussed in connection with overall energy supply. Our consideration of other new technologies led to the opinion that their contribution to the Northeast's energy balance would probably be insignificant: the cost of photovoltaic or thermal solar electricity production was found prohibitive; fusion power was expected not to be commercially feasible before 2000; and MHD power generation was found not to be competitive economically (or technically) with low-Btu coal gasification and combined-cycle plants. Two novel electricity-producing technologies, however, were deemed capable of playing a role under certain circumstances within the time period of this study; these involve the use of solid waste and wind power.

1. Solid Waste as an Energy Source*

Since the rapid rise in energy costs two years ago, interest has grown in recovering energy from solid waste, especially in using refuse as a supplementary fuel in utility boilers. Also, the increasing severity of urban solid waste disposal problems has motivated many Northeastern States to make statewide solid waste management plans focused on energy and resource recovery.

A detailed analysis has been made of the possible use of refuse as an energy source for the Northeast.²⁹ The viability of the concept depends strongly on the costs of refuse transportation (closely related to population density), of alternative disposal, and of competing fuels and also on the economics of the energy recovery technologies. Upper and lower bounds were derived for the conversion of refuse to energy and its potential contribution to energy supplies in the Northeast.

The most promising option, given foreseeable fuel prices, is to use refuse as a supplementary fuel in coal-fired boilers.

*This section is based on a report prepared for this study by Meier and McCoy.²⁹

The conversion of refuse to gas by pyrolysis or bioconversion or the burning of refuse to generate steam for district heating or industrial use is likely only under very special circumstances. It would take deregulation of natural gas, with delivered prices around $\$3/10^6$ Btu, to make conversion to gas worth while.

Since the potential contribution of energy from refuse is small, around 2.5% of total regional resource requirements by 2000, subsequent scenario development incorporates only one case of refuse utilization, contributing 0.6 quad of electricity and 0.02 quad of gas. This is equivalent to the upper bound, which is based on all Northeastern States implementing statewide solid waste management plans focused on energy and resource recovery, similar to those now being implemented in Connecticut and Massachusetts. Nevertheless, in terms of supplementing a particular energy form, the contribution possible from refuse may be substantial: for the Northeast reference case in 2000, if all refuse were burned as a supplementary fuel, the coal requirement could be reduced by about 9.5%; or, if all refuse were converted to gas, it could meet some 20% of the total gas requirement.

2. Wind power

Wind power could conceivably contribute significantly to the fuel supply of the Northeast within the next few decades for several reasons: (1) The amount of total wind energy resource available in the region is far greater than the demand for electricity; that is, there is no primary resource constraint. (2) Windmills will not require any exotic materials or fabrication processes. (3) U.S. industries currently manufacture products similar to the major components of a windmill (helicopter rotors, generators) and could easily scale up production to the requirements of a wind power program. (4) Except for possible esthetic effects

(visual pollution), virtually no environmental or health effects of wind power systems are known. (5) Unlike electricity generating systems based on thermal cycles, wind power requires no cooling water. (6) In contrast to large central-station generation facilities, windmills could have their major components mass-produced in factories and rapidly put together on site; this would keep interest costs low and minimize construction bottlenecks.

Recent NASA work³² suggests that electricity from windmills would cost between 2 and 4¢/Kwh. Jorgensen et al.³³ find that at the lower end of this range, with current prices for low-sulfur oil, wind power would be competitive when used simply as a fuel saver for existing oil-fired generators. For large-scale applications, a storage system or backup conventional generators (such as gas-turbine units) must be included for periods during which the windmill array suffers an outage due to simultaneous lack of wind and heavy demand for electricity.

Siting wind generators is easier in some respects and harder in others than siting conventional generating units. The cost of wind power is highly sensitive to the wind speed profile of the site, which should have high and fairly continuous winds. Ocean siting off the coast of New England satisfies this need, but it is not yet clear whether the more favorable winds offshore compensate for the higher costs (due to the requirement for windmill support structures and underwater transmission lines) compared with land siting. The generally lower wind speeds on land in the Northeast strictly limit site choices; the eastern sides of Lake Erie and Lake Ontario have been suggested as potential sites for wind arrays. A single windmill occupies a relatively small area and is compatible with other land uses such as agriculture, timbering, and recreation, but the visual pollution

issue could severely limit the choice of sites.

We have not carried out the kind of integrated economic and engineering system study required for adequate evaluation of the role of wind power in the Northeast, but we have constructed three cases to span the range of possibilities. For the low case, economic and institutional factors are assumed to prevent any use of wind power in the region during the period of our study. For the intermediate and high cases wind power is assumed not to contribute any energy until after 1985. Preliminary engineering design studies³² indicate that windmills in the 1 to 2 Mw range, costing about \$500/Kw (peak rated) and operating at a power factor of 0.4, are likely to be optimal for sites with average wind speeds of 15 to 18 mph. On this basis, a reference windmill capacity of 1.5 Mw was chosen for our scenarios.

For our intermediate case, we assumed that in 2000 wind power would generate 0.13 quads/year of electricity, about 4.5% of the total electricity demand. For such a small fraction, storage systems would probably not be required and the wind array would be used mainly as a fuel saver. The average rate of introduction of windmills between 1985 and 2000 is taken as 430 units per year, giving 6500 units by 2000.

For the high case, we assumed that in 2000 wind power would generate 0.5 quad of electricity, about 16% of the total electricity generated. For such a large fraction, storage and/or backup capacity would be required for periods when wind outages coincided with peak demands. This level of output would require 25,000 windmills by 2000, or an average introduction rate of 1700 units per year from 1985 to 2000.

3. Hydroelectric Power

Because of the limited resource available and the public opposition to its exploitation, we have assumed that there will be no increase in the amount of hydroelectric capacity in the region. The contribution of hydropower has been retained at 0.13 quad/year.

VI. SCENARIO ANALYSIS AND CONCLUSIONS

In this section, the results of the supply and demand analyses summarized in the preceding two sections are integrated into scenarios, which are used to investigate several key energy issues (described in Section II) facing the Northeast. First the study approach is described, then the scenario results are presented, and finally the results are analyzed.

A. Study Approach

The goal of this study is to provide an understanding of the major features of the Northeast energy system to the year 2000 and to provide rough quantitative estimates of the effects that a variety of factors can have on the future development of the system. The study is concerned especially with future energy resource needs--how those needs might be met and how they could be reduced--since the energy problems facing the Northeast arise primarily from its dependence on vulnerable imported resources and on those national resources in shortest supply. In 1972, such resources provided 85% of the region's energy needs. The study approach chosen closely reflects this primary concern regarding the ability of the Northeast to obtain energy resources to meet its needs in the future.

The study method employed is based on the development and analysis of a number of energy scenarios, each of which defines a hypothetical future course of the Northeast energy supply and consumption system up to the year 2000.* The energy system is viewed as a set of resource sectors that supply energy in the form

*The method is similar to that used by the Institute for Energy Analysis in studying the long-range energy future of the United States.³⁴

of fuels and three demand sectors that consume fuels. The fuels supplied and consumed are aggregated into one of the following four categories: liquids, gases, coal (used directly by final consumers of energy), and electricity (see Figure 3 in Section II). A scenario is specified by matching a set of estimated future fuel supplies from the resource sectors to a set of estimated future fuel demands from the demand sectors. Theoretically, a very large number of such matched combinations could be constructed; but only a small number of scenarios are of practical interest.

To facilitate rapid simplified analysis of the broad scope of energy problems and issues, a limited number of projections were developed for each resource supply sector and each demand sector. Each projection consists of a schedule of the four fuels supplied (resource sector) or consumed (demand sector) for the years 1972, 1985, and 2000. A typical projection is shown in Table 36.

Table 36

TYPICAL PROJECTION (in Quads/year):

Intermediate Coal; Low Electricity; High Low-Btu Gas

<u>Year</u>	<u>Liquids</u>	<u>Gases</u>	<u>Electricity</u>	<u>Direct coal</u>
1972	0	0	0.40	1.14
1985	0	0.20	0.52	1.49
2000	0	1.00	0.63	2.63

This is a projection for coal resources supplied to the region, and its specific assumptions are that coal will be supplied to the region at the intermediate level and that a low level of electricity and a high level of low-Btu gas will be produced

from this coal. The table shows the amounts of fuels produced from coal (including direct use of coal) and supplied for use in the Northeast. The 1972 figures are based on historical data. The figures for electricity are measured at the point of consumption and represent units of electrical energy (not the thermal input energy required to produce the electricity). The gas fuel produced is a low-Btu synthetic gas. Note that the same total resource supply level could have produced a different mix of fuels; other projections reflect such possibilities.

The projections used in this study were developed as described in various reports dealing with the resource and demand sectors and are listed in Appendix C. The projections implicitly incorporate full sets of assumptions regarding the geological, technological, policy, and socioeconomic factors relevant to each sector, and they span the range of supply or demand possibilities that can reasonably be expected for that sector under the variety of assumptions considered. Note that no projections were made for imported oil, the level of which was simply defined as the difference between domestic liquid supplies and liquid demands (but actions that could affect the level of imports were considered, see Sections VI.B and C); as a result, total liquid fuel supplies were always automatically matched to demands.

Although the detailed assumptions underlying the projections differed from one sector to another, several things were consistently taken into consideration. On the demand side, besides the base or reference-case projections, projections were primarily designed to reflect the effects of two factors, conservation and fuel shifts. Conservation includes all actions that reduce energy use whether they stem from price rises, technological improvements, or changes in consumer attitudes reducing fuel waste, etc. Fuel shifts involve the substitution of electricity and low-Btu gas

for scarce liquid fuels. In constructing scenarios, projections for the three demand sectors were always kept consistent with one another with respect to these factors. For this study, five sets of demand projections were employed: (1) base case, (2) base-level demands, fuel shifts, (3) moderate conservation, (4) moderate conservation, fuel shifts; and (5) strong conservation, fuel shifts. The fuel demands associated with these five cases are compared in Section IV.

On the resource side, the effects of the following factors on fuel supplies were incorporated into the various projections: (1) development of new resources (e.g., wind, shale, wastes and refuse), (2) introduction of new conversion technologies (e.g., for synthetics from coal), (3) uncertainties in oil and natural gas resources, (4) uncertainties in the regional allocation of total U.S. supply, and (5) constraints on the growth of nuclear power.

Although solar energy is an energy resource, its use for space conditioning and water heating was incorporated into our analysis of energy demand in the residential and commercial sector as a matter of convenience, because its use is integrally tied to other factors associated with that sector.

On the basis of the five factors listed above and various other considerations described in Section V, high, intermediate, and low resource supply projections were, in general, determined for the various resource supplies. The term *modest supplies* indicates that all resource projections were at the intermediate level or less. If the intermediate supplies of a given fuel exceeded the demands, we used our judgement to decide which of the resources producing that fuel should be assumed to have a lower supply level.

In constructing scenarios, a trial-and-error process was employed to devise a combination of supply and demand projections in which fuel supplies matched demands and which was consistent with the assumptions associated with the issue being studied. In all cases, the demand projections were chosen from one of the five sets listed above. To speed the process of finding a matched set of resource and demand projections, the projection data were stored in a computer and an interactive program was employed to perform the multitude of arithmetic computations required to compare total fuel supplies with total fuel demands for 1985 and 2000. It should be emphasized that all choices were made by the analyst and that the computer merely performed arithmetic computations; no optimizations or other decision-making algorithms were incorporated into the computer program. The use of a computer also facilitated the construction and use of resource projections intermediate between two available projections for a resource sector in which such a choice provided a better match of supplies and demands than the original projections.

Once a satisfactory match of fuel supplies and demands was achieved (in most cases with less than 5% difference allowed for each fuel), a computer printout in both tabular and plot form was obtained of the fuels consumed and the energy resource requirements in 1972, 1985, and 2000. In addition, pollutant emissions associated with the energy use pattern assumed in the scenario were computed and tabulated. (See Section VII for further discussion of the pollution indices and their implications.)

The approach employed here does not explicitly incorporate economic parameters--prices and elasticities--into the process of determining the quantity of fuels demanded, the choice of fuels

used, or the resources which produce the various fuels consumed in a given scenario. Although economic factors were considered in the development of projections, there were no built-in feedback effects between energy supply and demand. Since it is not possible to predict with confidence prices and elasticities of all the energy resources and fuels for several decades into the future, a model based on such parameters would not provide any deeper insights into the broad features of the long-run energy problems facing the Northeast.*

B. Scenario Results

The twelve scenarios used in this study are described and compared here, and the results are analyzed in Section VI.C. The scenarios and the supply and demand assumptions underlying them are listed in Table 37. The detailed numerical description of each scenario and a plot of the resource requirements associated with it are given in Appendix A. Further information on the assumptions underlying the scenarios can be found in Appendix C, where the projection data are listed; in the reports on the development of the projections; and in Sections IV and V above, which respectively summarize the various demand and resource reports.

1. Reference Scenario

A reference scenario (Scenario 1) was constructed to indicate the direction in which current patterns of population growth, economic growth, and government policies relative to energy supply and utilization are leading. The reference scenario is a combination of the base-case demand projections and the intermediate-supply projections for U.S. crude oil, natural gas, and

*A comparison with studies in which prices and elasticities were used as a basis for making projections indicates that their results are not substantially different from those of this study.

Table 37

NORTHEAST ENERGY SCENARIOS
Resource and Demand Assumptions

<u>Scenario</u>	<u>Subject</u>	<u>Demands</u>	<u>Supplies</u>
1	Reference Case	Base	Modest*
2	Fuel shifts	Base, fuel shifts	Modest
3	Conservation	Moderate conservation	Modest
4	Conservation	Moderate conservation fuel shifts	Modest
5	Conservation	Strong conservation fuel shifts	Modest
6	Import reduction	Base	Highest U.S. liquid supplies
7	Import reduction	Moderate conservation, fuel shifts	Highest U.S. liquid supplies
8	Nuclear curtailment	Base	Nuclear curtailment, substitute coal
9	Nuclear curtailment	Base	Nuclear curtailment, substitute coal, wind and waste
10	Nuclear curtailment	Moderate conservation	Nuclear curtailment, substitute wind and waste
11	Supply constraints	Moderate conservation fuel shifts	Low U.S. oil and natural gas, nuclear curtailment
12	Supply constraints	Strong conservation fuel shifts	Low U.S. oil and natural gas, nuclear curtailment
13	Supply constraints	Strong conservation fuel shifts	Low U.S. oil and natural gas, nuclear curtailment, sub- stitute wind and waste

*Modest indicates that all resource projections are at the intermediate level or less.

coal synthetics, with lower than intermediate projections for regional coal resource supply and nuclear power (reflecting that base-case electricity demand projections are lower than the total supplied in the intermediate-level coal, oil, and nuclear resource projections). Figure 33 is a plot of the resource requirements for the reference scenario for the period 1972 to 2000 (based, like subsequent plots, on three data points for each curve, i.e., those for 1972, 1985, and 2000). The gradual decline in the amount of U.S. crude oil and natural gas supplied to the region, coupled with continued growth in energy needs, leads to continued dependence on imported oil as the predominant energy resource even though the supplies of coal and of nuclear resources increase rapidly.

2. Fuel Shifts

Scenario 2 was constructed to study the effect of shifting fuel demands from liquids to electricity and gas (low-Btu gas produced from coal) given base-level demands and modest supplies. The result is a decrease in imported oil at the expense of greatly increased use of nuclear power (this is the only scenario requiring the intermediate-level nuclear resource projection) and slightly increased coal requirements (Figure 34). In addition, LNG imports are required because the introduction of low-Btu gas is insufficient to meet the increased gas demands.

3. Conservation

Scenarios 3, 4, and 5 were constructed to investigate the impact of conservation on the energy system, and concentrated particularly on potential reductions of the heavy reliance on imported oil that was assumed in the reference scenario. In Scenario 3 (Figure 35), moderate-conservation demands are combined with modest supplies; in Scenario 4, fuel shifts are super-

Figure 33. Scenario 1 (reference scenario).

Figure 34. Comparison of Scenarios 1 and 2.

Figure 35. Comparison of Scenarios 1 and 3.

imposed on the moderate-conservation demands; and in Scenario 5, (Figure 36), strong-conservation and fuel-shift demands are assumed. Compared with the reference scenario, the reductions are particularly dramatic for Scenario 5, in which the requirements for imported oil and nuclear resources are cut substantially and minor reductions in natural gas requirements are also possible. The coal requirements in Scenario 5 are increased because industrial use of coal directly as fuel is not materially affected by the combined program of conservation and fuel shifts and the level of coal synthetics supply is slightly increased by the introduction of low-Btu gas production in conjunction with the fuel shift.

4. Import Reductions from High U.S. Liquid Fuel Supplies

Scenarios 6 and 7 were designed to study the effect on oil imports of a vigorous U.S. program to develop resources and conversion facilities producing liquid fuels (shale and coal synthetic plants) occurring in conjunction with higher than expected discoveries of crude oil. Such a supply program is coupled to base-case demands in Scenario 6 (Figure 37) and to moderate-conservation demands in Scenario 7. For Scenario 6, the use of shale resources and the increase in U.S. crude oil and coal resources as shown in Figure 37 are attributable entirely to the assumed increased production of liquid fuels. The increase in nuclear resource usage in Scenario 6 results from the additional assumption that the use of oil to produce electricity is completely phased out by 2000 (in contrast to the 0.7 quad of oil still so used in the reference scenario) freeing still more oil for the liquid supply. The result of all these actions taken together would be a reduction in the year 2000 imported oil requirement of 4 quads.

Figure 36. Comparison of Scenarios 1 and 5.

Figure 37. Comparison of Scenarios 1 and 6.

5. Nuclear Curtailment

Scenarios 8, 9, and 10 were constructed to investigate the consequences of nuclear curtailment. In Scenario 8 (Figure 38), coal alone is used to make up for the decreased nuclear supply. The coal resource supply required in this case is 60% greater than the intermediate-level coal supply projection for the Northeast. In Scenario 9 (Figure 39), wind power and energy from solid wastes are used in conjunction with coal to make up for the reduction of nuclear supply. Note that the wind power resources are measured in terms of electricity output (there being no equivalent to the thermal input associated with the conversion of nuclear and fossil resources to electricity) and thus are not directly comparable with the nuclear and coal resources used for electricity generation. Scenario 10 (Figure 40), in which moderate conservation is coupled with the introduction of wind and waste resources, shows that, even with nuclear curtailment, a reduction in imported oil and natural gas requirements (compared with those in the reference scenario) is possible if moderate conservation measures are implemented. Comparison of Scenarios 3 and 10 (Figure 41), shows even more clearly that, given moderate conservation, the reduction in the use of nuclear resources can be almost entirely compensated for by the use of wind and waste resources.

6. Low U.S. Oil and Natural Gas Supplies and Nuclear Curtailment

Scenarios 11, 12, and 13 were constructed to study the implications of combined supply constraints: nuclear curtailment was coupled to low discoveries and a low fractional allocation to the Northeast of U.S. crude oil and natural gas, and production of synthetic fuels was assumed to be at the level of the low

Figure 38. Comparison of Scenarios 1 and 8.

Figure 39. Comparison of Scenarios 1 and 9.

Figure 40. Comparison of Scenarios 1 and 10.

Figure 41. Comparison of Scenarios 3 and 10.

projections. It was assumed that, in response to these supply constraints, conservation actions were taken to reduce demands, and that coal supplied to the region and imported energy supplies rose as necessary to balance supplies with demands.

In Figure 42, Scenario 11 (moderate conservation, fuel shifts, and the supply constraints) is compared with Scenario 4 (moderate conservation, fuel shifts, and modest supplies). To compensate for the supply constraints, 3.5 quads of additional coal and 3 quads of additional imported energy (half of which is LNG) are required in 2000 over the levels needed in Scenario 4. The resulting level of coal resource supplied to the region in 2000 (not including coal synthetics) is 70% greater in Scenario 11 than in the intermediate-supply projection.

If strong rather than moderate conservation actions are assumed to be taken, the need for coal and imported energy is reduced by 4 quads. In Figure 43, Scenario 12 (strong conservation, fuel shifts, and the supply constraints) is compared with Scenario 5 (strong conservation, fuel shifts, and modest supplies). Here, the supply constraints are compensated for by increasing coal usage by 2 quads and imports by 2.5 quads in 2000 over their levels in Scenario 5. The introduction of wind and waste resources reduces the need for coal to the level in the intermediate-supply projection.

Comparison of Scenario 13 with the reference scenario (Figure 44), clearly shows that, even with the supply constraints, the implementation of strong conservation and fuel shifts coupled with the introduction of wind and waste resources permits sizable reductions in the need for other U.S. resources and reduces imported energy requirements to about half their level in the reference scenario in 2000. (Note that about 1 quad of the imports will probably be in the form of LNG.)

Figure 42. Comparison of Scenarios 4 and 11.

Figure 43. Comparison of Scenarios 5 and 12.

Figure 44. Comparison of Scenarios 1 and 13.

C. Analysis of Results and Conclusions

1. Reference Scenario

A continuation of current trends in population, economic growth, and energy use patterns, and of current policies related to energy resource development and usage (the reference scenario in this report) would lead to an 80% increase in the demand for fuels in the Northeast and a 100% increase in energy resource requirements between 1972 and 2000. Under these assumptions, by 2000 the consumption of electricity is likely to increase threefold, that of liquid fuels by a factor of two, and that of gas fuels by 20%. The need for imported oil would increase by 85%. Coal and nuclear power each would supply roughly 20 to 25% of the total resources used by the Northeast in 2000.

2. Conservation

Conservation can play a major role in reducing the fuel and resource requirements of the Northeast: the moderate-conservation demand projection considered in this report can reduce fuel demands by 11% in 1985 and 18% in 2000 from the levels in the reference scenario, and the strong-conservation demand projection, by 19% and 32% respectively. Resources required to produce the fuels needed to meet these reduced demands are similarly decreased; moderate conservation leads to reductions of 9% in 1985 and 15% in 2000 and strong conservation to 15% and 29% respectively. (See Table 38 and Figures 45 and 46.) Most of the measures that comprise these two conservation strategies can be enacted or implemented at the State or local level.

The reduction in energy requirements resulting from conservation has four broad effects in the Northeast: (1) The reduction in energy resource requirements makes the Northeast less vulnerable

Table 38

REGIONAL FUEL AND RESOURCE REQUIREMENTS (10^{15} Btu/year)
FOR 1985 and 2000

(1972 levels: total fuels = 12.3; total resources = 15.8)

Resource requirements resulting from modest-supplies assumption (intermediate-level projection or less for all supplies) and demand assumption indicated in leftmost column. For detailed breakdowns, see scenario printouts in Appendix A. Resource combinations different from those employed in the modest-supplies scenarios would result in slightly different totals.

<u>Demand assumptions</u>	<u>Total fuels</u>		<u>Total resources</u>	
	<u>1985</u>	<u>2000</u>	<u>1985</u>	<u>2000</u>
Base case (reference scenario)	15.5	22.5	20.4	31.3
Base level, fuel shifts	15.4	21.9	20.3	33.0
Moderate conservation	13.8	18.8	18.7	25.7
Moderate conservation, fuel shifts	13.7	18.2	18.3	26.7
Strong conservation, fuel shifts	12.6	15.3	17.3	22.3

Figure 45. Total fuel requirements for the Northeast (fuel shifts result in small changes).

Figure 46. Total energy resource requirements for the Northeast (domestic and imported resources needed to produce fuels consumed).

to supply constraints and production bottlenecks and provides more options for dealing with them. (2) For most of the measures included in the two conservation programs, the substitution of devices and procedures consuming less energy results in net long-run monetary savings. (3) Conservation strategies have a potential for creating more jobs within the region than corresponding supply strategies. (4) Environmental and health benefits can result from the lower levels of resource extraction and energy use both within the region and outside it. We have not considered in any detail the indirect regional economic consequences of the various conservation measures. Some would clearly be beneficial; others could have negative impacts on certain sectors. These considerations are discussed in more detail in Section VII.B.

3. Imported Oil

Imported oil is likely to continue to play a major role as an energy resource for the Northeast. The reference scenario, based on the assumption that no new policy initiatives are undertaken to affect supply or demand, projects an increase in imported oil requirements from the 1972 level (6.5 quads) to 12 quads in 2000. This continued heavy reliance on imported oil would be inconsistent with national objectives as currently enunciated. Quotas, taxes, or other regulatory mechanisms adopted at the Federal level to reduce reliance on imported oil would tend to result in greater hardships for the Northeast, the chief energy-importing region of the United States, than for other regions. In addition, factors external to the United States--such as resource depletion and greater internal consumption in oil-exporting countries, deliberate supply constraints by producer cartels, and increasing worldwide demand for petroleum--can strongly affect the cost and availability of imported oil to the Northeast. The unreliability of the supply in both the short and the long run

makes it clear that a prudent approach to energy policy for the Northeast must include consideration of actions that would reduce the heavy reliance on imports. Several such actions are discussed below.

A vigorous U.S. effort to produce synthetic liquids from coal, to exploit oil shale resources, and to develop techniques for the enhanced recovery of conventional crude oil--coupled with a high level of crude oil discoveries--could reduce the need for imports to the Northeast by nearly 4 quads. For a variety of reasons, however, a liquid fuel supply augmentation of this magnitude appears problematic and is unlikely to be achieved.

On the demand side, moderate conservation could reduce the need for imports by about 2 quads from the reference level in 2000 and strong conservation by about 4 quads (assuming that the region's supplies of liquid fuels derived from U.S. resources remained constant). In addition consideration of a limited effort to substitute electricity and low-Btu gas produced from coal for liquid fuels (fuel shifts) in the industrial and the residential and commercial sectors indicated that this could reduce imports by 2.5 quads. Table 39 and Figure 47 show the effects of various combinations of the above actions and the effect of low U.S. supplies of oil and natural gas resources on oil import requirements.

A combination of all the above factors--vigorous U.S. supply development, strong conservation, and fuel shifts--would result in a halving of the import needs by 1985 from 1972 levels and in nearly zero imports by 2000. A more modest scenario, incorporating moderate conservation, fuel shifts, and an intermediate level of liquid fuel supplies, results in import requirements for 1985 and 2000 still at approximately the 1972 level. Clearly, a significant reduction in the level of imports, if it is deemed desirable and if

Table 39

REGIONAL OIL AND LNG IMPORT REQUIREMENTS UNDER VARIOUS ASSUMPTIONS

REGARDING REGIONAL DEMANDS AND U.S. SUPPLIES

(10¹⁵ Btu/year crude oil equivalent)

(1972 level of oil imports = 6.45)

<u>Demand Assumptions</u>	<u>Supply Assumptions</u>				
	High U.S. oil & N.G. supplies	Int. U.S. oil & N.G. supplies		Low U.S. oil & N.G. supplies	
	<u>Oil</u>	<u>Oil</u>	<u>LNG</u>	<u>Oil</u>	<u>LNG</u>
<u>1985</u>					
Base case	6.8*	7.7*		7.8	0.9
Base level, fuel shifts	5.9*	6.8*	0.4	6.9	1.3**
Moderate conservation	5.3	6.2		6.7	0.8
Moderate conservation, fuel shifts	4.5	5.4		5.9	1.0
Strong conservation, fuel shifts	3.7	4.6		5.1	0.8
<u>2000</u>					
Base case	8.0*	12.0*		12.7	1.0
Base level, fuel shifts	5.3*	9.3*	0.5	10.0	2.5**
Moderate conservation	5.0	8.8		10.2	1.5
Moderate conservation, fuel shifts	2.6	6.4		7.8	1.5
Strong conservation, fuel shifts	0.5	4.3		5.7	1.0

*In these scenarios, 1.4 quads oil are used to produce electricity in 1985 and 0.7 quads in 2000. In all other scenarios, these amounts are 1.0 quads and 0 quads respectively. At a given resource supply level, the oil used to produce electricity is assumed to reduce the liquid supply by an equivalent Btu amount. Thus the higher level of electricity generation using oil in these scenarios results in higher import requirements.

**This level of imports exceeds the high-LNG supply projection.

Figure 47. Imported oil going to the Northeast (intermediate domestic supplies assumed except as indicated).

it is to be achieved in a voluntary and orderly manner, can be brought about only through early, concerted action at both the Federal and the local level.

4. Offshore Oil and Gas

Estimates of the quantities of crude oil and natural gas recoverable from fields in the Atlantic Outer Continental Shelf are highly speculative because of the limited amount of exploratory drilling to date. USGS resource estimates²⁷ suggest that in 2000 the maximum likely production rates would be about 0.86 quads/year of oil and 0.56 quads/year of gas. The sum of these, 1.4 quads/year, amounts to 6% of the total fuels required for the region in 2000 in the reference scenario, but the OCS gas amounts to 20% of the total gas required. (See Table 40.) If this production rate were achieved and the gas were consumed totally

Table 40

IMPACT OF OFFSHORE OIL AND GAS (10^{15} Btu) IN THE NORTHEAST⁹

	<u>Oil (% of demand)</u>	<u>Gas (% of demand)</u>
Total recoverable resources	12-24	5-14
Fuel supply to Northeast in 2000*		
High	0.86(6)	0.56(20)
Intermediate	0.52(4)	0.34(12)
Low	0	0

*Average annual production assuming 20-year field life. High, intermediate, and low cases derived from high, average, and low estimates of resource base (high case assumes 80% of fuel goes to Northeast; intermediate case, 67%). Demand refers to liquid and gas fuel requirements as given in reference scenario.

in the Northeast, the offshore resources could provide a substantial fraction of the region's gas needs for two to three decades.

5. Nuclear Curtailment

In our low nuclear supply case we assume that no new construction is initiated after 1977 but that plants in operation or under construction at that time are unaffected. This would freeze the energy supplied by nuclear power to a level of 2.2 quads/year (thermal input to power plants--equivalent to 0.66 quads of electrical energy generated). In the absence of curtailment, nuclear power is projected to supply 6.5 quads in 2000 in the reference scenario. If coal alone were employed to make up the reduction in use of nuclear resources, the coal requirements in 2000 would be 60% above the intermediate regional coal supply

projection. Although still below the high coal supply projections, such a level of usage represents a very substantial departure from the reference scenario.

The effects of nuclear curtailment on the requirements for other resources would be considerably alleviated if the moderate-conservation program were followed. With moderate-conservation demand levels, nuclear power would provide 4.5 quads/year in 2000 without curtailment. The decrease to 2.2 quads/year under curtailment could be compensated for by the use of coal, raising the required regional coal supply levels to about 20% over the intermediate-supply level. Alternatively, moderate conservation coupled with vigorous implementation of wind power development and waste conversion to electricity could completely compensate for the decreased nuclear output so that no increase in coal use would be required.

Not all the possible substitutes for nuclear power have been examined. In particular, imports or coal synthetics could be used to compensate at least in part for a reduction in the use of nuclear fuel. However, the use of these resources would require even more imports or the production of synthetics at levels significantly higher than assumed in the reference scenario. If the substitutes for nuclear power are more expensive, the total cost to the region could be very high in terms both of the prices paid for electricity and of reduced economic growth.

6. New Resource Technologies

Three new energy resource technologies can play a role in the Northeast by 2000: solar energy for heating and cooling; wind power; and waste conversion to electricity and gas.*

*Coal liquefaction and gasification are treated as conversion technologies and were discussed in Section V.B.5.

No major technological barrier hinders the use of any of these technologies, but all are affected by institutional and other constraints.

The conversion of wastes is economically competitive today under some circumstances, but this resource is limited to a relatively minor role (approximately 0.2 quads of electricity and 0.02 quads of gas) because of the limited availability and collection of wastes.

While the use of solar energy for space conditioning is not now economically competitive in the Northeast, solar water heating systems are an attractive option in many cases for the new home builder. It is unlikely that the retrofitting of existing residential structures with solar systems will ever become economically justified on a large scale, but policy initiatives in the tax, regulatory, and financing areas could significantly alter the relative economics of solar space conditioning in new dwellings. The most rapid rate of introduction of solar systems assumed in this study is incorporated in the strong-conservation demand projection, in which it is assumed that solar systems would supply 25% of the total energy required for space heating and 70% of that for water heating in buildings constructed after 1985. This would result in a 20% reduction by 2000 in conventional fuel requirements in the residential and commercial sector (equivalent to 6% of the total projected fuel requirements in all sectors).

Wind power is the only new resource technology* that could contribute significantly to the fuel supply of the Northeast by 2000 (solar energy used for space conditioning does not add directly to the fuel supply). Wind energy is abundant, and the technology

*Coal liquefaction and gasification are treated as conversion technologies and were discussed in Section V.B.5.

required to build wind turbines does not require significant development. On the other hand, the economic competitiveness of wind power in electric utility applications is still uncertain, and public reaction to the visual impact of windmills could affect the level of wind power use by limiting available sites.

In the high wind power projection constructed for this study, it was assumed that wind power would provide 0.5 quad/year of electricity in 2000, which is 15 to 20% of the demand. This level of wind power use would displace about 1.5 quads/year of nuclear or fossil energy (thermal input) required to generate electricity, which amounts to about 5% of the resource requirements in the reference scenario. The production of 0.5 quad/year of electricity would require about 25,000 windmills of 1.5-MW rated capacity, each with storage facilities and/or backup capacity to supply power during periods when winds were low and electricity demands high.

7. Constraints on U.S. Resources

Constraints on the supply of U.S. oil and natural gas to the Northeast, reflecting a combination of lower than expected discoveries and a lower fractional allocation of the total U.S. production to the Northeast as defined in our low-supply projections, could halve the total supplies of these resources to the region in 2000. The future supply of natural gas is especially unclear because of uncertainties in the regulatory area, in price-supply relationships, and in the regional distribution of the U.S. natural gas supply. In the low-supply case, natural gas supply to the region drops from its current level of 2.3 quads/year to 0.3 quad in 2000. The supply constraints on oil and natural gas coupled to those arising from nuclear curtailment would result in a 23% decrease (7.3 quads) in resources available to the Northeast compared with the year 2000 reference scenario.

With base-level demands, this reduction of resources could be compensated for on the supply side by a doubling of the total U.S. coal resources used to supply energy to the Northeast by 2000 (primarily in the form of liquids and gases produced in coal conversion plants outside the region). It is considered unlikely that such coal and coal synthetics supply levels could be achieved. With moderate conservation and fuel shifts, the coal resource requirements would still be 70% above those in the reference scenario.

A strong-conservation and fuel-shift program would reduce the need for additional coal to a level about 30% over that of the reference scenario and would require no increase in imported energy from current levels through 2000.* If, in addition, wind and waste resources were introduced, no increase in coal use over that of the reference scenario would be required. This latter scenario--strong conservation, fuel shifts with supply constraints, and use of wind and waste--allows the postulated supply constraints to be accommodated with no increases in total import levels to 2000 and with the reference level coal supply projection.

Although constraints on the supply and utilization of coal in the Northeast could arise from a number of factors, they appear considerably less likely in the long run than constraints on the supplies of oil, gas, and nuclear resources. This is due in part to the variety of options available at every stage of the coal extraction, transportation, and conversion process. The U.S. coal resource base can easily support the highest production rates assumed in this study, and the resources are sufficiently widely dispersed geographically that problems associated with production

*It is likely that about 1 quad of the imports in 2000 would have to be in the form of LNG because of the rapid decline of U.S. natural gas supplies to the region.

in any one region should not, in the long run, substantially curtail national production levels. Currently, coal can be mined by either underground or surface techniques, and in situ gasification might provide a third option in the future. Coal can either be used directly by final consumers or converted into electricity, into high, intermediate, or low-Btu gas, or into a synthetic liquid such as methanol or synthetic crude for easier transmission and consumption. The flexibility in supply due to these options suggests that, in the long run, coal will rank as one of the more reliable energy resources available to the Northeast. Note, however, that environmental and health problems, although unrelated to the issue of supply reliability, could limit the use of coal in the region unless satisfactory technological solutions are devised and implemented. (See Section VII.C.)

8. Low-Btu Gas

The production of low-Btu (or intermediate-Btu) gas from coal within the Northeast would help reduce the region's reliance on scarce oil and natural gas resources. The high projection for low-Btu gas production in the Northeast incorporated in this study assumes that 1 quad/year would be produced by 2000. Coupling this high projection for low-Btu gas with the fuel-shift demand projection permits a shift of 1 quad of fuel demand away from liquids and results in a like reduction in oil import requirements.

The transmission of low-Btu gas over long distances is very costly because it requires a distribution network separate from high Btu gas. Thus, it is likely that low-Btu gas would be first introduced into large industrial or commercial centers where a single conversion plant could supply a relatively small number of large consumers through a short distribution network.

This augmentation of scarce natural gas and vulnerable liquid fuel supplies with locally produced low-Btu gas has received very little attention. The 1-quad/year high projection for 2000 used in this study (based on estimates derived from models of the national energy system) is not necessarily an upper bound on the supply. The potential benefits of this conversion process to the region, including a lower cost fuel than is likely to result from other coal or shale conversion processes, indicates that this conversion process deserves more serious study.

D. Final Conclusions

Unless concerted action is taken at both the Federal and State levels, the energy future of the Northeast will remain precarious. There are no panaceas: no single technology, no single conservation strategy goes very far toward reducing the region's dependence on foreign oil. The creation of an acceptable energy system for the region will require efforts in many directions in terms both of reducing demand and of developing a reliable and diversified supply.

The energy-related problems of the states in the Northeast have many common features. Collaboration among the states would increase the effectiveness of actions taken at the State level and help in focusing Federal efforts on the problems of greatest interest to the region.

E. Future Analysis

During the course of this study and through discussions of its conclusions with State and Federal energy planners it has become clear that an important function can be served by regional energy policy analysis. We consider this study as the first stage of a continuing development of increasingly sophisticated data, models, and policy analyses. The study has served to indicate

a number of ways in which the state-of-the-art of regional energy analysis requires improvement.

In this work we have emphasized large issues of energy supply and demand in the region, and the scenario approach developed for the study proved to be well designed to address these issues. In future work this approach will be extended in three areas:

(1) Models and data will be assembled to deal with economic issues in more detail than has been possible in this work. The relationship between fuel costs and supply and demand for those fuels will be incorporated into the analytical structure, as will regional economic and employment effects. (2) Health and environmental impacts will be dealt with in more detail and depth. (3) To make the analyses easier to interpret by State policy makers, the data and results of analyses will be disaggregated to the State level. The primary scale of analysis, however, will remain regional; this study has convinced us that regional analysis is a key to better energy decisions at both the State and the Federal level.

VII. OTHER CONSIDERATIONS

A. Introduction

As already pointed out, we have taken a broad perspective on the energy future of the Northeast but have addressed only a limited range of issues. In particular, not all the economic linkages between the various parts of the energy system, nor all the regional economic impacts, have been systematically incorporated into the analysis. Health and environmental impacts, although considered important, have not been an integral part of the study, but emissions to air and water from both area and point sources have been calculated for each scenario (See Appendix A).

To avoid the impression that we consider them unimportant, we review here some of the economic and environmental factors pertinent to the region and the results of some preliminary calculations of their effects. Although the period of the study extends only to 2000, we discuss briefly some implications for the Northeast's energy system beyond that time.

B. Regional Economic Considerations

The ultimate objectives of regional economic policy are improvements in individual welfare, opportunity, equity, and social harmony. Historically, this policy has been directed toward promoting increased per capita real incomes, full employment, a wide choice of kinds of work and life-styles for the individual, the minimization of external cyclical impacts (income security), and the reduction of income inequality. Recent events in regional energy markets have forced policy makers to add new objectives: they must now formulate policies to minimize the dislocation effects of these events, incorporating the energy

price and quantity implications inherent in the more traditional goals.

The Northeastern United States is a mature industrial and primarily urban region afflicted by relatively slow growth. The region's rate of growth has been below the national average for a decade in spite of its relatively high per capita real income. Unemployment is high and chronic, especially in urban areas. Outmigration of capital and skilled labor is heavy. The region has recently experienced a rapid deterioration in its interregional terms of trade with an adverse impact on its ability to compete with other regions. Also, the regional economy relies heavily on certain activities that have themselves slowed or ceased in growth. The massive inward migration of productive factors has left its mark. The diseconomies of past growth are manifest in the impairment of the quality of services, the destruction of local resources and amenities through overuse, and the obsolescence of facilities, neighborhoods, and institutions. The region has lost the dynamic growth characteristics that brought it to its historical peak of importance. Reversing this situation through analytical foresight and advance planning poses a major challenge to regional policy makers.

In assessing the response of the region to its new circumstances, several considerations emerge. One that is extremely important to regional authorities is the employment intensity associated with both energy and non-energy development strategies. Attention must be focused on both the price and the supply potential of new energy technologies and sources related to the strategies. This means finding the largest increment to energy supplies for the smallest increment to consumer costs.*

*External (e.g., health) costs must be included in the overall cost accounting. This is discussed below in Section C.

Any substitute for imports must be relatively inexpensive (while contributing substantially to the region's energy system) to minimize any future deterioration in the interregional terms of trade. However, supply is only one side of the energy issue. The Northeast must also be concerned with the price and demand reduction potential of conservation strategies. Policy must be developed so as to tread a fine line, maximizing conservation potential while minimizing deviations from targeted measures of regional economic welfare. Actions that conserve energy may have an adverse impact on income, employment, diversity, security, and equity.

The above economic considerations cannot be addressed independently: virtually no policy adopted to alleviate one problem will be neutral with respect to some other problem. For example, a policy formulated to attract new industries to the region will place additional pressures on the region's energy system. Attempts to attract less energy-intensive activities may have only a limited impact on unemployment. Similarly, the energy alternatives with least cost and largest supply potential for the region may generate the fewest employment opportunities and the most environmental degradation. The dilemma confronting regional decision makers stems from such complex interdependencies and trade-offs.

1. Implications of a Conservation Policy

The various scenarios for the future evolution of the energy system of the Northeast invoked a wide variety of possible policy and technological developments. It is convenient to distinguish two categories of such developments: those oriented toward increasing supplies, such as coal gasification and OCS resource development, and those oriented toward improving the efficiency of energy utilization, such as increased appliance efficiencies

and better insulation practices. A recent BNL study, summarized in Appendix B, indicates that there may be substantial differences between these two categories of programs in terms of national benefits measured by the reduction in consumer expenditures for energy. The programs with the largest benefits (discounted to the present over a projected implementation schedule) are those aimed at the improvement of residential, commercial, and industrial end-use efficiencies, the delivery of total energy systems to the residential and commercial sectors, and improvement of auto propulsion systems--the conservation or end-use technologies and policies.

The advantage of stressing improvements in end-use technologies is even more apparent in the Northeast, where regional employment considerations must be added to the criteria of choice. Conservation or demand-oriented strategies are among the most employment-intensive energy alternatives and, more importantly, can be used directly to eliminate regional unemployment. It is easier to train or retrain unemployed residents for traditional production activities than to provide them with the skills needed for many of the supply "fixes" currently being discussed. For the Northeast, many of these new supply technologies imply the importation of labor, which certainly would not alleviate the employment problems of the region.

Since conservation strategies are also the least destructive to the interregional terms of trade, the Northeast could continue to grow in spite of the relatively high marginal price it pays for energy. If the employment effects of such policies are realized and the trade effects are negligible, then the real price of conservation is minimal. Furthermore, as conservation policy options can be implemented via existing policy instruments, the administrative price of conservation is also minimized.

Distinct benefits can be gained from regional collaboration in approaching these strategies. For example, common standards for construction and for appliance performance would allow the region's manufacturing enterprises to invest in modifications in products and processes with the assurance of a substantial market.

C. Health and Environmental Impacts*

This study has focused primarily on future energy supply-demand balances in the Northeast. Although health and environmental impacts are a major concern in the Regional Energy Studies Program, they were not emphasized in this particular study. A number of the key scenarios discussed in Section VI were, however, examined to get an idea of the general level of health and environmental impacts and the degree to which they differed among scenarios. The results are reported elsewhere³⁵ and briefly summarized here.

1. Emission Factors

To link a particular scenario with a set of effects, one must first define the amount of various pollutants (or, more generally, residuals) discharged to the environment as a result of the activities carried on in the so-called energy sector. We have focused our attention on five air pollutants--sulfur oxides (SO_x), nitrogen oxides (NO_x), particulates, hydrocarbons (HC), and carbon monoxide (CO) --that result from fossil combustion; radiation doses to the population due to nuclear power plants; land use; and water consumption. Sources of pollutants were classified as either point sources (large electric utility and industrial plants) or dispersed sources

*This section is based on a report by L.D. Hamilton et al.³⁵

(transportation, residential and commercial heating, etc.). Calculation of emission coefficients (amounts of pollutants released per unit of energy going into the process) were based mostly on data in the BNL Energy Model Data Base.³⁶

For oil-fired steam electric plants it was assumed that the average sulfur content of the residual oil currently used in the region (0.64%) would prevail through 2000. The sulfur content of coal in the Northeast was projected to decrease from 2% in 1972 to 1.65% in 1985 and finally to 1.4% in 2000, but no other sulfur oxide control was assumed. Particulate emissions from controlled and from uncontrolled facilities differ; therefore, a new coefficient was needed for each reference year based on an assumed ratio of controlled to uncontrolled facilities in operation. For this study, the fraction of uncontrolled power plants was assumed to be 0.775 in 1972, 0.350 in 1985, and 0.00 in 2000. It was further assumed that combined-cycle facilities produce the same emissions as comparable oil or coal steam electric plants. The emission factors used are given in Table 41.

Table 41

EMISSION FACTORS (Tons/10 ¹² Btu) FOR ELECTRICITY GENERATION						
<u>Fuel</u>	<u>Year</u>	<u>SO_x</u>	<u>NO_x</u>	<u>Part.</u>	<u>HC</u>	<u>CO</u>
Oil	all	340	357	27.2	6.81	0.138
Coal	1972	1450	343	63.5	5.72	19.1
Coal	1985	1190	343	39.2	5.72	19.1
Coal	2000	1020	343	19.2	5.72	19.1

Separate calculations were made for emissions associated with industrial energy use for heat and power. Improvements were assumed in particulate control in coal burning (from 50%

in 1972 to 99% in 2000) and in the sulfur content of coal used (from 2% in 1972 to 1.4% in 2000). The results are shown in Table 42. Emission factors for the residential and commercial sector are given in Table 43.

Emission factors for the transportation sector were based on analyses of model-year mix and Federal standards³⁵ (see Table 44).

These various emission factors were combined with the levels of the pertinent energy-related activities to produce the total emissions shown in Appendix A for each scenario. These total emission levels were used as a starting point for our analysis of the health and environmental implications of the scenarios.

2. Health Effects of Air Pollution

Toxicological, clinical, and epidemiological studies all indicate that air pollution damages health. How much emissions from a smokestack in Ohio raise the death rate in New York City can now be calculated, but a great deal of uncertainty remains concerning the precise effects of air pollution on health, particularly as the mix of pollutants changes with time and distance from the source. Nevertheless, reasonable estimates can now be made of expected health consequences of relatively small changes in sulfur or particulate air pollution levels. The current hypothesis is that these damages are due to acid aerosols. Sulfur or particulate levels are often used as indices of health effects, but there is no certainty that the effects result solely from those pollutants. Contributing injury by other pollutants is possible--perhaps likely. Relations between health damage and nitrogen oxides, hydrocarbons, ozone, and low levels of carbon monoxide (aside from eye irritation, headache, and changes in respiratory function) are much less certain, as can be seen from recent reports.^{37,38}

Table 42

EMISSION FACTORS (Tons/10¹² Btu) FOR INDUSTRIAL ENERGY USE

<u>Fuel</u>	<u>Year</u>	<u>SO_x</u>	<u>NO_x</u>	<u>Part.</u>	<u>HC</u>	<u>CO</u>
Residual oil	all	655.0	200.0	76.8	10.0	13.4
Distillate oil	all	51.1	216.0	54.0	10.8	14.4
Natural gas	all	0.291	84.9	8.73	1.46	8.25
Coal	1972	1450.0	287.0	1240.0	19.1	38.2
	1985	1200.0	287.0	248.0	19.1	38.2
	2000	1020.0	287.0	24.8	19.1	38.2
Coke	all	195.0	0.78	10.2	82.1	27.4

Table 43

EMISSION FACTORS (Tons/10¹² Btu) FOR RESIDENTIAL AND COMMERCIAL
ENERGY USE

<u>Sector</u>	<u>Fuel</u>	<u>Activity</u>	<u>SO_x</u>	<u>NO_x</u>	<u>Part.</u>	<u>HC</u>	<u>CO</u>
Resid.	Dist. oil	Space heat	-	43.2	36.0	10.8	18.0
		Water heat					
Comm.	Dist. oil	Space heat	114.0	217.0	54.1	10.8	72.2
Comm.	Resid. oil	Space heat	894.0	201.0	76.9	10.0	0.671
Resid.	Nat. gas	Space heat	0.276	24.2	9.20	3.89	9.68
Resid.	Nat. gas	Water heat	0.292	26.7	9.22	3.89	9.70
Comm.	Nat. gas	Space heat	0.284	48.8	9.21	3.88	9.72
Comm.	Nat. gas	Water heat	0.284	53.4	9.21	3.88	9.71
		Air-cond.					

Table 44

EMISSION FACTORS (Tons/10¹² Btu) FOR THE TRANSPORTATION
SECTOR

<u>Mode</u>	<u>Year</u>	<u>SO_x</u>	<u>NO_x</u>	<u>Part</u>	<u>HC</u>	<u>CO</u>
Auto gas	1972	15.0	810	62.0	1170	9670
	1985	15.0	75.0	62.0	54.4	470
	2000	15.0	45.5	62.0	47.0	390
Truck & bus gas all		15.0	810	62.0	530	5390
All diesel	all	103	1410	49.6	141	860

For this study we used a single measure of health impact: excess deaths. It is reasonable to assume that morbidity, i.e., the incidence of various illnesses, is correspondingly increased. We assumed linear dose-effect relationships for sulfur and particulate pollutants. Although it is likely that exposure to multiple pollutants produces synergistic results, and that nonlinear functions and/or thresholds may apply, a linear approximation is reasonable where changes in pollution levels are relatively small.

In considering the health effects of the various scenarios, we distinguished between dispersed and point emission sources because population exposure is not necessarily directly proportional to emissions. A pound of CO emitted from an automobile in New York City, for example, has a much higher probability of being inhaled than a pound of CO emitted from a Con Edison stack. To take this effect into account we introduced an arbitrary factor of 0.4--our best judgement--to reduce the contribution of point-source emissions to population exposure.* The results with this

*Since our analysis is concerned primarily with differences between time periods and scenarios, this factor is important only if the ratio of point to area sources differs substantially between cases.

approach are in reasonable agreement with those of earlier studies in which the population exposures were determined more explicitly. This lends some confidence to the arbitrary way in which population exposure was determined here.

Table 45 summarizes the results of our analysis. What is the significance of these results? It is of primary importance to recognize the various uncertainties in this type of calculation. Technological changes in combustion equipment or pollution control equipment may change emission factors*; an extremely simplified model was used to estimate population exposure from emission factors; and the dose-response function was drawn from observed data and was possibly influenced by synergistic effects of other pollutants or by other factors. Given these multiple sources of error, the 90% confidence interval on the estimates probably extends at least a factor of 2 lower and higher than the estimates given.

Nevertheless, if the results of the analysis are indeed within a factor of two of the true values, then two things are clear. First, the level of energy use can have a significant effect on mortality in the region. Second, this effect will depend strongly on the type of energy system in existence. Scenarios in which demand is reduced (such as cases 2, 5, and 6) are much more benign than those in which supplies, particularly coal, are increased (such as case 3). Thus, health impacts, placed in the context of all other costs of energy systems, are important considerations in regional and state planning of the Northeast energy system.

3. Health Impacts of Nuclear Power Plants

The expected increase in cancers due to routine releases from nuclear power plants was calculated for each of the six

*Note that we assumed a reduction in the sulfur content of coal burned in the region but not widespread use of flue-gas desulfurization.

scenarios assuming a population dose per power plant equivalent to that existing today. The best estimates of the total number of deaths from cancer due to such exposure through the year 2000 range from 1 to 5 for all scenarios analyzed; at the upper limit of the range of error in these estimates, this number is higher by a factor of 10. Inclusion of the risk of reactor accidents does not significantly raise these estimates.

4. Environmental Considerations

Since most of the energy used in the Northeast is imported, many of the environmental impacts usually associated with the energy supply system are borne outside the region. The impacts within the region are difficult to review because of their variety and their local nature. Two aggregate impacts that can be analyzed, however, are the amount of land use and the amount of water use.

We treated the same six cases defined in Table 45. The amount of land and water used in extraction, transport, and conversion of all fuels, including synthetic natural gas, was divided between the region, the rest of the U.S., and foreign countries. The detailed assumptions are given by Hamilton et al.³⁵ Table 46 summarizes the results of the analysis for the U.S. and the Northeast.

The highest impacts were associated with case 4 (base-level demands with shift to electric and gas). Since the bulk of land use is in transmission-line corridors, a shift to electricity drives up overall land use of the entire fuel cycle. Similarly, since the largest single use of water is for cooling in power plants,* water use is greatest in a high-electric scenario.

*Only the water evaporated is considered to be used.

Table 45

SUMMARY OF HEALTH EFFECTS OF SULFUR AND PARTICULATE POLLUTANTS³⁵

Case	Year	Change in mortality from 1972 ^a	Annual excess death ^a	Annual excess deaths (relative to base)
1. Reference case: base demands-modest supplies	1985 2000	0.3 2.9	1,700 18,000	- -
2. Moderate conservation, shift to electric and gas-modest supplies	1985 2000	-0.9 -1.2	-5,100 7,600	-6,800 -25,600
3. Base demands--nuclear curtailment, substitute coal	1985 2000	0.8 5.3	4,500 34,000	2,800 16,000
4. Base demand, shift to electric and gas--modest supplies	1985 2000	-0.4 0.7	-2,300 4,400	-4,000 22,400
5. Moderate conservation--modest supplies	1985 2000	-0.4 -1.2	-2,300 -7,600	-4,000 -10,000
6. Strong conservation--shifts to electric and gas--modest supplies	1985 2000	-1.4 -2.6	-7,900 -16,000	-9,600 -34,000

^a Assumes base annual mortality rate = $9.2/10^3$; 1985 population = 61.4×10^6 ; 2000 population = 68.8×10^6 .

Table 46

LAND AND WATER USE FOR SCENARIOS

Year	Case (defined in Table 45)	Land use (10 ³ acres)		Water consumption (10 ³ acre-ft)	
		Northeast	U.S.	Northeast	U.S.
1972		1059	445	876	210
1985	1	1749	533	1582	276
2000	1	3167	711	2682	534
	2	2886	837	2582	844
	3	3436	755	2900	190
	4	3758	269	3291	444
	5	2579	599	2510	190
	6	2533	504	2191	763

The second highest impacts were found in case 3 (nuclear curtailment with substitute coal). Here, the electricity generation capacity did not rise as rapidly as in the high-electric scenario, and the increased coal production added relatively little to the overall land and water impacts.

Case 6 (strong conservation with shift to electric and gas--modest supplies) proved to be the most benign. Yet even here the regional impacts in terms of both land and water use more than doubled by 2000 in spite of the total energy consumption rising by only a factor of 1.25. The reason, again, is the substitution of electricity for direct use of fuel.

The amount of land and water used gives but a scanty idea of total impact. Some of the related environmental effects that are less easily quantified but of major concern to the Northeast should be mentioned.

Water-related impacts of energy production will be due primarily to coal extraction and offshore oil activities. The former requires nonconsumptive use of water, e.g., for washing of coal. Although environmental impacts from discharged water can be minimized by treatment to remove dissolved and suspended solids, serious problems remain due to acid mine drainage and solid loadings in runoff from the mining site. The latter can be mitigated by treatment in accordance with Federal and State requirements.

The environmental impacts of offshore oil production are of greater concern because of the size and scope of potential harm. Oil spills can often be detected only after significant leakage, e.g., after blowouts or structural failures. Techniques for stopping the discharge are slow. Thus large amounts of oil can enter the aquatic environment.³⁹ Furthermore, containment is far

more difficult than on land. The perturbations due to toxic hydrocarbons, many of them poorly understood, would affect the entire food chain, from microorganisms through phytoplankton, zooplankton, fish, and man. Containment of an oil slick or the cleaning of a polluted shore can mitigate short-term effects; but impacted benthic communities require very long periods to readjust as petroleum hydrocarbons concentrate and persist in marine sediments.

The transportation of fuels, both raw materials and finished products, will require more and larger barges and tankers, and this will necessitate improvements to waterways and harbors, including channelization and dredging, with accompanying solids loadings impacting the aquatic ecosystem. Fish habitats (spawning and feeding grounds) may be temporarily or permanently damaged, and shifts in species composition and diversity may ensue for all elements of the food chain. Oil spills from normal tanker and pipeline transfer operations, as well as from accidents such as releases from pipelines ruptured by towed anchors or from damaged tankers, will have the same effects as those described above for offshore leakage.

Transmission-line corridors require extensive land clearing, which has three impacts on water: (1) changes in local hydrology may result from construction of the corridors, (2) herbicides applied to maintain the corridors may enter waterways via runoff, and (3) the removal of vegetation may cause increased erosion.

Of special concern are the potential, although improbable, impacts of transporting nuclear fuels and wastes. Contamination of ground and surface water by accidental release of radioactive substances from ruptured containers, for example, would pose considerable containment and treatment problems. Environmental impacts could span the gamut of the biosphere.

Environmental impacts outside the region, but associated with a particular scenario, have a bearing on the probability that that scenario will materialize. For example, a Project Independence report⁴³ indicated that recovery of oil from shale at a production level of about 10^6 bbl/day (lower than in our high case) would fully commit the surface waters of the State of Colorado, and that production of only thousands of bbl/day would result in significant lowering of that state's groundwater resources. Coal gasification also requires the use of large amounts of water. The Northeast should be aware of the environmental impacts of alternative energy futures, not only within the region, but also elsewhere, and it should have regard for how those impacts are viewed by the citizens and governments of the affected states.

D. Beyond the Year 2000

The time period of this study ends in the year 2000. From the perspective of achieving innovation in the energy system, 2000 is just around the corner. For nuclear power, more than 30 years passed from the time its technical feasibility was proved until it contributed more than 1% of the country's energy. Although it may be asking too much of the political system to concentrate any attention on an era more than 25 years away, energy planning in the Nation and the region should not neglect the next century--in which most children born today will spend the larger part of their lives.

What does this study indicate about the post-2000 period? Many of the trends identified in the 1985-2000 period will accelerate after 2000. The most striking is shown in Figures 26 and 28: by 2000 our use of domestic oil and gas will be phasing out rapidly. The level of coal use may also reach limiting conditions

because of the effects both of mining it and of burning it.

In spite of future fuel shifts, the region will still require substantial amounts of imported oil (only one of the scenarios in Section VI projected a decrease in the level of imported oil use in the Northeast in 2000). However, for the Northeast to be able to import this oil, the oil-exporting countries will have to continue their present policy of not severely restricting the level of petroleum exports. Such a presumption should be the subject of some concern. Some of these countries have already announced national policies which would, if successful, capture a substantial fraction of the industrial activities associated with petroleum use as an energy fuel and as an essential feedstock for a variety of petrochemical products.

It appears, therefore, that an acceptable post-2000 energy future will have to depend in part on the successful development of a number of new technologies. Some of these have not yet advanced beyond the research state. Solar-generated electricity, fusion, and hot-rock geothermal energy will probably not be ready to enter the commercial market by the end of the century. Others, such as advanced synthetic fuel production from coal, wind power, and solar heating and cooling, can be expected to be in various stages and implementation by then. The necessary and much increased role of the new technologies beyond 2000 suggests that the region should give serious thought, and this is an area in which collective thought is particularly apt, to the priorities of the Federal energy research and development budget. It is that budget, perhaps more than anything else, that will create the energy choices available to the region beyond 2000.

APPENDIX A. SCENARIOS

List of Scenarios

<u>Number</u>	<u>Subject</u>	<u>Demands</u>	<u>Supplies</u>
1	Reference case	Base	Modest*
2	Fuel shifts	Base, fuel shifts	Modest
3	Conservation	Moderate conservation	Modest
4	Conservation	Moderate conservation, fuel shifts	Modest
5	Conservation	Strong conservation fuel shifts	Modest
6	Import reduction	Base	Highest U.S. liquid supplies
7	Import reduction	Moderate conservation, fuel shifts	Highest U.S. liquid supplies
8	Nuclear curtailment	Base	Nuclear curtailment, substitute coal
9	Nuclear curtailment	Base	Nuclear curtailment, substitute coal, wind and waste
10	Nuclear curtailment	Moderate conservation	Nuclear curtailment, substitute wind and waste
11	Supply constraints	Moderate conservation, fuel shifts	Low U.S. oil and natural gas, nuclear curtailment
12	Supply constraints	Strong conservation, fuel shifts	Low U.S. oil and natural gas, nuclear curtailment
13	Supply constraints	Strong conservation, fuel shifts	Low U.S. oil and natural gas, nuclear curtailment, substitute wind and waste

*Modest indicates that all resource projections are at the intermediate level or less.

Scenario 1

REFERENCE SCENARIO (BASE DEMANDS -- MODEST SUPPLIES)

SUPPLY SECTOR CHOICES		
1	COALL1	COAL LOW -- LOW ELECTRICITY, LOW LO-BTU GAS
4	COALI2	COAL INTERMEDIATE -- INTER. ELECTRICITY, LOW LO-BTU GAS
8	SYNLQ1	SYNTHETIC LIQUIDS FROM COAL LOW
11	SYNGS1	SYNTHETIC HI-BTU GAS FROM COAL INTERMEDIATE
18	OILIN2	OIL INTERMEDIATE -- INTERMEDIATE ELECTRICITY
24	NGREG1	NATURAL GAS, INTERMEDIATE REGIONAL SUPPLY
27	NGDOM1	NATURAL GAS, INTERMEDIATE DOMESTIC SUPPLY
33	NUCIN1	NUCLEAR BASE CASE
34	NUCLO1	NUCLEAR CURTAILMENT -- NO PLANTS CONSTRUCTED AFTER 1977
35	HYDRO1	HYDROELECTRICITY.

DEMAND SECTOR CHOICES		
39	R&CHI1	RESIDENTIAL AND COMMERCIAL -- BASE CASE
50	TRNH11	TRANSPORTATION -- BASE CASE
56	INDHI1	INDUSTRIAL HIGH -- BASE CASE

NOTE COMBINATION OF SUPPLY PROJECTIONS

50.0% OF COALL1(1) PLUS 50.0% OF COALI2(4)
60.0% OF NUCIN1(33) PLUS 40.0% OF NUCLO1(34)

--REGIONAL ENERGY CONSUMPTION-- (QUADRILLION BTU'S)

	---YEAR---		
	1972	1985	2000
FUELS REQUIRED			
LIQUIDS	7.71	9.73	14.53
GAS	2.30	2.48	2.78
ELECTRICITY	1.09	1.88	3.32
COAL (DIRECT USE ONLY)	1.22	1.43	1.84
TOTAL	12.32	15.51	22.47
U.S. RESOURCES REQUIRED			
CRUDE OIL	4.05	4.48	3.66
NATURAL GAS	2.38	2.40	1.39
COAL	2.51	3.39	8.02
NUCLEAR (THERMAL INPUT)	.23	2.45	6.51
HYDRO, WIND, WASTE	.13	.13	.13
SHALE OIL	0.00	0.00	0.00
IMPORTS			
OIL (CRUDE EQUIVALENT)	6.45	7.71	11.95
LIQUIFIED GAS	0.00	0.00	0.00
TOTAL RESOURCES REQUIRED	15.75	20.55	31.66

--POLLUTANT EMISSIONS-- (MILLION TONS)

DISPERSED EMISSIONS			
PARTICULATES	.32	.38	.53
NITROGEN OXIDES	2.87	1.59	2.19
SULFUR OXIDES	.86	1.11	1.87
HYDROCARBONS	2.94	.50	.65
CARBON MONOXIDE	24.39	4.29	5.63
POINT-SOURCE EMISSIONS			
PARTICULATES	.57	.32	.23
NITROGEN OXIDES	1.41	1.59	1.87
SULFUR OXIDES	3.53	3.99	4.71
HYDROCARBONS	.10	.12	.15
CARBON MONOXIDE	.07	.10	.14

FUEL USE BY SECTOR -- YEAR 2000

	LIQUIDS	GAS	ELECTRIC	COAL	TOTAL
RES. & COM.	4.31	1.34	2.44	0.00	8.09
TRANSPORTATION	6.62	0.00	.02	0.00	6.64
INDUSTRIAL	3.60	1.44	.86	1.84	7.73

Figure A-1. Reference scenario (base demands -- modest supplies).

Scenario 2

BASE LEVEL DEMANDS, FUEL SHIFT ELEC & GAS -- MODEST SUPPLIES

SUPPLY SECTOR CHOICES		
3	COAL11	COAL INTERMEDIATE -- LOW ELECTRICITY, HIGH LO-BTU GAS
5	COAL13	COAL INTERMEDIATE -- INTER. ELECTRICITY, HI LO-BTU GAS
8	SYNL0L	SYNTHETIC LIQUIDS FROM COAL LOW
11	SYNGS1	SYNTHETIC HI-BTU GAS FROM COAL INTERMEDIATE
18	OILIN2	OIL INTERMEDIATE -- INTERMEDIATE ELECTRICITY
24	NGREG1	NATURAL GAS, INTERMEDIATE REGIONAL SUPPLY
27	NGDOM1	NATURAL GAS, INTERMEDIATE DOMESTIC SUPPLY
29	LNGLO	LIQUIFIED GAS IMPORTS LOW
33	NUCIN1	NUCLEAR BASE CASE
35	HYDRO1	HYDROELECTRICITY.

DEMAND SECTOR CHOICES		
42	R&CH14	RES. & COM. -- BASE LEVEL, FUEL SHIFT TO ELEC AND GAS
51	TRNH12	TRANSPORTATION -- BASE LEVEL, FUEL SHIFT TO ELECT.
58	INDH13	INDUSTRIAL -- BASE LEVEL, FUEL SHIFT TO ELEC & GAS

NOTE COMBINATION OF SUPPLY PROJECTIONS
50.0% OF COAL11(3) PLUS 50.0% OF COAL13(5)

--REGIONAL ENERGY CONSUMPTION-- (QUADRILLION BTU'S)

	---YEAR---		
	1972	1985	2000
FUELS REQUIRED			
LIQUIDS	7.71	8.89	12.14
GAS	2.30	2.95	3.95
ELECTRICITY	1.09	2.12	4.07
COAL (DIRECT USE ONLY)	1.22	1.40	1.77
TOTAL	12.32	15.36	21.92
U.S. RESOURCES REQUIRED			
CRUDE OIL	4.05	4.48	3.66
NATURAL GAS	2.38	2.40	1.39
COAL	2.51	3.66	8.97
NUCLEAR (THERMAL INPUT)	.23	2.67	9.41
HYDRO, WIND, WASTE	.13	.13	.13
SHALE OIL	0.00	0.00	0.00
IMPORTS			
OIL (CRUDE EQUIVALENT)	6.45	6.79	9.31
LIQUIFIED GAS	0.00	.40	.50
TOTAL RESOURCES REQUIRED	15.75	20.53	32.37

--POLLUTANT EMISSIONS-- (MILLION TONS)

DISPERSED EMISSIONS			
PARTICULATES	.22	.35	.42
NITROGEN OXIDES	2.87	1.52	1.97
SULFUR OXIDES	.86	.90	1.22
HYDROCARBONS	2.94	.49	.62
CARBON MONOXIDE	24.39	4.28	5.41
POINT-SOURCE EMISSIONS			
PARTICULATES	.57	.30	.21
NITROGEN OXIDES	1.41	1.56	1.81
SULFUR OXIDES	3.53	3.89	4.51
HYDROCARBONS	.10	.12	.14
CARBON MONOXIDE	.07	.10	.14

FUEL USE BY SECTOR -- YEAR 2000

	LIQUIDS	GAS	ELECTRIC	COAL	TOTAL
RES. & COM.	2.95	2.15	2.81	0.00	7.91
TRANSPORTATION	6.13	0.00	.14	0.00	6.27
INDUSTRIAL	3.05	1.80	1.12	1.77	7.73

Figure A-2. Base level demands, fuel shift elec & gas -- modest supplies.

Scenario 3

MODERATE CONSERVATION -- MODEST SUPPLIES

SUPPLY SECTOR CHOICES

1	COALL1	COAL LOW -- LOW ELECTRICITY, LOW LO-BTU GAS
4	COALI2	COAL INTERMEDIATE -- INTER. ELECTRICITY, LOW LO-BTU GAS
8	SYNLQ1	SYNTHETIC LIQUIDS FROM COAL LOW
10	SYNGSL	SYNTHETIC HI-BTU GAS FROM COAL LOW
17	OILIN1	OIL INTERMEDIATE -- LOW ELECTRICITY
24	NGREG1	NATURAL GAS, INTERMEDIATE REGIONAL SUPPLY
27	NGDOM1	NATURAL GAS, INTERMEDIATE DOMESTIC SUPPLY
33	NUCIN1	NUCLEAR BASE CASE
34	NUCLO1	NUCLEAR Curtailment-- NO PLANTS CONSTRUCTED AFTER 1977
35	HYDRO1	HYDROELECTRICITY.

DEMAND SECTOR CHOICES

44	R&CIN1	RESIDENTIAL AND COMMERCIAL -- MODERATE CONSERVATION
52	TRNIN1	TRANSPORTATION -- MODERATE CONSERVATION
59	INDLO1	INDUSTRIAL -- MODERATE CONSERVATION

NOTE COMBINATION OF SUPPLY PROJECTIONS

25.0% OF COALL1(1) PLUS 75.0% OF COALI2(4)

33.6% OF NUCIN1(33) PLUS 66.4% OF NUCLO1(34)

--REGIONAL ENERGY CONSUMPTION-- (QUADRILLION BTU'S)

	1972	1985	2000
FUELS REQUIRED			
LIQUIDS	7.71	8.65	12.39
GAS	2.30	2.16	2.17
ELECTRICITY	1.09	1.64	2.59
COAL (DIRECT USE ONLY)	1.22	1.35	1.66
TOTAL	12.32	13.80	18.81
U.S. RESOURCES REQUIRED			
CRUDE OIL	4.05	4.48	3.66
NATURAL GAS	2.38	2.31	1.39
COAL	2.51	3.36	7.66
NUCLEAR (THERMAL INPUT)	.23	2.30	4.56
HYDRO, WIND, WASTE	.13	.13	.13
SHALE OIL	0.00	0.00	0.00
IMPORTS			
OIL (CRUDE EQUIVALENT)	6.45	6.15	8.80
LIQUIFIED GAS	0.00	0.00	0.00
TOTAL RESOURCES REQUIRED	15.75	18.74	26.34

--POLLUTANT EMISSIONS-- (MILLION TONS)

DISPERSED EMISSIONS			
PARTICULATES	.32	.33	.44
NITROGEN OXIDES	2.87	1.39	1.84
SULFUR OXIDES	.86	.92	1.41
HYDROCARBONS	2.94	.46	.60
CARBON MONOXIDE	24.39	4.06	5.31
POINT-SOURCE EMISSIONS			
PARTICULATES	.57	.28	.19
NITROGEN OXIDES	1.41	1.43	1.60
SULFUR OXIDES	3.53	3.82	4.57
HYDROCARBONS	.10	.12	.14
CARBON MONOXIDE	.07	.10	.14

FUEL USE BY SECTOR -- YEAR 2000

	LIQUIDS	GAS	ELECTRIC	COAL	TOTAL
RES. & COM.	3.37	1.11	1.93	0.00	6.41
TRANSPORTATION	5.96	0.00	.02	0.00	5.98
INDUSTRIAL	3.17	1.06	.63	1.66	6.51

Figure A-3. Moderate conservation
-- modest supplies.

Scenario 4

MODERATE CONSERVATION, FUEL SHIFT TO ELECTRICITY & GAS --MODEST SUPPLIES

SUPPLY SECTOR CHOICES

3	COAL11	COAL INTERMEDIATE -- LOW ELECTRICITY, HIGH LO-BTU GAS
5	COAL13	COAL INTERMEDIATE -- INTER. ELECTRICITY, HI LO-BTU GAS
8	SYNLQL	SYNTHETIC LIQUIDS FROM COAL LOW
10	SYNGSL	SYNTHETIC HI-BTU GAS FROM COAL LOW
17	OILIN1	OIL INTERMEDIATE -- LOW ELECTRICITY
24	NGREG1	NATURAL GAS, INTERMEDIATE REGIONAL SUPPLY
27	NGDOM1	NATURAL GAS, INTERMEDIATE DOMESTIC SUPPLY
33	NUCIN1	NUCLEAR BASE CASE
34	NUCLO1	NUCLEAR Curtailment -- NO PLANTS CONSTRUCTED AFTER 1977
35	HYDRO1	HYDROELECTRICITY.

DEMAND SECTOR CHOICES

46	R&CIN4	RES. & COM. -- MOD. CONS., FUEL SHIFT TO ELEC AND GAS
53	TRNIN2	TRANSPORTATION -- MOD. CONSERV., FUEL SHIFT TO ELECTR.
61	INDLO3	INDUSTRIAL -- MOD. CONS., FUEL SHIFT TO ELEC AND GAS

NOTE COMBINATION OF SUPPLY PROJECTIONS

35.0% OF COAL11(3) PLUS 65.0% OF COAL13(5)
60.0% OF NUCIN1(33) PLUS 40.0% OF NUCLO1(34)

--REGIONAL ENERGY CONSUMPTION-- (QUADRILLION BTU'S)

	1972	1985	2000
FUELS REQUIRED			
LIQUIDS	7.71	7.93	10.23
GAS	2.30	2.59	3.19
ELECTRICITY	1.09	1.84	3.14
COAL (DIRECT USE ONLY)	1.22	1.33	1.61
TOTAL	12.32	13.68	18.16
U.S. RESOURCES REQUIRED			
CRUDE OIL	4.05	4.48	3.66
NATURAL GAS	2.38	2.36	1.39
COAL	2.51	3.50	8.13
NUCLEAR (THERMAL INPUT)	.23	2.45	6.51
HYDRO, WIND, WASTE	.13	.13	.13
SHALE OIL	0.00	0.00	0.00
IMPORTS			
OIL (CRUDE EQUIVALENT)	6.45	5.35	6.43
LIQUIFIED GAS	0.00	0.00	0.00
TOTAL RESOURCES REQUIRED	15.75	18.27	26.71

--POLLUTANT EMISSIONS-- (MILLION TONS)

DISPERSED EMISSIONS			
PARTICULATES	.32	.31	.35
NITROGEN OXIDES	2.87	1.35	1.67
SULFUR OXIDES	.86	.78	.93
HYDROCARBONS	2.94	.46	.57
CARBON MONOXIDE	24.39	4.05	5.11
POINT-SOURCE EMISSIONS			
PARTICULATES	.57	.27	.16
NITROGEN OXIDES	1.41	1.39	1.49
SULFUR OXIDES	3.53	3.68	4.20
HYDROCARBONS	.10	.11	.13
CARBON MONOXIDE	.07	.10	.13

FUEL USE BY SECTOR -- YEAR 2000

	LIQUIDS	GAS	ELECTRIC	COAL	TOTAL
RES. & COM.	2.18	1.74	2.19	0.00	6.11
TRANSPORTATION	5.41	0.00	.12	0.00	5.54
INDUSTRIAL	2.64	1.44	.82	1.61	6.51

Figure A-4. Moderate conservation, fuel shift to electricity & gas -- modest supplies.

Scenario 5

STRONG CONSERVATION, FUEL SHIFT TO ELECTRICITY & GAS

--MODEST SUPPLIES

SUPPLY SECTOR CHOICES

3	COAL11	COAL INTERMEDIATE -- LOW ELECTRICITY, HIGH LO-BTU GAS
5	COAL13	COAL INTERMEDIATE -- INTER. ELECTRICITY, HI LO-BTU GAS
8	SYNL01	SYNTHETIC LIQUIDS FROM COAL LOW
10	SYNGSL	SYNTHETIC HI-BTU GAS FROM COAL LOW
17	OIL11	OIL INTERMEDIATE -- LOW ELECTRICITY
24	NGREG1	NATURAL GAS, INTERMEDIATE REGIONAL SUPPLY
27	NGDOM1	NATURAL GAS, INTERMEDIATE DOMESTIC SUPPLY
33	NUCIN1	NUCLEAR BASE CASE
34	NUCLO1	NUCLEAR Curtailment -- NO PLANTS CONSTRUCTED AFTER 1977
35	HYDRO1	HYDROELECTRICITY.

DEMAND SECTOR CHOICES

49	RESLO4	RES. & COM. -- STRONG CONS., FUEL SHIFT TO ELEC AND GAS
55	TRANLO2	TRANSPORTATION -- STRONG CONSERV., FUEL SHIFT TO ELEC.
61	INDLO3	INDUSTRIAL -- MOD. CONS., FUEL SHIFT TO ELEC AND GAS

NOTE COMBINATION OF SUPPLY PROJECTIONS

50.0% OF COAL11(3) PLUS 50.0% OF COAL13(5)

35.0% OF NUCIN1(33) PLUS 65.0% OF NUCLO1(34)

--REGIONAL ENERGY CONSUMPTION-- (QUADRILLION BTU'S)

	1972	1985	2000
FUELS REQUIRED			
LIQUIDS	7.71	7.27	8.33
GAS	2.30	2.33	2.73
ELECTRICITY	1.09	1.68	2.59
COAL (DIRECT USE ONLY)	1.22	1.33	1.61
TOTAL	12.32	12.60	15.26
U.S. RESOURCES REQUIRED			
CRUDE OIL	4.05	4.48	3.66
NATURAL GAS	2.38	2.29	1.39
COAL	2.51	3.50	8.13
NUCLEAR (THERMAL INPUT)	.23	2.31	4.71
HYDRO, WIND, WASTE	.13	.13	.13
SHALE OIL	0.00	0.00	0.00
IMPORTS			
OIL (CRUDE EQUIVALENT)	6.45	4.63	4.34
LIQUIFIED GAS	0.00	0.00	0.00
TOTAL RESOURCES REQUIRED	15.75	17.33	22.33

--POLLUTANT EMISSIONS-- (MILLION TONS)

DISPERSED EMISSIONS			
PARTICULATES	.32	.28	.21
NITROGEN OXIDES	2.87	1.29	1.19
SULFUR OXIDES	.86	.67	.66
HYDROCARBONS	2.94	.44	.41
CARBON MONOXIDE	24.39	3.94	3.71
POINT-SOURCE EMISSIONS			
PARTICULATES	.37	.26	.15
NITROGEN OXIDES	1.41	1.37	1.40
SULFUR OXIDES	3.53	3.61	3.92
HYDROCARBONS	.10	.11	.13
CARBON MONOXIDE	.07	.09	.12

FUEL USE BY SECTOR -- YEAR 2000

	LIQUIDS	GAS	ELECTRIC	COAL	TOTAL
RES. & COM.	1.56	1.29	1.67	0.00	4.52
TRANSPORTATION	4.13	0.00	.10	0.00	4.23
INDUSTRIAL	2.64	1.44	.82	1.61	6.51

Figure A-5. Strong conservation, fuel shift to electricity & gas -- modest supplies.

Scenario 6

BASE CASE DEMANDS -- HIGHEST LIQUID SUPPLIES

SUPPLY SECTOR CHOICES	
1 COALL1	COAL LOW -- LOW ELECTRICITY, LOW LO-BTU GAS
4 COALI2	COAL INTERMEDIATE -- INTER. ELECTRICITY, LOW LO-BTU GAS
9 SYNLOH	SYNTHETIC LIQUIDS FROM COAL HIGH
11 SYNGSI	SYNTHETIC HI-BTU GAS FROM COAL INTERMEDIATE
13 SHALEL	SHALE OIL LOW
20 OILHI1	OIL HIGH -- LOW ELECTRICITY
24 NGREG1	NATURAL GAS, INTERMEDIATE REGIONAL SUPPLY
27 NGDOM1	NATURAL GAS, INTERMEDIATE DOMESTIC SUPPLY
33 NUCIN1	NUCLEAR BASE CASE
34 NUCLO1	NUCLEAR CURTAILMENT -- NO PLANTS CONSTRUCTED AFTER 1977
35 HYDRO1	HYDROELECTRICITY.

DEMAND SECTOR CHOICES	
39 R&CHI1	RESIDENTIAL AND COMMERCIAL -- BASE CASE
50 TRNHI1	TRANSPORTATION -- BASE CASE
56 INDHI1	INDUSTRIAL HIGH -- BASE CASE

NOTE COMBINATION OF SUPPLY PROJECTIONS
 50.0% OF COALL1(1) PLUS 50.0% OF COALI2(4)
 75.0% OF NUCIN1(33) PLUS 25.0% OF NUCLO1(34)

--REGIONAL ENERGY CONSUMPTION-- (QUADRILLION BTU'S)

	---YEAR---		
	1972	1985	2000
FUELS REQUIRED			
LIQUIDS	7.71	9.73	14.53
GAS	2.30	2.48	2.78
ELECTRICITY	1.09	1.88	3.32
COAL (DIRECT USE ONLY)	1.22	1.43	1.84
TOTAL	12.32	15.51	22.47
U.S. RESOURCES REQUIRED			
CRUDE OIL	4.05	4.93	4.19
NATURAL GAS	2.38	2.40	1.39
COAL	2.51	3.98	10.89
NUCLEAR (THERMAL INPUT)	.23	2.53	7.60
HYDRO, WIND, WASTE	.13	.13	.13
SHALE OIL	0.00	.05	1.30
IMPORTS			
OIL (CRUDE EQUIVALENT)	6.45	6.44	7.33
LIQUIFIED GAS	0.00	0.00	0.00
TOTAL RESOURCES REQUIRED	15.75	20.46	32.83

--POLLUTANT EMISSIONS-- (MILLION TONS)

DISPERSED EMISSIONS			
PARTICULATES	.32	.38	.53
NITROGEN OXIDES	2.87	1.59	2.19
SULFUR OXIDES	.86	1.11	1.87
HYDROCARBONS	2.94	.50	.65
CARBON MONOXIDE	24.39	4.29	5.63
POINT-SOURCE EMISSIONS			
PARTICULATES	.57	.31	.21
NITROGEN OXIDES	1.41	1.47	1.61
SULFUR OXIDES	3.53	3.87	4.47
HYDROCARBONS	.10	.12	.14
CARBON MONOXIDE	.07	.10	.14

FUEL USE BY SECTOR -- YEAR 2000

	LIQUIDS	GAS	ELECTRIC	COAL	TOTAL
RES. & COM.	4.31	1.34	2.44	0.00	8.09
TRANSPORTATION	6.62	0.00	.02	0.00	6.64
INDUSTRIAL	3.60	1.44	.86	1.84	7.73

Scenario 7

MODERATE CONSERVATION, FUEL SHIFT TO ELECTRICITY & GAS
--HIGHEST U.S. LIQUID SUPPLIES

SUPPLY SECTOR CHOICES

2	COALL2	COAL LOW -- LOW ELECTRICITY, HIGH LO-BTU GAS
3	COALI1	COAL INTERMEDIATE -- LOW ELECTRICITY, HIGH LO-BTU GAS
9	SYNLOH	SYNTHETIC LIQUIDS FROM COAL HIGH
11	SYNGSI	SYNTHETIC HI-BTU GAS FROM COAL INTERMEDIATE
13	SHAEL	SHALE OIL LOW
20	DILHI1	OIL HIGH -- LOW ELECTRICITY
23	NGREG1	NATURAL GAS, LOW REGIONAL SUPPLY
27	NGDOM1	NATURAL GAS, INTERMEDIATE DOMESTIC SUPPLY
33	NUCIN1	NUCLEAR BASE CASE
34	NUCLO1	NUCLEAR Curtailment -- NO PLANTS CONSTRUCTED AFTER 1977
35	HYDRO1	HYDROELECTRICITY.
37	WINDHI	WIND POWER HIGH -- .5 QUAD OF ELECTRICITY IN 2000
38	WASTES	WASTES AND REFUSE -- CONVERSION TO ELECTRICITY AND GAS

DEMAND SECTOR CHOICES

46	R&CIN4	RES. & COM. -- MOD. CONS. DEMANDS, HIGH ELEC. AND GAS
53	TRMIN2	TRANSPORTATION -- MOD. CONSERV., MODE SHIFT TO ELECTR.
60	INDLO3	INDUSTRIAL LOW -- MODE SHIFT TO ELEC. AND GAS

NOTE COMBINATION OF SUPPLY PROJECTIONS

50.0% OF COALL2(2) PLUS 50.0% OF COALI1(3)
60.0% OF NUCIN1(33) PLUS 40.0% OF NUCLO1(34)

--REGIONAL ENERGY CONSUMPTION-- (QUADRILLION BTU'S)

	1972	1985	2000
FUELS REQUIRED			
LIQUIDS	7.71	7.93	10.23
GAS	2.30	2.59	3.19
ELECTRICITY	1.09	1.84	3.14
COAL (DIRECT USE ONLY)	1.22	1.33	1.61
TOTAL	12.32	13.68	18.16
U.S. RESOURCES REQUIRED			
CRUDE OIL	4.05	4.93	4.19
NATURAL GAS	2.38	2.24	1.05
COAL	2.51	3.98	10.89
NUCLEAR (THERMAL INPUT)	.23	2.45	6.51
HYDRO, WIND, WASTE	.13	.19	.84
IMPORTS			
OIL (CRUDE EQUIVALENT)	6.45	4.46	2.60
LIQUIFIED GAS	0.00	0.00	0.00
TOTAL RESOURCES REQUIRED	15.75	18.24	26.08

--POLLUTANT EMISSIONS-- (MILLION TONS)

DISPERSED EMISSIONS			
PARTICULATES	.32	.31	.35
NITROGEN OXIDES	2.87	1.35	1.67
SULFUR OXIDES	.86	.78	.93
HYDROCARBONS	2.94	.46	.57
CARBON MONOXIDE	24.39	4.05	5.11
POINT-SOURCE EMISSIONS			
PARTICULATES	.57	.25	.13
NITROGEN OXIDES	1.41	1.30	1.08
SULFUR OXIDES	3.53	3.37	2.98
HYDROCARBONS	.10	.11	.13
CARBON MONOXIDE	.07	.09	.11

FUEL USE BY SECTOR -- YEAR 2000

	LIQUIDS	GAS	ELECTRIC	COAL	TOTAL
RES. & COM.	2.18	1.74	2.19	0.00	6.11
TRANSPORTATION	5.41	0.00	.12	0.00	5.54
INDUSTRIAL	2.64	1.44	.82	1.61	6.51

Figure A-6. Base case demands -- highest liquid supplies.

Figure A-7. Moderate conservation, fuel
 shift to electricity & gas -- highest U.S.
 liquid supplies.

Scenario 8

BASE CASE DEMANDS -- NUCLEAR CURTAILMENT, SUBSTITUTE COAL

SUPPLY SECTOR CHOICES		
4	COAL12	COAL INTERMEDIATE -- INTER. ELECTRICITY, LOW LO-BTU GAS
6	COALH1	COAL HIGH -- HIGH ELECTRICITY, LOW LO-BTU GAS
8	SYNLQ1	SYNTHETIC LIQUIDS FROM COAL LOW
11	SYNGS1	SYNTHETIC HI-BTU GAS FROM COAL INTERMEDIATE
18	OILIN2	OIL INTERMEDIATE -- INTERMEDIATE ELECTRICITY
24	NGREG1	NATURAL GAS, INTERMEDIATE REGIONAL SUPPLY
27	NGDOM1	NATURAL GAS, INTERMEDIATE DOMESTIC SUPPLY
34	NUCLO1	NUCLEAR CURTAILMENT -- NO PLANTS CONSTRUCTED AFTER 1977
35	HYDRO1	HYDROELECTRICITY.

DEMAND SECTOR CHOICES		
39	R&CHI1	RESIDENTIAL AND COMMERCIAL -- BASE CASE
50	TRNH11	TRANSPORTATION -- BASE CASE
56	INDHI1	INDUSTRIAL HIGH -- BASE CASE

NOTE COMBINATION OF SUPPLY PROJECTIONS
40.0% OF COAL12 (4) PLUS 60.0% OF COALH1 (6)

---REGIONAL ENERGY CONSUMPTION--- (QUADRILLION BTU'S)

	1972	1985	2000
FUELS REQUIRED			
LIQUIDS	7.71	9.73	14.53
GAS	2.30	2.48	2.78
ELECTRICITY	1.09	1.88	3.32
COAL (DIRECT USE ONLY)	1.22	1.43	1.84
TOTAL	12.32	15.51	22.47
U.S. RESOURCES REQUIRED			
CRUDE OIL	4.05	4.48	3.66
NATURAL GAS	2.38	2.40	1.39
COAL	2.51	4.31	12.22
NUCLEAR (THERMAL INPUT)	.23	2.11	2.18
HYDRO, WIND, WASTE	.13	.13	.13
SHALE OIL	0.00	0.00	0.00
IMPORTS			
OIL (CRUDE EQUIVALENT)	6.45	7.71	11.95
LIQUIFIED GAS	0.00	0.00	0.00
TOTAL RESOURCES REQUIRED	15.75	21.14	31.53

--POLLUTANT EMISSIONS-- (MILLION TONS)

DISPERSED EMISSIONS			
PARTICULATES	.32	.38	.53
NITROGEN OXIDES	2.87	1.59	2.19
SULFUR OXIDES	.86	1.11	1.87
HYDROCARBONS	2.94	.50	.65
CARBON MONOXIDE	24.39	4.29	5.63
POINT-SOURCE EMISSIONS			
PARTICULATES	.57	.33	.30
NITROGEN OXIDES	1.41	1.73	3.18
SULFUR OXIDES	3.53	4.47	8.62
HYDROCARBONS	.10	.12	.17
CARBON MONOXIDE	.07	.11	.22

FUEL USE BY SECTOR -- YEAR 2000

	LIQUIDS	GAS	ELECTRIC	COAL	TOTAL
RES. & COM.	4.31	1.34	2.44	0.00	8.09
TRANSPORTATION	6.62	0.00	.02	0.00	6.64
INDUSTRIAL	3.60	1.44	.86	1.84	7.73

Figure A-8. Base case demands -- nuclear curtailment, substitute coal.

Scenario 9

BASE CASE DEMANDS -- NUCLEAR CURTAILMENT, SUBSTITUTE WIND,WASTE

SUPPLY SECTOR CHOICES		
4	COAL12	COAL INTERMEDIATE -- INTER. ELECTRICITY, LOW LO-BTU GAS
6	COALH1	COAL HIGH -- HIGH ELECTRICITY, LOW LO-BTU GAS
8	SYNLQ1	SYNTHETIC LIQUIDS FROM COAL LOW
11	SYNGS1	SYNTHETIC HI-BTU GAS FROM COAL INTERMEDIATE
18	OILIN2	OIL INTERMEDIATE -- INTERMEDIATE ELECTRICITY
24	NGREG1	NATURAL GAS, INTERMEDIATE REGIONAL SUPPLY
27	NGDOM1	NATURAL GAS, INTERMEDIATE DOMESTIC SUPPLY
34	NUCLO1	NUCLEAR CURTAILMENT -- NO PLANTS CONSTRUCTED AFTER 1977
35	HYDRO1	HYDROELECTRICITY.
37	WINDH1	WIND POWER HIGH -- .5 QUAD OF ELECTRICITY IN 2000
38	WASTES	WASTES AND REFUSE -- CONVERSION TO ELECTRICITY AND GAS

DEMAND SECTOR CHOICES		
39	R&CHI1	RESIDENTIAL AND COMMERCIAL -- BASE CASE
50	TRANH1	TRANSPORTATION -- BASE CASE
56	INDH11	INDUSTRIAL HIGH -- BASE CASE

NOTE COMBINATION OF SUPPLY PROJECTIONS
75.0% OF COAL12(4) PLUS 25.0% OF COALH1(6)

--REGIONAL ENERGY CONSUMPTION-- (QUADRILLION BTU'S)

	1972	1985	2000
FUELS REQUIRED			
LIQUIDS	7.71	9.73	14.53
GAS	2.30	2.48	2.78
ELECTRICITY	1.09	1.88	3.32
COAL (DIRECT USE ONLY)	1.22	1.43	1.84
TOTAL	12.32	15.51	22.47
U.S. RESOURCES REQUIRED			
CRUDE OIL	4.05	4.48	3.66
NATURAL GAS	2.38	2.40	1.39
COAL	2.51	3.93	10.33
NUCLEAR (THERMAL INPUT)	.23	2.11	2.18
HYDRO, WIND, WASTE	.13	.19	.84
SHALE OIL	0.00	0.00	0.00
IMPORTS			
OIL (CRUDE EQUIVALENT)	6.45	7.71	11.95
LIQUIFIED GAS	0.00	0.00	0.00
TOTAL RESOURCES REQUIRED	15.75	20.82	30.34

--POLLUTANT EMISSIONS-- (MILLION TONS)

DISPERSED EMISSIONS				
PARTICULATES	.32	.38	.53	
NITROGEN OXIDES	2.87	1.59	2.19	
SULFUR OXIDES	.86	1.11	1.87	
HYDROCARBONS	2.94	.50	.63	
CARBON MONOXIDE	24.39	4.29	5.63	
POINT-SOURCE EMISSIONS				
PARTICULATES	.57	.33	.27	
NITROGEN OXIDES	1.41	1.69	2.60	
SULFUR OXIDES	3.53	4.33	6.89	
HYDROCARBONS	.10	.12	.16	
CARBON MONOXIDE	.07	.11	.18	

FUEL USE BY SECTOR -- YEAR 2000

	LIQUIDS	GAS	ELECTRIC	COAL	TOTAL
RES. & COM.	4.31	1.34	2.44	0.00	8.09
TRANSPORTATION	6.62	0.00	.02	0.00	6.64
INDUSTRIAL	3.60	1.44	.86	1.84	7.73

Figure A-9. Base case demands -- nuclear curtailment, substitute wind, waste.

Scenario 10

MODERATE CONSERVATION--NUCLEAR CURTAILMENT SUBSTITUTE WIND & WASTE

SUPPLY SECTOR CHOICES

1	COALL1	COAL LOW -- LOW ELECTRICITY, LOW LO-BTU GAS
4	COALI2	COAL INTERMEDIATE -- INTER. ELECTRICITY, LOW LO-BTU GAS
8	SYNLQ1	SYNTHETIC LIQUIDS FROM COAL LOW
10	SYNGSL	SYNTHETIC HI-BTU GAS FROM COAL LOW
18	OILIN2	OIL INTERMEDIATE -- INTERMEDIATE ELECTRICITY
24	NGREG1	NATURAL GAS, INTERMEDIATE REGIONAL SUPPLY
27	NGDOM1	NATURAL GAS, INTERMEDIATE DOMESTIC SUPPLY
34	NUCLO1	NUCLEAR Curtailment-- NO PLANTS CONSTRUCTED AFTER 1977
35	HYDRO1	HYDROELECTRICITY.
37	WINDH1	WIND POWER HIGH -- .5 QUAD OF ELECTRICITY IN 2000
38	WASTES	WASTES AND REFUSE -- CONVERSION TO ELECTRICITY AND GAS

DEMAND SECTOR CHOICES

44	R&CIN1	RESIDENTIAL AND COMMERCIAL -- MODERATE CONSERVATION
52	TRINI1	TRANSPORTATION -- MODERATE CONSERVATION
59	INDLO1	INDUSTRIAL -- MODERATE CONSERVATION

NOTE COMBINATION OF SUPPLY PROJECTIONS

40.0% OF COALL1(1) PLUS 60.0% OF COALI2(4)

--REGIONAL ENERGY CONSUMPTION-- (QUADRILLION BTU'S)

	---YEAR---		
	1972	1985	2000
FUELS REQUIRED			
LIQUIDS	7.71	8.65	12.39
GAS	2.30	2.16	2.17
ELECTRICITY	1.09	1.64	2.59
COAL (DIRECT USE ONLY)	1.22	1.35	1.66
TOTAL	12.32	13.80	18.81
U.S. RESOURCES REQUIRED			
CRUDE OIL	4.05	4.48	3.66
NATURAL GAS	2.38	2.30	1.39
COAL	2.51	3.28	7.37
NUCLEAR (THERMAL INPUT)	.23	2.11	2.18
HYDRO, WIND, WASTE	.13	.19	.84
SHALE OIL	0.00	0.00	0.00
IMPORTS			
OIL (CRUDE EQUIVALENT)	6.40	0.50	9.59
LIQUIFIED GAS	0.00	0.00	0.00
TOTAL RESOURCES REQUIRED	15.75	18.89	25.09

--POLLUTANT EMISSIONS-- (MILLION TONS)

DISPERSED EMISSIONS			
PARTICULATES	.32	.30	.44
NITROGEN OXIDES	2.87	1.39	1.84
SULFUR OXIDES	.86	.92	1.41
HYDROCARBONS	2.94	.46	.60
CARBON MONOXIDE	24.39	4.06	5.31
POINT-SOURCE EMISSIONS			
PARTICULATES	.57	.29	.19
NITROGEN OXIDES	1.41	1.53	1.76
SULFUR OXIDES	3.53	3.86	4.53
HYDROCARBONS	.10	.12	.14
CARBON MONOXIDE	.07	.10	.13

FUEL USE BY SECTOR -- YEAR 2000

	LIQUIDS	GAS	ELECTRIC	COAL	TOTAL
RES. & COM.	3.37	1.11	1.93	0.00	6.41
TRANSPORTATION	5.86	0.00	.02	0.00	5.88
INDUSTRIAL	3.17	1.06	.63	1.66	6.51

Figure A-10. Moderate conservation -- nuclear curtailment, substitute wind & waste.

Scenario 11

MOD. CONS., FUEL SHIFTS -- LOW U.S. OIL & N.G., NUC. CURTAILMENT

SUPPLY SECTOR CHOICES

5	COAL13	COAL INTERMEDIATE -- INTER. ELECTRICITY, HI LO-BTU GAS
7	COALH2	COAL HIGH -- HIGH ELECTRICITY, HIGH LO-BTU GAS
8	SYNL0L	SYNTHETIC LIQUIDS FROM COAL LOW
10	SYNSSL	SYNTHETIC HI-BTU GAS FROM COAL LOW
15	OILL01	OIL LOW -- LOW ELECTRICITY
23	NGRESL	NATURAL GAS, LOW REGIONAL SUPPLY
25	NGDOML	NATURAL GAS, LOW DOMESTIC SUPPLY
30	LNSIN	LIQUIFIED GAS IMPORTS INTERMEDIATE
31	LNSHI	LIQUIFIED GAS IMPORTS HIGH
34	NUCL01	NUCLEAR MORATORIUM -- NO PLANTS CONSTRUCTED AFTER 1977
35	HYDRO1	HYDROELECTRICITY.

DEMAND SECTOR CHOICES

46	R&CIN4	RES. & COM. -- MOD. CONS., FUEL SHIFT TO ELEC AND GAS
53	TRAN12	TRANSPORTATION -- MOD. CONSERV., FUEL SHIFT TO ELECTR.
51	INDL03	INDUSTRIAL -- MOD. CONS., FUEL SHIFT TO ELEC AND GAS

NOTE COMBINATION OF SUPPLY PROJECTIONS

33.0% OF COAL13 (5) PLUS 37.0% OF COALH2 (7)
50.0% OF LNSIN (30) PLUS 50.0% OF LNSHI (31)

--REGIONAL ENERGY CONSUMPTION-- (QUADRILLION BTU'S)

	---YEAR---		
	1972	1985	2000
ENERGY CARRIERS CONSUMED			
LIQUIDS	7.71	7.93	10.23
	1972	1985	2000
ENERGY CARRIERS CONSUMED			
LIQUIDS	7.71	7.93	10.23
GAS	2.30	2.50	3.19
ELECTRICITY	1.09	1.94	3.14
COAL (DIRECT USE ONLY)	1.22	1.33	1.51
TOTAL	12.32	13.69	19.16
U.S. RESOURCES REQUIRED			
CRUDE OIL	4.05	3.96	2.27
NATURAL GAS	2.39	1.50	.30
COAL	2.51	4.22	11.75
NUCLEAR (THERMAL INPUT)	.23	2.11	2.13
HYDRO, WIND, WASTE	.13	.13	.13
SHALE OIL	0.00	0.00	0.00
IMPORTS			
OIL (CRUDE EQUIVALENT)	6.45	5.97	7.30
LIQUIFIED GAS	0.00	.95	1.50
TOTAL RESOURCES REQUIRED	15.75	19.74	25.94

--POLLUTANT EMISSIONS-- (MILLION TONS)

DISPERSED EMISSIONS			
PARTICULATES	.32	.31	.35
NITROGEN OXIDES	2.97	1.35	1.57
SULFUR OXIDES	.96	.79	.93
HYDROCARBONS	2.94	.46	.57
CARBON MONOXIDE	24.39	4.05	5.11
POINT-SOURCE EMISSIONS			
PARTICULATES	.57	.29	.23
NITROGEN OXIDES	1.41	1.52	2.93
SULFUR OXIDES	3.53	4.12	9.13
HYDROCARBONS	.10	.12	.16
CARBON MONOXIDE	.07	.10	.20

ENERGY CARRIER USE BY SECTOR -- YEAR 2000

	LIQUIDS	GAS	ELECTRIC	COAL	TOTAL
RES. & COM.	2.13	1.74	2.19	0.00	6.11
TRANSPORTATION	5.41	0.00	.12	0.00	5.54
INDUSTRIAL	2.54	1.44	.32	1.51	6.51

RESOURCES REQUIRED

Figure A-11. Moderate conservation, fuel shifts -- low U.S. oil & N.S., nuclear curtailment.

Scenario 12

STRONG CONS., FUEL SHIFTS -- LOW U.S. OIL & N.G., NUC. CURTAIL.

SUPPLY SECTOR CHOICES

5	COAL13	COAL INTERMEDIATE -- INTER. ELECTRICITY, HI LO-BTU GAS
7	COALH2	COAL HIGH -- HIGH ELECTRICITY, HIGH LO-BTU GAS
8	SYNLQ1	SYNTHETIC LIQUIDS FROM COAL LOW
10	SYNGSL	SYNTHETIC HI-BTU GAS FROM COAL LOW
15	OILL01	OIL LOW -- LOW ELECTRICITY
23	NGREG1	NATURAL GAS, LOW REGIONAL SUPPLY
26	NGDOM1	NATURAL GAS, LOW DOMESTIC SUPPLY
30	LNGIN1	LIQUIFIED GAS IMPORTS INTERMEDIATE
34	NUCLO1	NUCLEAR CURTAILMENT -- NO PLANTS CONSTRUCTED AFTER 1977
35	HYDRO1	HYDROELECTRICITY.

DEMAND SECTOR CHOICES

49	R&CLO4	RES. & COM. -- STRONG CONS., FUEL SHIFT TO ELEC AND GAS
55	TRNLO2	TRANSPORTATION -- STRONG CONSERV., FUEL SHIFT TO ELEC.
61	INDLO3	INDUSTRIAL -- MOD. CONS., FUEL SHIFT TO ELEC AND GAS

NOTE COMBINATION OF SUPPLY PROJECTIONS
60.0% OF COAL13 (5) PLUS 40.0% OF COALH2 (7)

--REGIONAL ENERGY CONSUMPTION-- (QUADRILLION BTU'S)

	---YEAR---		
	1972	1985	2000
FUELS REQUIRED			
LIQUIDS	7.71	7.27	8.33
GAS	2.30	0.90	2.73
ELECTRICITY	1.09	1.68	2.59
COAL (DIRECT USE ONLY)	1.22	1.33	1.61
TOTAL	12.32	12.60	15.26
U.S. RESOURCES REQUIRED			
CRUDE OIL	4.05	3.96	2.27
NATURAL GAS	2.38	1.50	.30
COAL	2.51	3.93	10.30
NUCLEAR (THERMAL INPUT)	.23	2.11	2.18
HYDRO, WIND, WASTE	.13	.10	.13
SHALE OIL	0.00	0.00	0.00
IMPORTS			
OIL (CRUDE EQUIVALENT)	6.45	3.14	5.71
LIQUIFIED GAS	0.00	.80	1.00
TOTAL RESOURCES REQUIRED	15.75	17.53	21.39

--POLLUTANT EMISSIONS-- (MILLION TONS)

DISPERSED EMISSIONS			
PARTICULATES	.32	.28	.21
NITROGEN OXIDES	2.87	1.29	1.19
SULFUR OXIDES	.86	.67	.66
HYDROCARBONS	2.94	.44	.41
CARBON MONOXIDE	24.39	3.94	3.71
POINT-SOURCE EMISSIONS			
PARTICULATES	.57	.28	.21
NITROGEN OXIDES	1.41	1.49	2.38
SULFUR OXIDES	3.53	4.01	6.84
HYDROCARBONS	.10	.12	.15
CARBON MONOXIDE	.07	.10	.18

FUEL USE BY SECTOR -- YEAR 2000

	LIQUIDS	GAS	ELECTRIC	COAL	TOTAL
RES. & COM.	1.56	1.29	1.67	0.00	4.52
TRANSPORTATION	4.13	0.00	.10	0.00	4.23
INDUSTRIAL	2.64	1.44	.82	1.61	6.51

Figure A-12. Strong conservation, fuel shifts -- low U.S. oil & N.G., nuclear curtailment.

Scenario 13

STRONG CONSERVATION, FUEL SHIFTS TO ELECTRICITY & GAS
--LOW U.S. SUPPLIES OF OIL & N.G., NUCLEAR CURTAILMENT

SUPPLY SECTOR CHOICES		
3	COAL11	COAL INTERMEDIATE -- LOW ELECTRICITY, HIGH LO-BTU GAS
5	COAL13	COAL INTERMEDIATE -- INTER. ELECTRICITY, HI LO-BTU GAS
8	SYNL01	SYNTHETIC LIQUIDS FROM COAL LOW
10	SYNGSL	SYNTHETIC HI-BTU GAS FROM COAL LOW
15	OIL01	OIL LOW -- LOW ELECTRICITY
23	NGREG1	NATURAL GAS, LOW REGIONAL SUPPLY
26	NGDOM1	NATURAL GAS, LOW DOMESTIC SUPPLY
30	LNGIN	LIQUIFIED GAS IMPORTS INTERMEDIATE
34	NUCLO1	NUCLEAR Curtailment-- NO PLANTS CONSTRUCTED AFTER 1977
35	HYDRO1	HYDROELECTRICITY.
37	WINDH1	WIND POWER HIGH -- .5 QUAD OF ELECTRICITY IN 2000
38	WASTES	WASTES AND REFUSE -- CONVERSION TO ELECTRICITY AND GAS

DEMAND SECTOR CHOICES		
49	R&CLO4	RES. & COM. -- STRONG CONS., FUEL SHIFT TO ELEC AND GAS
55	TRAN02	TRANSPORTATION -- STRONG CONSERV., FUEL SHIFT TO ELEC.
61	IND03	INDUSTRIAL -- MOD; CONS., FUEL SHIFT TO ELEC AND GAS

NOTE COMBINATION OF SUPPLY PROJECTIONS
25.0% OF COAL11(3) PLUS 75.0% OF COAL13(5)

--REGIONAL ENERGY CONSUMPTION-- (QUADRILLION BTU'S)

	---YEAR---		
	1972	1985	2000
FUELS REQUIRED			
LIQUIDS	7.71	7.27	8.33
GAS	2.30	2.33	2.73
ELECTRICITY	1.09	1.68	2.59
COAL (DIRECT USE ONLY)	1.22	1.33	1.61
TOTAL	12.32	12.60	15.26
U.S. RESOURCES REQUIRED			
CRUDE OIL	4.05	3.96	2.27
NATURAL GAS	2.38	1.50	.30
COAL	2.51	3.50	8.13
NUCLEAR (THERMAL INPUT)	.23	2.11	2.18
HYDRO, WIND, WASTE	.13	.19	.84
SHALE OIL	0.00	0.00	0.00
IMPORTS			
OIL (CRUDE EQUIVALENT)	6.45	5.14	5.71
LIQUIFIED GAS	0.00	.80	1.00
TOTAL RESOURCES REQUIRED	15.75	17.21	20.43

--POLLUTANT EMISSIONS-- (MILLION TONS)

DISPERSED EMISSIONS			
PARTICULATES	.32	.28	.21
NITROGEN OXIDES	2.87	1.29	1.19
SULFUR OXIDES	.86	.67	.66
HYDROCARBONS	2.94	.44	.41
CARBON MONOXIDE	24.39	3.94	3.71
POINT-SOURCE EMISSIONS			
PARTICULATES	.37	.27	.16
NITROGEN OXIDES	1.41	1.41	1.55
SULFUR OXIDES	3.53	3.73	4.39
HYDROCARBONS	.10	.12	.13
CARBON MONOXIDE	.07	.10	.13

FUEL USE BY SECTOR--YEAR 2000

	LIQUIDS	GAS	ELECTRIC	COAL	TOTAL
RES. & COM.	1.56	1.29	1.67	0.00	4.52
TRANSPORTATION	4.13	0.00	.10	0.00	4.23
INDUSTRIAL	2.64	1.44	.82	1.61	6.51

RESOURCES REQUIRED

Figure A-13. Strong conservation, fuel shifts to electricity & gas -- low U.S. supplies of oil & N.G., nuclear curtailment.

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APPENDIX B

FEDERAL ENERGY RESEARCH AND DEVELOPMENT AND THE INTERESTS OF THE NORTHEAST

One of the benefits to be gained by a regional perspective on energy problems is the identification of common interests with regard to Federal energy policy. Over the long run it is Federal research and development (R&D) policy that will be particularly important in determining what fuels and technologies are available to the region.

An analysis of the interests of the Northeast in relation to Federal R&D policy is just beginning within the Regional Energy Studies Program. However, a recent BNL study of the Federal costs and consumer benefits of various ERDA R&D programs,⁴⁰ although carried out with a national perspective, produced some results with direct pertinence to the region. The study was designed to assist in the allocation of future energy R&D funds among competing programs. Its relevance for the Northeast region lies in two major areas.

1. A simple ordered ranking of programs according to their benefits can provide regional decision makers with useful information about the relative advantages of alternative technology R&D programs. This ordering also permits the identification of those energy technologies that could involve the lowest consumer expenditures for energy or produce the highest employment. This latter evaluation can be made only on a qualitative basis at present.

2. Since the benefit ordering is based on national considerations, regional decision makers can get a view of how regional interests have been reflected in proposed Federal R&D funding.

This is especially important because the successful completion of ERDA-sponsored R&D will provide new technology for the supply and/or utilization of energy which will displace current technology and in most cases will change the total delivered cost of energy to the Nation's energy consumers.

The benefits from an energy R&D program were taken to be the expected change in national energy expenditures that can be attributed to the program.

If the expected benefits for a program are positive, it means that, in a competitive market, the future discounted stream of consumer expenditures for energy will be less when that technology is used than when it is not; if the expected benefits are negative, it means that they will be greater. In the latter case, if the technology is desirable considering all its impacts, a subsidy will be needed to ensure its utilization because the cost of producing (or saving) energy with the new technology will be greater than the price consumers would be willing to pay if alternative cheaper energy sources or technologies are available. In this analysis it is assumed that the subsidy is paid by the Government directly to the producers. Note, however, that it adds to actual consumer expenditures for energy because consumers provide the money to the government through taxes. (Other forms of subsidization are also possible.)

R&D benefits for future years were estimated with the BNL Energy System Optimization Model.⁴⁴ The general procedure was to calculate economic benefits for each program against a base case containing none of the new technologies. Each new technology was then forced into a model solution at a predetermined level of implementation. For this analysis it was assumed that the Federal R&D expenditures produce the desired technical objectives of the

R&D program. Total consumer expenditures for energy were first calculated for the base case, assuming that only current energy supply and utilization technology are available. They were then calculated with inclusion of a postulated level of utilization of the new technology. The difference in total consumer expenditure is the expected R&D benefit for the year being analyzed.

Benefits were calculated for all years after 1980 and then discounted at a 10% annual rate to 1975 to establish a discounted present value for all future expected benefits.

Programs are ordered from the most favorable to the least favorable according to their discounted present value of benefits. Table B-1 presents the results for a low oil price assumption and Table B-2, for a higher oil price assumption.

Before the implications of this study are discussed, a number of qualifying statements must be made. This study is the first in which benefits have been calculated for major ERDA programs, and the results are preliminary at best. Future analyses will require a rigorous examination of the data used to evaluate each program and the sensitivity of the program evaluations to their assumptions, and should take into account other potential benefits (or costs) besides total consumer energy expenditures. They must also incorporate the policy options associated with subsidy methods, and they must be sure to estimate only those benefits directly attributable to ERDA R&D expenditures. Finally, the sensitivity of the program ordering to energy costs other than those of oil and end-use devices must be examined.

Even with these qualifications, a number of conclusions emerge that should be of interest to Northeast policy makers. First, note the sensitivity of the benefit streams of several programs to the assumptions concerning future oil prices,

Table B-1

BENEFIT RANKING: LOW OIL PRICES (\$12.50/bbl in 1985;
\$16.50/bbl in 2000)

<u>ERDA R&D Program</u>	<u>Ranking of discounted present benefit (1974 dollars) streams (Highest to lowest)</u>	
Residential & commercial end- use efficiency improvement	1	
Industrial end-use efficiency improvement	2	
Shale oil - surface & underground	3	
Improved auto propulsion	3	
Residential & commercial total energy programs	4	
Shale oil <u>in situ</u>	4	
Enhanced oil recovery	5	
Low-Btu coal gas	6	
MHD topping	7	
Fluidized-bed combustion	8	
Coal liquefaction	9	
Coal combined cycle	10	
Geothermal	11	
Electrical transmission & distribution	12	
Potassium topping	13	
HTGR	14	
Electric storage - fuel cells	15	Positive benefits
batteries	16	Negative benefits
Ocean thermal conversion	17	
Heat pump	18	
Wind conversion	19	
Photovoltaic	20	
Solar electric from thermal	21	
Battery autos	22	
Biomass	23	
Pipeline coal gas	24	
Solar heating & cooling	25	

Table B-2

BENEFIT RANKING: HIGH OIL PRICES (\$18.00/bbl in 1985;
\$23.00/bbl in 2000)

<u>ERDA R&D Program</u>	<u>Ranking of discounted present benefit (1974 dollars) streams (Highest to lowest)</u>	
Residential & commercial end- use efficiency improvement	1	
Industrial end-use efficiency improvement	2	
Shale oil - surface & underground	3	
Shale oil <u>in situ</u>	4	
Improved auto propulsion	5	
Enhanced oil recovery	5	
Residential & commercial total energy systems	6	
Low-Btu coal gas	7	
Coal liquefaction	8	
MHD topping	9	
Fluidized-bed combustion	10	
Heat pump	11	
Geothermal	12	
Coal combined cycle	13	
Electrical transmission & distribution	14	
Pipeline coal gas	15	
Potassium topping	16	
ETGR	17	
Electric storage - fuel cells	18	
batteries	19	Positive benefits
Wind conversion	20	Negative benefits
Ocean thermal conversion	21	
Battery autos	22	
Photovoltaic	23	
Solar Electric from thermal	24	
Biomass	25	
Solar heating and cooling	26	

especially the heat-pump and the pipeline (high-Btu) coal-gas technologies. More subtle is the apparent reversal of rank between improved auto propulsion (a demand technology) and shale oil in situ (a supply technology). Although this change in ranking is not great, it suggests that regional R&D priorities must be adaptable to changing relative prices and circumstances. It will not pay for regional authorities to adopt policy positions regarding Federal R&D programs which lock them into a particular strategy.

Second, note the relatively low positions of direct solar heating and cooling, wind power, and ocean thermal conversion (all have negative benefits as defined in the study). Because the calculations were performed on a national average basis, many regional factors that would justify such technologies (and raise the benefit stream) were understated. This result is particularly interesting because of the possibly important role that solar and wind power could play in the region.* This suggests that Federal energy R&D decisions taken without direct regional input might not adequately represent regional interests. It must also be kept in mind that the benefit principle used in the analysis is very narrowly defined. In terms of regional benefits and the employment and environmental considerations excluded here, solar heating and cooling may move from the lowest benefit position to a much higher one for certain regions.

The most interesting and useful result of the study is its indication of which programs consistently yield the largest benefit streams. They are the programs aimed at improving residential and

*Although the cost of solar heat in the Northeast is greater than its national average cost (because of the higher cost of storage or backup energy), the competing fuels are also more expensive. Thus the net discounted benefit could be higher in the Northeast than on a national average.

and commercial and industrial end-use efficiencies, developing total-energy systems for the residential and commercial sector, and improving automobile propulsion systems. These involve demand-oriented technologies and thus are indicative of the role of conservation and conservation policies in alleviating the region's energy problems. In fact, the only supply technology in Tables B-1 and B-2 that now appears attractive for the Northeast and also offers a substantial employment potential is low-Btu coal gasification.

It has been estimated that securing a barrel of oil via efficiency improvements in the residential sector costs one-fifth as much as obtaining it from coal-derived synthetic natural gas. Furthermore, the regional employment intensities associated with a more rapid replacement of inefficient appliances or the retrofitting of insulation, storm windows, and weather stripping may dwarf those associated with landing North Atlantic OCS oil and gas. The implications are clear: for a given cost, conservation technologies and measures are more apt to yield higher regional benefits, in terms of energy costs and amounts and employment than will policies directed at increasing energy supplies. This does not mean that other high risk, high cost research and development activities should not be undertaken. Such programs may be entirely justified from a broader national perspective, and because of a desire to maintain the flow of domestic fuels into the region.

The high ranking of utilization technologies in the tables suggests one direction for regional policy to take. In promoting the implementation of conservation strategies, regional authorities have considerable leverage in the form of building codes, materials standards, land-use requirements, zoning restrictions, environmental standards, overhead capital policies, trade laws, and locational investment incentives. The use of such instruments to encourage

the efficient use of energy imposes a minimum burden on local administrative resources. In principle such policies are easily adopted, relatively inexpensive to monitor, and readily modified. Regardless of Federal policy, the implementation of energy conservation programs is an attractive option for the States in the Northeast.

APPENDIX C
ENERGY SUPPLY AND DEMAND PROJECTIONS FOR THE NORTHEAST

(Note: All fuels measured in units of 10^{15} Btu)

Resource to Fuel Supply Projections

<u>Year</u>	<u>Liquid</u>	<u>Gas</u>	<u>Electricity</u>	<u>Coal (Direct Use)</u>
1	COAL LOW -- LOW ELECTRICITY, LOW LO-BTU GAS			
1972	0.000	0.000	.400	1.140
1985	0.000	0.000	.520	1.160
2000	0.000	.300	.630	1.500
2	COAL LOW -- LOW ELECTRICITY, HIGH LO-BTU GAS			
1972	0.000	0.000	.400	1.140
1985	0.000	.200	.520	.940
2000	0.000	1.000	.630	.730
3	COAL INTERMEDIATE -- LOW ELECTRICITY, HIGH LO-BTU GAS			
1972	0.000	0.000	.400	1.140
1985	0.000	.200	.520	1.490
2000	0.000	1.000	.630	2.630
4	COAL INTERMEDIATE -- INTER. ELECTRICITY, LOW LO-BTU GAS			
1972	0.000	0.000	.400	1.140
1985	0.000	0.000	.640	1.320
2000	0.000	.300	1.250	1.660
5	COAL INTERMEDIATE -- INTER. ELECTRICITY, HI LO-BTU GAS			
1972	0.000	0.000	.400	1.140
1985	0.000	.200	.640	1.100
2000	0.000	1.000	1.250	.890
6	COAL HIGH -- HIGH ELECTRICITY, LOW LO-BTU GAS			
1972	0.000	0.000	.400	1.140
1985	0.000	0.000	.740	2.060
2000	0.000	.300	2.880	2.510
7	COAL HIGH -- HIGH ELECTRICITY, HIGH LO-BTU GAS			
1972	0.000	0.000	.400	1.140
1985	0.000	.200	.740	1.840
2000	0.000	1.000	2.880	1.740
8	SYNTHETIC LIQUIDS FROM COAL LOW			
1972	0.000	-0.000	-0.000	-0.000
1985	.050	-0.000	-0.000	-0.000
2000	1.100	-0.000	-0.000	-0.000
9	SYNTHETIC LIQUIDS FROM COAL HIGH			
1972	0.000	-0.000	-0.000	-0.000
1985	.400	-0.000	-0.000	-0.000
2000	2.800	-0.000	-0.000	-0.000

		<u>Coal</u>			
<u>Year</u>	<u>Liquid</u>	<u>Gas</u>	<u>Electricity</u>	<u>(Direct Use)</u>	
10	SYNGSL	SYNTHETIC HI-BTU GAS FROM COAL	LOW		
1972	-0.000	0.000	-0.000		-0.000
1985	-0.000	0.000	-0.000		-0.000
2000	-0.000	.500	-0.000		-0.000
11	SYNGSI	SYNTHETIC HI-BTU GAS FROM COAL	INTERMEDIATE		
1972	-0.000	0.000	-0.000		-0.000
1985	-0.000	.100	-0.000		-0.000
2000	-0.000	1.000	-0.000		-0.000
12	SYNGSH	SYNTHETIC HI-BTU GAS FROM COAL	HIGH		
1972	-0.000	0.000	-0.000		-0.000
1985	-0.000	.300	-0.000		-0.000
2000	-0.000	1.600	-0.000		-0.000
13	SHALEL	SHALE OIL	LOW		
1972	0.000	-0.000	-0.000		-0.000
1985	.050	-0.000	-0.000		-0.000
2000	1.300	-0.000	-0.000		-0.000
14	SHALEH	SHALE OIL	HIGH		
1972	0.000	-0.000	-0.000		-0.000
1985	.090	-0.000	-0.000		-0.000
2000	2.300	-0.000	-0.000		-0.000
15	DILL01	OIL LOW -- LOW ELECTRICITY			
1972	1.840	0.000	.510		-0.000
1985	2.540	0.000	.300		-0.000
2000	2.040	0.000	0.000		-0.000
16	DILL02	OIL LOW -- INTERMEDIATE ELECTRICITY			
1972	1.840	0.000	.510		-0.000
1985	2.200	0.000	.400		-0.000
2000	1.320	0.000	.250		-0.000
17	DILIN1	OIL INTERMEDIATE -- LOW ELECTRICITY			
1972	1.840	0.000	.510		-0.000
1985	3.010	0.000	.300		-0.000
2000	3.290	0.000	0.000		-0.000
18	DILIN2	OIL INTERMEDIATE -- INTERMEDIATE ELECTRICITY			
1972	1.840	0.000	.510		-0.000
1985	2.670	0.000	.400		-0.000
2000	2.570	0.000	.250		-0.000
19	DILIN3	OIL INTERMEDIATE -- HIGH ELECTRICITY			
1972	1.840	0.000	.510		-0.000
1985	2.200	0.000	.540		-0.000
2000	1.740	0.000	.540		-0.000
20	DILHI1	OIL HIGH -- LOW ELECTRICITY			
1972	1.840	0.000	.510		-0.000
1985	3.420	0.000	.300		-0.000
2000	3.770	0.000	0.000		-0.000

		<u>Coal</u>			
<u>Year</u>	<u>Liquid</u>	<u>Gas</u>	<u>Electricity</u>	<u>(Direct Use)</u>	
21	DILHI2	OIL HIGH -- INTERMEDIATE ELECTRICITY			
1972	1.840	0.000	.510	-0.000	
1985	3.080	0.000	.400	-0.000	
2000	3.030	0.000	.250	-0.000	
22	DILHI3	OIL HIGH -- HIGH ELECTRICITY			
1972	1.840	0.000	.510	-0.000	
1985	2.610	0.000	.540	-0.000	
2000	2.220	0.000	.540	-0.000	
23	NGREGL	NATURAL GAS, LOW REGIONAL SUPPLY			
1972	0.000	.080	0.000	0.000	
1985	0.000	.140	0.000	0.000	
2000	0.000	0.000	0.000	0.000	
24	NGREGI	NATURAL GAS, INTERMEDIATE REGIONAL SUPPLY			
1972	0.000	.080	-0.000	-0.000	
1985	0.000	.260	-0.000	-0.000	
2000	0.000	.800	-0.000	-0.000	
25	NGREGH	NATURAL GAS, HIGH REGIONAL SUPPLY			
1972	0.000	.080	0.000	0.000	
1985	0.000	.520	0.000	0.000	
2000	0.000	1.730	0.000	0.000	
26	NGDOML	NATURAL GAS, LOW DOMESTIC SUPPLY			
1972	0.000	2.300	.030	0.000	
1985	0.000	1.360	0.000	0.000	
2000	0.000	.300	0.000	0.000	
27	NGDOMI	NATURAL GAS, INTERMEDIATE DOMESTIC SUPPLY			
1972	0.000	2.300	.030	0.000	
1985	0.000	2.100	.030	0.000	
2000	0.000	1.050	0.000	0.000	
28	NGDOMH	NATURAL GAS, HIGH DOMESTIC SUPPLY			
1972	0.000	2.300	.030	0.000	
1985	0.000	2.540	.030	0.000	
2000	0.000	1.740	0.000	0.000	
29	LNGLO	LIQUIFIED GAS IMPORTS LOW			
1972	-0.000	0.000	-0.000	-0.000	
1985	-0.000	.400	-0.000	-0.000	
2000	-0.000	.500	-0.000	-0.000	
30	LNGIN	LIQUIFIED GAS IMPORTS INTERMEDIATE			
1972	-0.000	0.000	-0.000	-0.000	
1985	-0.000	.800	-0.000	-0.000	
2000	-0.000	1.000	-0.000	-0.000	

	<u>Year</u>	<u>Liquid</u>	<u>Gas</u>	<u>Electricity</u>	<u>Coal (Direct Use)</u>
31	LNGHI	LIQUIFIED GAS IMPORTS HIGH			
	1972	-0.000	0.000	-0.000	-0.000
	1985	-0.000	1.100	-0.000	-0.000
	2000	-0.000	2.000	-0.000	-0.000
32	NUCHI1	NUCLEAR HIGH GROWTH			
	1972	0.000	0.000	.070	-0.000
	1985	0.000	0.000	.880	-0.000
	2000	0.000	0.000	3.980	-0.000
33	NUCIN1	NUCLEAR BASE CASE			
	1972	0.000	0.000	.070	-0.000
	1985	0.000	0.000	.810	-0.000
	2000	0.000	0.000	2.850	-0.000
34	NUCLO1	NUCLEAR MORATORIUM -- NO PLANTS CONSTRUCTED AFTER 1977			
	1972	0.000	0.000	.070	-0.000
	1985	0.000	0.000	.640	-0.000
	2000	0.000	0.000	.660	-0.000
35	HYDRO1	HYDROELECTRICITY.			
	1972	0.000	0.000	.130	-0.000
	1985	0.000	0.000	.130	-0.000
	2000	0.000	0.000	.130	-0.000
36	WINDLO	WIND POWER LOW -- .13 QUAD OF ELECTRICITY IN 2000			
	1972	0.000	0.000	0.000	-0.000
	1985	0.000	0.000	0.000	-0.000
	2000	0.000	0.000	.130	-0.000
37	WINDHI	WIND POWER HIGH -- .5 QUAD OF ELECTRICITY IN 2000			
	1972	0.000	0.000	0.000	-0.000
	1985	0.000	0.000	0.000	-0.000
	2000	0.000	0.000	.500	-0.000
38	WASTES	WASTES AND REFUSE -- CONVERSION TO ELECTRICITY AND GAS			
	1972	0.000	0.000	0.000	-0.000
	1985	0.000	.006	.060	-0.000
	2000	0.000	.021	.205	-0.000

Fuel To End Use Demand Projections

<u>Year</u>	<u>Liquid</u>	<u>Gas</u>	<u>Electricity</u>	<u>Coal (Direct Use)</u>
9 R&CHI1	RESIDENTIAL AND COMMERCIAL -- BASE CASE			
1972	2.687	1.558	.666	.105
1985	3.095	1.441	1.270	0.000
2000	4.312	1.337	2.441	0.000
40 R&CHI2	RES. AND COM. -- BASE LEVEL, HI LIQUID & GAS			
1972	2.687	1.558	.666	.105
1985	3.163	1.460	1.230	0.000
2000	4.552	1.397	2.330	0.000
41 R&CHI3	RES. & COM. -- BASE LEVEL, FUEL SHIFT TO ELEC.			
1972	2.687	1.558	.666	.105
1985	2.816	1.403	1.398	0.000
2000	3.567	1.280	2.812	0.000
42 R&CHI4	RES. & COM. -- BASE LEVEL, FUEL SHIFT TO ELEC AND GAS			
1972	2.687	1.558	.666	.105
1985	2.517	1.739	1.398	0.000
2000	2.954	2.147	2.812	0.000
43 R&CHI5	RESIDENTIAL AND COMMERCIAL -- HIGH			
1972	2.687	1.558	.666	.105
1985	3.435	1.588	1.402	0.000
2000	4.916	1.588	2.837	0.000
44 R&CIN1	RESIDENTIAL AND COMMERCIAL -- MODERATE CONSERVATION			
1972	2.687	1.558	.666	.105
1985	2.736	1.297	1.128	0.000
2000	3.367	1.112	1.934	0.000
45 R&CIN3	RES. & COM. -- MOD. CONS., FUEL SHIFT TO ELEC.			
1972	2.687	1.558	.666	.105
1985	2.512	1.261	1.227	0.000
2000	2.838	1.066	2.191	0.000
46 R&CIN4	RES. & COM. -- MOD. CONS., FUEL SHIFT TO ELEC AND GAS			
1972	2.687	1.558	.666	.105
1985	2.255	1.555	1.227	0.000
2000	2.177	1.744	2.191	0.000
47 R&CLO1	RESIDENTIAL AND COMMERCIAL -- STRONG CONSERVATION			
1972	2.687	1.558	.666	.105
1985	2.241	1.073	.995	0.000
2000	2.418	.821	1.485	0.000
48 R&CLO3	RES. & COM. -- STRONG CONS., FUEL SHIFT TO ELEC.			
1972	2.687	1.558	.666	.105
1985	2.061	1.043	1.070	0.000
2000	2.027	.791	1.666	0.000
49 R&CLO4	RES. & COM. -- STRONG CONS., FUEL SHIFT TO ELEC AND GAS			
1972	2.687	1.558	.666	.105
1985	1.851	1.290	1.070	0.000
2000	1.562	1.287	1.666	0.000
50 TRNHI1	TRANSPORTATION -- BASE CASE			
1972	3.524	0.000	.012	0.000
1985	4.336	0.000	.016	0.000
2000	6.623	0.000	.022	0.000

<u>Year</u>	<u>Liquid</u>	<u>Gas</u>	<u>Electricity</u>	<u>Coal (Direct Use)</u>
51 TRNHI2	TRANSPORTATION -- BASE LEVEL, FUEL SHIFT TO ELECT.			
1972	3.524	0.000	.012	0.000
1985	4.336	0.000	.016	0.000
2000	6.134	0.000	.136	0.000
52 TRNIN1	TRANSPORTATION -- MODERATE CONSERVATION			
1972	3.524	0.000	.012	0.000
1985	3.805	0.000	.016	0.000
2000	5.857	0.000	.022	0.000
53 TRNIN2	TRANSPORTATION -- MOD. CONSERV., FUEL SHIFT TO ELECT.			
1972	3.524	0.000	.012	0.000
1985	3.805	0.000	.016	0.000
2000	5.414	0.000	.125	0.000
54 TRNLO1	TRANSPORTATION -- STRONG CONSERVATION			
1972	3.524	0.000	.012	0.000
1985	3.551	0.000	.016	0.000
2000	4.368	0.000	.022	0.000
55 TRNLO2	TRANSPORTATION -- STRONG CONSERV., FUEL SHIFT TO ELEC.			
1972	3.524	0.000	.012	0.000
1985	3.551	0.000	.016	0.000
2000	4.131	0.000	.101	0.000
56 INDHI1	INDUSTRIAL HIGH -- BASE CASE			
1972	1.495	.746	.415	1.112
1985	2.297	1.036	.597	1.425
2000	3.596	1.444	.859	1.835
57 INDHI2	INDUSTRIAL -- BASE LEVEL, FUEL SHIFT TO ELECTRICITY			
1972	1.495	.746	.415	1.112
1985	2.246	1.003	.710	1.397
2000	3.515	1.331	1.121	1.766
58 INDHI3	INDUSTRIAL -- BASE LEVEL, FUEL SHIFT TO ELEC & GAS			
1972	1.495	.746	.415	1.112
1985	2.040	1.208	.710	1.397
2000	3.047	1.799	1.121	1.766
59 INDLO1	INDUSTRIAL -- MODERATE CONSERVATION			
1972	1.495	.746	.415	1.112
1985	2.113	.859	.498	1.348
2000	3.168	1.058	.632	1.656
60 INDLO2	INDUSTRIAL -- MOD. CONS., FUEL SHIFT TO ELECTRICITY			
1972	1.495	.746	.415	1.112
1985	2.070	.831	.592	1.325
2000	3.108	.976	.824	1.606
61 INDLO3	INDUSTRIAL -- MOD. CONS., FUEL SHIFT TO ELEC AND GAS			
1972	1.495	.746	.415	1.112
1985	1.863	1.036	.592	1.325
2000	2.640	1.444	.824	1.606

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