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FUTURE OIL SUPPLY TO THE NORTHEAST UNITED STATES

Harold Bronheim

June 1976

**POLICY ANALYSIS DIVISION
NATIONAL CENTER FOR ANALYSIS OF ENERGY SYSTEMS
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FOREWORD

This report is one of a number of issue papers prepared as part of the Brookhaven National Laboratory Northeast Energy Perspectives Study. The analyses in these papers were performed specifically to assist us in our first integrated study of the energy future of the northeastern United States.

Topics covered by the issue papers include the potential supply of energy to the Northeast from coal, oil, natural gas, liquefied natural gas (LNG), nuclear power, municipal waste, solar energy, and wind power, and the demand for energy in the Northeast from the industrial, transportation, and residential and commercial sectors. In each case a range of estimates of energy supply or demand was constructed to reflect not only a variety of possible policy and technological developments, but also the basic uncertainties of all such future projections. The integrative analysis which relates the supply and demand picture is presented in "A Perspective on the Energy Future of the Northeast United States."

The issue papers prepared for the Northeast Energy Perspectives Study and the summary report will be available from:

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The issue papers and summary report 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.
- J. Brainard et al., Editors, "A Perspective on the Energy Future of the Northeast United States," BNL 50550 (June 1976).

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ABSTRACT

The Northeast consumed some 4.6 million bbls/day of petroleum products in 1972. Nearly 63% of that supply was of foreign origin, making the Northeast the single largest oil importing region in the nation. The remainder of its supply originated mainly in states on The Gulf of Mexico.

Oil consumption has been growing rapidly in the Northeast as it has become the "swing fuel" for shifting patterns in the energy system. The phasing out of the coal as a major utility boiler fuel and the curtailment of natural gas sales to the Northeast have led to the rapid increase in the use of petroleum products.

Nationwide oil production reached a peak of 11.3 million bbls/day in 1970 and has been declining yearly ever since. The Northeast in particular has led the movement to foreign imports because of its coastal location, its distance from domestic sources, the competitive pricing of foreign oils, and because of environmental considerations (e.g., sulfur emission regulations).

Under various assumptions of total U.S. reserves of oil (discovered as well as undiscovered) coupled to alternate schedules of national resource development, projections of crude oil production were made for the years 1985 and 2000. The projections indicate that even under optimistic conditions crude oil production will be declining in the post 1985 period, if not earlier. This is primarily because oil recovery is technologically limited and generally unaffected by "moderate" price movements. Of these, the amount of domestically produced oil allocated to the Northeast was based on further assumptions with regard to supplies from historical sources as well as from future frontier areas in Alaska and the Atlantic Outer Continental Shelf.

The scenarios consistently indicate that domestic oil production and the Northeast's regional share will be heavily constrained by 1985, and rapidly declining thereafter. On the other hand production of oil worldwide will concentrate further in the hands of the Arab OPEC nations who are likely to exercise growing control over pricing and the international supply of crude oil.

I. INTRODUCTION

Viewpoint of This Paper

Within the last two years, the availability and cost of oil have become high priority issues in Washington and in every state across the nation. Yet the U.S. as a whole, and the Northeast in particular, is more vulnerable now to supply interruptions than it was at the time of the oil embargo of 1973-74.

Currently, over 60% of all crude and petroleum products consumed in the Northeast is of foreign origin, and that percentage is steadily growing. However, the states of the Northeast, which are the most dependent on oil and especially nonsecure foreign supplies, have done little, collectively or individually, to alter or even to analyze their precarious position. This is, perhaps, not surprising in view of the lack of effective Federal action. Nevertheless, because of the long lead times necessary to implement alternative energy policies for the future, concerted action is required soon. Furthermore, as the states of the Gulf Coast move to exert more regional control over their dwindling oil and gas resources, effective Federal action may be further delayed through legal and political maneuvering. Texas, for example, is expected to be a net importer of oil by 1985, following present growth patterns.¹ It is likely, therefore, that a dwindling supply of domestic oil will be available to the Northeast.

This being the case, as part of the Northeast Energy Perspectives Study, we have embarked on an effort to characterize the oil supply picture and to discuss the factors and issues that have shaped the energy system in the past and might have an impact on it in the future. Primary emphasis in this study has

been placed on those factors that are of significance in determining the region's ability to respond to oil supply interruptions. These factors include the degree of dependence on foreign oil and its effect on prices in the regional economy, the availability of storage facilities and other physical capacities, the ability to substitute domestic oil in the future, and environmental concerns that limit our flexibility. Each of these factors tends in the Northeast to affect the resilience of the system and has contributed to the energy-related problems in the region.

Offshore oil development is one of the most immediate issues with respect to energy policy in the Northeast today, with debates ranging from questions of environmental and coastal impacts to questions of regional economic jurisdiction. Since this subject extends well beyond the scope of this paper, it will not be discussed here in depth. In passing, however, we note that the most crucial issue with respect to offshore oil development involves the question of "Just how much oil and gas is out there?" If the latest resource estimates released by the U.S. Geological Survey are correct, offshore oil development on the Atlantic OCS would not significantly alter the oil supply problems facing the Northeast today.² (The potential effect on regional gas supplies, however, is significantly greater.) Until exploratory drilling is undertaken to assess the potential size of that resource base, all debate and legal maneuvering on this issue may be a raging storm in a teacup. In the meantime, other more critical regional energy issues go unheeded and unresolved.

The Northeast faces many energy-related decisions. These decisions should be based on the best available knowledge of the regional energy system and the impacts of energy policy alternatives. No recommendations or solutions are proposed in this

paper; this study is rather an effort to delineate the problems at hand, the options open to regional decision-makers, and some of their implications.

The Domestic Scene

After two years of level oil consumption brought about by the price increases of 1972-73, domestic demand in the U.S. appears again to be on the rise. And, as the economy slowly climbs out of a recession, foreign oil is once again the "swing fuel" filling the supply-demand gap. Because domestic production is still on the decline (as is the supply of Canadian oil), we are again becoming increasingly dependent upon nonsecure foreign supplies. As shown in Table 1, the fraction of national oil consumption supplied by foreign sources has been steadily increasing over the past seven years and in all likelihood, will reach 40% by mid-1976.

In 1974, oil consumption was 10% below the level predicted for that year by pre-embargo consumption patterns. However, analysts generally believe that roughly half of that reduction was brought about by higher prices and the other half by industrial recession and the effects of a milder than normal winter. Thus, for the most part, conservation brought about so far has been mainly in response to higher prices arbitrarily imposed by foreign oil producers.

In two years, the Federal Government has not been able to develop a working energy program and a cohesive plan of action of the kind instituted in developed countries throughout Europe. Neither programs to lower demand nor programs to increase supply are being implemented.

Therefore, because of our inaction and our lack of a national energy program that would limit oil consumption or stimulate domestic production, our vulnerability to another embargo and

Table 1
NATIONAL OIL SUPPLY^{3,4}
(10⁶ bbl/day)

<u>Year</u>	<u>Domestic production*</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

*Including natural gas liquids.

**Oil and Gas Journal Projections.

its potential ill effects has not diminished. In fact, the overall amount of belt-tightening that has occurred, combined with our growing reliance on foreign oil, indicates that our flexibility in the event of another crisis is even more limited than it was prior to the embargo. Furthermore, it is difficult to argue that the probability of another embargo has decreased significantly in the last two years. Clearly, national and regional energy policy must take the possibility of supply interruptions seriously indeed.

II. OIL USE IN THE NORTHEAST

Crude Supply and Refining

The Northeast contains a highly developed crude oil refining industry that had a total operating crude capacity in 1974 of ~1.6 million barrels a day (Table 2). The majority of this refining capacity, however is centered in two general locations, one in New Jersey in the New York Harbor west of Staten Island, and the second in the states of Delaware, New Jersey, and Pennsylvania along the Delaware River and Delaware Bay near Philadelphia. Two obvious reasons for the development of refining sites at these locations are the proximity of major market centers and ideal port and harbor facilities.

Figure 1 is a schematic representation of the flow of crude oil to the major refineries in the Northeast in 1972. The overwhelming mode of transport of crude oil into the region was by barge and tanker. Nearly 90% arrived by this mode. Of the total supply of oil to refineries in the region, 75% originated in foreign nations and 20% came from the Gulf Coast states of Texas and Louisiana. Table 3 provides a breakdown of foreign crude supply by country of origin. OPEC furnished 85% of the foreign crude oil supply, with the largest share (33%) coming from Arab OPEC members. Although accounting for only 11% of the nation's refinery capacity, the Northeast handled nearly 65% of the non-Canadian foreign crude imported into the U.S. Since their output is consumed within the region, these facilities contribute to the petroleum product supply vulnerability described further below. In all, 458 million barrels of crude oil were refined in 1972. Thus, the refineries operated at about 80% of their capacity

Table 2.

NUMBER AND CAPACITY OF NORTHEAST REFINERIES AS OF JAN. 1

	<u>Petroleum refineries</u>			<u>Crude oil throughput capacity, bbls/d*</u>					<u>Gasoline output capacity, bbls/d**</u>				
	<u>Operating</u>	<u>Shutdown</u>	<u>Total</u>	<u>Operating</u>	<u>Operable</u>	<u>Inoperable</u>	<u>Total</u>	<u>Building</u>	<u>Operating</u>	<u>Operable</u>	<u>Inoperable</u>	<u>Total</u>	<u>Building</u>
Delaware	1	-	1	140,000	-	-	140,000	-	79,200	-	-	79,200	-
Maryland	1	1	2	10,000	13,500	-	23,500	-	-	-	-	-	-
New Jersey	6	-	6	612,000	10,000	-	622,000	110,000	228,300	200	-	228,530	27,000
New York	2	-	2	106,800	-	-	106,800	-	42,100	-	-	42,100	-
Pennsylvania	11	1	12	693,820	-	1,400	695,220	95,000	315,220	9,452	-	324,672	42,700
Rhode Island	1	-	1	7,500	-	-	7,500	-	-	-	-	-	-
Total	22	2	24	1,510,120	23,500	1,400	1,595,020	205,000	664,850	9,652	-	674,502	69,700

*Crude oil distillation.

**Cracking, reforming, coking, and alkylation.

Figure 1. Crude supply to the Northeast, 1972 (10^6 bbl).⁸⁻¹⁰

Table 3
NORTHEASTERN IMPORTS OF CRUDE
BY COUNTRY OF ORIGIN, 1973
(10³ bbl/day)

	Total U.S. imports	Approximate Regional share*, %	North- eastern imports	% of Total
<u>OPEC</u>				
<u>Arab</u>				
Middle East	290.4	60	174.2	15.6
Mediterranean	196.2	100	196.2	17.6
Subtotal	486.6	76	370.4	33.2
<u>Non-Arab</u>				
Iran	135.8	60	81.5	7.4
Venezuela	254.9	95	242.2	21.7
Nigeria	242.9	100	242.9	21.8
Other	177.5	5	8.9	.8
Subtotal	811.1	71	575.5	51.7
Total OPEC	1,297.7	73	945.9	84.9
<u>Non-OPEC</u>				
Canada	853.7	13	110.0	9.9
Others	64.8	90	58.3	5.2
Total Non-OPEC	918.5	18	161.3	15.1
Grand total	2,216.2	50	1,114.2	100

*Derived from Figure 8.

throughout the year (approximate average for all refinery operating capacity in the U.S.).

Although oil consumption across the nation and in the Northeast has been growing rapidly (3.5% per annum) throughout the sixties and early seventies, crude oil refining and refinery capacity has grown at a much slower pace.¹¹ Figure 2 shows that between 1960 and 1974 regional refining capability grew only a modest 7.5 percent.^{5,12} Since 1971, sizable growth and expansion have occurred. However, because of the rapid growth in the rate of consumption in the past decade, the reliance on foreign refined petroleum products has also grown rapidly.

Throughout the sixties, the fraction of oil refined within the region that was of foreign origin was stable at about 50% (Figure 3). Low points of nearly 45% were attained in 1967 and 1970 during years when domestic oil production was reaching relative peaks.* After 1971, there was an upsurge in reliance on foreign crude reaching 85% by 1973. Two factors are thought to be responsible for this significant shift in supply: the decline in domestic oil production occurring yearly since 1970, and the new air pollutant emission standards instituted in the early 1970's. The first factor would have influenced a slow transition to foreign supply sources. The very rapid switch that actually occurred probably resulted, therefore, from the need to meet the new emission standards, which could be accomplished immediately only through the substitution of low-sulfur foreign crude for the generally high-sulfur domestic product.

Petroleum Products - Supply and Consumption

Petroleum products account for a significantly larger share of energy consumption in the Northeast than they do on a national

*1970 was the peak year of domestic crude production at 9.6 million barrels/day.⁴

Figure 2. Refinery capacity and crude runs in the Northeast.^{5,8,12}

Figure 3. Foreign crude runs as percent of total.⁸

average basis. Whereas 45% of U.S. total energy consumption is based on oil, in the Northeast the fraction is 63%. It would appear (Table 4) that this region compensates for its less than average natural gas consumption through its higher use of oil, especially imported foreign refined products.

Table 4
COMPARISON OF NORTHEAST AND U.S. RESOURCE
CONSUMPTION BY TYPE, 1972
(10^{15} Btu)

<u>Resource</u>	<u>Northeast region</u>		<u>United States^{13,14}</u>	
	<u>Consumption</u>	<u>% of Total</u>	<u>Consumption</u>	<u>% of Total</u>
Oil	9.68	63	32.97	45
Gas	2.82	18	23.12	32
Coal	2.64	17	12.60	18
Hydro	0.17	1	2.89	4
Nuclear	0.15	1	0.58	1
Total	15.44	100	72.16	100

Although total oil consumption per capita in the Northeast is close to the national average (Table 5), the relative levels of energy consumption by end-use sector in the Northeast differ markedly from those in the rest of the nation (Table 4). The Northeast uses more oil per capita in its residential and commercial sectors because of the general unavailability of natural gas and also because its climate is colder than the U.S. average. Regionally, oil consumption by the electric utilities is also greater because of environmental restrictions and the unavailability of local fossil fuel alternatives. Since the Northeast has more densely populated urban areas and better developed alternative mass transit modes, less oil is consumed per capita in the

Table 5

COMPARISON OF NORTHEAST AND U.S. OIL CONSUMPTION

BY SECTOR AND PER CAPITA, 1972¹⁴

Sector	Northeast Region			United States		
	Consumption (10 ¹² Btu)	% of Total	Per Capita (10 ⁶ Btu/ person)	Consumption (10 ¹² Btu)	% of Total	Per capita (10 ⁶ Btu/ person)
Residential	1,647	17.0	27.86	4,253	12.9	20.42
Commercial	1,041	10.7	17.62	2,647	8.0	12.71
Industrial	1,495	15.4	25.30	5,668	17.2	27.22
Transportation	3,693	38.2	62.49	17,264	52.4	82.90
Electric Utility	1,808	18.7	30.59	3,134	9.5	15.05
Total	9,684	100.0	163.86	32,966	100.0	158.30

NORTHEAST

U.S.

Figure 4. Per Capita consumption of oil by end-use sector, 1972 (10⁶ Btu).

transportation sector. Comparatively equal amounts of oil are consumed in the industrial sectors because of the existence of major petrochemical industries in the Mid-Atlantic States.

Petroleum product consumption in the Northeast is presented historically in Table 6. The growth in oil usage from 1960 through 1971 proceeded at a steady average yearly growth rate of 3.5%, only slightly higher than the national average growth rate in the same period. Between 1971 and 1972, U.S. oil consumption climbed 5.8% but oil consumption in the Northeast jumped a striking 10%. The timing and magnitude of this increase suggest factors over and above the normal pattern of yearly growth in oil usage. The institution of sulfur emission standards in this period probably accelerated switchovers from coal to oil. In addition, decreased domestic natural gas production had resulted in curtailments of gas supply to the Northeast in that year. Once again,

Table 6

PETROLEUM PRODUCT CONSUMPTION IN NORTHEAST^{11,15}
(10¹² Btu)

	<u>1960</u>	<u>1965</u>	<u>1971</u>	<u>1972</u>
New England	1587	1782	2351	2588
Central Atlantic ^a	4383	5324	2665	7096
Northeast total	5970	7106	8810	9684

^aIncludes New York, New Jersey, Pennsylvania, Maryland, Delaware, and the District of Columbia

oil, the "swing" fuel, filled the gap. Finally, industry, bouncing back from a recession that had engulfed the economy for two years, contributed to the unusual increase in the demand for oil.

Although considerable, the refining capacity in the Northeast cannot meet the region's total demand for petroleum products. In 1972, regional refineries contributed only 25% of the region's petroleum product needs. Forty percent, imported directly as petroleum products, was from foreign sources. The remaining 35% was received in the Northeast from the Gulf Coast, arriving by pipeline and by water routes (see Figure 5). In reality, the system is considerably less flexible than Figure 5 might indicate.

Figure 5. Petroleum products supply to the Northeast, 1972
(10⁶ bbl). 8,9, 16-18

The breakdown of supply by product (Table 7) shows much higher reliance on foreign supplies of particular products such as residual oil. Nearly 90% of this product is imported. In addition, in some New England states, not reached by the product pipelines from the Gulf, the reliance on foreign petroleum products of all types is much higher than in the rest of the Northeast.

The ability of the transportation sector to act as a cushion in the event of a supply disruption is also limited. Even though 99% of gasoline supply originates domestically, switching refineries from gasoline production to other fuels would have only modest impact.* Refineries in the Northeast are themselves 85% dependent upon foreign crude; furthermore, the consumption of other petroleum products in the region is considerably greater than the regional production of gasoline. Ensuring the adequate supply of residual oil to the Northeast is a primary concern to policymakers in the region. Currently the majority (54%) of foreign refining for the Northeast occurs in the Caribbean, with the U.S. Virgin Islands accounting for as much as 20%. The next major refining center is South America (26% with Venezuela the largest supplier). Thus, the refining step would appear to be considerably more secure than the supply of crude oil. This is of little comfort in the event of an embargo aimed at refineries that supply the U.S. In addition, future imports of petroleum products may also shift to the Middle East, since the world's

*Currently 48% of the output of the Northeast refineries is gasoline.

Table 7

BREAKDOWN OF PETROLEUM PRODUCT SUPPLY TO THE NORTHEAST
(10⁶ bbls/year) - 1972^{8,9,11,16,17,18}

	<u>Regional Demand</u>	<u>Regional^e Refinery Production</u>	<u>Receipts from Pipeline</u>	<u>Gulf Coast Barge</u>	<u>Foreign Imports</u>
Gasoline	534.5	235.9	166.0	130.9	1.7
Jet Fuel	78.3 ^d	12.0	24.7 ^b	22.3	19.3 ^c
Kerosene	23.8	6.2	4.1 ^d	13.5	- ^f
Distillate	390.5	118.6	92.7	106.1	73.1 ^a
Residual	494.9	30.9	-	25.5	438.5
Others	159.4 ^d	31.0	-	1.9	126.5
Total Consumption	<u>1,681.4</u>	<u>434.6</u>	<u>287.5</u>	<u>300.2</u>	<u>659.1</u>

a Include 30.4 million bbls of No. 4 Distillate Oil and 80% of East Coast Distillate Imports.

b 50% of pipeline shipments from PAD III to I.

c 50% of imports to PAD I.

d Estimated.

e Does not include lubricants and other products.

f Included with distillate imports.

oil producers appear to be intent on capturing more and more of the oil processing and refining operations for themselves.

In terms of the physical supply system itself, the Northeast is primarily (80%) dependent on ocean-going transport for the initial transport of oil to its ports. Indeed, the coastal character of the Northeast has been a significant factor in the region's dependence on foreign oil. This characteristic of Northeast oil supply also has environmental implications, and the environmental impacts of alternative energy supply systems must be balanced against the impact of oil spills associated with tanker and barge shipment of oil.

III. MAJOR TRENDS IN REGIONAL OIL SUPPLY AND PRICE

Background

Several significant trends in regional energy supply prior to the winter of 1973-74 contributed to the Northeast region's dependence on foreign sources and its vulnerability to supply interruptions. As previously mentioned, in 1972 the Northeast relied on oil for ~ 63% of its energy needs, as compared with only 43% for the nation as a whole. The major regional trends can be summarized as follows:

1. The use of foreign oil was encouraged by the relative proximity to low-cost foreign oil markets and a slowdown in domestic production. The resulting dependence on foreign oil, however, exposed the region to the uncertainties of international trade and politics. Year-round access to major supply routes and refining centers discouraged investment in regional storage capacity.
2. Regional electric utilities have grown increasingly dependent on oil as a fuel. A combination of transportation, handling, storage, and pollution difficulties made coal unpopular as an urban energy source. The high sulfur content of Eastern coal has precluded its use as a major regional energy source. The shift from coal to oil for electricity production was accompanied by a decrease in normal operating inventory levels.
3. Natural gas was originally introduced as a clean, low-cost, and abundant energy source. Its use in the Northeast was made economically feasible by the construction of a nationwide transmission system. Federally mandated restrictions on natural gas use, however, have discouraged any expansion in regional gas

consumption, with the Northeast at a disadvantage in bidding for available supplies, had experienced extensive curtailment of industrial and commercial gas customers. Many of these potential users have therefore turned to oil.

4. Domestic refinery output has tended to maximize gasoline yield. This trend was due to a combination of price incentives and rapid growth in the transportation sector. The emphasis on gasoline production has concentrated our foreign fuel dependence on two petroleum products, distillate and residual oil. Both are vitally important to the region's energy system. The relatively limited flexibility of East Coast refinery output has also increased the region's vulnerability to short-term supply fluctuations.

A major factor in the region's vulnerability and overall oil supply position has been its geographic location relative to foreign and domestic supply sources. The reliance on a small number of supply sources and fuel types has intensified this vulnerability. Technical, environmental, supply, and economic constraints have further reduced the short-term flexibility of the regional energy system, whether in the area of electric generation or refinery output mix. A combination of these supply characteristics and the special nature of urban energy use contributed to the severity of the 1973-74 regional energy emergency.

This is not to say that the Northeast's energy supply system has been irrational in its design. For many years prior to the embargo of 1973-74, the oil delivery system had been effectively providing the variety of petroleum products at prices that were economically stable and relatively cheap in comparison with other items in the consumer index. Indeed, the Northeast may have reached its present position because the system functioned too well in providing abundant, cheap oil to an ever-growing energy system.

The Embargo

During the winter of 1973-74, the Northeast encountered significant fuel shortages, rapidly escalating fuel prices, major supply and demand uncertainties, and government intervention in the energy market place. Fortunately, because of a combination of mild weather and private and governmental sector actions, the region survived these energy problems without major dislocations. However, supply disruptions may recur in the future, perhaps with greater severity. As a basis for understanding the implications of such disruptions, it is worthwhile to review briefly the events of that period.

Total imports of crude oil into the region during the winter months of the embargo of 1973-74 were at the same level as the previous year. While crude oil imports from Canada and other non-OPEC countries remained relatively constant for the two time periods, there occurred a major shift from Arab OPEC to non-Arab OPEC crude supply sources. Previous to the embargo, Arab OPEC members supplied 33% of the crude oil imported into the region. The remainder was imported from non-Arab OPEC members (52%) and from Canada (non-OPEC, 15%).

Besides crude oil, nearly 90% of the nation's petroleum product imports are received in harbors on the East Coast. During the embargo, imports of petroleum products fell an average of 5% with declines of 6 and 12% for distillate and residual oils respectively.¹⁹

Substantial changes occurred in both the input and output mixes of East Coast refineries during the 1973-74 winter period. In October 1973, immediately prior to the Arab embargo, 92% (7% above the 1972 average) of the crude oil was of foreign origin. This decreased to a low of 72% in February, a change of 20% in

four months. Output mix also varied considerably during the embargo. Gasoline output dropped from 45% of the total in October 1973 to 42.6% in December, but increased with unusual rapidity to about 50% of output in February. Distillate production peaked in December and January at 29.5 and 28.6% respectively, whereas residual oil production was maintained at a steady 9.8 to 10.8%.

These data on production mixes serve two purposes: (1) They describe the changing supply pattern and the Federal and private reaction to them, and (2) they point out the limitations of regional flexibility. When the embargo first materialized, with the fear of major dislocations in home heating oil supply, especially in the Northeast, refineries were mandated to maximize distillate oil output at the expense of gasoline production. However, because of the effects of an unusually mild winter and residential conservation efforts, gasoline output was again maximized to alleviate the chaos developing at gas station pumps and the disruptions generated throughout the transportation sector. For the users of residual oil (apartment and commercial buildings, industrial boilers, and electric utilities), there were few options but to cut back and conserve. Supply stocks were diminished, utilities were ordered to slash electrical production, and environmental variances were granted to switch to coal burning. Limits to the flexibility of usage patterns were quickly reached, however. Ninety percent of the residual oil in the Northeast is of foreign origin and, therefore, the most severely affected by the embargo. Storage in the region amounted only to as much as existed in terminals, pipelines, gas stations, industrial and residential tanks--in all, about a month's supply.

The crucial point is that significant increases in flexibility which might buffer the energy system and mitigate the effects of an immediate interruption of foreign supplies, be they programs

of increased domestic production, refinery self-sufficiency, or increased regional storage, require years of commitment and effort, whereas the system currently operates in a way that makes major dislocations felt in a period of weeks or months. At the time of the first embargo, the Northeast was not prepared to do much, outside of riding it out as best as possible. And in the two years since the embargo, we have not appreciably altered our position in this respect except perhaps to worsen it.

Crude Oil and Petroleum Products Prices

Perhaps one of the most important factors underlying the strength and supporting the continuous expansion of our national economy has been the availability of cheap energy resources, especially oil. For the twenty years prior to the embargo, the price of crude oil increased only 80¢, from \$2.60 to \$3.40/bbl.⁷ Similarly (Table 8), because of the very stable pattern of crude oil prices, gasoline, kerosene, residual oil, etc., also remained very stable and relatively low. However, since 1973 the prices of crude oil and its products have jumped considerably. The first major crude oil increase of ~ 60¢/bbl was allowed in August 1973 in response to shortage conditions beginning to appear at fuel stations. A further increase of \$1/bbl for crude oil was allowed in December 1973; this brought the price up to its current level of \$5.25*by the end of 1973.⁸

Only 60% of domestic crude oil production remained fixed at \$5.25/bbl. The other 40% was uncontrolled and entered the market at increasingly high prices. Table 9 shows how the composite price of controlled and uncontrolled domestic oil had been growing. New controls recently enacted by Congress will now fix a maximum for the composite price of domestic crude oil. Under the

*average crude price in 1973 was \$3.89/bbl.

TABLE 8

WHOLESALE PRICE TRENDS SINCE 1950⁷

Year	Motor gasoline	Kero- sene	Light fuel	Heavy fuel	Average 4 products		Crude \$/bbl	Margin \$/bbl	Consumer Price Index 1967=100
	¢/gal	¢/gal	¢/gal	¢/gal	¢/gal	\$/bbl			
1972	12.47	12.47	10.35	6.85	10.47	4.40	3.400	1.000	120.5
1971	12.33	12.45	10.44	7.33	10.55	4.43	3.398	1.032	117.5
1970	11.88	12.05	10.23	6.07	9.90	4.16	3.132	1.028	113.0
1969	11.80	11.98	10.06	4.20	9.27	3.89	3.077	0.813	107.9
1968	11.55	12.03	9.84	4.30	9.14	3.84	2.941	0.899	103.5
1967	11.84	11.96	9.71	4.53	9.33	3.92	2.913	1.007	100.0
1966	11.59	11.49	9.09	4.73	9.15	3.84	2.882	0.958	97.5
1965	11.52	11.28	9.04	4.81	9.12	3.83	2.864	0.966	95.1
1964	11.27	10.93	8.65	4.50	8.83	3.71	2.877	0.833	93.9
1963	11.35	11.51	9.18	4.61	9.01	3.79	2.894	0.896	92.7
1962	11.52	11.42	9.11	4.78	9.13	3.84	2.905	0.935	91.7
1961	11.62	11.49	9.10	4.85	9.21	3.87	2.886	0.984	90.8
1960	11.61	11.17	8.79	4.88	9.15	3.84	2.882	0.958	89.9
1955	11.62	10.53	9.08	4.53	9.06	3.81	2.765	1.045	81.1
1950	10.86	9.39	7.97	3.98	8.29	3.48	2.515	0.965	72.5

TABLE 9
REFINER ACQUISITION COSTS²¹
(Dollars per Barrel)

		<u>Old</u>	<u>New</u>	<u>Domestic</u>	<u>Imported</u>	<u>Composite</u>
1974	January	5.25	9.82	6.72	9.59	7.46
	February	5.25	9.87	7.08	12.45	8.57
	March	5.25	9.88	7.05	12.73	8.68
	April	5.25	9.88	7.21	12.72	9.13
	May	5.25	9.88	7.26	13.02	9.44
	June	5.25	9.95	7.20	13.06	9.45
	July	5.25	9.95	7.19	12.75	9.30
	August	5.25	9.98	7.20	12.68	9.17
	September	5.25	10.10	7.18	12.53	9.13
	October	5.25	10.74	7.26	12.44	9.22
	November	5.25	10.90	7.46	12.53	9.41
	December	5.25	11.08	7.39	12.82	9.28
1975	January	5.25	11.28	7.78	12.77	9.48
	February	5.25	11.39	8.29	13.05	10.09
	March	5.25	11.47	8.38	13.28	9.91
	April	5.25	11.64	8.23	13.26	9.83
	May	5.25	11.69	8.33	13.27	9.79
	June	5.25	11.73	8.33	14.15	10.33
	July	5.25	12.30*	8.37*	14.03*	10.57*

*preliminary figures.

new pricing formula, composite oil prices (Alaskan oil excluded) will be rolled back briefly (for one year) from their current level of \$7.66/bbl. By the end of 1976 they will rise to \$8.43, and then to \$9.38 in 1977, \$10.88 in 1988, and \$11.21 by April 1979.²⁰ However, the market seems willing to bear even higher crude prices because foreign oils are being bought at considerably more. Table 10 indicates the range of landed crude prices of oil from a selected group of foreign countries. Peak prices of over \$14.50/bbl were paid in the months immediately following the end of the embargo. Even these levels have been surpassed if one includes the \$2 in import fees added to each barrel of foreign crude (a \$1 import fee was imposed in February 1975 and again in June 1975, but these were removed at the beginning of 1976).

The simultaneous OPEC increase of \$1.50/bbl will offset most of the savings from the removal of the \$2 in import fees; the average acquisition costs of crude oil will be increased by nearly 1.5¢/gal.²² Since price controls will still be in effect, wholesale and retail dealers will be limited to penny-for-penny pass-through of crude oil costs and will not be able to reestablish percentage profit margins that would have significantly inflated prices at the retail level.

The Northeast is heavily reliant on foreign oil supplies and therefore might be expected to pay higher prices. An interesting aspect of heating oil and gasoline prices in this region is their closeness to national average fuel prices. Comparing, for example, Long Island's residential gas, oil, and electric prices with the U.S. average 1973 residential prices shows that although the cost of natural gas was 88% higher on Long Island than the U.S. average and electricity was 26% higher, oil was only 4% higher.²³

TABLE 10

ESTIMATED LANDED COST OF IMPORTED CRUDE PETROLEUM FROM SELECTED COUNTRIES²¹
(dollars per barrel)

		Algeria	Canada	Indonesia	Iran	Nigeria	Arabia	Emirates	Venezuela
1973	December	NA	6.42	6.42	6.37	8.54	5.49	NA	6.70
1974	January	NA	6.70	NA	8.53	12.13	NA	NA	10.28
	February	NA	10.90	NA	12.11	12.74	NA	NA	11.31
	March	NA	11.14	12.13	13.02	13.26	NA	NA	11.78
	April	13.63	11.02	12.49	12.83	13.67	11.59	NA	11.38
	May	14.67	11.47	12.95	13.84	13.83	11.53	NA	11.28
	June	14.43	12.56	13.21	13.44	13.03	11.32	13.06	10.39
	July	13.65	12.65	13.77	13.02	12.75	11.97	12.34	10.64
	August	13.96	12.49	14.38	12.31	12.70	12.16	12.69	11.20
	September	13.83	12.51	13.42	11.87	12.28	11.45	NA	11.01
	October	13.20	12.53	14.24	12.07	12.12	11.51	12.84	10.95
	November	13.43	12.33	13.45	12.15	12.83	12.15	13.54	11.15
	December	13.08	12.15	14.15	11.63	12.88	11.75	14.59	11.37
1975	January	12.72	12.43	13.30	12.11	12.07	12.07	13.14	11.37
	February*	12.11	12.15	13.52	11.86	12.18	11.94	12.67	11.56
	March*	12.46	12.79	13.94	12.08	12.56	11.78	13.40	11.66
	April*	12.36	12.95	13.71	12.34	12.46	12.16	12.55	11.61
	May*	12.41	12.08	13.71	11.93	12.34	12.27	13.29	11.54
	June*	12.37	11.90	13.73	12.51	12.49	11.93	12.48	11.51
	July*	12.69	12.15	13.98	11.83	12.37	12.08	12.78	11.46

NA - Not available.

*Does not include \$1.00 import fee imposed on February 1, 1975, nor the additional \$1.00 fee imposed on June.

An examination of Tables 11 and 12 indicates that prices in the Northeast for gasoline and heating oil are higher than the national average by only about 1¢/gal. In addition, the prices for oil used in the residential, commercial, and industrial sectors deviate very little. This is quite different from the consumption of gas and electricity. The U.S. average industrial gas and electric prices were lower by 164 and 110% respectively, than the U.S. average residential gas and electric prices (1972 averages). Regional differences in electric generation mix, transportation costs, composition of demand sectors (industrial-residential-commercial mix) and regulatory climate are some of the factors contributing to the much greater disparity in gas and electric prices.

TABLE 11
REGULAR GASOLINE PRICES
August 1975²¹
(¢/gallon)

<u>Marketing Region</u>	<u>Branded Jobber Price</u>	<u>Regional Jobber Margin</u>	<u>Retail Dealer Price</u>	<u>Dealer Margin</u>	<u>Retail Selling Price*</u>	<u>FEA Region**</u>
Northeast	35.27	4.39	39.66	7.9	57.9	New England (1A)
Mid-Atlantic	35.14	3.57	39.01	8.2	60.7	Mid-Atlantic (1B)
Southeast	34.64	3.81	38.45	8.4	59.4	Lower Atlantic (1C)
Central	35.59	4.16	39.75	8.1	59.3	Mid-Continent (2)
Western	35.17	3.74	38.91	9.3	59.2	Rocky Mountains (4)
Southwest	34.12	4.00	38.12	9.6	56.7	Gulf Coast (3)
Pacific	34.47	3.74	38.21	8.2	59.9	West Coast (5)
National Average	34.91	3.96	38.87	8.4	59.2	National Average

*Includes tax.

**Retail gasoline distribution.

TABLE 12
HEATING OIL PRICES²¹

		Institutional and		
		<u>Residential</u>	<u>Utility</u>	<u>Industrial</u>
July 1974	M.A.*	35.2	33.2	34.3
	U.S.**	35.2	33.2	34.4
August	M.A.	36.1	34.9	33.1
	U.S.	35.5	34.2	33.1
September	M.A.	36.5	34.5	30.7
	U.S.	36.3	34.5	30.9
October	M.A.	35.9	34.7	33.5
	U.S.	35.6	34.1	33.3
November	M.A.	38.7	34.4	37.0
	U.S.	37.9	33.2	36.2
December	M.A.	37.8	37.1	36.2
	U.S.	36.6	36.2	35.3
January 1975	M.A.	37.5	36.1	36.5
	U.S.	36.2	34.9	34.9

*Mid-Atlantic

**United States

IV. NATIONAL PRODUCTION AND REGIONAL SUPPLY

National Production and Resource Depletion

We next consider the central question, "How will the Northeast meet its oil demands in the coming decades?" With due allowance for the uncertainty of political, economic, social, and technological events that will shape the future of the energy system, the first issue requiring examination is, "What can the Northeast expect from future domestic oil exploration and production?" At this juncture, policymakers in the Northeast are waiting for an energy program and a plan of action to emerge from the Federal Government. However, as discussed later, there are definite limits on how much oil may be ultimately extracted, no matter what bold programs to stimulate new domestic supply may be initiated.

In the past several years, a number of widely ranging estimates have been made of future national oil production. Some of the most prominent are shown in Figure 6. The estimates are based on a variety of projection methods, running the gamut from the highly econometric to those based on simple resource production curves.

The econometric projections use historical data to correlate production with a combination of economic factors. Production is then projected on the basis of estimated changes in these factors. Although of great value in making short-run forecasts and predicting fluctuations in oil production, they will be inaccurate over the long run for two reasons: (1) the errors associated with the economic factors increase substantially over an extended period, and (2) the mode of estimation does not take into account

Figure 6. Domestic oil production estimates (10^6 bbl/day).^{24,42,43}

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)

large changes in the descriptive parameters due to significant depletion over time. In contrast, the use of Hubbert curves to model future resource production produces, in most cases, little short-term accuracy, but by keeping close track of the depletion of the resource, such a model can give useful insight into the more distant future. The general form of these curves is discussed below in terms of oil production beyond 1985 and in the Appendix.

Lying somewhere between the two extreme projection methodologies are the models developed by the National Petroleum Council which have been modified by the Project Independence (PI) Oil Task Force. The most important determinants of production are the physical inputs of projected drilling rates (number of feet drilled per year) and the finding rates (amount of reserves added per foot drilled). The general approach is to construct scenarios for drilling activity and then, using values for finding rates calculated either from historical data or geological information, to formulate production levels on the basis of yearly additions to reserves. However, exploration and development drilling is to be undertaken only if found to be economically viable in a given region. To determine financial viability, the outcome of drilling was analyzed by the PI Task Force using a discounted cash-flow method which considers initial investment, annual operating expenses, taxes, and revenues. Thus, the level of production possible from a given region was formulated on a physical basis. However, of that amount, the quantity of oil actually expected to be produced and to enter the supply system is highly dependent on the price that may be received for the oil. Thus, in its report, the task force projected increasingly higher levels of production at higher prices per barrel.

Of the projections presented in Figure 6, the PI Business as Usual (BAU) case will be used as the production estimate for our high scenario.* It has been chosen because (a) it is one of the highest estimates that is qualitatively reasonable with respect to the likely available resource base, (b) it is accurately predictive of 1975 behavior and the near-term declines in production currently being observed, and (c) it is a fairly recent estimate, based on 1973 and 1974 data. For the low case, we have chosen the production estimates used by ERDA in their recent report on the national energy supply.²⁵ This projected production curve is almost identical to the one estimated by Hubbert (Figure 6). For the intermediate scenario, we have used the projections estimated by ERDA of the effects on oil production of enhanced recovery techniques.

Project Independence and now FEA have made projections of production levels at \$8 and \$13/bbl of crude oil. Although prior to the enactment of the Energy Policy and Conservation Act (EPCA) 40% of the crude oil was controlled and sold at \$5.25/bbl, the composite domestic price with uncontrolled oil was near \$8.50/bbl. Since in the next few years the composite price of crude oil will almost certainly reach \$13/bbl, and since in the interim the effect on total production of a lower price is slight, we have chosen the \$13/bbl value for our scenarios. It will probably be closer to the actual price that will determine production in 1985 than the \$8 case. However, because production is limited by such time-

*The results of the PI Task Force report have been reworked in the FEA's 1976 National Energy Outlook. The new BAU oil supply scenario for 1985 has not changed significantly from the previous version. Therefore, we have continued to use the BAU projection in Figure 6 as our high scenario here and have not found cause for altering the construction of our regional supply projection or any of the conclusions drawn below.

dependent physical factors as drilling rates and finding rates, we have used the BAU scenario as our highest case even if prices do rise in quickly above \$13 a barrel.

A Hubbert depletion curve analysis may be used to extend the BAU projection past 1985. On extrapolating to the year 2000 the physical and economic variables used above becomes less meaningful as they are overshadowed by the effects of resource depletion. By using both historical and projected production data, Hubbert's logistics equations may be skewed to pass through a projected 1985 point. Thus, the production curve that is generated incorporates actual historical production experience as well as physical and economic determinants considered significant in short-run projections. While this formulation relies on a fit to historical data, it subsumes all the economic specifics into a single, empirically reasonable equation whose most sensitive parameter is the size of the ultimately recoverable resource base. However, as Table 13 indicates, the size of that base is the subject of great controversy. The latest estimates, those of the U.S. Geological Survey (USGS), for ultimately recoverable oil are (with a 95% probability) somewhere between 217 and 295 billion barrels (statistical mean, 250). This represents a considerable reduction by the USGS of their resource base compared with previous estimates.*

The range of national supply scenarios, together with historical production levels, is presented in Figure 7. The range of possible future production levels is wide, depending on how much oil is recoverable and how quickly it is extracted. If optimistic

* In classifying resources as either economic or subeconomic, the USGS relies primarily on historical extraction rates, which are technologically as well as economically limited. Strictly econometric methods are not used in their extraction and resource estimates .

TABLE 13

ESTIMATES OF TOTAL ULTIMATELY RECOVERABLE
NATURAL LIQUIDS AND GAS FOR THE U.S.²⁶Petroleum and Natural Gas Liquids (Billions of barrels)*

	<u>Low</u>	<u>Intermediate</u>	<u>High</u>
Mobil Oil	203		
Latest USGS (low)	229		
Hubbert	231		
Oil & Gas Journal		250-300	
Zapp (1961)		300	
NPC (1970)		307	
Previous USGS (low)		315	
Latest USGS (high)		317	
Moore			436
Elliot & Linden			450
Weeks			460
Previous USGS (high)			515

*Includes 115 billion barrels extracted through 1973.

Natural Gas-Dry (Trillions of Cubic Feet)*

	<u>Low</u>	<u>Intermediate</u>	<u>High</u>
Mobil Oil	890		
Weeks	1000		
Hubbert	1200		
Latest USGS (low)	1292		
Previous USGS (low)		1437	
Moore		1547	
Latest USGS (high)		1575	
Elliot & Linden			1740
PGC			1860
Previous USGS (high)			2437

*Includes 437 trillion cu. ft. extracted through 1973.

Figure 7. Projected Domestic Crude Production

- A. Historical Production
- B. FEA, Business as Usual
- C. ERDA, Enhanced Recovery
- D. ERDA, Business as Usual

estimates of ultimately recoverable resources hold true, then production in the year 2000 will not fall as low or as rapidly as the levels projected in Figure 7. Thus, whereas the ERDA scenario is based on a low estimate of ultimately recoverable oil of ~220 billion barrels (low case of USGS estimates), the PI case is coupled to a Hubbert depletion curve from 250 billion barrels of oil (median of the USGS resource estimates). Since enhanced recovery is a technological method of extending the recoverable resource base, its effect is to increase cumulative oil production. Interestingly enough, by the year 2000 production through enhanced recovery begins to approach the high scenario levels.

The Project Independence BAU curve indicates that domestic crude production will peak just past 1985. The ERDA BAU projection shows production declining in the future without recovering sufficiently to pass earlier peak years. In the intermediate scenario, the 1970 peak production level is once again attained; however, by the year 2000 in both ERDA cases production levels are well past their peaks and are rapidly declining. The depletion curve coupled to the BAU case of Project Independence indicates that its rate of decline by the year 2000 would also be very rapid as a result of the increasing production activity between now and 1985. That is because the Hubbert curve is the guardian of the integral, whose area under the curve must equal the total resource base. Unless this base is significantly extended or oil recovery technology is dramatically improved, production will respond as shown.*

*The resource base used here excludes shale oil, tar sand, or other exotic sources which, although not immediately limited, are not currently economically competitive. They are unlikely to remain economically constrained as future production falls off.

From a national perspective, these projected domestic production levels indicate that without a concurrent substantial national effort to develop alternative energy supplies, a policy of immediate maximum domestic production will render the U.S. even more dependent on foreign energy supplies by the last decade. Thus, through its present actions or inactions the U.S. could be preparing for itself a future position that is even more uncomfortable politically and economically than its present position.

Regional Share of Domestic Production

Only a limited portion of the domestic production estimated for 1985-2000 (Figure 7) will be available for consumption in the Northeast. Less than 1% of the Northeast's present supply comes from internal regional production. Nearly all the remaining domestic supply is from the Gulf Coast. In 1972, 700 million barrels of domestic crude production went to satisfy demand in the Northeast. This represented 20% of total national crude production in that year. Since it is impossible to predict the fraction of domestic production that will actually be available to the Northeast in the future, we have made the generally optimistic assumption that the Northeast will retain its 20% share of the total supply. In the natural gas supply system, the Northeast's share of domestic production has been declining steadily because of pricing policy differences between interstate and intrastate sales. Such has not been the case, however, in oil supply. Historically, oil has been sold nationally under a more competitive, "free market" system that has led to a more even price distribution. Therefore, in assuming that the Northeast will maintain its historical fraction of domestic oil production, we are assuming that the system will continue to be economically competitive and that regional differences in pricing will balance

the forces that would differentially retain supplies in other regions.

In developing our regional oil supply scenarios, we have also considered allocations from two special production areas, Alaska and the Atlantic outer continental shelf (OCS).²⁷ In the low case we have assumed that Alaskan production will be absorbed by western and midwestern states, offsetting foreign imports in those regions and not resulting in a displacement of other domestic supplies eastward. In the intermediate case Alaskan production results in a 50% displacement of oil flow to the Northeast, and in the high case we have assumed a 100% displacement of flow, with the Northeast capturing its 20% share. Production in Alaska is assured to be 2 million bbl/day in 1985 and half that by 2000.

The difficulty of assessing the potential impacts of OCS development is further compounded by the very large uncertainty that there is any petroleum out there. Serious exploratory drilling has only just been carried out in the Baltimore Canyon and on George's Bank. Estimates of the recoverable resource base vary between none and several billion barrels, but even the center of that range has little significance. Given the nature of petroleum exploration, the probability of finding either large fields or no oil at all is high. Thus, the OCS may yield several billion barrels of oil, or nothing.

Our high estimates of possible OCS production are based on the range of recoverable resources reported by the USGS. In our high case, production is assumed to start in 1981 and reach a level of 75 million bbl/year in 1985. Following a peak in the early 1990's, production would decline through 2000, when we estimate that it would be about 150 million bbl/year. The intermediate case, based on the median USGS recoverable resource estimate,

is taken to be about 60% of the high value. In both cases we have assumed that the region will capture 100% of the total production, although, as observed above, the possibility that no oil at all will be produced in the Atlantic OCS cannot be neglected. However, in all cases offshore oil is expected to play only a very limited role in decreasing the region's reliance on foreign oil.

All three regional supply scenarios are presented in Table 14. They paint a bleak picture, showing that if oil consumption in the Northeast grows only a modest 2% annually through 1985, even under conditions of highest domestic supply the region will still grow more dependent upon foreign sources. The low scenario indicates that domestic oil supply will be significantly less and dependence on foreign sources massive. By the year 2000, the problems are multiplied. It must be stressed that the assumptions made and numbers used in constructing these scenarios have been generally optimistic. They have been optimistic in the estimate of Atlantic OCS production, total domestic production, and regional allocation. On the basis of recent domestic exploration alone, many would choose the low case as perhaps the most realistic.

The projections developed above indicate strongly that policy, whether regional or national in scope, aimed solely at increasing oil production will not solve the region's energy problems. Under several conditions, a policy of immediate increased production may actually intensify problems in later years. It is essential, therefore, that these possible effects be taken into account in formulating national and regional energy policy.

Short-Term Outlook

Domestic oil production is expected to decline through 1975 and 1976 because of the long lead times required to bring new

Table 14

SUMMARY OF DOMESTIC OIL SUPPLY CASES^a
 (10⁶ bbl/day to the Northeast)

Source	1985			2000		
	Low	Intermediate	High	Low	Intermediate	High
Lower 48 state production ^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	0.24	0.40
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
Shale ^e	0.00	0.00	0.03	0.00	0.00	0.61
Total		2.07			2.24	

^aNote that 1972 domestic supply to the Northeast was 1.79 million bbl/day and foreign imports were 2.82 billion bbl/day.

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

^cLow case assumes Alaskan production replaces imports in Western states. Intermediate and high cases assume average oil allocation of 20%.

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

^eRegional allocation for synthetic liquids from coal and oil shale is taken to be 28%.

petroleum production on stream. In 1977 some recovery is expected, with modest increases in domestic production. Even so, leaders of major oil companies are pessimistic. They contend that "they are handcuffed by the lack of a national energy policy, hamstrung by Federal controls, hounded by environmentalists, picked at by politicians, misunderstood by the press, and distrusted by almost everyone else."²⁸ Their efforts to find new oil and develop alternative resources continue to be delayed by a myriad of conflicting priorities proposed within and existing between states and the Federal Government.

Debate on the issue of future production has centered on the advisability of various levels of control of domestic oil prices. Supporters of decontrol, including the oil industry and the Ford administration, argued that by lifting controls and allowing prices to rise to their free market level, new production would be stimulated. Detractors argued that the oil companies had artificially limited production and had engaged in other "shabby practices" to keep prices high and reap larger profits. In their view, production could be increased without lifting price controls.

Although in the past the major oil companies have benefited from joint actions, particularly in influencing world oil prices, it is unlikely that significant collusion exists among them to limit production. Unlike the natural gas industry, production and marketing of oil has historically been a very competitive industry. Until the embargo, for example, domestic producers had to compete vigorously with cheap foreign supplies as well as among themselves; as a result, oil prices throughout the sixties and early seventies rose much less than the consumer price index. The two-tier price system, however, undoubtedly provided an incentive to differentially hold back production of "old oil" when prices were regulated below those for "new oil." Nevertheless, a well represents a significant investment, to be made whenever the existing price of oil determines it to be

worthwhile. Purposely delaying production is expensive and is justified only if higher prices are imminent. Thus, a wholesale slowdown by the oil industry is unlikely at a time when price increases or decontrols are very uncertain. Finally, the prevailing tendency among oil companies is to increase production and maximize current profits--the antithesis of delay. For all these reasons, many anti-oil company arguments may be considered invalid.

A third viewpoint considers the problem to be more technological and geological in nature than economic. According to this view, both supply and demand are generally insensitive to moderate price increases at this stage in the exploitation of domestic oil production. An increase in oil prices as a result of decontrol, it is argued, would not significantly increase production and would be inflationary and hard on consumers in an economy that is slowly recovering from a recent recession.

It is generally agreed that an increase in crude oil price would result in an increase in drilling activity. In 1973 the price per barrel of crude oil at the wellhead was \$3.89. The price two years later is more than two times as great, reaching \$8.68/bbl (average of controlled (\$5.25/bbl) and uncontrolled prices). Annual drilling activity has climbed dramatically from 136 million to 160 million feet (estimated). Domestic production, however, has continued to decline. On the other hand, between 1960 and 1973, when crude oil prices rose a modest \$1/bbl, domestic production grew continuously, limited only by how fast the oil could be found and pumped out. Therefore, geological and technological factors are more likely to determine crude production than are moderate price changes at this point.

Although the above cannot be considered an adequate treatment of this difficult subject, there is reason to suspect that decontrol might not necessarily lead to significantly increased production.

Under the previous oil pricing program, decontrol would certainly not increase production from new wells or the incentive to drill them inasmuch as the prices obtained for production from these sources were already at the free market level. It would affect only production from "old" wells, from areas that we supposedly know most about with respect to economically recoverable resources. Although the oil industry repeatedly argues that decontrolling oil prices would increase production in these areas, they cannot say with any accuracy how much. If indeed oil production is resource and technologically limited, then decontrolling prices would not significantly affect oil supply. However, a sudden lifting of controls could have a serious effect on the economy (estimated by the Congressional Budget Office as a 1.5% increase in the general price level and an additional 0.5% in unemployment by the end of 1976, growing by the end of 1977 to 1.0% and 0.6%, respectively). If prices are to be decontrolled, the process should be gradual so that the effects may be more accurately ascertained. The entire issue has been resolved at least temporarily, in favor of a new formulation against immediate price decontrol. Controls will gradually be phased out over the next 40 months. Composite prices for new and old crude oil have been set. Under this new formulation, however, if "old oil" is held constant at its present level in 1976, the price of "new oil" must decrease. Accordingly, leaders within the oil industry have suggested that "further exploration in Alaska and exploration in other high-cost frontier areas, such as the OCS, will be seriously curtailed."²⁹ If so, the new domestic oil price formulation may have serious consequences for crude production in the next decade. This assessment, however, may be overly pessimistic. Since lead times of several years are associated with investment in production activities, the near-term reduction in crude oil prices might not be a significant disincentive for new private commitments.³⁰

Until 1980, then, the outlook for potential production and oil supply to the Northeast is unchanged. Demand will probably begin to rise again at an increasingly faster rate, and domestic oil production will not be able to keep pace. The Northeast will therefore grow even more dependent on foreign suppliers to meet their oil needs.

V. PHYSICAL SUPPLY SYSTEM

Among the alternative energy issues facing the Northeast today are the need for additional refinery and storage capacity, and deep-water port construction or expansion. Although the great majority of such construction is decided upon and undertaken privately by interested oil companies, the pervasive opposition to such projects among the public and governmental bodies in the Northeast makes it unlikely that major new construction will be initiated in the near future without a regional consensus to do so. Thus, a discussion of the issues related to such projects is important for energy policy planning in the Northeast today.

The Northeast at present is far from capable of meeting its own demand for petroleum products. Only 25% of its oil supply is refined within the region. The first issue to address, therefore, is whether a 100% regional or even domestic self-sufficiency in refining capacity is a desirable or realistic goal.

At a Congressional hearing on the need for additional refining capacity, the Assistant to the Secretary of the Interior stated that "One hundred percent domestic self-sufficiency in refining capacity is probably a desirable goal although it is not realistic for the immediate future."³¹ Essentially all developed industrial nations do have refining self-sufficiency. The outstanding exception is the U.S.

Refining self-sufficiency would strengthen our national security. Outside of uncovering massive new oil reserves, self-sufficiency in refining is perhaps one of the most effective measures for circumventing foreign control of the world oil supply. The massive new refinery construction currently under way in the Middle East underlines the urgency of countermeasures to be taken by the U.S. and

implemented in the Northeast. If refined products are imported from abroad, in the event of a supply intervention from a major source or a massive increase in petroleum product prices, virtually no alternative product supply sources are available. Most of the world's refineries work on tight production schedules for specific markets and cannot make large swings in output to accomodate a new customer. If refining is done locally and a major crude oil supply source is cut off, there are other areas to turn to for crude oil. Additionally, maximum control could be executed within the U.S. and the region to fix product output and selectivity control consumption in all end use sectors. Flexibility and freedom of action would also be assured through the increased stockpiling of crude oil by the industry itself. Close to 3 months' worth of crude oil is maintained within the system to provide for temporary perturbations in supply resulting from such events as transport delays, accidents, and temporary demand peaks.

If refinery self-sufficiency has these advantages, why is the region so deficient in refining capacity?

Three factors have contributed to the lack of domestic refinery construction, particularly in the Northeast in the early 1970's. The first and perhaps most significant was the dwindling supply of crude oil. Domestic crude oil was becoming difficult to obtain. Under the then existing national oil import control programs, foreign crude was strictly limited by quota. Construction could not be undertaken because of the uncertainty of future crude supply. When foreign crude import restrictions were modified in April 1973, major plans for new refinery construction and expansion were initiated.

In the early 1970's, the growth in petroleum demand was primarily for one type of product, residual oil. It was the "swing fuel" for shifting demand patterns developing in the energy system, especially

in the Northeast. Demand for other petroleum products was not growing as rapidly as anticipated. However, under the previous oil import program, domestic refineries were not able to manufacture residual fuel oil in competition with foreign capacity. The fact that foreign residual oil was allowed essentially unlimited access to the Northeast markets adversely affected domestic refinery construction. In addition, constructing a major refinery to manufacture residual oil as well as other products has inherent advantages. Such a refinery initially requires only a slightly higher capital investment and its daily operating cost is appreciably lower, but it can turn out exactly the same amount of lighter products (gasoline, kerosene, etc.) with a significant increase in residual oil production (Table 15). The construction of refineries with the residual oil capability described in Table 15 was sufficiently attractive to make oil companies reluctant to add new capacity pending potential changes in oil import policy.

Environmental considerations have also contributed significantly to the lack of new refinery construction in the Northeast. Environmental constraints have created situations in which a company seeking to construct a refinery is blocked by environmentalists. Some companies that have been blocked from refinery construction are listed in Table 16. Together they have accounted for a staggering 600 thousand bbl/day or a 35% increase in the current level of refinery capacity. This additional capacity would have been available about now or in the near future. Ironically, Fuels Desulfurization and Supermarine, two of the companies whose projects were blocked on environmental grounds, were attempting to construct refineries that could run on cheaper higher sulfur crude and produce cleaner low sulfur fuel oil to meet the stringent air quality standards.

Table 15

COMPARISON OF A HIGH SEVERITY REFINERY OPERATION
WITH A
BALANCED LOWER SEVERITY REFINERY OPERATION³¹

<u>Description</u>	<u>Typical U.S. high severity operation</u>	<u>Balanced low severity operation</u>
Crude oil feed rate, bbl/day	150,000	215,000
Total investment, \$ Million	321	355
Plant fuel requirement, MM Btu/D	90,400	75,700
Operating cost (ex. food, taxes, etc.), \$/D	100,000	92,200
Product Rate, B/D		
Motor gasoline	53,340	53,340
Jet fuel	30,120	30,120
Distillate fuel	26,460	26,460
Kerosene & aviation fuel	1,240	1,240
Liquid petroleum gas	3,440	3,440
Asphalt	3,660	3,660
Naptha (for chemical or SNG)	4,500	11,490
Residual fuel oil		
Bunker 2.0% sulfur	4,850	4,850
No. 6 1.0% sulfur	3,670	4,670
No. 6 0.7% sulfur	3,200	43,740
No. 6 0.3% sulfur	-	15,810

Table 16

REFINERIES PLANNED BUT NOT CONSTRUCTED BECAUSE OF OPPOSITION ON ENVIRONMENTAL GROUNDS³¹

<u>Company</u>	<u>Location</u>	<u>Size, bbl/day</u>	<u>Final Action Blocking Project</u>
Shell Oil Co.	Delaware Bay, Del.	150,000	State Legislature passed bill forbidding refineries in coastal area
Fuels Desulfurization*	Riverhead, L.I.	200,000	City Council opposed project and would not change zoning
Maine Clean Fuels*	South Portland, Me.	200,000	City Council rejected proposal
Maine Clean Fuels*	Searsport, Me.	200,000	Maine Environmental Protection Board rejected proposal
Northeast Petroleum	Tiverton, R.I.	65,000	City Council rejected proposal
Supermarine, Inc.	Hoboken, N.J.	100,000	Project withdrew under pressure from environmentalist groups. Site near Paulsboro, N.J., being considered
Commerce Oil	Jamestown Island, R.I.	50,000	Opposed by local organizations and contested in court

* Maine Clean Fuels is a subsidiary of Fuels Desulfurization and the refinery involved is the same, so the capacity in bbl/d is not additive, but the incidents are independent and additive.

These three factors led to little new refinery construction in the Northeast in the early 1970's. Instead, they led to refinery additions in the Caribbean and other foreign supply centers. The added cost of supplying Northeast markets from offshore refineries rather than regional facilities has been estimated by the National Petroleum Council to be about \$0.40/bbl. The removal of the quota system and substitution of the license fee system under the oil import program has created new incentives for domestic refinery construction. This has contributed to the pronounced shifts in oil imports observed in 1974 and 1975. Whereas crude oil imports are up 20%, this has been offset by a 24% decline in imports of petroleum products.³⁰

Currently, major new construction and expansion are continuing in and around refining centers in New Jersey and Pennsylvania. Proposed plans would expand refining capacity 60% in New Jersey alone by 1980.³² Very little, if any, capacity is being planned for virgin areas outside these sites. Given the existing governmental and regulatory climate, it is unlikely that any such new construction will occur. Thus, to a large extent, total Northeast regional oil refining policy is being determined piecemeal by the actions or inactions of local municipalities and public interest groups. Decisions that fundamentally affect the future of Northeast oil supply are being made without broad-scale responsible planning.

A related but not necessarily dependent issue is the question of deepwater ports. In 1972, 90% of the crude oil entering the region arrived by waterway. The average size of tankers used to transport these petroleum supplies to the U.S. and the Northeast is 30,000 to 35,000 deadweight tons (dwt).³³ However, on a world scale, the need to transport ever larger volumes of oil over long distances has led to the development and increasing use of very large crude carriers (VLCC's), ranging in size from 200,000 to 500,000 dwt. These "supertankers" can transport large volumes of oil on a long-haul voyage at lower cost than tankers of smaller size. Because they require substantial water depth in which to maneuver (up to 70 ft.), deepwater ports are necessary to accommodate them. These

ports may be a naturally deep or dredged area close to shore or may take the form of unloading structures located in naturally deep waters some distance offshore. The oil is then usually transported onshore via pipelines. Because of the lack of deep enough natural water harbors close to major centers in the U.S., it is generally agreed that offshore terminals offer the greatest environmental as well as economic advantages for the unloading and transport of oil from VLCC's. The structure that is most commonly used and has been proposed for installation off U.S. shores is a monobuoy structure known as the single-point mooring buoy. Although current industry proposals call for the development of deepwater ports with throughput as high as 3 to 4 million bbl/day, a facility accommodating 4 million bbl/day is economically feasible. Recall that total refining capacity in the Northeast amounted to only 1.6 million bbl/day in 1974.

Oddly enough, the debate over deepwater port construction in the Northeast from the regional point of view has been mainly environmental in nature on both sides. Supertanker transport, because of economies of scale, are more economical for oil companies to operate. However, the reduction in cost per barrel is thought to be too small to reduce the price of gasoline, for example, by 1¢/gal. Proponents of supertankers and deepwater ports argue that without supertankers, normal tanker traffic will quadruple by 1985, with the likelihood of near-shore oil spills increasing dramatically because of tanker collisions. If supertankers are used, tanker movements will decrease below 1970 levels. In addition, the likelihood of collision offshore per tanker movement is less, and the effects of a spill, if one occurs, are greatly reduced out at sea.

Opponents of deepwater ports and tankers argue that because supertankers are so large and carry such a vast quantity of oil (2 million bbl.), any accident would be disastrous. They note that the largest oil spill in the world, at Torrey Canyon, involved 30 million gallons over a period of 55 days. However, the main opposition lies in concern about the impact on

the coastal areas of deepwater port and resultant refinery and petro-chemical industry development. Several Northeastern states, including Delaware, New Jersey, and Maine, have proposed or enacted strong coastal-zone management programs that will effectively prohibit or severely limit deepwater port development. Some major political figures such as Governor Byrne of New Jersey have also made known their opposition to any such plans.

Nevertheless, offshore deepwater ports remain an important issue in the Northeast. Maine is currently assessing the relative cost-benefit of refinery and terminal development at various proposed sites. Delaware and New Jersey are considering the advantages of a state-owned or controlled terminal for minimizing environmental degradation in the coastal regions. In spite of such proposals, public opposition remains strong and in all likelihood will effectively block or substantially delay any such development in the coastal states.

The construction of storage facilities for the maintenance of immediate supplies during periods of interruption does not appear to be an active issue in the Northeast today. Storage of crude oil amounting to 3 peak months of imported crude oil will be undertaken as part of a National Reserve Program.^{20,34} In regions where more than 25% of a particular petroleum product is imported, the program requires the same 3-month reserve (10% for No. 2 heating oil). It will take seven years, however, to officially establish these reserves.

Additional storage in the Northeast can be expected to be undertaken by the oil industry only as part of their normal operations. Both refinery construction and deepwater port development would require increased storage to meet temporary supply shortfalls. Thus indirect benefit of new construction programs is the coincident addition of storage capacity, which might temporarily buffer the adverse impacts of a sudden supply interruption.

Because of the efforts of environmentalists and citizens' groups, a new awareness has developed in private industry which

has brought forth a new refining technology that is economical, efficient, and also relatively responsive environmentally. Construction of these facilities will not solve the energy crisis. That will require changes in consumption patterns and utilization of more diverse and plentiful fuel resources. However, a coordinated and well-planned construction program for onshore refineries and related facilities could give us more regional control in the allocation of fuel supplies, greater freedom of action in the international field, and more time to develop alternative supply strategies.

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VI. THE IMPACT OF ENVIRONMENTAL CONSIDERATIONS

In this section, the major environmental issues are separated into subgroups and their impacts on the past and present oil supply picture examined. The intent is to show how, in the absence of unified and coherent regional energy planning, decisions affecting the entire regional energy system are made, usually without considering the larger potential problems. That is not to say that any action to prevent a particular project is wrong, only that it is uncoordinated. The total regional energy system should be considered and alternatives should be chosen on the basis of the effects on the total regional environment. The discussion below briefly describes the issues affecting the oil supply directly.

Federal Clean Air Act

From 1960 through 1971, oil consumption in the Northeast grew at an average annual rate of 3.5%; in 1972, it increased 10%. From 1960 through 1970, refineries in the region ran on 50% foreign crude. One year later, the foreign share grew to 75%, and another year later to 85%. One of the most significant factors in this rapid evolution in oil supply and consumption has been the institution of air emission regulations under the Federal Clean Air Act of 1970. Prior to the passage of this legislation, air pollution requirements in the Northeast related primarily to the smoke and particulate content of emissions. In 1971, states in the region began prohibiting the use of fuels with a sulfur content above 2%, and some states prohibited fuels with a sulfur content above 1%.³⁵ The immediate effect was a general switchover from high to low sulfur oil and completion of the switchover from coal to oil begun in the late 1960's. To meet the high demand for low sulfur oil, suppliers had to turn to foreign sources. Additionally, between 1970 and 1972, when the EPA was formulating its air emission standards, refinery and utility plant construction plans were shelved

because of uncertainty concerning the new environmental regulations and the new refinery technologies that would be necessary.

The aim of the much stricter sulfur emission standards is to reduce the levels of this noxious gas in areas of high population density. The benefits to human health are thought to be considerable. Thus the costs to the region's oil system must be weighed against the social health benefits to its residents. As is often the case in social programs, the decision to implement them cannot be made on a strictly quantifiable basis.

Refinery Siting Opposition

The opposition of environmental and local citizens' groups has been perhaps the main stimulus in upgrading refinery technology to make it more efficient and less environmentally upsetting. However, planned refinery expansion has been halted, and no new plans for construction outside of present refinery centers are likely to be made because of stiff opposition to almost any proposed site. As shown earlier (Table 16), such opposition led to the shelving of plans for new refinery capacity that would have increased the region's flexibility. In some instances, repeated attempts to find an acceptable site were blocked. Ironically, in one case, a company was granted special privileges to import high sulfur oil in order to produce clean, low sulfur fuel oils through a desulfurization process. Because of siting problems, this effort was also aborted. The opposition here, however, may have been more a matter of local municipal zoning and general opposition by citizens. The present and future effects of opposition of this type are further discussed below.

Offshore Oil Development

Since offshore oil will be treated in a separate paper, it will be discussed only in general terms here. Offshore oil development in the Atlantic OCS has met with intense opposition. First and foremost, coastal residents fear that an oil spill of the kind that occurred near Santa Barbara might pollute the waters, degrade the shoreline, and disrupt the recreation

industries that depend on them. Second, OCS drilling if permitted, will require onshore facilities such as refineries, storage depots, pipeline right-of-ways, and general industrial, residential, and transportation development that will alter the character and degrade the environment of the coastal zone for the foreseeable future. Lastly, those concerned with the depletion of our domestic resource base argue that OCS development should not proceed until there is a national energy policy with clearly defined plans for the future. This argument may be the most significant, since it is currently being used as the main argument in a suit brought by Suffolk County to the Supreme Court against not only Atlantic OCS exploration but all OCS oil development.

The proponents of offshore oil development argue that, with or without drilling, oil will be consumed and transported to the region, mainly by barges. The likelihood of a near-shore spill by barge is greater than for either drilling or piping operations. Second, they point out that the nearly 20,000 oil wells drilled offshore the Gulf Coast have been responsible for only three major accidents. Third, they argue that a large body of evidence obtained after intensive investigation supports the conclusion that the effects of spills are temporary and that no irreversible ecological disruptions have ever occurred because of their operations. Finally, they say, the country, and especially the Northeast, needs the oil for its economic, social, and political well-being.

The most important question is, "how much oil actually lies out in the Atlantic OCS?" Estimates by the USGS indicate that the absolute volume may be extremely small or nil, and therefore would not contribute significantly to oil supply in the Northeast. Until exploration is conducted, the extent of the resource base will not be known and the issue of what to do with it is moot. Under the existing leasing program, after the exploratory drilling phase is conducted an environmental impact statement must be filed before final approval for commercial production is granted. Since an assessment of the situation can be made only after conducting exploration of the resource, the period immediately following exploration would be the most opportune for considering

the merits of future production.

Land Use Management and Regulation

A major development in the 1970's that will have a continuing impact on oil supply and all other energy facility configurations in the Northeast was the passage of land use management acts. In 1972, a Federal Coastal Zone Management Act allowed individual states to develop management programs which, if acceptable to the Secretary of the Department of Commerce, obligate all Federal plans in the zone to fit the states' blueprints for the region. Since then, a number of states, including Connecticut, Massachusetts, and Maryland, have enacted general environmental acts that require environmental impact statements (EIS) for all facility siting in their states. New Jersey and Delaware have enacted similar legislation for their coastal regions. Delaware's Coastal Zone Act, for example, excludes heavy industrial development in the coastal zone. Vermont and Maine have land use planning acts applying to the location of all facilities. Almost all states in the Northeast have created siting councils.³⁶ The effect of these coastal zone protection laws, in addition to requiring more application and licensing (as many as 35 to 40 licenses are necessary to construct a major facility), has been to prevent or severely limit deepwater port development, refinery or storage tank construction, and indirectly perhaps all oil production in the Atlantic OCS.

VII. FOREIGN PETROLEUM SUPPLY

World Reserves and Production

Since the Northeast, even under favorable conditions, will continue to depend on foreign sources of oil, some attention should be given to the availability and location of worldwide oil resources.

World crude oil production in 1974 amounted to 20.5 billion bbl, with the Soviet Union becoming the world's largest oil producing country in late 1974.³⁷ The Soviet Union produced 3.4 billion bbl of crude oil, compared with 3.2 billion bbl for the second highest ranked country, the U.S. The only other countries to produce more than a billion bbl/year were Saudi Arabia, Iran, and Venezuela (Table 17).

Preliminary data for the first half of 1975 indicate that major reductions are occurring in world crude oil production. In Saudi Arabia, Iran, and Kuwait, the three largest oil producers in the Middle East, oil production has dropped 19, 12, and 27%, respectively. Venezuela, another OPEC member, announced that crude oil production in the first 8 months of 1975 had dropped 19%. These reductions are said to be in response to the decrease in world demand resulting from the price increases of the past two years. It has been suggested, however, that a deliberate attempt is being made to squeeze supply in preparation for a new round of price increases.

A look at the total world crude oil reserves situation (Table 18) further demonstrates the preeminence of the OPEC nations, particularly in the Arab world. The Arab-OPEC nations possess nearly 45% of all crude oil reserves. Thus, while there is no immediate cause for worry about the foreign oil resource base itself (existing proved reserves alone, not including undiscovered recoverables and enhanced recovery, could supply total world demand through the end of this century), its

Table 17
WORLD CRUDE OIL PRODUCTION IN 1974²² (10³ bbl)

Country	1974	1973	Percent change
North America:			
Canada	616,532	648,348	-4.9
Mexico	238,271	191,482	+24.4
United States *	3,199,328	3,360,903	-4.8
Subtotal	4,054,131	4,200,733	-3.5
Central America and Caribbean:			
Cuba *	775	775	--
South America:			
Argentina	151,110	153,539	-1.6
Barbados	48	10	+480.0
Bolivia	16,603	17,226	-3.8
Brazil	64,751	62,122	+4.2
Chile	10,055	11,429	-12.0
Colombia	63,300	66,844	-5.3
Ecuador	64,616	76,221	-15.2
Peru	28,069	25,767	+8.9
Trinidad	68,131	60,666	+12.3
Venezuela	1,086,332	1,228,594	-11.6
Subtotal	1,553,015	1,702,458	-8.8
Western Europe:			
Austria	15,609	17,982	-13.2
Denmark	689	1,460	-47.2
France	7,863	9,152	-14.1
Germany, West	44,718	47,944	-6.7
Italy	6,956	7,082	-1.8
Netherlands	10,906	10,169	+7.3
Norway	12,707	11,166	+13.8
Spain	14,334	5,932	+240.0
United Kingdom *	3,289	2,946	+11.0
Yugoslavia	25,613	24,680	+3.8
Subtotal	142,684	138,513	+3.0
Middle East:			
Bahrain	24,597	24,948	-1.4
Iran	2,210,627	2,139,229	+3.3
Iraq *	679,803	736,607	-7.7
Israel	36,500	32,193	+13.4
Kuwait	830,580	1,007,002	-17.5
Neutral Zone	198,195	190,888	+3.8
Oman	106,046	106,926	-0.8
Qatar	189,348	208,152	-9.0
Saudi Arabia	2,996,543	2,677,146	+11.9
Syria	45,352	38,170	+18.8
Turkey	24,555	24,273	+1.2
United Arab Emirates	616,485	559,399	+10.2
Subtotal	7,958,631	7,744,933	+2.8
Africa:			
Algeria	372,753	400,515	-6.9
Angola	61,392	58,910	+4.2
Congo	22,434	12,713	+76.5
Egypt	53,715	60,483	-11.2
Gabon	13,914	55,045	-101.3
Libya	555,291	793,839	-30.1
Morocco	191	320	-40.3
Nigeria	111,347	749,876	-19.0
Tunisia	31,841	29,828	+6.86.8
Subtotal	1,994,878	2,161,473	-7.7
Asiatic Area:			
Australia	140,890	142,277	-1.0
Brunei	73,730	78,673	-6.3
Burma	7,501	7,514	-0.0
India	54,305	55,388	-1.8
Indonesia	501,838	488,536	+2.7
Japan	4,936	5,142	-4.0
Malaysia *	29,537	33,054	-10.6
New Zealand	1,385	1,290	+7.4
Pakistan	2,923	2,871	+1.8
Taiwan *	1,321	1,055	+25.2
Thailand	42	45	-6.7
Subtotal	818,568	815,845	+0.3
Total Free World	16,522,682	16,764,730	-1.4
East Europe and People's Republic of China:			
Albania	15,346	14,058	+9.2
Bulgaria	1,095	1,460	-25.0
Czechoslovakia	1,085	1,221	-11.1
Germany, East	2,500	2,500	--
Hungary	15,237	15,176	+0.4
People's Republic of China	474,500	365,000	+30.0
Poland	4,080	2,908	+40.3
Romania	107,964	106,578	+1.3
USSR *	3,373,650	3,094,350	+9.0
Total	3,995,457	3,603,251	+10.9

* Estimate

Table 18
WORLD PROVED CRUDE OIL RESERVES, 1973^{5,38}
(10⁹ bbl)

<u>Arab OPEC</u>	<u>Reserves</u>	<u>Percentage</u>
Algeria	9.8	1.47
Iraq	33.1	4.99
Libya	28.0	4.24
Kuwait	66.0	9.96
Qatar	4.8	0.74
Saudi Arabia	137.0	20.67
United Arab Emirates	15.1	2.27
Total Arab OPEC	293.8	44.34
<u>Non-Arab OPEC</u>		
Ecuador	6.1	0.94
Indonesia	10.7	1.62
Iran	65.0	9.80
Nigeria	10.0	1.50
Venezuela	13.7	2.06
Total Non-Arab OPEC	105.5	15.92
Total OPEC	399.3	60.26
U.S.	38.1	5.75
Other Free World	127.2	19.19
Communist World	98.0	14.80
Total world proved crude reserves	662.6	100.00

concentration in the Arab world and OPEC nations indicates that foreign oil supply will rapidly shift to these centers in the near future (Figure 8).

Pronounced shifts are occurring in the character, source, and relative volumes of oil transported in the web of supply movements to the Northeast. Continuous perturbations in the supply picture emerge as private oil companies respond to the changing world oil scene and compete to maintain a competitive edge in the oil market. Current trends clearly indicate a shift from historically established supply sources to more exotic supply patterns relying on crude oil

Acceptable Level of Foreign Dependence

The dislocations in the energy system and the general economy brought about by the embargo have furnished some insight into the question of "How much foreign dependence is acceptable?" Our experiences during the embargo point to three important criteria. The first relates to the diversity of foreign supply, and the second depends on the degree to which consumption patterns may be altered without significant dislocation. Lastly, the tolerable limit of foreign supply will depend, even for secure imports, on the ability of the economy to absorb the effects of escalating prices without excessive inflation, unemployment, and balance of payments deficits.

Theoretically, reliance on foreign supply sources is tolerable as long as the sources are spread among many countries. In the event of an interruption in supply from one or more sources, other producers can fill the supply gap. This works as long as oil exporters do not act in concert to control supply and as long as there is sufficient flexibility of supply among the remaining sources. Although the U.S. imports oil from many different countries, most of it comes from two major acting cooperatives: the Arab OPEC and non-Arab OPEC countries. The non-Arab OPEC nations did not participate in the embargo against the U.S., but they support higher prices no less firmly than their Arab colleagues. Indeed, perhaps the strongest voice for moderation in price increases has come from Saudi Arabia. The problem of foreign supply sources is further compounded by the fact that our imports are not exclusively of crude oil, and it is more difficult to find alternative supply sources in the event of an interruption in the supply of petroleum products.

Thus, foreign oil imports are tolerable as long as the quantity of "insecure" oil does not rise above some "domestic danger level." The percentage of imports from insecure sources corresponding to the danger level should not exceed the amount potentially available through a shift to alternative foreign supply sources plus the implementation of a national or regional

conservation and storage program. If, for example, in the event of an embargo by the Arab OPEC members, an extra 5% in oil supply can be derived from our other oil producing sources, as in the last embargo, and if a 15% reduction in domestic consumption can be achieved through conservation programs (without severe social or economic disruption), then the danger level for that portion of the oil use supplied by the Arab block would be set at 20%.

The experience of the last embargo indicates that the system could tolerate a reduction in oil supply of about 15%, but the cost would be high. The Federal Energy Administration has estimated that the last embargo cost the economy some \$20 billion in gross national product and five million jobs.³⁹

In conclusion, a degree of reliance on foreign oil supplies is tolerable, its extent depending somewhat on the amount of flexibility in our system. Because flexibility due to conservation is a one-time affair, programs instituted now to reduce consumption levels would lessen flexibility in the event of a future embargo. On the other hand, at least in the short run, the degree of reliance on foreign supplies would level off, if not decrease. Although some doubt remains as to the benefits of immediate conservation (reduced flexibility and inhibited economic expansion) the vast body of reason indicates that conservation is the preferred energy policy route for the short term. Conservation strategies are discussed in a separate paper in this series.

Threat of Future Embargo

Although the situation in the Middle East has stabilized considerably since 1973-74, the threat, and therefore the possibility, of another oil embargo remains. An examination reveals a considerable number of threatened or actual disruptions. Since 1948, the following events have occurred in the Middle East:⁴⁰

(1) At the start of the 1948 Arab-Israeli War, Iraq shut down a pipeline to the Mediterranean at considerable financial loss to itself. It also prohibited the completion of other lines (still unfinished).

(2) In 1951, Iran seized the properties of the Anglo-Iranian Oil Company, and production was shut down for three years.

(3) During the 1956-57 Arab-Israeli War, the Suez Canal was closed. The pipeline from Iraq to the Mediterranean was sabotaged.

(4) In 1961, Iraq seized a giant undeveloped oil field. Although the issue is still not settled, Iraq has developed and exploited the field with Russian help.

(5) In 1966, Syria, seeking higher transit fees, shut down the Iraq Petroleum Company's pipelines that cross Syrian territory. This was a case in which a country's vital need for oil production revenues did not prevent an interdiction. It was Iraqi oil that was shut in, not Syrian.

(6) Nigerian oil production was sharply reduced during much of the 1967-70 civil war.

(7) At the start of the 1967 Arab-Israeli War, production was temporarily stopped by Arab producers. The Trans Arabian Pipe Line was shut down; shipments to three countries were embargoed; and the Suez Canal was closed and remained closed until 1975.

(8) On several occasions in 1969, the Trans Arabian Pipe Line was sabotaged by Arab guerrillas. The economic cost to the guerrillas was nil, since it was American-owned Saudi Arabian oil that was shut in. The guerrilla organization was reported to have called this action the beginning of a confrontation with American interests in the area.

(9) The Trans Arabian Pipe Line was shut down in the spring of 1970 because, despite the protests of Saudi Arabia, the government of Syria refused to permit repair of an accidental break in the line. Early in 1971, a new government in Syria negotiated the reopening of the line. Acts of sabotage occurred again in September 1971.

(10) In mid-1970, the government of Libya ordered oil production cut back substantially and interdicted shipments of

liquefied natural gas. Some restrictions on oil production are still in effect. After imposing these restrictions, and with the Suez Canal and the Trans Arabian Pipe Line closed, Libya was able to force the companies to increase their tax payments by about 15%.

(11) Late in 1971, Libya seized the Libyan properties of British Petroleum because of the British government's failure to prevent Iran from occupying strategic islands in the Persian Gulf (2000 miles from Libya) one day before the British were scheduled to withdraw from the coast.

(12) Perhaps the most significant development has been the strengthening of the OPEC consortium which has made it possible to maintain an oil embargo against the U.S. for its support of Israel and to collectively raise oil prices and limit oil production at will. It is noteworthy that the OPEC organization has been threatening international oil companies and indirectly the U.S. with an embargo since 1970 if its member nations do not receive higher revenues for its oil.

(13) Finally came the successful 1973-74 oil embargo, successful not so much in accomplishing political goals as in creating acceptance in the consuming nations of much higher prices for oil as long as the oil was forthcoming.

Thus interruption of oil supplies has not been an isolated occurrence in the Middle East. The OPEC consortium has emerged as a new economic and political power block in the world, willing to use their "oil weapon" and petrodollars to control international and foreign domestic affairs, including those of the U.S. The possibility of another embargo as well as of sudden and arbitrary increases in oil prices should be taken seriously in the Northeast.

VIII. CONCLUSIONS

Energy policy planning requires informed and balanced consideration of the interrelated variables of supply, price, and socioenvironmental costs. In a period of dwindling supply and increasing demand, policy aimed at affecting only one corner of this triangle, although perhaps beneficial in the short run, will be limiting if not self-defeating in the long term. A comprehensive analysis of the entire energy system and an overview of all its potential pitfalls are necessary in the Northeast and the country as a whole.

It is evident a future oil embargo by the OPEC countries would place this country and especially the Northeast in an awkward and potentially dangerous position. In the recent embargo, the nation was able to respond effectively only because the amount of insecure foreign supplies was comparable in degree to the excess fat in our energy system. Unless innovative energy programs are initiated soon, an embargo during the mid 1980's will find us in a significantly less flexible and more vulnerable position.

It is not at all clear that national energy policy is being formulated with adequate sensitivity to the special needs and situations of the regions of the country. Thus, it is important that the states of the Northeast establish at least the outlines of a regional energy policy. That policy is necessary as a basis not only for decisions within the region but also for energy decisions made in Washington that affect the states of the region.

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APPENDIX
HUBBERT'S ANALYSIS

Unlike econometric projections which are fitted to a myriad of economic parameters, the logistic curves of Hubbert derive from a least-squares fit of only two arbitrary constants. One begins, in this approach, with the perception that the cumulative production of a resource throughout its history can reasonably be described by

$$Q_e = Q_\infty / (1 + ae^{-bt}).$$

Q_e , the cumulative production, is the total amount of the resource removed from the ground since the beginning of time; Q_∞ is the amount ultimately recoverable; t is time (with the zero of time arbitrary); and a and b are the fitted constants. Rearranging the equation and taking logs,

$$\ln[(Q_\infty/Q_e) - 1] = \ln(a) - bt,$$

which implies an easy solution for a and b using linear regression on historic values of Q_e for a given Q_∞ .

The expression for Q_e doubly asymptotic, resting at zero for $t = -\infty$ and bounded by Q_∞ for $t = +\infty$. This, at least, is demanded of a model of resource utilization. Figure A-1 illustrates the behavior of Q_e in more detail. In the early history of the resource the exponential term dominates which is an exponential rise in production. Later, as the term achieves the same magnitude as $1/2Q_\infty$, the progression in cumulative production becomes nearly linear, and the slope begins gently to turn over. It is here that the slope is steepest, i.e., the rate of production is greatest. As the resource becomes depleted, the exponential term approaches zero and Q_e approaches Q_∞ .

Figure A-1. Typical logistic curves of cumulative production. The four curves correspond to different values of a and b .

Figure A-2. The effect of skew on a Hubbert curve for fixed Q_∞ .

The exact shape of the curve is governed by the values of a and b. But in this form the curve is symmetric around the point of peak production as is its derivative, the annual production:

$$\frac{dQ_e}{dt} = \frac{abQ_\infty e^{-bt}}{(1+ae^{-bt})^2} = \frac{abQ_e e^{-bt}}{1+ae^{-bt}}$$

A parameter s, for skew can be introduced, however, to distort the shape of the curves without changing their general properties.

$$Q_e = \frac{Q_\infty}{(1 + ae^{-bt})^s}, \quad \frac{dQ_e}{dt} = \frac{sabQ_\infty e^{-bt}}{(1 + ae^{-bt})^{s+1}}$$

Figure A-2 depicts the effect of skew on the annual production curve. An exponent of unity implies a symmetric curve; exponents < 1 tend to sharpen the peak while diminishing rates of future production; and exponents > 1 tend to smooth the curve's peak while increasing future production.

Crude oil and natural gas, as depletable resources, can be expected to follow a growth and depletion pattern similar to that indicated by the Hubbert curves. Furthermore, the isolatability of U.S. production from other sources makes this commodity particularly suitable for a Hubbert-type analysis, especially if the country is considered a well-explored closed system for which Q_∞ can be known to good accuracy (which may or may not be strictly true). The disadvantage of the logistic-curve approach is that it is essentially a physically based method that subsumes, or deals implicitly with, the economics of the resource. In practice, a Hubbert curve can be seen as a marker of trend, a sort of pure waveform beneath the noise imposed by economic and

policy variables on the production rate curve.

Perhaps the most important feature of a Hubbert curve is its role as guardian of the integral. The ultimate resource, Q_{∞} , is the area under the annual production curve, the integral of dQ/dt over all time. Although much debated, the total resource base is a number that one can approximate, or at least set limits on, and must be considered in carrying out projections. Logistic Gaussian curves serve as a visual guide to how much integral is allowed and make it easy to tell what value of Q_{∞} is implied by the curve of a particular projection. Production rate curves with non-unity skew also retain this integral-maintenance property, which permits easy assessment of the effect in the future of an accelerated rate in the near term and, conversely, the long-term effects of a present-day reduction in production. Table A-1 is an example of the output obtainable through the use of Hubbert analysis. Here in this case, the curve has been skewed to pass through the 1985 BAU oil production case. The effects on future annual and cumulative production are then produced.

Table A-1

Hubbert Analysis Output: Annual and Cumulative Production

<u>Year</u>	<u>Cumulative Production</u>	<u>Annual Production</u>
1959	61.290	2.273
1960	63.603	2.352
1961	65.995	2.433
1962	68.469	2.515
1963	71.025	2.599
1964	73.666	2.684
1965	76.398	2.770
1966	79.206	2.857
1967	82.107	2.945
1968	85.096	3.033
1969	88.174	3.122
1970	91.340	3.210
1971	94.594	3.298
1972	97.935	3.384
1973	101.362	3.470
1974	104.874	3.552
1975	108.466	3.633
1976	112.138	3.709
1977	115.884	3.782
1978	119.700	3.850
1979	123.583	3.913
1980	127.524	3.969
1981	131.519	4.019
1982	135.559	4.060
1983	139.637	4.094
1984	143.743	4.118
1985	147.869	4.132
1986	152.004	4.136
1987	156.138	4.129
1988	160.259	4.111
1989	164.356	4.081
1990	168.418	4.040
1991	172.433	3.988
1992	176.389	3.924
1993	180.277	3.849
1994	184.083	3.763
1995	187.800	3.668
1996	191.417	3.564
1997	194.925	3.452
1998	198.318	3.332
1999	201.588	3.207
2000	204.730	3.077
2001	207.741	2.943
2002	210.616	2.807
2003	213.353	2.609
2004	215.953	2.530
2005	218.414	2.393
2006	220.739	2.257
2007	222.929	2.123
2008	224.987	1.998
2009	226.916	1.866
2010	228.720	1.744
2011	230.405	1.625

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