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AUTHOR Gutmanis, Ivars; And Others
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ABSTRACT

The primary purpose of the study was to develop and apply a methodology for estimating the need for scientists and engineers by specialty in energy and energy-related industries. The projections methodology was based on the Case 1 estimates by the National Petroleum Council of the results of "maximum efforts" to develop domestic fuel sources by 1980 and 1985. It is based on seven energy-related industries: electric generation; petroleum and natural gas extraction and petroleum refining; natural gas production, transmission, and distribution; coal mining; nuclear power production and radioactive waste disposal; manufacture of selected producers' durable equipment for electric companies; and energy-related construction. Employment of engineers and scientists is expected to increase 117 percent from 1970 to 1985, with a more rapid growth of demand for engineers than for scientists. Physicists, with an increase of 186 percent, and chemists, with an increase of 110 percent, are expected to comprise about 61 percent of the total demand for scientists. Demands for geologists and geophysicists will also continue. The projections indicate an average, annual additional requirement of about 11,200 engineers and 4,300 scientists by 1985; the future supply of engineers and scientists may be inadequate to meet the demands of energy/energy-related industries. (EA)

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The Demand for Scientific and Technical Manpower in Selected Energy-Related Industries, 1970-85: A Methodology Applied to a Selected Scenario of Energy Output. A Summary

BY IVARS GUTMANIS
With the assistance of
L. STEPHEN GUILAND
RITA A. McBRAYER
RICHARD P. McKENNA

national planning association

NPA is an independent, private, nonprofit, nonpolitical organization that carries on research and policy formulation in the public interest. NPA was founded during the Great Depression of the 1930s when conflicts among the major economic groups—business, farmers, labor—threatened to paralyze national decision making on the critical issues confronting American society. It was dedicated, in the words of its statement of purpose, to the task "of getting (these) diverse groups to work together . . . to narrow areas of controversy and broaden areas of agreement . . . (and) to provide on specific problems concrete programs for action planned in the best traditions of a functioning democracy." From the beginning, NPA has been committed to the view that the survival of a functioning American democracy under the increasingly rigorous conditions of the 20th century could not be assured only by more effective governmental policies and programs. Equally essential, NPA believes, are the preservation of private economic initiative and activity dispersed throughout the society and the continuous development by the major private groups themselves of a substantial consensus on how to cope with the problems confronting the nation at home and abroad.

Pursuant to these objectives, NPA has evolved a mode of operation that today brings together influential and knowledgeable leaders from business, labor, agriculture, and the applied and academic professions to serve on policy committees. These committees analyze and agree upon recommendations for dealing with domestic and international developments affecting the well-being of the United States. The research and writing for these committees are provided by NPA's professional staff and, as required, by outside experts.

In addition, NPA's professional staff undertakes a wide variety of technical research activities designed to provide data and ideas for policy makers and planners in government and the private sector. These activities include the preparation on a regular basis of economic and demographic projections for the national economy, regions, states, and metropolitan areas; program planning and evaluation for federal, state and local agencies; research on national goals and priorities; planning studies for manpower training, vocational education, medical care, environmental protection, energy needs, and other economic and social problems confronting American society; and analyses and forecasts of changing international realities and their implications for U.S. policies. In developing its staff capabilities, NPA has increasingly emphasized two related qualifications—the interdisciplinary knowledge required to understand the complex nature of many real-life problems, and the ability to bridge the gap between the theoretical or highly technical research of the universities and other professional institutions and the practical needs of policy makers and planners in government and the private sector.

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I. PREFACE

This report presents the results of the latest of a series of NPA studies of the manpower requirements associated with national goals and objectives.

Following the enunciation of a set of broad national goals by a presidential commission in 1960, NPA undertook a study of the manpower requirements for the achievement of these objectives. This involved specification of the public and private activities required to reach levels of achievement deemed feasible by knowledgeable people. From these activities the related bills of goods were derived and these in turn were converted into estimates of manpower demand, by occupation, through the use of input-output and occupation-industry matrices. The overall finding was that simultaneous pursuit of all of the defined goals would be precluded by a shortfall in total manpower and severe shortages in particular occupations. NPA's conclusion was challenged at the time by many who were then caught up in the notion that automation would result in widespread labor redundancy.

The major purpose of the NPA study, of course, was not to stifle studies of how Americans would live with two-day work weeks but rather to demonstrate the need for national priority choices and to illuminate their effects on manpower demand. It was hoped that NPA's initial study and those that followed would foster national decision making in the light of critical manpower considerations. The setting of timetables for the achievement of various targets and the development of policies to increase the supply of qualified personnel for occupations where shortages are in prospect are two major areas in which manpower projections related to priority choices could be highly beneficial.

Events of the last decade forcefully demonstrated the unfortunate results of a lack of manpower planning in the pursuit of national objectives. Medicare with its impacts on the salaries of health personnel and the space program--which first drove up the price of scientific and engineering personnel while preempting them from other activities and then dropped a surplus, at existing prices, onto the market bringing downward pressure on salaries and deterring the development of new scientists and engineers--provides striking examples. Moreover, it is also apparent that without more adequate information on future manpower demands the country's educational and training institutions cannot be expected to provide a mix of graduates that will match the real needs of the future.

More recently, NPA performed a study of the impacts of alternative priorities for improvement of environmental quality on the demand for scientists and engineers. This project--the immediate precursor of the present effort--examined the differences in demand for scientists and engineers, by speciality, under three scenarios corresponding to the level of pollution abatement prevalent in the late 1960s, that resulting from "present policy," and that which would occur if the high standards of the Clean Water Act Amendments of 1972 were generalized. Significant differences in the aggregate and in specific fields of science and engineering were found to result from the varying priorities for environmental improvement. The project was undertaken with the support of the National Science Foundation.

The present study has carried the analysis of the demand for scientists and engineers into the area of energy supply. The objective was to develop and apply a methodology that would allow estimation of the need for scientists and engineers by specialty in energy and energy-related industries. Using the resulting methodology, preliminary estimates of scientific and technical manpower demand have been made based on a selected scenario of domestic energy production. This required the collection of data from more than 100 individuals and 40 firms in energy-related businesses and other organizations. NPA would like to express its appreciation for their outstanding cooperation and assistance in providing information for this study.

The results are presented in the following summary, along with NPA's assessment of the deficiencies of the data and methodology and its view of additional research needs. It might be said here that the ultimate use of this methodology should be to project scientific and engineering manpower demand under alternative scenarios, to compare these projections to estimates of supply, and to identify price effects, potential bottlenecks, and other factors that may affect the nation's choice of energy policies.

Since the completion of this study, NPA has developed information on the labor requirements of the energy sector for all occupational categories. These data will serve as an input to analyses being prepared by the Department of Labor and the Federal Energy Administration in the planning for "Operation Independence."

This study was directed by Ivars Gutmanis, Director of Resource Analysis of the National Planning Association. L. Stephen Guiland, Richard P. McKenna, Rita A. McBrayer and Randall Smith performed most of the data collection and

analysis. The study was also given assistance during its early stages by Robert Dennis. A more complete report on this study, "The Demand for Scientific and Technical Manpower in Selected Energy-Related Industries, 1970-1985: A Methodology Applied to a Selected Scenario of Energy Output," is available from the National Science Foundation.

NPA gratefully acknowledges the support of the National Science Foundation, under its grant GR 32464, and the support and guidance of the NSF project monitor, Robert W. Cain.

Everard Munsey
Executive Vice President

II. PROJECTIONS AND IMPLICATIONS

The recent adoption of a national objective of assuring adequate supplies of energy from domestic sources, or at least of reducing the nation's dependence on energy from foreign countries, will have major impacts on future requirements for scientists and engineers.

Assessment of these requirements is, in turn, important in energy and educational policy making since the cost and availability of critical science and engineering skills are bound to affect the desirability and even the feasibility of national energy options.

In this study, the projections methodology described hereafter was applied to an energy production scenario that assumed increased domestic exploration and production of oil and gas, production of much larger volumes of coal, greatly increased use of nuclear power by utilities, and related energy-related research and development. It does not take into account recently proposed expanded Federal energy R&D programs.

This accelerated production scenario is based on the so-called Case I estimates by the National Petroleum Council of the results of "maximum efforts" to develop domestic fuel sources by 1980 and 1985. NPC estimates for natural gas, petroleum and coal, together with estimates by the Edison Electric Institute for electricity generation from hydro and nuclear sources, constitute the scenario's stipulation of primary energy production. The following table shows the outputs for each of these sectors under this scenario.

Table 1

Energy Supply Trends Assuming Maximum Effort to Develop Domestic Fuel Sources, 1970-1985

(Trillion BTUs /Year)

DOMESTIC SUPPLY	1970	1980	1985
Oil, all sources	21,048	28,229	34,656
Gas, all sources	22,388	27,464	35,214
Hydropower	2,677	3,240	3,320
Geothermal	7	782	1,395
Coal	13,062	21,200	27,100
Nuclear	240	11,349	29,810
Total domestic supply	59,422	92,264	131,495
IMPORTED SUPPLY	**1970**	**1980**	**1985**
Oil	7,455	12,258	7,547
Gas	950	3,900	5,900
Total imported supply	8,405	16,158	13,447

Source: National Petroleum Council, U.S. Energy Outlook, 1972.

This output would provide 131.5 quadrillion BTUs of energy in 1985. For the purposes of this study, NPA did not attempt to calculate the price levels required to elicit these volumes of output or the effects of these price levels upon energy demand. However, if it is assumed that total domestic energy consumption in 1985 would amount to 145.0 quadrillion BTUs only

9.3 percent would be imported under this scenario. Figure 1 portrays an estimate of the growth of U.S. energy consumption through 1990.

Imported resources in 1985 under the NPC Case I amount to 3.6 million barrels per day of crude and refined petroleum and 5.9 trillion cubic feet per day of natural gas from Mexico and Canada. In contrast, continuation of recent past trends in the domestic production of petroleum, natural gas and coal would result in 77.6 quadrillion BTUs of energy from domestic sources, leaving the nation dependent upon foreign sources for about 38 percent of its consumption.

In estimating the demand for scientific and engineering manpower, NPA has considered not only the primary energy production cited above, but the production of electric power from fossil fuels, the manufacture of equipment for electric utilities, the design and construction of energy facilities, and energy-related research and development outlays. Demand estimates for scientists and engineers involved in nuclear power generation include not only those employed in the electric industry but those engaged in the nuclear fuel cycle from uranium mining to waste disposal.

The outputs or levels of activity of the seven energy-related industries and of their research and development, as specified in this scenario, are shown in Table 2.

The "industries" considered in this study were:

1. Electric generation -- SIC 491, electric companies and systems, parts of SIC 493, combination companies and systems, and federal, municipal and cooperative electric utility systems and operating companies.

Figure 1

U.S. Energy Consumption

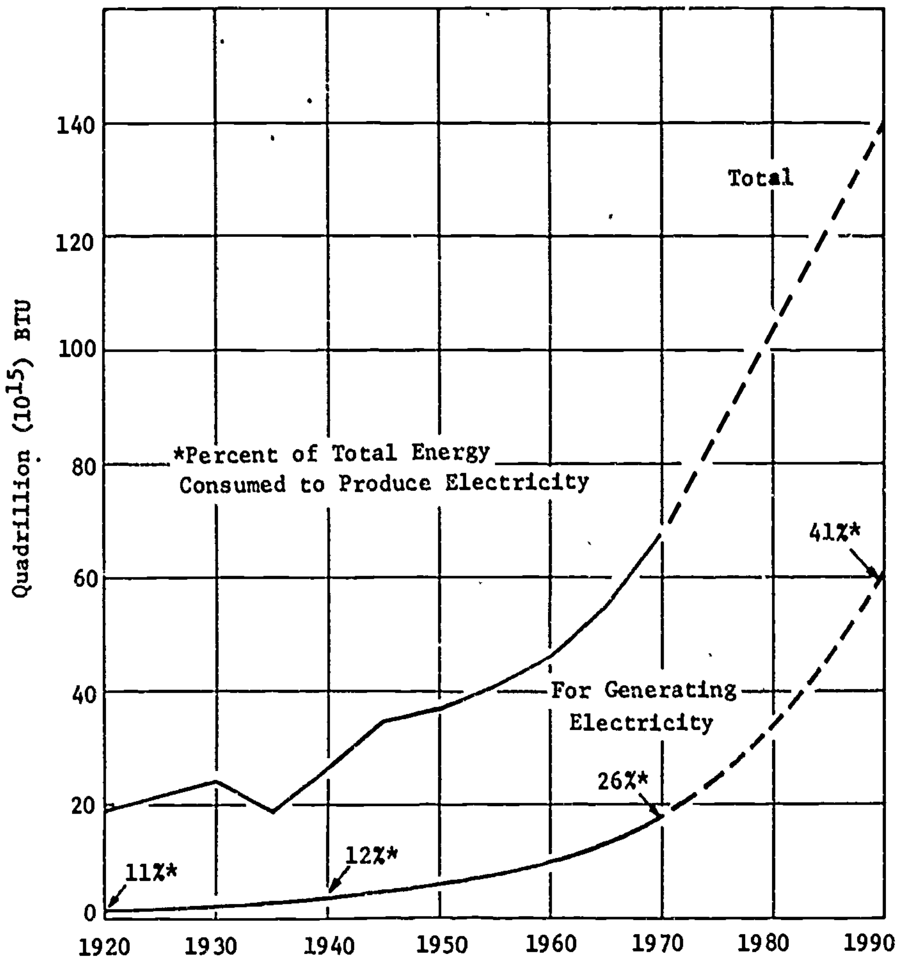


Table 2

Energy Output Measures Assuming Maximum Effort to Develop Domestic Fuel Sources, 1970, 1980 and

Activities	Output Measure		1970	1980
Electric Utilities	Megawatt-hours of electric power generated by type of power source	From All Sources, Total	$1,524x10^6$	3,082x1
		From Fossil Fuels, Total	$1,256x10^6$	1,796x1
		From Oil	$177x10^6$	210x1
		From Coal	$707x10^6$	998x1
		From Gas	$371x10^6$	588x1
		From Hydro-electric	$247x10^6$	341x1
		From Nuclear	Neg.	945x1
Natural Gas Production and Transmission	Million cubic feet of gas produced daily	Alternative #1 Domestic Production	61,096	73,4
		Domestic Production Imports and Gas From Coal	63,288	78,6
Oil and Gas Exploration, Oil Production and Oil Refining	Refinery runs of thousand barrels daily	Alternative #1 Domestic Production	11,300	13,5
		Domestic Production and Crude Imports	12,600	13,6
Coal Mining	Million tons of coal produced	Alternative #1 Domestic Production	519	8
		Domestic Production Including Coal for Synthetic Fuels	519	8
NUCLEAR FUEL CYCLE				
Uranium Milling	Thousand tons of uranium processed		9.0	34
Nuclear Fuel Element Fabrication and Recovery	Metric tons of element processed			5,
Production of Nuclear Feed Materials and Fuel Enrichment	Metric tons of feed materials processed			26,
Chemical Reprocessing of Irridated Fuel	Metric tons of fuel reprocessed			3,
Waste Disposal	Metric tons of fuel used			26,

Table 2

utput Measures Assuming Maximum Effort to Develop Domestic Fuel Sources, 1970, 1980 and 1985

	Output Measure		1970	1980	1985
	Megawatt-hours of electric power generated by type of power source	From All Sources, Total	1,524x10^{6}	3,082x10^{6}	4,256x10^{6}
		From Fossil Fuels, Total	1,256x10^{6}	1,796x10^{6}	1,871x10^{6}
		From Oil	177x10^{6}	210x10^{6}	184x10^{6}
		From Coal	707x10^{6}	998x10^{6}	1,059x10^{6}
		From Gas	371x10^{6}	588x10^{6}	628x10^{6}
		From Hydro-electric	247x10^{6}	341x10^{6}	460x10^{6}
		From Nuclear	Neg.	945x10^{6}	1,925x10^{6}
on	Million cubic feet of gas produced daily	Alternative #1			
		Domestic Production	61,096	73,425	90,959
		Domestic Production Imports and Gas From Coal	63,288	78,630	100,000
- h	Refinery runs of thousand barrels daily	Alternative #1			
		Domestic Production	11,300	13,580	15,460
		Domestic Production and Crude Imports	12,600	13,670	15,490
	Million tons of coal produced	Alternative #1			
		Domestic Production	519	851	1,093
		Domestic Production Including Coal for Synthetic Fuels	519	851	1,432
	Thousand tons of uranium processed		9.0	34.2	59.3
t	Metric tons of element processed			5,673	9,800
ar	Metric tons of feed materials processed			26,600	37,000
ng	Metric tons of fuel reprocessed			3,400	5,500
	[illegible]ic tons of fuel			26,600	37,000

Table 2 - Continued

Activities	Output Measure		1970	19[...]
Manufacturing of Selected Producers Durable Equipment for Electric Utilities	Sales in millions of dollars		3,800	5,[...]
Design and Construction of Oil Refineries	Number of oil refineries designed and constructed by size of capacity	Refinery Capacity Distribution:		
		4 to 30 MBD	2	1[...]
		31 to 70 MBD	1	2[...]
		71 MBD and above	5	1[...]
Design and Construction of Fossil-Fueled Steam-Electric Generation Power Plants	Number of power plants of 750 MW capacity designed and constructed		15	5[...]
Design and Construction of Nuclear Power Plants	Number of nuclear power plants of 1000 MW capacity designed and constructed		21	8[...]
RESEARCH AND DEVELOPMENT ACTIVITIES				
Electric Utilities	R&D expenditures in millions of dollars		58	6[...]
Integrated Petroleum Refining Industry	R&D expenditures in millions of dollars		626	1,1[...]
Coal Mining	R&D expenditures in millions of dollars		17	2[...]
Coal Gasification and Liquefication	R&D expenditures in millions of dollars		33	2,0[...]
Manufacturing of Selected Producers Durable Equipment for Electric Utilities	R&D expenditures in millions of dollars		105	1[...]
Nuclear Power	R&D expenditures in millions of dollars		335	1,5[...]

Table 2 - Continued

	Output Measure		1970	1980	1985
or	Sales in millions of dollars		3,800	5,910	7,500
- ies	Number of oil refineries designed and constructed by size of capacity	Refinery Capacity Distribution:			
		4 to 30 MBD	2	10	10
		31 to 70 MBD	1	20	20
		71 MBD and above	5	10	10
- ed ra-	Number of power plants of 750 MW capacity designed and constructed		15	51	19
-	Number of nuclear power plants of 1000 MW capacity designed and constructed		21	80	140
P-	R&D expenditures in millions of dollars		58	604	668
m .	R&D expenditures in millions of dollars		626	1,100	1,500
	R&D expenditures in millions of dollars		17	200	260
	R&D expenditures in millions of dollars		33	2,000	2,000
or	R&D expenditures in millions of dollars		105	160	200
	R&D expenditures in millions of dollars		335	1,500	2,400

2. <u>Petroleum and natural gas extraction and petroleum refining</u> -- SIC 291, petroleum refining and SIC 13, petroleum and natural gas extraction.

3. <u>Natural gas production, transmission and distribution</u> -- SIC 4922, natural gas transmission, SIC 4923, natural gas distribution, and parts of SIC 1311, natural gas production.

4. <u>Coal mining</u> -- SIC 12, bituminous and lignite mining.

5. <u>Nuclear power production and radioactive waste disposal</u> -- SIC 1094, mining and milling of uranium, parts of SIC 2819, industrial, organic, chemical, nec., i.e., fuel element fabrication; and enrichment and waste disposal activities of the U.S. Atomic Energy Commission.

6. <u>Manufacture of selected producers durable equipment for electric companies</u> -- SIC 3511, steam engines; steam, gas and hydraulic turbine generator set units; SIC 3612, power, distribution, and specialty transformers; and parts of SIC 3443, fabricated plate works.

7. <u>Energy-related construction</u> -- parts of SIC 16, heavy construction contractors, and force account construction by utilities and integrated petroleum companies.

It should be noted that the seven industries considered do not account for all energy-related manpower demand. Except in the case of producers of durable equipment for electric utilities, this study was not able to take account of the second-tier effects--the increased demand for scientific and technical manpower in the industries supplying the energy sector. Secondly, estimates were not made of the demand arising from production from new energy sources such as oil shale, geothermal or solar heat (coal gasification and liquefaction).

Significant production from these sources is not likely during the projections period, but manpower demand associated with R&D will be important, especially in the later years, and this was included in the projections.

With the increased domestic production of energy stipulated in this scenario, NPA projected that requirements for scientists and engineers in the seven energy-related industries (including R&D) in 1985 would be more than double those of 1970.

In 1970, a total of some 141,000 engineers and scientists were employed in the seven energy-related industries. By 1985, this total employment is expected to have reached 307,000, an increase of 117 percent, as shown in Table 3.

These increased demands for the principal occupational disciplines are also displayed graphically in Figure 2. The overall totals for scientists and engineers are shown in a larger linear scale in Figure 3.

NPA's projections indicate a faster growth of demand for engineers than for scientists. The requirement for engineers is projected to increase from 101,000 to 225,000 in the 1970 to 1985 period, an increase of some 122 percent, whereas the need for all scientists is expected to rise by 108 percent. This difference is due to the changing technologies in several of the seven industries under study. It is also due, however, to the fact that in these industries, R&D activities (which traditionally utilize a large number of engineers) will increase substantially over the 1970 to 1985 period.

Among engineers, the largest demand in 1985 will be for electrical engineers, followed by chemical and mechanical. These three engineering disciplines will, in the year 1985, represent 29, 23 and 13 percent, respec-

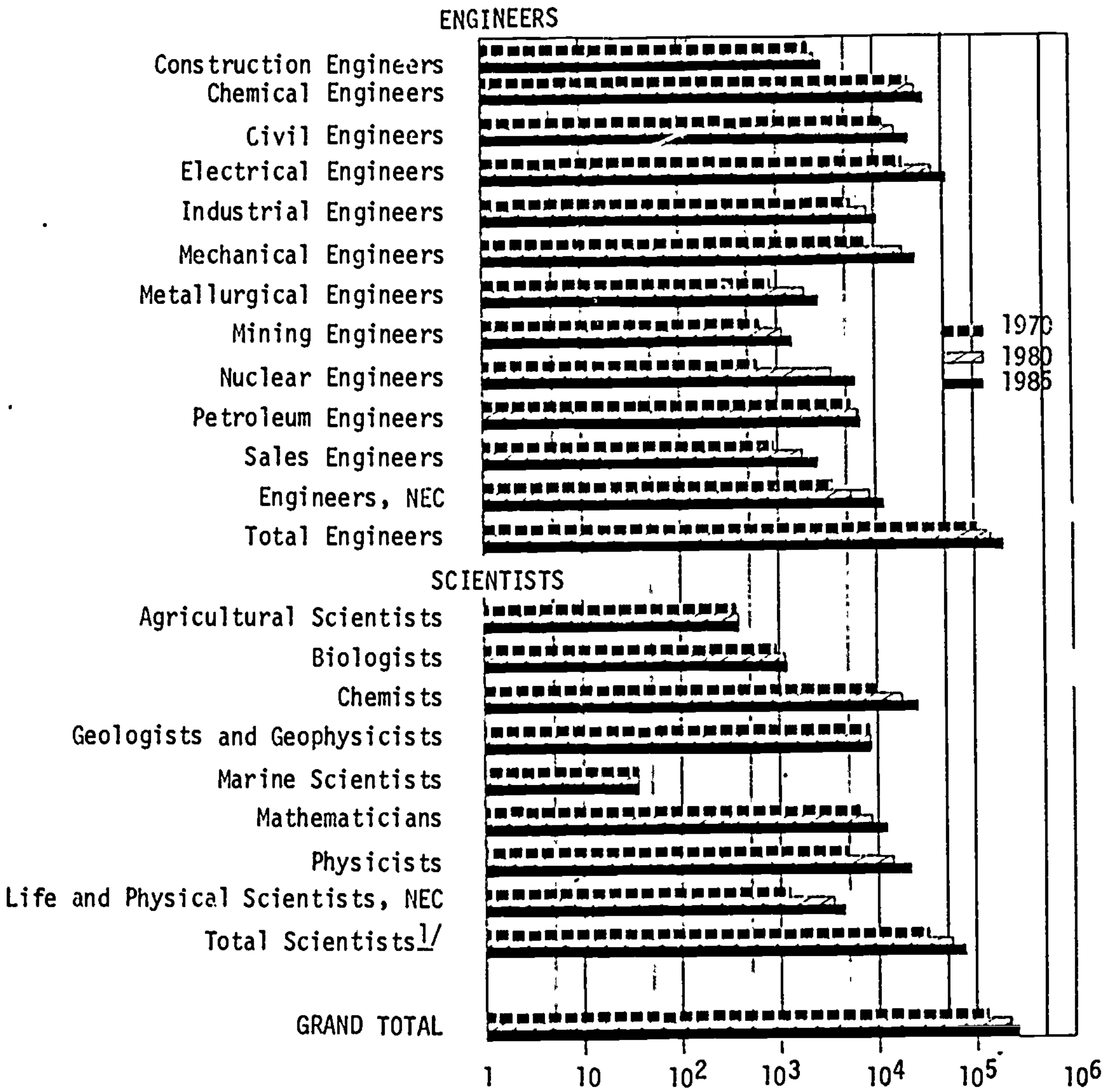
Table 3

Requirements for Engineers and Scientists by Type in Selected Energy-Related Sectors in the United States, Assuming Maximum Effort to Develop Domestic Fuel Sources, 1970, 1980 and 1985

ENGINEERS	1970	1980	1985
Construction Engineers	2,500	3,100	3,300
Chemical Engineers	33,600	42,300	51,500
Civil Engineers	14,200	18,300	27,200
Electrical Engineers	25,600	50,000	65,500
Industrial Engineers	6,000	8,700	12,000
Mechanical Engineers	8,000	19,900	30,500
Metallurgical Engineers	900	1,900	2,700
Mining Engineers	700	1,400	2,200
Nuclear Engineers	600	3,600	6,200
Petroleum Engineers	5,600	7,300	9,600
Sales Engineers	900	1,900	2,600
Engineers, Nec	3,700	9,700	11,600
Engineers, Total	101,300	168,500	224,700
SCIENTISTS	1970	1980	1985
Agricultural Scientists	400	400	500
Biologists	900	1,300	1,500
Chemists	13,200	19,100	27.800
Geologists and Geophysicists	8,100	9,900	11,100
Marine Scientists	38	41	46
Mathematicians	7,500	10,000	13,900
Physicists	8,000	16,500	22,800
Life and Physical Scientists, Nec	1,613	3,600	4,900
Scientists, Total	39,700	61,000	82,800
GRAND TOTAL	141,000	229,500	307,500

Figure 2

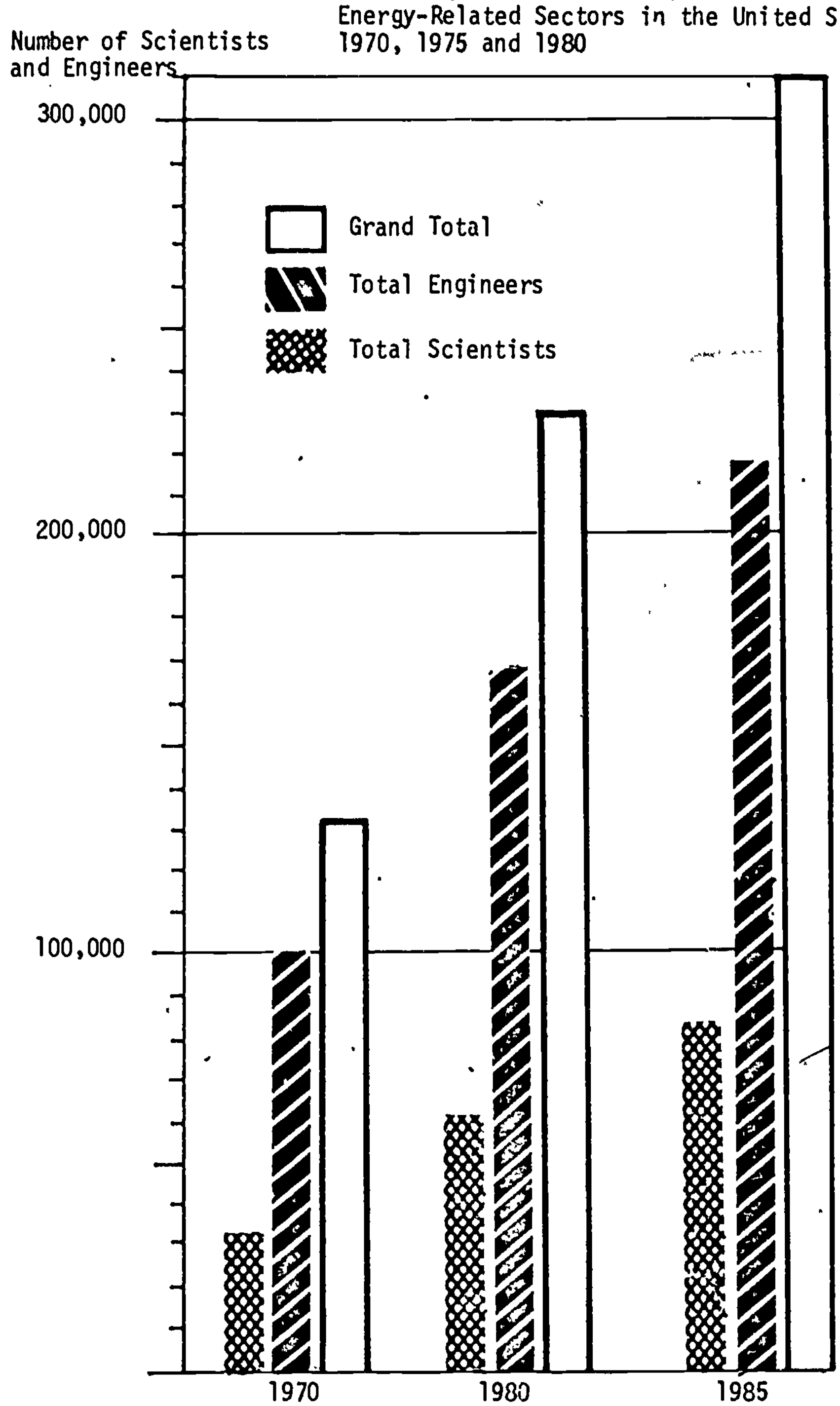
Requirements for Engineers and Scientists by Type in Selected Energy-Related Sectors in the United States, Assuming Accelerated Domestic Production, 1970, 1980 and 1985



1/ Totals include unallocated requirements for scientists and engineers.

Figure 3

Total Requirements for Engineers and Scientists in Energy-Related Sectors in the United States, 1970, 1975 and 1980



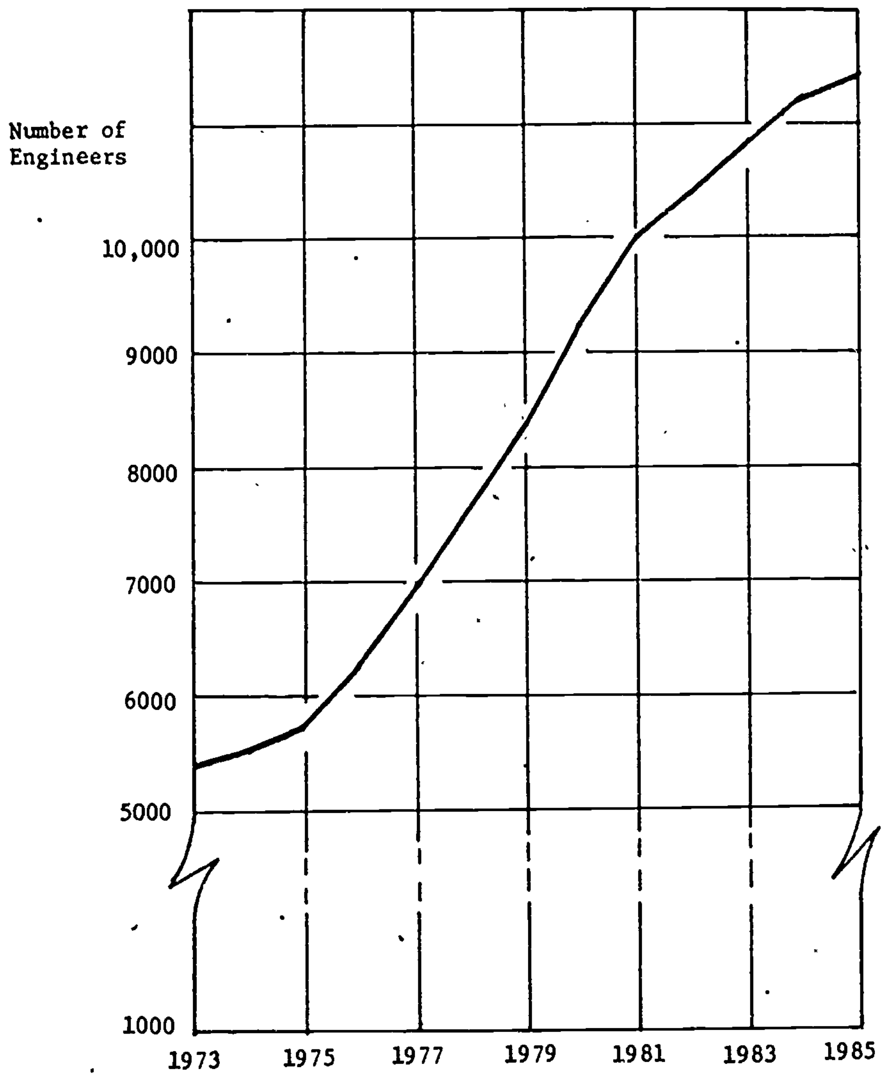
tively, of the total requirement. In 1970, three engineering disciplines most in demand were electrical, chemical and civil, with electrical engineers accounting for only 25 percent of all engineers instead of 29, as projected for 1985. Conversely, chemical engineers, who will represent 23 percent of the total requirement in the seven energy-related sectors in 1985, comprised 32 percent of the total in 1970. These and other changes in the proportion of engineering disciplines required in 1985 as compared to 1970 reflect changes in the energy production technologies in general and the rapid increase in the nuclear power generating units in particular. For example, engineering requirements for the design and on-site construction of nuclear power plants is expected to more than double by 1985, as displayed in Figure 4; on the other hand, the same factors will cause a decrease in the number of engineers required for the same function in fossil-fueled steam-electric power plants during this period, as shown in Figure 5.

The rapid increase of nuclear power is also the reason for the relatively large increase in requirements for physicists, an increase of 186 percent as compared to chemists (the second largest science discipline) who will increase only 110 percent during the same time period. However, physicists together with chemists will continue to be predominant among scientists in 1985, as they were in 1970. In 1985, these two disciplines will comprise about 61 percent of the total requirements for scientists; in 1970, the corresponding figure was 53 percent.

The continuing dominance of these two scientific disciplines together with geologists and geophysicists over all other scientists is supported by judgmental information NPA obtained in interviews with the energy industries;

Figure 4

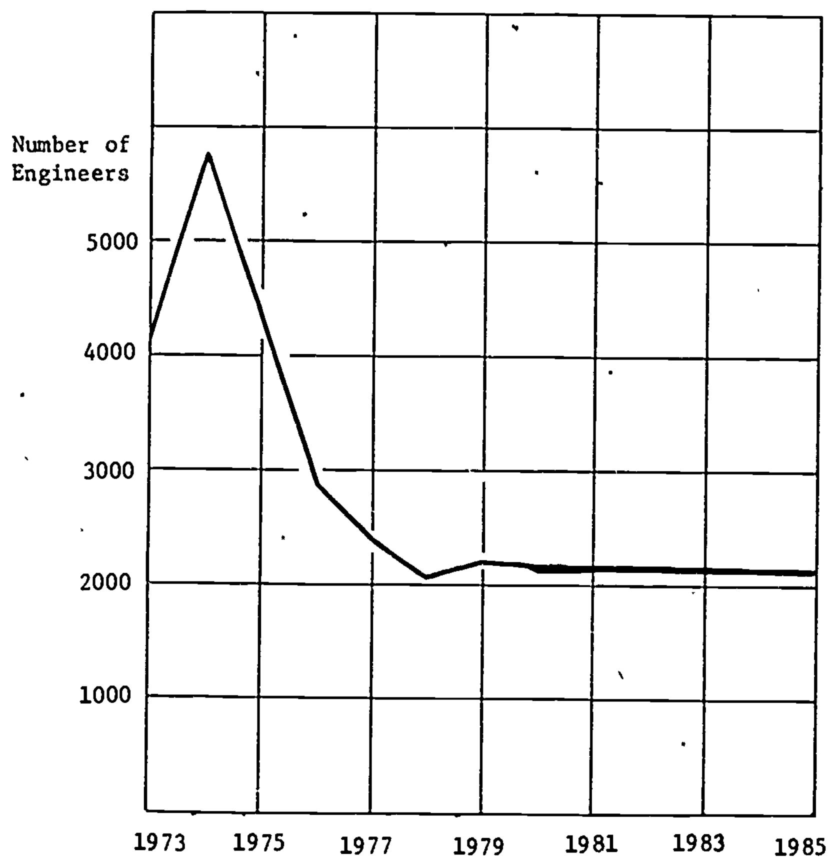
Employment Trends of Engineers Engaged in the Design and in the On-site Construction of Nuclear ,ower Plants in the United States, 1973 to 1985



Source: National Planning Association

Figure 5

Employment Trends of Engineers in the Design and On-site Construction of Fossil-fueled Steam-electric Generation Power Plants in the United States, 1973 to 1985



Source: National Planning Association

much larger numbers of physicists and chemists will be required in the production of energy because of the increase in nuclear power plants; the demand for geologists and geophysicists will continue at the present high levels because of rapidly increasing exploration activities and attempts to increase secondary recovery of crude oil. The increased requirements for mathematicians of about 85 percent between 1970 and 1985 can be also attributed to the growth of nuclear industry.

Because of the aforementioned rapid increase in nuclear power plants, the most rapid rise in the requirements for scientific and engineering manpower is expected in the nuclear power cycle as shown in Tables 4 and 5. The growth of activities in this industry, including research and development, calls for an increase from about 14,000 scientists and engineers in 1970 to about 65,000 by 1985. This increase is, of course, exceptional and is not matched by any of the other energy-related sectors. Electric utilities rank second in the increased requirements for scientists and engineers; they are projected to increase from about 23,000 in 1970 to about 75,000 in 1985, an increase of over 200 percent.

The other energy-related sectors under study indicate increasing requirements for scientists and engineers varying from 30 to 60 percent by 1985.

Increases in these requirements by the manufacturing activities producing selected durable equipment for electric utilities deserve special emphasis for two reasons. For one thing, this increase is exceptionally large, the projected requirements for scientists and engineers for 1985 being about 34,000 as compared to 17,000 in 1970. In addition, this industry, alone among the seven sectors under study, represents a so-called secondary industry.

In summary, the projected requirements for scientists and engineers indicate on the average an annual additional requirement of about 6,700 engineers by 1980 and 11,200 by 1985 for the seven energy-related industries considered in this report, assuming no attrition losses. For scientists, the corresponding figures are: 2,200 by 1980 and 4,300 by 1985.

Projections of attrition losses for scientists and engineers are not readily available; however, assuming an annual attrition rate of 1.5 percent, the annual demand for engineers in the seven industries will reach 9,200 by 1980 and increase to about 14,600 by 1985. For scientists, the corresponding projections indicate an annual need for about 3,000 by 1980 and about 5,500 by 1985.

Any radical departure from established trends and policies, such as that required by Project Independence, requires a significant period for the planning and preparation of activities to be undertaken under the new policy. This implies that an opportunity may exist for industry and/or government to study and plan manpower requirements and even to undertake the necessary training for those occupations which appear to be moving toward short supply.

It should be emphasized that the demand projections presented herein result from the particular levels and the mix of energy-related activities specified in this analysis. Alternative scenarios for increased domestic production would produce different results which might place greater or less strain on the nation's engineering and scientific manpower resources. Further research should explore the manpower implications of other energy production scenarios and should take into account feedback effects.

Table 4

Requirements for Engineers and Scientists by Industry in Selected Energy-Related Sectors in the United States, 1970, 1980 and 1985

INDUSTRY	OCCUPATION	1970	1980	1985
Gas	Engineers	4,900	6,000	7,600
	Scientists	1,800	2,200	2,700
	Total	6,700	8,200	10,300
Oil	Engineers	43,700	53,500	66,500
	Scientists	22,300	27,500	32,600
	Total	66,000	81,000	99,100
Coal	Engineers	1,100	2,300	3,500
	Scientists	200	500	700
	Total	1,300	2,800	4,200
Electric Utilities	Engineers	22,300	51,300	71,900
	Scientists	800	2,300	3,000
	Total	23,100	53,600	74,900
Nuclear Fuels	Engineers	2,900	17,300	28,200
	Scientists	11,300	23,400	37,000
	Total	14,200	40,700	65,200
Electric Equipment	Engineers	14,000	21,600	27,300
	Scientists	3,400	5,300	6,700
	Total	17,400	26,900	34,000
Construction	Engineers	12,700	16,600	19,600
	Scientists	-	-	-
	Total	12,700	16,600	19,600
Total	Engineers	101,600	168,600	224,600
	Scientists	39,800	61,200	82,700
	Total	141,400	229,800	307,300

Table 5

Requirements for Engineers and Scientists Engaged in Research and Development in Energy-Related Industries, United States, 1970, 1980 and 1985

INDUSTRY	OCCUPATION	1970	1980	1985
Oil	Engineers	7,400	13,000	17,600
	Scientists	3,500	6,100	8,300
	Total	10,900	19,100	25,900
Coal	Engineers	100	700	900
	Scientists	--	200	200
	Total	100	900	1,100
Electric Utilities	Engineers	400	3,800	4,200
	Scientists	100	700	800
	Total	500	4,500	5,000
Nuclear Fuels	Engineers	1,600	7,400	11,800
	Scientists	10,700	18,900	30,000
	Total	12,300	26,300	41,800
Electric Equipment	Engineers	2,000	3,000	3,700
	Scientists	500	700	900
	Total	2,500	3,700	4,600
Total	Engineers	11,400	27,700	38,200
	Scientists	14,700	26,600	40,300
	Total	26,100	54,300	78,500

Forecasting the overall impacts of the increased demand for scientists and engineers due to expanded domestic energy production would require information about the future demand for these personnel in other sectors of the economy and the prospective supply as it is determined by attrition, new graduations and retraining. While the scope of the present study did not permit a thorough investigation of these factors, available information provides indications of significant ex ante shortages of scientific and engineering manpower that would lead to higher prices and increased competition for such personnel.

The dimensions of the impact of these projected increases in requirements for scientists and engineers in the seven industries studied can be illustrated by comparing them with recent estimates of future increases in the supply of scientists and engineers. For instance, according to the U.S. Office of Education, about 34,000 persons a year are expected to receive bachelor's degrees in engineering in the mid 1970s. However, the supply situation will become considerably worse beyond the mid 1970s if current trends continue toward an overall decrease in the number of graduating physical scientists and engineers.

Given these trends, the number of engineers graduating in 1985 may be as low as 28,000. Furthermore, only a portion of graduates are actually available for direct employment in energy industries. Assuming, however, that all graduates will indeed become available, requirements in the seven energy-related industries analyzed in this report would be sufficient to absorb about 20 to 30 percent of all new engineers by 1975 and 1980 and more than 30 percent by 1985. Further, about one-third of all graduates with a physical science degree would be in demand by these seven industries.

However, since these industries employed only about 10 percent of all engineers and 15 percent of all scientists employed in the United States in 1970, it can be seen that the expanded demand in energy sectors would be in competition with probable demand in other sectors of the U.S. economy, assuming no drastic changes in the shares of scientists and engineers needed in the nonenergy-related industries. This already bleak future supply/demand relationships for the scientists and engineers required for energy production is further complicated by the fact that, in most cases, experienced scientists and engineers and/or those with skills beyond the bachelor's degree are needed.

The rapid increase in nuclear power plants, with its accompanying more advanced engineering requirements, is an excellent example of a source of additional skill needs. In the past, the required experience and additional skills were, as a rule, obtained by on-the-job training. The interviews conducted during this study, however, indicate that this time-tested and accepted method is already being by-passed in several sectors (notably construction, and oil exploration and production) because of severe shortages of experienced engineers and scientists. In its place, the firms requiring experienced engineers and scientists resort to either competitive hiring of experienced personnel from other firms or hiring of engineers and scientists from abroad. Neither of these practices is satisfactory in the long run. The former, of course, does not solve the economy-wide shortages of experienced personnel. The latter is unsatisfactory since the supply of foreign engineers and scientists is diminishing and since many of them lack the skills required and/or are frequently not familiar with U.S. engineering practices. Our interviews indicated that the need to be familiar with engineering practices used by the industries studied in this report is apparently a significant issue. Lack of such knowledge has been and continues to be one of the principal reasons why most of the firms interviewed in the course of this study avoid hiring unemployed aerospace scientists and engineers.

In conclusion, this study indicates that the future supply of engineers and scientists may be inadequate to meet the demands of activities designed to increase domestic energy supplies. These shortages may become increasingly severe if other programs that place heavy demands on scientific and engineering skills are implemented at the same time. Better understanding of the role of the federal government as an independent and major source of changes in demand for scientists and engineers is, therefore, mandatory and will contribute to the attainment of national goals, such as those embodied in Project Independence, and to the more effective utilization of scientific and engineering manpower.

III. METHODOLOGY

The methodology designed and used in this study was conceptually simple and sufficiently flexible to allow estimates of the scientific and engineering manpower requirements for any specified future energy supply scenario.

Essentially, the methodology had two steps:

(1) development of satisfactory scientific and engineering manpower coefficients for all energy-related industries and/or activities for all years including the base year; and

(2) application of these coefficients to the energy-related industries and/or activities projected into the future.

Estimation of the manpower coefficients was, of course, the critical element in this methodology. As an initial step, an "Activity-Occupation Matrix" was developed, which described the kinds of scientific and technical manpower currently employed in various activities within an industry. The "Activity-Occupation Matrix" distinguished between the activity in which a person was engaged and his occupation. For example, one might find a mechanical engineer (occupation) working on environmental problems in electricity generation (activity).

An "activity" is, on the other hand, a function within an industry. It can be defined down to almost any level of detail, for example, from "hydroelectric power generation" to "designing blades for turbine rotors to be used in hydroelectric power generation." The morphology thus developed can be conveniently visualized in "trees," which display the relationship between more and less aggregated activities and subactivities. Such trees were prepared for all energy-related sectors of economy. Data were sought for the activities at the ends of the branches, but if information could not be obtained on these highly disaggregated activities, or if it was incomplete, information was used at higher levels of aggregation. Thus, each "node" or branching point on the tree represented a possible category for data collection.

The information needed on each activity was as follows:

(1) An "activity level indicator," dated. This was to be some measure of the level of effort in that activity with the most appropriate measure being different for different activities. Thus, for "operations and maintenance in hydroelectric power generation," appropriate activity measures would be--

- total employment in hydroelectric power,
- KWH from hydroelectric power,
- sales receipts from hydroelectric power.

Similarly, for "R&D in hydroelectric power," appropriate measures might be--

- total R&D employment in hydroelectric power,
- total R&D expenditures in hydroelectric power including materials and plant,
- sometimes the number of patents/year.

(2) As complete a breakdown as possible of the number of scientists, engineers and technicians employed in the activity at a particular date, which should be the same as that for the "activity level indicator."

The cells of the resulting Activity-Occupation Matrix, each corresponding to some activity and some occupation, would contain a count of the number of people employed in that activity who correspond to that occupational category. The contemplated matrix would thus uniquely specify scientific and technical manpower for each of the energy-related industries included in this study.

From this information, scientific and technical manpower coefficients could be calculated relating the number of scientists, engineers and technical personnel by specialty to a level of activity such as units of output, or dollars of sales or investment.

Data for the matrix of all activities were collected from a selected group of firms in the energy sector which were considered to be representative. For each energy-related industry an attempt was made to select several firms representing "small," "medium" and "large" organizations (measured in terms of employment), as well as firms representing the various technologies used in their activities. However, no attempt was made to select a statistically valid sample.

After the resulting 40-odd representative firms were selected, contact was made by telephone, followed by a letter, then personal interviews and the actual data collection effort. Typically, the information obtained in these field interviews consisted of a firm's payroll data for a specified project and/or activity.

For all sectors and/or activities, at least five independent coefficients were estimated from the information obtained in the interviews. The estimated coefficients were then compared and checked for validity and reliability.

If the coefficients were comparable--i.e., showed differences of less than 5 percent--an average coefficient was calculated. If differences among the coefficients were larger than 5 percent, additional investigation was undertaken and/or other coefficients were obtained in field interviews until an acceptable coefficient could be determined.

Given output levels in energy industries, activity levels are determined through the application of input-output coefficients. Demand for scientific and engineering manpower can then be calculated simply by multiplying the activity levels by the scientific and engineering manpower coefficients. As noted previously, in the present study, the output levels in seven energy-related industries were specified in a scenario based chiefly on independent estimates.

This approach and its application in the study have shortcomings which are more or less susceptible to correction.

There is a concern that the firms selected were not representative and that the manpower coefficients which resulted are atypical of the industry. This difficulty can be corrected by using a larger sample and/or statistical techniques. In addition, there are significant problems of classification since firms vary in their terminology and the titles assigned to similar or identical work. The answer here involves more probing examination of job characteristics and employees' skills and training.

Two major problems with the methodology must also be considered. It assumes that the relation between scientific and technical manpower inputs and activity levels is linear--that is, that manpower usage increases or decreases in proportion to changes in output levels. In fact, however substantial changes in the level of activities are likely to cause or be accompanied by changes in the amount and pattern of manpower needs. Such scale effects need to be investigated especially since a number of energy activities, such as nuclear waste disposal, are currently small but likely to burgeon in the future.

Secondly, the method cannot adequately account for changes in manpower coefficients due to new technology and changes in relative prices. Coefficient changes estimated in the current study are limited to those resulting from extension of technology already at least in a development stage and the diffusion of advanced technology already in use.

Estimation of the direction and extent of such changes poses difficult problems, but more can be done to take into account these prospective changes.