World Petroleum Availability 1980-2000

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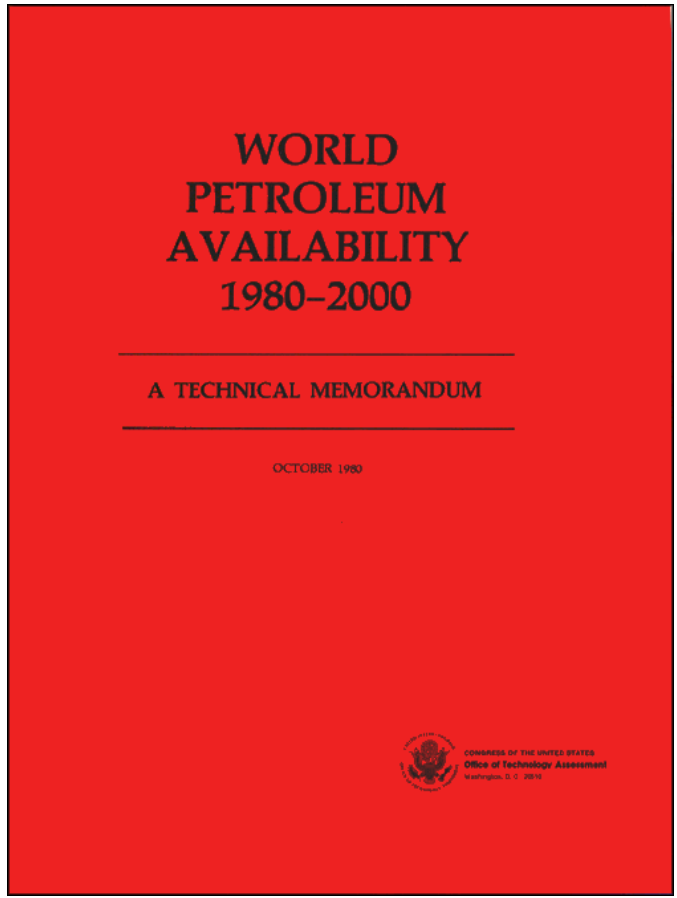

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PREFACE

The dependence by a large portion of the world on imported petroleum makes knowledge about the future availability of petroleum on the world market of great importance. This is particularly important for the United States and other developed countries, because of the large volume of oil they import. Most of the energy decisions faced by the United States in the next two decades depend critically on the oil import issue. The level of conservation we pursue, the rate at which we develop synthetic fuels, the resolution of the nuclear power debate, as well as other energy issues all depend on the availability, and consequent cost, of imported oil. Recent events in the Middle East illustrate that the availability of foreign oil is far more precarious than the physical resource base alone might suggest.

In response to a Senate Foreign Relations Committee request for a review of global energy trends, OTA undertook this study, which estimates plausible levels of world oil production to the year 2000 and assesses the factors likely to determine which levels are actually reached. To determine that potential range of production, the study critically examines country-by-country capabilities for oil production, various estimates of what each country will actually produce, and prospects for new discoveries. Several world petroleum experts have reviewed the results of OTA's analysis.

This analysis indicates it is highly likely that there will be little or no increase in world oil production from conventional sources over current levels. Therefore, we will most likely not be able to increase the imports above our current level and, indeed, we will probably face intense competition before the close of this century at even lower levels. It would be prudent to consider this likelihood in U.S. policy actions designed to reduce our heavy dependence on petroleum.

This technical memorandum is intended to assist Congress in the debate over these and related foreign policy issues by discussing the amount of oil available and the factors that control it. This study will also serve as background for two other ongoing OTA studies on technology and Soviet energy availability and alternative energy futures.

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Table of Contents

SUMMARY

In spite of the importance of the issue, uncertainties about world supplies of oil from conventional sources during the next two decades are surprisingly large. Nevertheless, it is highly likely that there will be little or no increase in world production of oil from conventional sources. Prudent planning should consider this possibility.

Oil production in the industrialized non-Communist world could begin to decline by the early 1980's. While it may be physically possible to increase world production of oil significantly (perhaps 33%) by the 1990's, substantial increases are extremely unlikely because the nations capable of contributing to such an increase have no financial or political incentive to do so and because a number of practical problems would arise if a significant increase in production were attempted.

Enough is known about world oil supplies to make a few specific observations:

(1) Assuming political stability in the major exporters, non-Communist world oil supply is likely to range between 45-60 MBD* in 1985 and 40-60 MBD in 2000 (compared to 52 MBD in 1979). The sizes of potential increases in Saudi Arabia, Mexico, and Iraq and of the decrease in the United States account for a major portion of the variation in production possibilities (10 MBD or approximately 50% of the variation in the year 2000).

* Throughout this paper oil production will be given in millions of (42 gallon) barrels per day (MBD). Unless otherwise specified, oil production will include liquids associated with production of natural gas.

68-047 0 - 80 - 2

(2) As a group, the non-Communist industrialized countries will experience no significant increase in production. In fact, production in these countries may decrease by as much as 50% by the year 2000.

(3) In the short term, U.S. production may decline from its current level of 10.2 MBD to a level of 7.2-8.5 MBD in 1985. Production in the year 2000 may range between 4-7 MBD. The high estimate for the year 2000 (7 MBD) depends on both the annual addition of 1 billion barrels to proven reserves and the extensive use of enhanced recovery techniques.

(4) OPEC production during the next 20 years will not differ significantly from its current level of 31 MBD. Any increases in the production rate will be strongly dependent upon Arab OPEC producers. Except for Iran, only Saudi Arabia, Kuwait, and United Arab Emirates have the reserves and Iraq the estimated potential to increase production rates. Substantial dependence on Arab OPEC (the Persian Gulf region) is likely to continue with its obvious implications for foreign policy. In particular, Saudi Arabia retains its central position in OPEC. Although the Saudis have reserves which could permit an increase in production capacity to 16 MDB, they have announced their intentions to not exceed a maximum sustainable capacity of 12 MBD, and plan to reach this level of capacity in 1987 at the earliest.

(5) Although production in the non-OPEC less developed countries (LDC's) will increase above its current level (principally as a result of increases in Mexican production), much, if not all, of the increase in LDC oil supply will be offset by increases in LDC demand.

(6) The Communist countries may cease being a net exporter of oil to the free world by the early 1980's as a result of declines in Soviet production. The increased pressure caused by the entry of the Eastern European countries (currently more than 80% dependent on the Soviet Union for their imported source of oil) and conceivably the Soviet Union itself as buyers on the world oil market has serious implications both for price and foreign policy. While the Soviet Union has potentially promising areas for increases in oil production, most of the petroleum "frontier" Soviet areas lie either north of the Arctic Circle or in deep water where drilling is expensive and slow; development is at least a decade away. Many technical difficulties have already been encountered and it appears that the Soviets have not accumulated enough technology or experience to develop these areas rapidly. The Office of Technology Assessment has a study underway of the contributions which U.S. and other Western technologies could make to Soviet oil production.

(7) In addition to Mexico, some new large discoveries are possible outside the Middle East, but there appears little possibility that the Middle East oil fields will be duplicated elsewhere. All promising areas for large discoveries outside the Middle East are either in the Arctic or involve areas of territorial dispute (the Malvinas basin off the Falkland Islands and the South China Sea). Even under optimistic discovery assumptions, it is unlikely that substantial production from new sources will occur in this decade. Because of the remoteness of most prospective areas, there would be a considerable delay between the time of discovery and significant production from any new discoveries in these areas.

(8) Major additions to the world's known oil supplies are likely to result from additional recovery in known fields rather than new field discoveries. These new additions are not expected to alter the dominance of the Middle East since over half of the new additions are expected to be in the Middle East. Moreover, the world distribution of ultimately recoverable oil is not believed to differ significantly from the known distribution today.

(9) There is some speculation regarding the petroleum potential of the deep ocean areas and Antarctica. The technology and the price of oil are not sufficient now to encourage active exploration and development of either of these regions. Future development of these areas may also necessitate new international agreements.

INTRODUCTION

The availability of petroleum in world markets is a paramount energy issue. The conflict between Iran and Iraq has emphasized that the supply of petroleum is far more precarious than indicated by its mere physical availability. This report summarizes and interprets available information concerning two main topics. The first topic is a review of available information concerning the geological occurrence of petroleum:

(1) What are the known reserves of petroleum and what additional petroleum resources may be added to these reserves? What is the basis for this knowledge?

Establishing the resource base is not alone sufficient to determine future production rates. In addition to reserve and resource considerations, future production rates will be determined by a combination of political, technical, and economic considerations. The second topic is a projection of future non-Communist world oil supply based on all these factors.

(2) What is a likely range of non-Communist world oil availability for the near term (1985) and the longer term (2000) and what are the geologic, economic, political, and technical factors that will determine these levels of availability?

The first chapter of the report gives a brief review of petroleum geology. The second chapter addresses estimates of world reserves and resources.

Chapter 3 discusses non-Communist world oil supply which is determined by its production and the imports and exports of the Communist countries.

Non-Communist world production is discussed first, followed by an analysis of the potential effect of the Communist countries. In Chapter 4, our analysis is compared to the projections in other studies.

Only conventional sources are treated in this report. Production from Canadian tar sands, the Orinoco belt in Venezuela, oil shale or synthetic products from biomass or coal are not included in the estimates given here.

This report does not address any foreign policy or domestic policy considerations that may arise from these forecasts.

1. Petroleum Geology

A brief review of petroleum geology is helpful to understand world oil resources and production rates since geology sets the upper bound on production potential from the finite petroleum resource.

Geologists generally agree that petroleum deposits were formed from the remains of enormous quantities of aquatic plants and organisms which became mixed with sand and mud at the bottom of bodies of water. If a certain regime of temperatures and pressures existed, this biological material was converted into petroleum during geologic time. The pressure in the earth's crust forced the petroleum into the tiny open spaces between the grains of imbedded sandstone and other coarse textured strata (and not into vast underground pools). For petroleum to be present in commercial quantities some sort of trapping mechanism must have been present to prevent its escape. In addition, these traps must have not been breached by natural means after accumulation occurred.

There are two major kinds of trapping mechanisms. Structural traps are created by a deformation of the earth's crust; the folding or faulting of rocks results in the entrapment of petroleum. Stratigraphic traps result from the relative difference in the porosity and permeability of the oil-bearing rocks compared to less porous and permeable adjacent rocks, which then serve to prevent the further movement of oil. Many traps are combinations having both structural and stratigraphic features.

Since the oil reservoir (a rock formation or trap holding an accumulation of petroleum) was formed from sea sediments, most reservoirs also contain salt water. In addition, natural gas is almost always present

either dissolved in the oil or as free gas separate from the oil. The associated water and natural gas are important in maintaining pressure during petroleum production.

The theory of petroleum formation and occurence has led to the search for areas containing thick beds of sedimentary rocks. Geophysical techniques have led to the discovery of approximately six hundred basins (a tract of land in which the rock strata are tilted toward a common center), both onshore and offshore, which may contain oil or natural gas. Sufficient seismic work has been done to give an indication of their prospective petroleum area and their general structural aspects. In approximately four hundred of these basins exploratory drilling in varying amounts and degrees of success have taken place; commercial quantities of oil and gas are being produced from approximately 160 of these basins.

There remain approximately 200 basins which have not been drilled. However, the size, characteristics of the sediments, and the gross structural features of these basins have been determined by geophysical work.* This lack of drilling has been due to many factors including the location of the areas, restriction on access caused by individual governments and territorial disputes, and most importantly, judgments about their potential for yielding petroleum. In particular, some of these basins lie in the offshore Arctic for which the past prices of oil have not been sufficient to justify exploration (although this appears to be changing).

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* M. Halbouty, "Acceleration in Global Exploration," American Association of Petroleum Geologists Bulletin, May 1978.

Although oil has been found in commercial quantities in approximately 160 basins, 25 of the 160 basins (containing discoveries of over 10 billion barrels) have accounted for over 80% of total discoveries.* Not only have oil discoveries been concentrated in a few basins, but the majority of oil has been found in a relatively small number of large fields.**

Over 90% of the oil has been found in a small number of large fields containing at least 100 million barrels of liquid petroleum or liquid - equivalent (liquids plus natural gas) resources. Thus, of the more than 20,000 fields discovered, 1700 contain over approximately 900 of the 1000 billion barrels which had been produced or were known to exist at the end of 1975.*** Further, an even smaller number of approximately 280 giant fields (containing at least 500 million barrels in liquids or liquids equivalent) contained approximately 75% of the oil found through 1975.

The U.S. has a smaller share of oil found in large fields than the worldwide average of 90%. However, approximately 70% of the oil found in the U.S. has been found in large fields containing at least 100 million barrels of liquid petroleum or liquids equivalent. The significance of large fields for the U.S. is illustrated by the petroleum discoveries in the Permian Basin, which were responsible for 18% of the crude oil and 10% of the natural gas discovered in the U.S. through 1974. The Permian Basin has been extensively explored, resulting in the discovery of over 4000 oil and gas fields by the end of 1974. At that time over 60% of the oil and gas had

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*D.R Root and E.D. Attanasi "World Petroleum Availability," United States Geological Survey, 1979.

**Field is used to refer to a single accumulation (in which case it is synonymous with reservoir) or a set of closely related accumulations of petroleum.

***R. Nehring, Giant Oil Fields and World Oil Resources. Rand Corp., June 1978, p. Vii.

68-047 - 80 - 3

been discovered in the 70 largest fields while only 2% had been discovered in the 2700 smallest fields (fields containing less than 1 million barrels of oil or equivalent).*

Many experts expect the importance of large fields for new discoveries to continue, for both upon geologic and economic reasons. In new offshore areas, only large fields are economical to develop at today's oil prices ($30 per barrel), although in places where the associated infrastructure (pipelines, etc.) exists, smaller finds may be sought and developed.

The earliest discoveries of oil and gas made over a century ago were based on surface seepages and analyses of surface geology. After a century of exploration, petroleum exploration has become extremely sophisticated. New techniques and instrumentation, such as geophysical surveys, geochemical analysis and subsurface logging, combined with the use of computers, provide information on structural characteristics of the subsurface.

These techniques provide only raw data which must be evaluated by geologists and geophysicists; the room for judgment and, therefore, differences in interpretation remains great. Drilling remains the only way to determine the actual existence of petroleum resources, with the other exploration techniques providing guidance as to the most promising locations within a basin.

*D. H. Root, L. J. Drew, "The Pattern of Petroleum Discovery Rates" in American Scientist, vol. 67 (1979), pp. 648-652.

An example illustrating the geologic uncertainties and risks in oil exploration is the Destin Dome located in the Gulf of Mexico. Over six hundred million dollars was paid by oil companies for leases around the Destin Dome in view of its extremely promising petroleum potential. After drilling many dry holes, the companies involved returned the leases to the government with no petroleum produced.

Once oil is found in commercial quantities, there is a substantial delay until production begins, and such delays can last several years in many offshore areas. After the initial discovery further drilling and planning is necessary to determine the optimum way to exploit the find. In addition, the necessary infrastructure (pipelines, other supporting equipment and people) must be located and bought. In many Arctic areas the technology to allow production must still be developed.

Production begins initially with the oil allowed to flow naturally from the high pressure area underground to the surface. This natural recovery, called primary recovery, depends on reservoir pressure and the natural drive mechanism. The drive mechanism refers to the sources of energy within the reservoir that will assist production, and depends upon the physical properties of the oil, gas and water found in a reservoir and upon their relative proportions and locations.

Secondary recovery is another procedure used to boost recovery from a reservoir. This procedure consists of reinfecting either associated gas or water near the well to maintain underground pressure. In the past, secondary recovery techniques followed the use of primary recovery techniques; today these techniques may be used simultaneously to increase total production.

The percentage of the oil in place recovered using primary and secondary recovery varies greatly from field to field. Thirty three percent is sometimes used as an average figure based upon experience in the U.S.; however, recovery in the East Texas oil field which has a natural water drive may exceed 75%.

Production rates are limited by the drive mechanism and other geologic factors. In addition, economic and resource maximization considerations (production at too fast a rate would lead to a reduction in total recovery) also influence production rates. A general planning guide for a country or region is that 1/15 of the recoverable oil remaining can be produced each year; this is referred to as the 15 to 1 reserves to production ratio. This planning guide is only a rough estimate and is, to some extent, a function of well density. Production from U.S., Canadian and Australian fields, which are in a mature state of development, exceed the 1/15 ratio. In the U.S. the figure is about 1/10.

With the increased price of oil since the 1973 embargo, other procedures have become economical for recovering additional oil from existing fields where primary and secondary techniques have already been used. This is especially true for the U.S., since many early U.S. fields were exploited ineffectively causing a large portion of oil to be left in the ground. These additional techniques, called enhanced recovery techniques, consist of injecting heat or chemicals into the reservoir.

Except for heat injection, most of these techniques are currently in a developmental stage.* The success of these techniques varies greatly from

*See the OTA report Enhanced Oil Recovery Potential in the United States, January 1978, for a more detailed review of these techniques.

field to field. A range of approximately 2-10% has been given as the additional percentage of oil in place that can be recovered in the U.S. using enhanced recovery techniques.* Since enhanced recovery techniques are expensive and require energy for their utilization, the extent of the use of these techniques will depend upon the future price of oil and the price of the chemicals and steam required for their implementation.

The production of heavy oil requiring steam for its primary recovery is not included in enhanced recovery estimates. However, heavy oil fields for which some production is possible without steam injection are included in enhanced recovery estimates. Thus most heavy oil fields in California are included in enhanced recovery estimates.

About 95% of the production of liquid petroleum in the world and 85% in the U.S. is of crude oil from primary, secondary, and enhanced recovery techniques. The remaining 5%, 15% in the U.S., is natural gas liquids resulting form natural gas production. The term liquid petroleum is used to refer to the sum of crude oil and natural gas liquids production.

In some publications production and resource estimates are given for crude oil while in other publications these estimates are given for liquid petroleum. These differences lead to potential confusion in comparing resource and production estimates from various sources. Unless otherwise specified, estimates in this paper will be liquid petroleum estimates.

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* Ibid.

2* World Oil Resources

A. Reserves

One method for determining "How much oil is there?" is to respond with an estimate of the amount of oil reserves that can be proved from the known oil in place. Unfortunately, any estimate of oil reserves must be treated as an approximation for two main reasons. First, the volume of oil in place, even in a well-defined field, can never be precisely known. Second, even if the volume is known, estimates of production would depend on assumptions about the techniques that are used to recover the oil and the levels of success of these techniques.

For the United States, the American Petroleum Institute has adopted a conservative definition of proven (or proved) reserves. According to the American Petroleum Institute, proven reserves are "the estimated quantities of all liquids statistically defined as crude oil, which geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under existing economic and operating conditions".*

From this definition one infers that there are additions to proven reserves when new discoveries are made, recovery techniques are improved or when increases in the price of oil make additional fields economical to develop. In general, estimates of proven reserves for the U.S. include oil obtainable from primary and secondary recovery but not enhanced recovery.

* American Petroleum Institute, Reserves of Crude Oil, Natural Gas Liquids, and Natural Gas in the U.S. and Canada, as of December 31, 1977, Vol. 32, Washington, D.C., June, 1978, p. 14.

It is important to recognize that while estimates of proven reserves are the most reliable estimates available in world oil statistics, most industry officials consider the estimate for the U.S. to be accurate only within 20%. A study published by the National Academy of Sciences in 1976 underscored the range of possible error in estimating the oil and natural gas reserves in an individual field. Two consulting firms were asked to check the Federal Power Commission estimates of gas reserves under lease in certain fields in the Gulf of Mexico. This was done for a random sample of 19 out of 168 fields. For 9 of the 18 fields checked the two consulting firms differed by a factor of over 100%.*

Outside the U.S., the American Petroleum Institute definition for proven reserves is not strictly followed in determining an estimate of reserves. In addition to proven reserves, an allowance is sometimes made for probable reserves. Probable reserves are those situated in a conjectural part of the field or reservoir which is as yet incompletely evaluated, undrilled, and where the characteristics of the producing zone and its fluid content are assumed favorable for commercial production.

One of the few private compilations of estimates of proven crude oil reserves is the Oil and Gas Journal.** The Oil and Gas Journal does not make its own independent appraisal; their estimates are obtained from oil

* National Academy of Sciences, Gas Reserves Estimation of Offshore Producible Shut-in-Leases in the Gulf of Mexico, Washington, D.C., March, 1976.

** Annually (in August) World Oil magazine releases its estimates for proven reserves for the beginning of the year. This estimate is comparable (typically 15% lower) with the Oil and Gas Journal. Lower estimates are normally given for Saudi Arabia, Iran, Mexico, and the North Sea resulting from a more conservative estimate of proven reserves.

companies, governments, and other petroleum organizations. Although these estimates are listed as proven reserves, many estimates include reserves that would not be classified as proven reserves according to the American Petroleum Institute definition. In particular, the Mexican proved reserves estimates, taken from the Mexican government oil company Petroleos Mexicanos, include 11 billion barrels for the Chicontepec field which would not be classified as proven reserves according to the American Petroleum Institute definition.

Non-communist proven crude oil reserves were estimated at approximately 550 billion barrels in December 1979 as shown in Table 1.

Several features of this estimate deserve mention. First the world's reserves are concentrated in a small number of countries. The eleven countries with reserves of over 10 billion barrels contain 482 billion barrels or over 87% of the non-Communist world's reserves. Saudi Arabia alone contains over 30% of the non-Communist world's reserves. These facts are illustrated graphically in Table 2.

The dominance of the Middle East region (Egypt, Iran, Iraq, Kuwait, Libya, Oman, Qatar, Saudi Arabia, Syria, and United Arab Emirates) and of Arab OPEC (Algeria, Bahrain, Egypt, Iraq, Kuwait, Libya, Qatar, Saudi Arabia, Syria, United Arab Emirates) is also apparent. The 362 billion barrels of reserves in the Middle East represent over two thirds of the non-Communist oil reserves while the 336 billion barrels in Arab OPEC represent approximately 60%. On the other hand the industrialized countries, which are the major consumers of oil, possess only 11%. A breakdown by geographical region of the world's oil reserves is illustrated graphically in Table 3.

TABLE 1

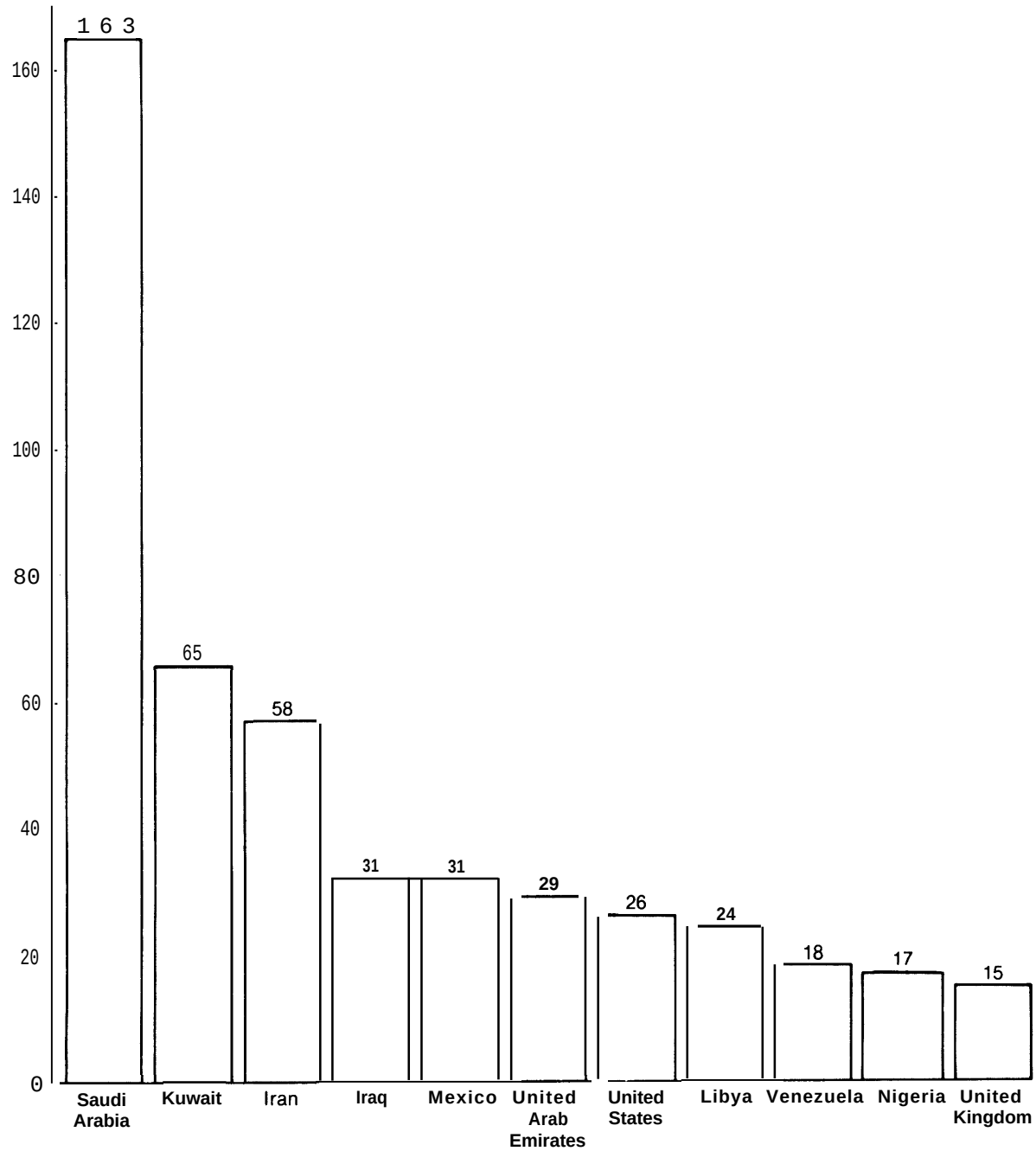
NON-COMMUNIST WORLD PROVED CRUDE OIL RESERVES

	BILLION (109) Barrels January 1, 19801
OECD GROUP COUNTRIES	
United States	26.5
Canada	6.8
Western Europe	23.4
Japan, Australia, N.Z.	2.1
TOTAL	58.8
NON-OPEC DEVELOPING COUNTRIES	
Latin America	
Mexico	31.2
Other	7.3
Africa	7.2
Middle East	4.5
Asia	7.6
TOTAL	57.8
OPEC	
Saudi Arabia	163.4
Iran	58.0
Iraq	3100
Kuwait	65.4
UAE	29.4
Qatar	3.8
Neutral Zone	6.3
Nigeria	17.4
Libya	23.5
Algeria	8.4
Gabon	.5
Venezuela	17*9
Ecuador	101
Indonesia	9.6
TOTAL	435.7
Total Non-Communist World (totals do not add due to rounding)	551.6

1 Oil and Gas Journal, December 31, 1979, pp. 70-71.

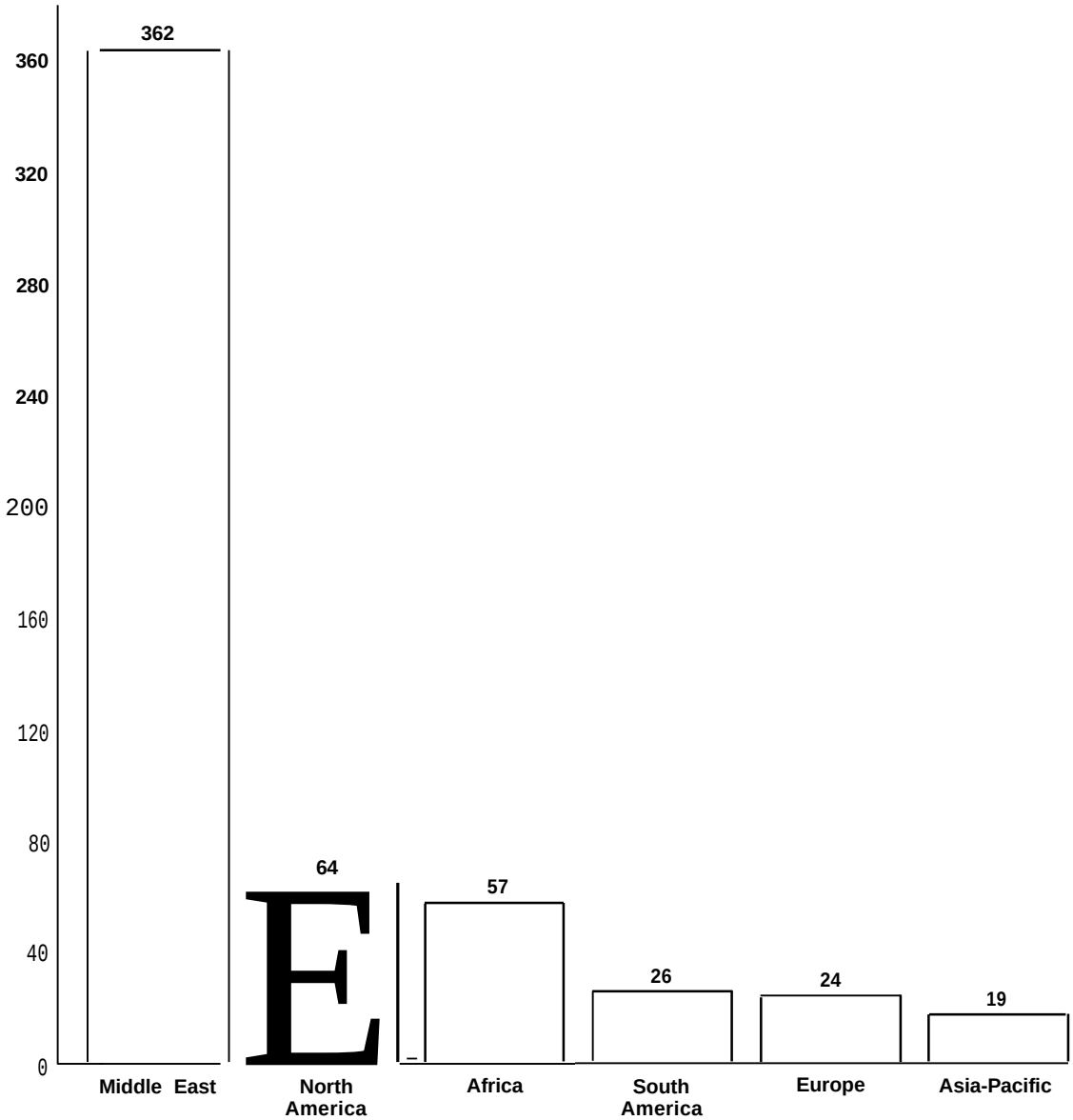
68-047 O - 80 - 4

Table 2.—Non-Communist Countries With Reserves in Excess of 10 Billion Barrels



SOURCE: *Oil and Gas Journal,* Dec. 31, 1979, pp. 70-71

Table 3.—Regional Distribution of Non-Communist Oil Reserves



SOURCE 0il *and Gas Journal,* Dec. 31, 1979, pp. 70-71

The importance of proven (and probable) reserves is that they are the major source of oil production in the short term (1-7 years). Additional discoveries and enhanced recovery techniques will add to the estimates in Table 1 but these contributions will have negligible effects on short-term production potential.

The size of these reserves can be illustrated by the following statements:

a. The 552 billion barrels of reserves correspond to approximately 31 years of production at today's non-Communist crude oil production rate of approximately 48.2 million barrels per day. (17.6 billion barrels per year).

b. The 26.5 billion barrels of U.S. reserves correspond to approximately 8.5 years of production for the United States at the current production rate of 8.5 million barrels per day (3.1 billion barrels per year).

c. The 163.4 billion barrels of reserves correspond to approximately 48 years of production for Saudi Arabia at the current crude oil production rate of 9.5 million barrels per day (3.5 billion barrels per year).

However, these production rates cannot be maintained for the entire period without further reserve additions as explained above.

For the Communist areas the overwhelming majority of the proven oil reserves lie in the Soviet Union and China. Estimates of the Soviet Union and China must be treated as very rough approximations due to the limited availability of data. Three estimates are given in Table 4, the much lower estimate for the Soviet Union given by the Central Intelligence Agency is based upon their estimate of proven reserves. The Oil and Gas Journal estimate is the Soviet Union estimate for "explored reserves" which includes an undetermined amount in addition to proven and probable reserves.

TABLE 4

COMMUNIST AREA OIL RESERVES

	LIQUID PETROLEUM	CRUDE OIL	
USSR	40	67	58
China	20	20	20
Other	5	3	2
Total	651	90[2]	80[3]

[1] Central Intelligence Agency, International Energy Statistical Review, March 2, 1979, proved reserves estimate.

[2] Oil and Gas Journal, December 31, 1979, pp. 70-71, "explored reserves."

[3] World Oil, August 15, 1979, estimate for end of 1978, proven reserves.

B. Total Potential Resources

A different way to answer the question "How much oil is there?" is to estimate the quantity of oil which will ultimately be recovered. This quantity called the ultimate recovery estimate includes:

1) oil that has already been produced (cumulative production)

2) proven reserves

3) oil from additions to known fields through extensions, full development and enhanced recovery techniques

4) oil from new discoveries.

The last three items constitute remaining resources which will determine future production rates.

It must be stressed, however, that the rate at which additional quantities in (3), (4) are added to reserves may be the critical factor in determining the production rates for the next several decades. Additions to

reserves in the non-Communist world have been declining from over 20 billion barrels annually through the 1950's to approximately 13 billion barrels in the late 1970's (1975-78). During the period 1975-1978 production exceeded additions to reserves through new discoveries.*

Several methods for estimating ultimate recovery exist. For any method, the uncertainties are large, and methods can only be expected to yield rough approximations. A principal reason for the lack of precision is the necessity for an assumption about the size and number of new discoveries. This assumption requires a subjective estimate of the quantity of oil in unexplored (by drilling) or partially explored areas based upon a comparison with those geologically similar areas which have been sufficiently explored to determine their ultimate recovery. The limited success of recent drilling in the Baltimore Canyon and the Gulf of Alaska illustrates the range of error possible in this assumption. A second reason for the lack of precision in the ultimate recovery estimate is the necessity of an assumption about the price of oil which will influence both the extent to which enhanced recovery techniques will be employed and also the size and location of new finds that will be sought and developed if found.

The importance of large fields mentioned earlier suggested a determination of the remaining undiscovered resource by a consideration of the expected number and size of new discoveries with particular emphasis on large fields. This approach is based upon the belief that large fields will contain the majority of the remaining future discoveries. Even in the

* Petroleum Intelligence Weekly (3/24/80) quoting an Exxon report. Estimates of additions in each period are averaged additions. Revisions in estimates of fields are attributed to the period of initial discovery.

extensively explored U. S., which contains a relatively large number of small fields, large fields containing at least 100 million barrels of recoverable oil account for 70% of the oil discovered.

This emphasis on large fields is sometimes criticized because of a belief that small fields will play a larger role in the future than they have in the past. The U.S., is cited, incorrectly, as an example to support this argument. Some observers have speculated that the amount of oil produced from small fields in the U.S. results from the fact that the U.S. oil resources are closer to depletion than fields elsewhere in the world. It is speculated that the importance of small fields will increase in other countries as exploration and development continues.

However, drilling experience in the United States does not in fact support the criticism of the emphasis on large fields. If the U.S. had been forced to turn to small fields because of the depletion of larger areas, it would be expected that the significance of smaller fields in the U.S. would be increasing. This is not the case. The proportion of oil found in smaller fields (less than 100 million barrels of known recovery) in the U.S. was 30.0% between 1961-1976 compared to 29.5% since 1859.*

It appears instead that the relatively high production from small fields in the U.S. results primarily from the unique geology of the Gulf Coast Syncline which consists of several adjacent major and intermediate size provinces with large numbers of small fields. Most of the larger provinces in the world have been explored sufficiently to eliminate the possibility of this type of reoccurrence elsewhere.

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* R. Nehring, Giant Oil Fields and World Oil Resources; Rand Corporation, June, 1978, pp. 72-73.

(1) Nehring's Estimates of World Crude Oil Resources

In 1978, Nehring* conducted a comprehensive analysis of recoverable resources including Communist areas with emphasis on large fields for new discoveries. Ultimately recoverable crude oil resources were estimated in the range of 1700-2300 billion barrels. This estimate includes 1000 billion barrels of proven reserves and cumulative production that were known at the end of 1975. Thus, the study estimates that approximately 700-1300 billion barrels will be added to the world's known oil from additional recovery and new field discoveries.** Tables 5, 6 detail and illustrate graphically a breakdown by type and region.

Additional recovery, consisting of additions to known fields through extensions, full development and enhanced recovery is expected to add an estimated 420-730 billion barrels to the known oil total. The major contribution to this total, about 250-400 billion barrels, will come from the Middle East.

New discoveries, while expected to be less than additional recovery, are still a large source and are estimated world-wide at 263-555 billion barrels. The breakdown of the new discoveries by size and number, illustrating the expected continuing importance of large fields, is given in Table 7. Outside the Middle East, a large portion of the total of 263-555 billion barrels is expected to come from offshore areas. Many of these promising areas lie in the area of the Arctic Circle, which will be very expensive and slow to

*Ibid

** Recently, Nehring has updated this study based upon further work. His estimate has been lowered to 1600-2000 billion barrels for the ultimately recoverable liquid petroleum resource. This work was outlined at the UNITAR Conference on Long-Term Energy Resources in Montreal, Canada, November 26 - December 7, 1979.

TABLE 5

ULTIMATELY RECOVERABLE WORLD CRUDE OIL RESOURCES**

	Known	Additional Recovery[1]	Additional Recovery[1] & New Discoveries	Ultima Recoverable Estimate	Cumulative Production Through 1975	Remaining Resource**
North America*	179.8	43-95	100-200	280-380	122	60-260
South America	58.3	20-40	52-92			80
Western Europe	24.6	5-10	25-45	0		0 0
Eastern Europe/ Soviet Union	102.4	20-40	63-123	165-225	51	110-170
Africa	75.6	15-30	45-94	120-170	21	100-150
Middle East	509.9	250-400	350-630	860-1140	85	780-1060
Asia/Oceanic	50.8	15-25	54-104	105-155	13	90-140
Unspecified	X	50-90	X	X	X	X
— *	000	420-730	700-1300	1700-2300	336	1360-1960

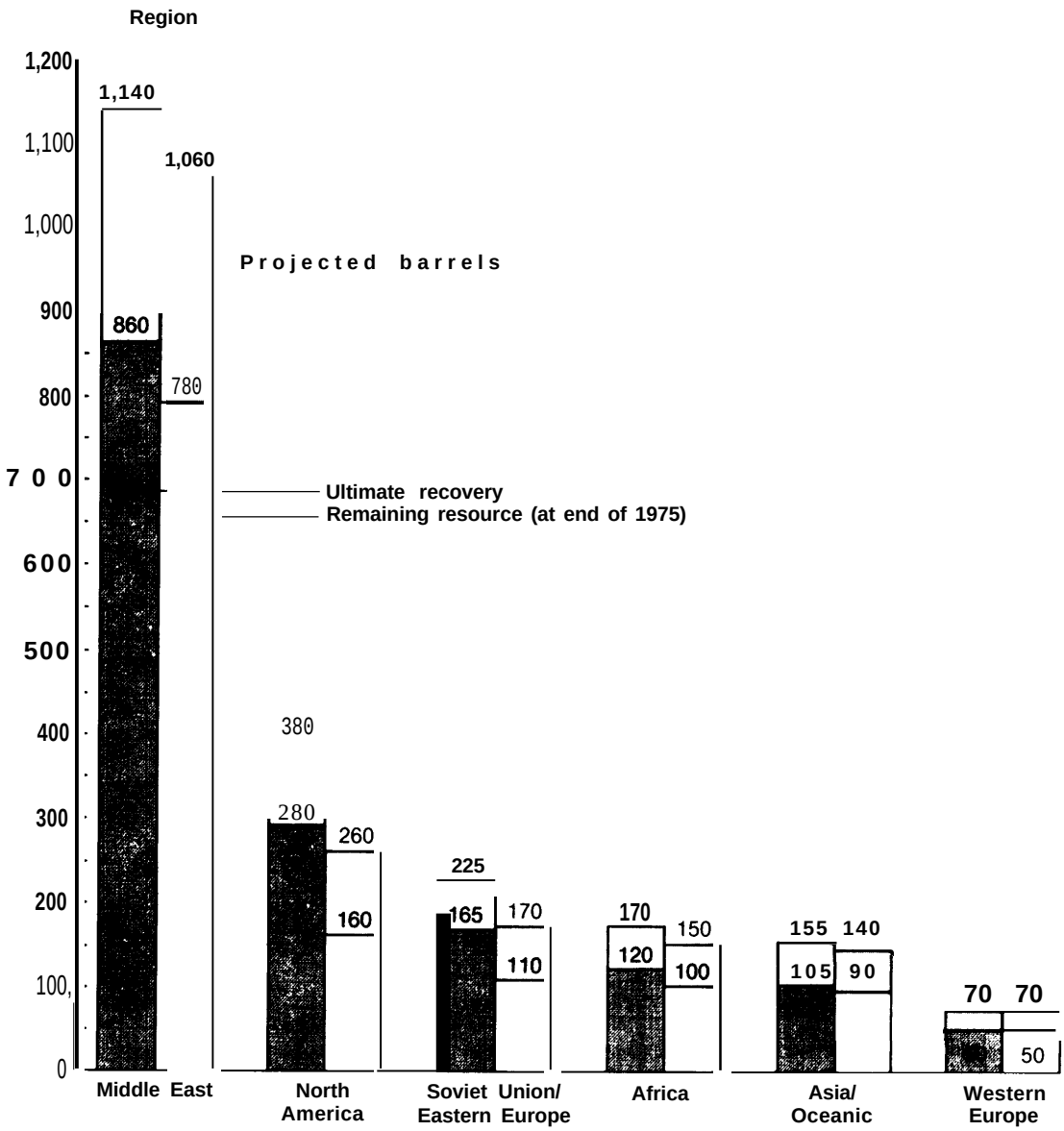
** May not add due to rounding

1 In known fields

* includes Mexico)

Source: Nehring: Giant Oil Fields and World Oil Resources, Rand Corp., June 1978, p. 88.

Table 6.—Estimate of Regional Distribution of Oil Resource



SOURCE, Nehring, *Giant 0il Fields and World 0il Resources,* RAND Corp , June 1978, p 88

TABLE 7

EXPECTED FUTURE DISCOVERIES *

TYPE	NUMBER	TOTAL RECOVERY (in billion barrels)
Super-giants (7.5 to 10 billion barrels each)	4-1o	30-100
Giants (.8 to 1 billion barrels each)	125-175	100-175
Large Non-Giants (150 to 200 million barrels each)	400-800	60-160
Smaller	x	73-120
Total		263-555

SOURCE: R. Nehring, Giant Oil Fields and World Oil Resources, Rand Corporation, June 1978, pp. 54-84.

develop because of their severe climate. As mentioned earlier some of the potentially promising major new areas involve regions of territorial dispute. These regions include the Malvinas basin off the Falkland Islands, the South China Sea, and Spitsbergen.

On the basis of the Nehring study, the overall dominance of the Middle East can be expected to continue since 775-1055 billion barrels (or over 50%) of the remaining resources are believed to occur there. The breakdown by region given in Table 5 illustrates, in addition to the continued dominance of the Middle East, that the worldwide distribution of ultimately recoverable oil resources is not expected to differ significantly from the distribution that exists today.

(2) Other Estimates of World Oil Resources

It is difficult to compare the Nehring resource estimate with other studies due to their limited documentation. Moreover, all studies do not make explicit an estimate of what ultimate price of oil will influence the areas explored and developed and the extent of enhanced recovery utilization.

The total of 1700-2300 billion barrels in the Nehring study is in general agreement with the average of most other recent estimates. Several studies and their estimates are given in Table 8. Since many of these estimates borrowed common information and each other's work, these estimates cannot be considered independent. In particular, the World Energy Conference estimate was obtained by means of a Delphi poll among 29 government, academic, and industry geologists.

Nehring differs substantially from other studies in his appraisal of the Middle East and the Soviet Union. He presents a larger estimate (775-1055 billion barrels) for the Middle East than most studies (630 in Moody-Esser).*

In addition, the Nehring estimate of 125-225 billion barrels for the Soviet Union presents a more pessimistic view than some of the other recent studies. For example, the earlier work of Moody/Esser (1974)** had estimated Communist resources, including the People's Republic of China, at 500 billion barrels. This basis for this analysis is not known; it may have simply been based upon a volumetric analysis. The more pessimistic view of Nehring is partially based upon the information learned since 1974 that most new discoveries in potential petroleum areas of the Soviet Union are turning out to be natural gas rather than oil.

* J.D. Moody, R.W. Esser, Mobil Oil Corporation, 1974.
** Ibid.

TABLE 8

ESTIMATE OF ULTIMATELY RECOVERABLE WORLD CRUDE OIL RESOURCES

AUTHOR	ORGANIZATION	DATE OF ESTIMATE	QUANTITY IN BILLION BARRELS
H.R. Warman[1]	British Petroleum Ltd.	1973	1915
J.D. Moody and R.W. Esser[1]	Mobil Oil Corporation	1974	2000
M. King Hubbert[1]	U.S. Geological Survey	1974	2000
B. Grossling[2]	U.S. Geological Survey	1974	2600-6500
Delphi Approach[3]	World Energy Conference	1977	2230 (average of 28 est.)
R. Nehring[4]	Rand Corporation	1978	1700-2300
R. Nehring[5]	Rand Corporation	1979	1600-2000

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[1] Source: From M. King Hubbert, "World Oil and Natural Gas Resources" in Project Independence, Library of Congress, Washington, D.C., 1977, Committee Print 95-33, pp. 632-644.

[2] B. Grossling, U.S.G.S. Survey Circular 724, 1974.

[3] World Energy Conference, Oil and Gas Resources. IPC Science and Technology Press, 1978, p. 30.

[4] R. Nehring (June 1978) previously cited.

[5] R. Nehring (December 1979) at the UNITAR Conference in Montreal.

Although most estimates for ultimate recovery have centered around 2000 billion barrels, a recent study by Grosling* has suggested that a much higher figure is possible. That study claims that many of the prospective petroleum areas, primarily those in underdeveloped countries and offshore areas, have been insufficiently explored out causing their total potential to be underestimated significantly. This premise leads one to estimate the ultimate recovery of these prospective petroleum areas by using the ultimate recovery figure of certain areas, which have been so thoroughly developed that their estimate of ultimate recovery can be estimated accurately (referred to as benchmark areas).

The principal difficulty with this approach is that wide ranges of estimates are possible depending upon the choice of benchmark areas. Using certain areas in the Soviet Union as benchmark areas, Grossing** obtains an estimate of approximately 6000 billion barrels as the total expected ultimate recovery for the world, which is triple most recent estimates. While within the realm of possibility, given the uncertainty in the benchmark figures for the Soviet Union (recent CIA work suggests that their expected recovery may be inflated), this estimate does not appear plausible. Indeed, the benchmark figure used in that portion of Grossling's study is 200,000 barrels per square mile of prospective petroleum area. For the entire conterminous U.S. and Canada, the comparable figure is approximately 45,000 to 60,000 barrels

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* **Grossling,** "A critical Survey of World Petroleum Opportunities", in Project Interdependence, Library of Congress, 1977, Committee Print 95-33, pp. 645-658.

**Ibid.

per square mile of prospective area. * With the "benchmark" figure of 45,000 (60,000) barrels an estimate is obtained of 2125 (2500) barrels for the total world ultimate recovery.** These numbers are in rough agreement with the previous estimate of 1700-2300 billion barrels.

Additionally, the premise of using "benchmark" estimation has been challenged by some oil companies.*** These companies argue that extrapolative analysis is not valid since most of the world's sedimentary basins have been assessed at least by geophysical methods and that exploratory activity is justified only if the initial geophysical assessment looks promising. Some areas, while sedimentary and nominally prospective, do not contain all the requisite features that are expected for petroleum deposits.

(3) The Deep Ocean and Anarctica

Estimates of the world's ultimately recoverable oil typically do not include any amount for the deep ocean or Anarctica. There is considerable speculation over the oil potential of both of these areas, but the technology for developing these areas and the necessary economic incentives do not exist now even if oil is found in large quantities.

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* The conterminous U.S. and Canada have a total prospective petroleum area of 4,421,000 square miles. Using an estimate of 195-245 billion barrels adapted from Nehring as the expected ultimate recovery (15 billion barrels from Alaska have been subtracted), one obtains the above estimates.

** The total prospective petroleum area outside the Middle East is approximately 25,000 square miles (See Grossing). Using the "benchmark" figure of 45,000 (60,000) barrels per sqpare mile, one obtains an estimate of 1125 (1500) billion barrels as the total recovery outside the Midel East. Adding 1,000 billion barrels as the recovery for the Middle East, one obtains the above numbers.

*** Exxon, Exploration in Developing Countries, May, 1978.

Currently, American oil companies are beginning to drill in one thousand feet of water in the Gulf of Mexico, which would be the deepest water in which petroleum has ever been produced. This drilling is somewhat deeper than the North Sea finds, which are in less than six hundred feet of water. However, the Gulf of Mexico drilling is considerably less than the depth of the Atlantic region in which the United States Geological Survey announced on August 31, 1979, as a potential resource on the basis of seismic work alone. That region occurs at depths of 12,000 feet of which the first six thousand feet are water.

3. Future Non-Communist World Oil Supply

Introduction

Estimating the geological resource, as was done in Section 2, is not sufficient to determine non-Communist world oil supply (the rate in million barrels per day (MBD) of oil available to the non-Communist world). Non-Communist oil supply will not actually reach the limits set by geological considerations. Future supply depends on production which in turn depends upon political, technical, and economic factors as well as geology.

The relative importance of these factors varies in time and between countries. For example, the geologic resource is the primary factor determining production levels in the United States. On the other hand, reserves do not limit production in Kuwait. Instead a decision by the Kuwaiti government to limit production, based on political and economic considerations, is the limiting factor.

These factors introduce a large uncertainty associated with any answer to the second question in the introduction "At what rate will oil from conventional sources be available?" Nevertheless, based on analysis discussed in this section, OTA projects high confidence that non-Communist world oil supply will be between 47-60 MBD in 1985 and 40-62 MBD in the year 2000 (compared with 52 MBD in 1979).

For the years 1985 and 2000 the highest and lowest estimates are less probable since those estimates depend upon a unique combination of circumstances. Moreover, these projections assume that there are no major disruptions (such as the revolution in Iran) which could lead to temporary or permanent disruptions in the production of major suppliers.

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It should be noticed that even the high estimates of world production given here are below most estimates of future world production made before December 1978. Prior to the revolution in Iran, many projections simply assumed that oil exporters would produce at (or close to) their maximum production rates in order to meet the anticipated world demands.

The events in Iran have made it clear that an overly rapid increase in national income could be socially disruptive and that maximum production may not be consistent with optimum economic development programs. Moreover, many exporters have reduced production in anticipation of further price increases. These exporters perceive oil left in the ground as the best investment for the future.

Approach

The analysis here of future oil supply is divided into sections considering the following regions:

(A) the production rate of the developed countries.

(B) the production rate of OPEC.

(C) the production rate of the non-OPEC LDC's.

(D) effect of the Communist countries on non-Communist world oil supply.

For each of these regions the consequences of the known or estimated geologic, technical, economic, and political factors are used in making projections. Details are given below for each of the major suppliers.

OTA has utilized various sources in determining the estimates of production utilized in this report. Published information in various periodicals (Petroleum Intelligence Weekly, World Oil, Oil and Gas Journal,

and Middle East Economic Survey, and others) as well as reports by DOE, CIA, United States Geological Survey, and other organizations (Rand Corporation, etc.) have been used. In addition, OTA has contacted experts in oil companies, government organizations, and other petroleum related organizations.

No primary geological assessments have been attempted in the course of preparing this report.

A. Developed Countries

Production in the developed countries will decline, with a significant reduction in production possible by the year 2000. Geology is the primary limiting factor.

Production in the developed countries, averaging 14.9 MBD* in 1979, may range between 13-15.5 MBD in 1985 and 7.5-13 MBD in the year 2000 (see Table 9). Although production in the North Sea by the United Kingdom and Norway will increase for the next few years, this increase will be offset by declining production in the United States.

The basis for the OTA estimates of production rates for the developed countries is described in detail below.

TABLE 9

FUTURE PETROLEUM PRODUCTION RATES IN THE DEVELOPED COUNTRIES (MBD)

	1979	1985	2000
United States	1002	7.2-8.6	4-7
North Sea	201	2.8-4	1.7-3
Canada	1.8	106-108	
Other Developed Countries	.8	.8*	
TOTAL (may not add due to rounding)	1409	13-15.5	7.5-13

* range of production considered insignificant for estimates of total petroleum availability.

SOURCE: OTA estimates based upon assumptions stated in text.

* MBD = million of (42 gallon) barrels per day.

U.S. Production

Based upon the reasoning discussed in this section, OTA estimates that liquid petroleum production will decline from the 1979 average production rate of 10.2 MBD to a level of approximately 7.2-8.5 MBD in 1985. In the year 2000, U.S. production could be as low as 4 MBD although under optimistic assumptions U.S.production could be 7 MBD (see Table 10).

TABLE 10

FUTURE U.S. PETROLEUM LIQUIDS PRODUCTION (MBD)

	Year				
	1979	1985	1990	1995	2000
Primary and secondary recovery from existing 1979 reserves	8.1	4.7	2.7	1*4	008
Primary and secondary recovery from addition to reserves		0.8-1.5	0.8-2.1	0.7-2.4	0.7-2.5
Natural gas liquids	107	1.2-1.5	1.1-1.4	1*1-1.3	1.0-1.25
Production from enhanced recovery techniques	0.4	0.5-0.9	0.7-104	101-2	1.5-2.5
TOTALS (may not add due to rounding)	10.2	7.2-8.6	5.3-7.6	4*3-7*1	4.0-7.0

SOURCE: OTA estimates based upon assumptions stated in text.

Future U.S. production will arise from the following four sources: (1) primary and secondary recovery from existing (as of January 1979) proved reserves of 26.5 billion barrels, (2) primary and secondary recovery from additions to existing reserves, (3) natural gas liquids and (4) applications of enhanced recovery techniques. Production from each of these sources is

discussed below in detail.

(1) Primary and secondary recovery from existing reserves may decrease from approximately 8.1 MBD in 1979 to 4.7 MBD in 1985 and .8 MBD in the year 2000. (This estimate assumes that U.S. fields can produce at a rate where annual production is 1/8 of known reserves subject to a near term upper production constraint of 1.6 MBD from existing Alaskan reserves.)

(2) The second source of future production is primary and secondary recovery from additions to reserves. Additions to reserves totalled approximately 1.3 billion barrels in each of the years 1977 and 1978.* This quantity includes additions due to the use of enhanced recovery techniques on existing fields (which will be considered separately as the fourth source). Hence, additions to reserves for which primary and secondary recovery will be utilized averaged less than 1.3 billion barrels.

Moreover, additions to reserves for primary and secondary recovery can be expected to decline. A portion of the 1.3 billion barrel total is due to extensions of old reservoirs. As U.S. fields reach a more mature state of development, these extensions can be expected to decrease. New discoveries, on the other hand, have averaged only .3 billion barrels annually in 1977 and 1978.**

For these reasons, OTA estimates a range for the level of additions for primary and secondary recovery. The high level is 1 billion barrels annually through the year 2000 while the low level is 1 billion barrels in the year 1980 declining linearly to 0.5 billion barrels in the year 2000.

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* American Petroleum Institute, Reserves of Crude Oil, Natural Gase Liquids, and Natural Gas in the United States and Canada, volume 32, p. 10 and volume 33, p. 10.

** Ibid

If additions occurred at the high level, production from this source would result in production of 1.5 MBD in the year 1985 and 2.5 MBD in the year 2 000. * On the other hand, if additions occurred at the lower level, then production of O. 8 MBD in 1985 and 0.7 MBD in the year 2000 would result.

Summarizing, OTA estimates a range of production levels of .8-1.5 MBD in the year 1985 and .7-2.5 MBD in the year 2000.

(3) The third source is natural gas liquids production which was 1.7 MBD in 1979. Future production levels are dependent upon conventional natural gas production for which declining production has been projected.** Production levels of 1.2-1.5 MBD in 1985 and 1-1.25 MBD in the year 2000 are estimated based on these declines.

(4) Enhanced recovery, the fourth source, contributed approximately .4 MBD to 1979 production. Over two-thirds of this contribution arose from steam recovery of heavy oil in California while a recovery process involving the use of carbon dioxide ($C0_2$) was responsible for the majority of the remaining enhanced recovery production.***

Enhanced recovery production is anticipated to increase through this century, but the production rate is subject to much uncertainty. Because of this uncertainty, OTA projected in its January 1978 report**** a wide range of production possibilities for enhanced recovery. This report included a scenario where enhanced recovery could contribute as much as 5 MBD in the

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*Assuming annual production of 1/8 of known reserves.

**Exxon, World Energy Outlook, December 1979.

*** Oil and Gas Journal, March 31, 1980, p. 79.

**** OTA, Enhanced Oil Recovery Potential in the United States, January 1978.

year 2000. As stated in that report, however, the estimate was heavily dependent upon the following conditions:

(1) satisfactory development of the CO_2 and surfactant/polymer processes which were then in an early development stage.

(2) a low inflation rate making a rate of return of 10% on capital satisfactory.

(3) availability at a certain price of large amounts of CO_2 required for enhanced recovery using the CO_2 Process.

None of these conditions have occurred as expected. First, the surfactant/polymer process, which was expected to account for 20% of year 2000 production, has not performed as well as expected.* Second, high inflation rates have made a 10% return on capital less satisfactory. Third, the price of CO_2, which has a significant effect on the extent of the use of CO_2-enhanced recovery, has risen much faster than anticipated in the scenario. Consequently, the production of levels approaching 5 MBD from enhanced recovery seems much less likely now than in January 1978 in spite of oil price increases.

Production levels of .5-.9 MBD in 1985 and 1.5-2.5 MBD in the year 2000 are now estimated for enhanced recovery production.** Steam recovery of heavy oil may account for .4-.6 MBD in 1985 and .4-.7 MBD in the year 2000. Production from the CO_2 Process is anticipated to account for much of the remaining enhanced recovery production.

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* Oil and Gas Journal, March 31, 1980, p. 94.

**Estimates are based on results in the OTA report cited above.

U.S. Production Summary

Adding the totals from the four sources, one obtains the OTA range of production of 7.2-8.5 MBD in 1985, 5.3-7.6 MBD in 1990, and 4-7 MBD in the year 2000 (See Table 10). In its recent forecast Exxon* forecasts U.S. production at 6.1 MBD in 1990 and 6.3 MBD in the year 2000 which fall within the range given here.

North Sea (United Kingdom and Norway)

Liquid petroleum production in the North Sea has risen sharply from less than 0.1 MBD in 1973 to over 2 MBD in 1979. Increases will continue over the next few years as existing fields are developed. Peak production will occur in the mid-1980's with declines probably before the year 2000 due to diminishing reserves.

OTA estimates that production in 1985 will range between 2.8-4 MBD based upon industry and government plans. The basis for this estimate is discussed below.

Recently, the UK government has released its estimate of oil production in the UK waters of the North Sea for the five year period 1980-1984. The UK government estimates production to increase from 1.6-1.7 MBD in 1980 to 1.9-2.8 MBD in 1984.** The high estimate of 2.8 MBD has been suggested as peak production from fields currently under development. OTA estimates production levels of 1.9-2.8 MBD in the year 1985 based upon the 1984 estimate.

* Exxon, World Energy Outlook, December 1979.

** oil and Gas Journal, July 7. 1980 P. 61.

Current development plans of the Statjord oil fields call for increasing total Norwegian production from .4 MBD in 1979 to .9 MBD in 1984 and 1.2 MBD in 1985.* Since some slippage in development is possible, OTA estimates production levels of .9-1.2 MBD in 1985.

Adding the OTA estimates for UK and Norwegian production, one obtains a range of production of 2.8-4 MBD for the year 1985.

The current reserves** of 15.8 billion barrels in the UK sector and 5.8 in the Norwegian sector are insufficient to maintain peak production long. Without any reserve additions, North Sea production would be as low as 1 MBD in the year 2000.

However, reserve additions are likely and 10 billion barrels has been suggested as a reasonable estimate of additions to the existing 21 billion barrels of reserves by the year 2000.*** OTA estimates that the additions would permit North Sea production of 1.7-3 MBD in the year 2000 depending upon the peak level of production achieved in the mid-1980's. If peak production was 4 MBD, OTA estimates that production would be 1.7 MBD. If peak production was held to 3 MBD for conservationist reasons, OTA estimates that these additions would enable production to be maintained at 3 MBD up to the year 2000.****

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*Petroleum Intelligence Weekly, April 7, 1980.

**Oil and Gas Journal, December 31, 1979, pp. 70-71. Estimate for end of 1979.

***Based on R. Nehring, Giant Oil Fields and World Oil Resources, and private communication.

****Estimates are based on the following calculations. Ten billion barrels are added to existing reserves during the period 1980-2000. These reserves are added at a rate declining linearly in time with 1 billion barrels added in 1980 and no additions in the year 2000. Annual joint UK and Norwegian production is assumed 1/8 of existing reserves subject to a post-1985 upper production constraint. This constraint is either 3 or 4 MBD depending upon the 1985 production level.

OTA estimates include no allowance for production from the Norwegian offshore prospective petroleum areas north of the 620 parallel. Norway has delayed exploration and development of these areas due to environmental as well as economic considerations.

Exxon* forecasts 4 MBD as the production rate in the year 2000 from the North Sea which is higher than the range of OTA estimates (1.7-3 MBD). This Exxon estimate would require 1.7 times the level of additions to reserve assumed by OTA for its estimate.**

Canada

OTA estimates that conventional liquid petroleum production is unlikely to increase with declines occurring before the mid-1990's. OTA estimates production levels of 1.6-1.8 MBD in the year 1985 and 1-2 MBD in the year 2000.

There have been no large oil discoveries in established areas since the mid-1960's. As a result of its deteriorating reserves situation, the Canadian government began to limit production in 1973, reducing production from 2.1 MBD. During 1976-78 Canadian production averaged 1.6 MBD, while in 1979 production was raised to 1.8 MBD following the Iranian revolution. OTA estimates that levels of production of 1.6-1.8 MBD are probable for 1985.

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*Exxon, World Energy Outlook, December 1979.

**Based on OTA calculation. Calculation assumes production increases to 4 MBD in 1985 with level production of 4 MBD through the year 2000. Production during 1980-2000 would use approximately 27 billion barrels. Production of 4 MBD in the year 2000 would require reserves in 2000 of 11 billion barrels based upon a reserves to production ratio of 8 to 1. The 38 (27 + 11) billion barrels of required reserves in the year 2000 plus production in the period 1980-2000 would require 17 billion barrels of additions to current reserves of 21 billion barrels.

***See footnote below for calculation.

Declines thereafter are likely. Based upon an addition to reserves of 3 billion barrels by 1995, OTA estimates that conventional production would be as low as 1-1.3 MBD in 1995.*

Beginning in the mid-1990's, potential production from some promising Arctic areas, such as the Beaufort sea, may be able to stem the decline in conventional production. Increases are also possible if large discoveries are made and developed. Hence, production levels of 1-2 MBD are projected for the year 2000.**

OTA estimates do not include any amount for unconventional production from tar sands and heavy oil. Production from these sources may be able to offset the projected declines in conventional oil production. Exxon*** has projected total Canadian production in the year 2000 at 2 MBD including 1 MBD from unconventional sources.

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* The basis for the estimate is as follows. Canadian National Energy Board (Canadian Oil: supply and Requirements, Sept. 1978) estimated potential reserve addition of 4.9 billion barrels including 2.8 billion barrels through enhanced recovery. Given the slow rates of development of enhanced recovery, OTA estimates that 3 billion barrels of the remaining 4.9 billion barrels would be added by 1995. These additions are assumed added at a uniform rate of .2 billion barrels annually. Annual production is assumed 1/8 of existing reserves subject to conventional petroleum production constraints of 1.4-1.7 MBD (crude production constraints of 1.1-1.4 MBD).

** Low estimate assumes additions added .2 billion barrels annually during 1995-2000, equal to the assumed 1980-1995 rate. High estimate includes a 1 MBD allowance which requires a new large discovery (approximately 10 billion barrels, the size of Prudhoe Bay fields). Production from the Prudhoe Bay fields in 1980 was approximately 1.5 MBD. Production commenced in 1977 seven years after the fields were added to reserves. Production from any Canadian Artic areas will require as long, if not longer, lead times between discovery and production"

*** Exxon, World Energy Outlook, December 1979.

Other developed countries

Production in the other developed countries (principally Australia with contribution by some countries in Western Europe) is currently small (.8 MBD). Production prospects are not particularly bright due to limited geologic resources.

OTA estimates that production will be approximately .8 MBD through the year 2000 with some declines probable after 1985.*

OPEC Production

Future OPEC production is not likely to differ significantly from the 1979 average production rate of 31.4 MBD. Since the year of the Arab embargo 1973, total OPEC production has remained relatively constant, differing by less than 1 MBD of the 1979 average.

It is possible that OPEC production both in the year 1985 and the year 2000 will be less than the 1979 rate. OTA's subjective review of OPEC production possibilities indicates that a reasonable range of estimates would be 28.5-35 MBD in the year 1985 and 27-37 MBD in the year 2000. (In its latest world outlook, Exxon** estimates OPEC liquid petroleum production at 33 MBD both in 1990 and 2000.) Our analysis of the future production

* Range of decline considered insignificant for estimating total world petroleum availability. However, percentage declines in some countries may be inportant for those countries

** Exxon, World Energy Outlook, December 1979.

possibilities given in Table 11 is described below for each individual country.

TABLE 11

FUTURE OPEC LIQUID PETROLEUM PRODUCTION (MBD)

	Year 1979	1985	2000
Saudi Arabia*	9.803	9.1-1101	9. 1-12.6
Iraq	3.445	2.7-4.5	3-5
Iran	3.045	3-4	3-4
United Arab Emirates	1.865	1.9-2.5	1• 9-3
Kuwait*	2.622	1.9-2.4	1.9-2.4
Other OPEC Countries	10.575	9.5-1005	8-10
Algeria	1.165		
Ecuador	.215		
Gabon	.205		
Indonesia	1.630		
Libya	2.105		
Nigeria	2.305		
Qatar	.515		
Venezuela	2.435		
TOTAL (may not add ue to rounding)	31.4	28.5-35	27-37.0

* Including share of Neutral Zone

SOURCE: OTA estimates based upon assumptions stated in text.

The dominance of the Arab OPEC countries and the Persian Gulf region is expected to continue. Except for Iran, only the Arab OPEC countries of Saudi Arabia, United Arab Emirates (UAE), and Kuwait have sufficient reserves and Iraq the estimated potential to sustain more than marginal increases in production (see Table 11, 12). However, existing government restrictions on production levels in the countries of Saudi Arabia, UAE, Kuwait and Iran, if continued, would limit OPEC production to no more than 32 MBD (5 MBD less than the highest OTA estimate of year 2000 production).

TABLE 12

OPEC PRODUCTION DATA

Country	Reserves Barrels	1979 Crude Production Barrels	(Reserves) Production	Current Production Could Be Sustained With New Additions
Saudi Arabia	163.4	9.245	48.4	40.4
Iraq	31.0	3.435	24.7	16.7
Iran	58.0	3.035	52.4	42.4
United Arab Emirates	29.4	1.835	43.9	35.9
Kuwait	65.4	2.215	80.9	72.9
Algeria	8.4	1.025	22.5	14.5
Ecuador	1.1	.215	14.0	6.0
Gabon	.5	.205	6.7	0.0
Indonesia	9.6	1.590	16.5	8.5
	23.5	2.065	31.2	23.2
Nigeria	17.4	2.305	20.7	12.7
Qatar	3.8	.505	20.6	12.6
Venezuela	17.9	2.355	20.8	12.8

* Assuming reserve to production ratio of to 1 would be feasible.

Source:

There appears to be a growing tendency among other OPEC exporters to limit production for conservation reasons and in expectation of higher prices. Libya, for example, has recently announced its intention to cut liquid petroleum production from 2.1 to 1.7 MBD. * Clearly, the higher production numbers given here will also not occur if this tendency is sustained.

Detailed Country Descriptions

Saudi Arabia. In the early 1970's Saudi Arabia had been projected in many forecasts to substantially increase productive capacity levels to 16-20 MBD.** However, in 1977 the Saudi's announced officially a lower target of 12 MBD for maximum sustained productive capacity and imposed financial constraints that deferred attainment of this target level until 1987 at the earliest. Production of 12 MBD level could be sustained through 2005 with existing reserves.***

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*Based on Petroleum Intelligence Weekly, May 19, 1980.

**For example, the CIA projected net capacity in 1985 of at most 18 MBD in their April 1977 report, The International Energy Situation: Outlook to 1985.

***The Future of Saudi Arabian Oil Production, U.S. Senate Committee on Foreign Relations, April 1979.

It has been reported recently that construction has begun on the planned capacity expansion.* However, production of 12 MBD is not guaranteed even if construction does take place. The Saudi's have frequently expressed their desire to stretch their petroleum producing horizon. As stated by Crown Price Fahd on April 19, 1978,

> "Saudi Arabia has worked and is working sincerely and earnestly to provide an appropriate level of oil and gas production as an expression of its feeling of shared responsibility in the internatonal community, but our feelings of responsibility toward future generations in Saudi Arabia also claim careful consideration and the establishment of a calculated balance between the present and the future.

Moreover, Yamani, the Saudi oil minister, has announced that Saudi intentions are not to exceed production of 9.5 MBD even under higher levels of capacity.***

On the basis of these facts, Saudi Arabian crude oil production for 1985 is projected to lie between the official ceiling in early 1978 of 8.5 MBD (the Saudi's have raised at least temporarily the ceiling to 9.5 MBD following the Iranian disruption) and 10.5 MBD (approximately the current maximum sustainable production rate).**** For the year 2000 crude oil production is projected to range between 8.5 MBD and 12.0 MBD.

Adding to each of these estimates .3 MBD from the Saudi's share of the Neutral Zone and .3 MBD of natural gas liquids, OTA obtains ranges of 9. 1-11.1 MBD in the year 1985 and 9. 1-12.6 MBD in the year 2000 for liquid petroleum production. However, it should be emphasized that current Saudi statements indicate that future liquid petroleum production will not exceed 10.1 MBD.

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*Petroleum Intelligence Weekly, June 2, 1980.

**The Future of Saudi Arabian Oil Production, U.S. Senate Committee on Foreign Relations, April 1979.

***Petroleum Intelligence Weekly, June 2, 1980.

****Petroleum Intelligence Weekly, May 19, 1980.

Iraq

Production possibilities for Iraq are subject to much speculation. This speculation is due to both geological and political considerations.

Geologically, there is an enormous number of undrilled structures. These undrilled structures suggest that increases are possible above the 1979 average production rate of 3.4 MBD. Current existing reserves are sufficient to maintain through the year 2000 the 1979 rate of production (assuming that a reserves to production ratio of 8 to 1 is feasible).

Politically, the Iraqis have expressed contradictory views regarding future production levels. On the one hand, the CIA* has reported that the Iraqi oil minister has expressed a preference to produce at 60% of capacity. This statement suggests that production declines might occur since current capacity is estimated at 3.8 MBD.**

On the other hand, the Iraqi government is attempting to assert its influence in the developing world. For example, it has been reported that the Iraqi government has awarded 15 long term low interest loans in compensation for oil price increases.*** It is thought that the Iraqi government will maintain and possibly increase production to use both the produced petroleum and generated revenues to maintain influence in the developing world.

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*CIA, The World Oil Market in the Years Ahead, August 1979.

**petroleum Intelligence Weekly, May 19, 1980.

***Petroleum Intelligence Weekly, April 28, 1980.

Consequent y, there is considerable uncertainty regarding future Iraqi prod uc t ion. In 1977, the CIA* suggested productive capacity levels of 5-6 MBD were possible for the year 1985. These levels now appear too optimistic based upon current development plans. Current development plans indicate an increase in sustained production to approximately 4.5 MBD with some further increase possible after 1985.

Based on the above information, OTA estimates that production will range between 2.7-4.5 MBD in the year 1985 and 3-5 MBD in the year 2000.

*CIA, International Energy Situation: Outlook to 1985. April 1977.

Iran

The current turmoil in Iran has made projecting future production levels difficult . Current estimates of production fluctuate weekly. In April 1980, the production rate was reported at 2.7 MBD while in May 1980 it was reported as low as 1.1 MBD.* Both of these weekly estimates are below the 1979 (post revolution) average production rate of 3 MBD.

Iran has announced a production ceiling of 3 MBD.** According to several sources sustained levels above 4 MBD are unlikely without significant external assistance.*** Gas injection, now required in older fields, will be required in all fields by the late 1980's.

Based on this information, OTA estimates production levels of 3-4 MBD through the year 2000 assuming Iran regains political stability.

United Arab Emirates (UAE)

Abu Dhabi, the principal UAE producer, has plans to increase output capacity from 2 to approximately 3 MBD before the end of the 1980's.**** However, higher production goals have not been announced. In fact, government restrictions now limit production in Abu Dhabi to 1.4 MBD (or only 70% of current sustainable capacity). Production in the other two emirates, Duban and Sharjah, totals approximately .4 MBD, and no increases in production are likely.

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*Petroleum Intelligence Weekly, May 19, 1980.

**Petroleum Intelligence Weekly, March 10, 1980.

*** CIA, World Market in the Years Ahead, August 1979, Petroleum Intelligence Weekly, October 29, 1979.

**** Oil and Gas Journal, July 19, 1979, pp. 74-113.

OTA estimates that UAE production levels will range between current production levels (1.9 MBD) and those that would be possible if government restriction were lifted. OTA estimates production levels of 1.9-2.5 MBD in the year 1985 and 1.9-3 MBD in the year 2000.

Kuwait

Consistent Kuwait production policy is aimed at conserving resources. Production was approximately 2 MBD in the years 1974-1978 in spite of installed production capacity that would have permitted increased production.

Kuwait temporarily increased crude oil production in 1979 during the aftermath of the Iranian revolution to 2.2 MBD. However, Kuwait has recently announced plans to reduce crude oil production to 1.5 MBD.* Hence, OTA estimates that crude oil production in this century will range between 1.5-2 MBD.

Adding Kuwait's share of production in the Neutral Zone (.3 MBD) and natural gas liquids (.1 MBD), one obtains a range of 1.9-2.4 MBD for the OTA estimate of liquid petroleum production.

Other OPEC Countries (Algeria, Ecuador, Gabon, Indonesia, Libya, Qatar, Venezuela)

The remaining OPEC countries are currently producing at close to their maximum possible production rates.** Only marginal increases by individual countries in production are thought possible. Declines from their current production rates are probable in Indonesia, Ecuador, and Gabon by 1985 due to insufficient reserves (see Table 12). Other countries may reduce production

*Petroleum Intelligence Weekly, May 19, 1980

**Ibid.

rates for conservationist reasons. Nigeria has recently announced plans to reduce production 10% from its 1979 average and Libya has announced plans to cut production from 2.1 to 1.7 MBD. * OTA estimates that 1985 liquid petroleum production in these other OPEC countries is anticipated to range between 9.5-10.5 MBD (compared to the 1979 average of 10.5 MBD).

Except for Libya, current reserves are not adequate in the remaining OPEC countries to support existing production levels through the year 2000. Additional declines are likely in Indonesia and declines may occur in some of the remaining countries depending upon the rate of reserve additions.

OTA's estimate of production levels for the year 2000 is 8-10 MBD. This estimate is based upon current capacity levels and possible declines in production due to diminishing reserves in some countries and other potential cutbacks for conservationist reasons.

In this group of countries only Venezuela has the potential of increasing its production from unconventional reserves, but this is unlikely to change the picture materially until well after the year 2000. Venezuela has enormous reserves of very heavy hydrocarbons in the Orinoco region, but the cost of producing and processing these materials is very high. Venezuelan plans call for production to reach 100,000 barrels per day by 1990 growing gradually to as much as 300,000 barrels per day by the year 2000.** In general, Venezuelan policymakers view these resources as a form of alternative energy, likely to become competitive as petroleum substitutes, such as syncrudes, gradually enter the market in the next century,

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* Ibid.

** Outlook on Venezuela: Petroleum Policy, prepared for the Joint Economic Committee, Congress of the United States by the Congressional Research Service. (Wash., D.C.: USGPO, June, 1979).

OPEC Summary

Based on the above analysis, OTA obtains a range of 28.5-35 MBD in the year 1985 and a range of 27-37 MBD in the year 2000 for OPEC production possibilities (a detailed breakdown was given in Table 11). This assumes political stability in OPEC.

Neither the high nor low estimates for each year are likely to occur, since they depend upon an unlikely combination of circumstances described above. In particular, the high estimate would require the removal of production restrictions currently existing in the UAE, Kuwait, Saudi Arabia, and Iran. In addition, stability in Iran and continued exploration, development and production of Iraqi oil fields would be necessary.

Recently, Exxon has forecasted OPEC production at 33 MBD in the years 1990 and 2000. These estimates fall within the OTA range of projections.

Non-OPEC LDC's Production

Production in the non-OPEC Less Developed Countries (LDC's) may rise significantly above the 1979 liquid petroleum production level of approximately 5.1 MBD. OTA estimates production ranges of 7.5-9 MBD in 1985 and 7.5-11.5 MBD in the year 2000 based upon the assumptions stated here. Mexican production, which could be as high as 5.5 MBD in the year 2000, may account for over half of non-OPEC LDC production.

Mexico

Future Mexican oil production will be governed by the size of the Mexican oil resource and political decisions by the Mexican government concerning the rate of utilization of the oil resource. The potential

Mexican oil resource is discussed first.

Mexican proven reserves, at the end of 1979, were 31 billion barrels according to PEMEX, the Mexican oil company.* This estimate of reserves included 11 billion barrels in Chicontepec. Classification of the Chicontepec region as proved reserves is considered doubtful by some experts due to its producing characteristics. A Mexican drilling program to develop the Chicontepec area has been Indefinitely postponed pending exploration of other areas. This ambitious drilling program would have required 16,000 wells in order to reach a production in Chicontepec of 0.7 MBD.**

However, sizable additions to reserves are considered likely. The Rand Corporation*** estimates that there is a 90% probability that ultimate Mexican production will exceed 70 billion barrels, a 50% probability production will exceed 90 billion barrels, and a 10% probability production will exceed 120 billion barrels. These estimates include the 7 billion barrels of oil already produced from Mexican oil fields in addition to current reserves.

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*Oil and Gas Journal, December 31, 1979, pp. 70-71.

**Oil and Gas Journal, August 20, 1979, pp. 73-85.

***R. Nehring, D. Ronfeldt, A. Gandara, Mexico's Petroleum and U.S. Policy:Implications for the 1980's, Rand Corp. report R2510/1-DOE to DOE, Executive Summary, June 1980.

This report concludes that the Mexican potential is concentrated in a small number of highly productive areas. Approximately half of the potential is expected to lie in the offshore Campeche area of southeastern Mexico. The next most important area is the Reforma area, which was the site of the major discoveries touching off Mexico's recent oil boom. The Reforma-Campeche area, constituting one petroleum province, is likely to be the second most important province in the world, trailing only the Arabian-Iranian province (the Middle East). However, it is estimated that the Reforma-Campeche area will possess less than 1/10 the ultimate recovery of the Middle East.

The Rand Corporation's high estimate of 120 billion barrels is near the PEMEX estimate for ultimate recovery. PEMEX estimates total hydrocarbon potential, including natural gas, at 200 billion barrels.* Assuming that the current proportion of natural gas in hydrocarbon reserves is maintained (approximately 1/3), the PEMEX estimate for liquid petroleum ultimate recovery is 134 billion barrels.

The Rand Corporation report suggested several production profiles for Mexico. One production profile is based upon peak annual production equal to approximately 1/60 of the total resource. This assumption leads to a production range for the year 2000 of 3.5 MBD-5.5 MBD corresponding to the 70-120 billion barrel range of the ultimate resource.** OTA estimates production levels of 3.0-4.0 MBD for the year 1985 based upon the peak rates of 3.5-5.5 MBD.

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*Petroleum Intelligence Weekly, March 24, 1980.

**Other production profiles are given in the Rand report to illustrate the effects of certain production strategies. A peak rate of 2.5 MBD is given if the Mexican oil resource is limited to 70 billion barrels and Mexico follows a self-sufficiency policy. A peak production of 7.5 MBD is given if the Mexican resource achieves the high estimate of 120 billion barrels and Mexico decides to pursue rapid development in order to be a major exporter.

These production levels can be analyzed in terms of current Mexican oil policy. Current policy has targeted production so that exports do not exceed internal consumption. The official 1980 production estimate was set at 2.25 MBD with exports targeted at 1.1* or slightly less than half of total production.

Mexican internal consumption is approximately 1 MBD and growing at the rate of 7%-8% per year. At this rate consumption would be approximately 4 MBD in the year 2000. This rate may be reduced, however. If consumption reaches 3 MBD in the year 2000, then production in the 3.5-5.5 MBD range suggested by the Rand report would permit exports of 0.5-2.5 MBD. Under these assumptions about internal consumption, these levels or production in the year 2000 would allow the Mexican policy of internal consumption exceeding exports to be in effect to 2000.

Based on the Rand Corporation analysis, OTA estimates Mexican production as 3-4 MBD in the year 1985 and 3.5-5.5 MBD in the year 2000.

Other Non-OPEC Production

Crude oil production in the non-OPEC countries, excluding Mexico, totaled approximately 3.5 MBD in 1979. Table 13 lists these countries and their production rates. OTA estimates that production in 1985 in the non-OPEC LDC's, excluding Mexico, will total 4.5-5 MBD.

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* Petroleum Intelligence Weekly, March 24, 1980, Rand Corporation report on Mexico.

TABLE 13

1979 CRUDE OIL PRODUCTION IN NON-OPEC DEVELOPING COUNTRIES*

	MBD
AFRICA	
Angola	.143
Cameroon	.032
Congo Republic	.057
Egypt	.500
Tunisia	.105
Zaire	.021
TOTAL	.860

	MBD
ASIA - PACIFIC	
Burma	.030
Brunei	.255
India	.240
Malaysia	.270
Pakistan	.011
Phillipines	.015
TOTAL	.821

WESTERN HEMISPHERE	
Argentina	.470
Bolivia	.030
Brazil	165
Chile	:018
Colombia	.125
Mexico	1.490
Peru	.195
Trinidad	.215
TOTAL	2.708

MIDDLE EAST	
Bahrain	.050
Oman	.290
Syria	.165
Turkey	.056
TOTAL	.561

* Oil and Gas Journal, December 31, 1979.

The OTA estimate relies partially on a DOE report of 1985 production estimates for 21 non-OPEC LDC's (all countries in Table 13 except those in the Middle East, Mexico, and the Phillipines) .* This report estimates 1985 production in these countries to total 3.9 MBD. Egypt is expected to remain the largest producer in the group with production of approximately .75 MBD. Indian production is expected to increase joining Argentina and Malaysia-Brunei as producers of approximately .5 MBD each. Three countries (Trinidad, Brazil, and Angola) are projected to produce .25 MBD while only three other countries (Tunisia, Peru, and Colombia) are projected to producer over .1 MBD .

The CIA** has projected that some minor increases above the DOE estimate would be possible for the countries of Egypt, Brazil, Argentina, and Peru. These increases suggest that production would total as much as 4.4 MBD (or .5 MBD more than the DOE estimate). OTA estimates a range of production of 3.9-4.4 MBD for these 21 countries.

Based upon their current reserves, OTA estimates that no significant increases are likely from the four non-OPEC countries in the Middle East (Bahrain, Oman, Syria and Turkey). OTA estimates that these countries will produce approximately .6 MBD (equal to their 1979 total). The OTA estimate of 4.5-5 MBD for total production in the non-OPEC LDC's, excluding Mexico, is obtained by adding the Middle East production estimate to the estimate of production outside the Middle East. Production from new sources till have a negligible effect on 1985 production due to the normal lag time between discovery and significant production.

DOE (Art Warner), The 1985 Oil Production of 21 Oil Producing Non-OPEC Countries, 1979.

** CIA, The World Oil Market in the Years Ahead, 1979.

The current reserves in the non-OPEC LDC's, excluding Mexico, total approximately 26 billion barrels. These reserves are insufficient to support through the year 2000 the 1985 levels of production estimated by OTA. However, modest additions to reserves are thought likely in most producing countries and small discoveries may be made in some non-producing countries.*

Based on this information, OTA estimates that production in these areas will range between 4-6 MBD in the year 2000 unless new large discoveries are made. The possibility of large discoveries is considered small since the only non-Communist LDC region with significant potential is the Malvinas basin between Argentina and the Falkland Islands.

Some studies have speculated about the possibility of higher production from these areas in the year 2000. These studies have suggested that these areas have not been explored extensively. They predict that increased oil prices will lead to a significant increase in the exploration, development, and production from these areas. In general, these studies do not pinpoint the areas where these large increases in production will be made.**

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* Based on R. Nehring, Giant Oil Fields and World Oil Resources, and private communications. Reserve additions, however, have not equalled production in the last two years. According to the Oil and Gas Journal annual estimates, reserves have declined from 29 billion barrels on January 1, 1978 to 26 billion barrels on January 1, 1980.

** For example, W. Brown and H. Kahn (in "Why OPEC is Vulnerable," Fortune, July 14, 1980, pp. 66-69) project non-OPEC oil production to increase at a rate of 5-7% in the 1980's. This rate of increase would result in non-OPEC production increasing from the current level of approximately 20 MBD to 30-40 MBD by 19900 The percentage of this production which will arise form the non-OPEC LDC's is not stated. The authors of this paper cite rising prices and advancing technology as reasons for projecting the increase.

The proposition that increased oil prices will lead to increased exploration is qualitatively true. However, OTA estimates that the effect of increased exploration in these areas will not have as pronounced a quantitative effect on total worldwide oil production as suggested in these other studies.

OTA expects that new discoveries in non-producing countries will be made, but that most will be minor. For example, oil was first discovered in 1975 in Guatemala in a field of approximately 25 million barrels.* Production in 1980 from this field is estimated to be only 0.005 MBD (five thousand barrels a day).** This production will have an insignificant effect on total world production, although it may be significant for Guatemala.

Summary of Non-OPEC LDC Production

Adding the non-Mexican and Mexican production estimates, OTA obtains a range of production of 7.5-9 MBD in 1985 and 7.5-11.5 MBD in the year 2000.

The high estimate here for non-OPEC LDC production in the year 2000 is comparable to the recent Exxon forecast.*** The Exxon forecast projected the combination of Australia, non-OPEC LDC, and Western Europe excluding the North Sea at 12 MBD in 1990 and 14 MBD in the year 2000. Assuming constant production for the Western European area and Australia, the Exxon estimate is 11 MBD in 1990 and 13 MBD in the year 2000 for non-OPEC LDC.

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* R. Nehring, Giant Oil Fields and World Oil Resources, Rand Corporation, 1978, p. 103.

** Petroleum Intelligence Weekly, April 21, 1980.

*** Exxon, World Energy Outlook, December 1979.

SUMMARY OF NON-COMMUNIST WORLD OIL PRODUCTION

Based upon the above analysis of the production rates of the developed countries, OPEC, and the non-OPEC LDC's, non-Communist world oil production is projected to range between 49-60 MBD in 1985 and 42-62 MBD in 2000 (compared to 51.4 MBD in 1979). The projections of production rates of each of the individual areas are given in Table 14.

TABLE 14
PROJECTIONS OF FUTURE NON-COMMUNIST WORLD OIL PRODUCTION (MBD)

	1978	1985	2000
Developed Countries	14.9	13-1505	7.5-13
OPEC	31.4	28.5-35	27-37
Non-OPEC LDC's	5.1	7.5-9	705-1105
Total	51.4	49-60	42-62

(may not add due to rounding)
Source: OTA estimates based upon assumptions stated in text.

The remaining factor determining non-Communist world oil supply is the effect of the Communist countries. This factor is discussed next.

D. EFFECT OF THE COMMUNIST COUNTRIES ON NON-COMMUNIST WORLD OIL SUPPLY*

Historical

Throughout this decade the Communist countries have been net exporters of oil to the non-Communist world with net exports varying from .413 MBD in

*This section relies heavily on non-classified CIA documents. OTA estimates for the year 2000 are subject to much uncertainty as indicated in this section. OTA is currently assessing the impact of U.S. and other Western technology might have on future Soviet production.

1973 to .955 MBD in 1977. These exports arose principally from the Soviet Union which increased petroleum production from 8.6 MBD in 1973 to 10.9 MBD in 1977 (and further to 11.7 in 1979), making it the world's largest producer.

In 1977 the Soviet Union exported 1.4 MBD to the free world of which over 1 MBD went to Western Europe. The People's Republic of China (PRC) has also increased production from 1.1 MBD in 1973 to 1.8 MBD in 1977 (and further to 2.1 MBD in 1979). However, internal needs have absorbed almost all of the increase with only a small amount .17 MBD in 1977 being exported to Japan. Partially offsetting these exports by the Soviet Union and the PRC were imports of .465 MBD by the Eastern bloc countries from OPEC.*

The Situation Until 1985

In their 1977 report,** the CIA estimated that the net exporting trend of the Communist countries will not continue. In this report, the People's Republic of China (PRC) is predicted to be able to supply its growing internal need through increases in production.

Based upon a comprehensive examination of future Soviet petroleum availability, the CIA projected a sharp decline in Soviet production to a level of 8-10 MBD by 1985. A decline of this magnitude could result in a

* CIA, International Energy Statistical Review, 27 June 1979.

** CIA, International Energy Situation: Outlook to 1985, April 1977.

deficit of up to 1.9 MBD for the Eastern bloc countries as a whole by 1985* Part of this deficit may be met by conservation strategies and by the substitution of natural gas and nuclear power for oil, but to the extent that these do not make up the difference, the USSR and its Eastern bloc trading partners face serious dilemmas. The Soviet Union earns approximately half of its badly needed hard currency from oil exports to the West. The cessation of these exports would be a serious economic blow to the Soviet economy, Moreover, the import of significant amounts of oil from non-Communist sources would likely place an intolerable burden on remaining hard currency reserves. These considerations might well lead the Soviet Union to cut back or stabilize its soft-currency exports to Eastern Europe, forcing those nations increasingly onto world markets for oil.

The complexity of this situation and the variety of political and economic factors which will probably influence Soviet policies make uncertain the implications of declining Soviet production. This uncertainty, together with the disagreements which have arisen over the CIA'S conclusions regarding Soviet production and consumption, have made the CIA projections quite controversial. This will be one of the issues examined in OTA's forthcoming study of Technology and Soviet Energy Availability.

*CIA, Soviet Energy Problems and Prospects, 9 February 1979.

The Es stern European bloc countries (Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, Romania, and Yugoslavia) and Cuba can be expected to be particularly hard hit by any sharp decline in Soviet production.

In 1977 the Soviet Union exported 1.8 MBD to these areas with the majority (1.386 MBD) going to Eastern Europe. In 1977, the Eastern European countries were 60% dependent on the Soviet Union for their oil supplies while less than 20% was met by domestic production. The remaining 20% came from imports from OPEC, principally Iran and Iraq.* The Eastern European bloc countries, with proved reserves of only 1.5 billion barrels, will be unable to increase production above the level of .4 MBD.

If Soviet exports to Eastern Europe were to cease in the early 1980's, then the Eastern European countries would be forced to import nearly 2 MBD at today's consumption and production levels. Moreover, since production in Eastern Europe is concentrated almost entirely in the countries of Romania, Yugoslavia, and Hungary, then the remaining countries (Bulgaria, Czechoslovakia, East Germany, and Poland) would be completely dependent on external sources for their oil consumption needs. Currently, however, Soviet policy states that they will maintain oil exports to Eastern Europe. Therefore the most likely occurence is no increase in these imports rather than cessation. A breakdown on consumption and production by country for Eastern Europe is given in Table 15.

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* CIA, International Energy Statistical Review, 27 June 1979.

TABLE 15

1977 EASTERN EUROPEAN PRODUCTION AND CONSUMPTION BY COUNTRY (MBD)

	Product ion	Consumption
Bulgaria	.002	.284
Czechoslovakia	.003	.383
East Germany	.001	.341
Hungary	.043	.212
Poland	.009	.359
Romania	.308	.348
Yugoslavia	.078	.288
TOTAL	.443	2.215

Source: CIA, International Energy Statistical Review, 27 June 1979.

The Situation After 1985

After 1985 the rate of Soviet oil production is highly uncertain. There are promising geological areas near Sakhalin in the Sea of Okhotsk, in the deep structures of the Caspian Sea, in the East Siberian lowlands, and over much of the Arctic offshore regions.

Currently, the Japanese and the Soviet Union are jointly exploring Sakhalin. Exploration so far in the East Siberian lowlands indicates that it may be a natural gas area rather than oil. Soviet offshore drilling is still in its infancy and the Soviet Union lacks both equipment and experience to undertake the deep well drilling in the Caspian region without external technical assistance. Production from these three areas is possible before 2000; however, it is unlikely that the offshore Arctic areas

will be developed this century. The conditions in these areas are such that the technology for development does not currently exist even in the West.

It is therefore possible that Soviet petroleum production may not exceed 8-10 MBD through the period of 1985-2000. Even the maintenance of the production rate of 10 MBD requires, between 1980-2000, the addition of 55 billion barrels to reserves (based upon the CIA estimate (Table 4) of 40 billion barrels for Soviet proved oil reserves).

Unless consumption were reduced these production levels would leave a deficit that could conceivably have to be filled by imports. OTA estimates that if this is the case, net imports could total up to 2 MBD, although substitution of nuclear energy and natural gas for oil could help reduce this.

Production levels higher than 10 MBD may be possible if large discoveries are made. But Soviet oil production will be extremely expensive in terms of both capital, manpower, and equipment. Therefore, it appears likely that the Soviet Union will attempt to achieve only the levels necessary to meet its domestic needs and those of its satellite countries.

While the PRC is expected to increase production until 1985 over its current level of 2.3 MBD; the situation after 1985 is unclear and further increases in production after 1985 will depend upon the rate of new discoveries. A promising region for supporting increases is the offshore areas in the South China Sea where ownership is disputed. The rate at which this area may be explored and developed will depend upon the willingness of the PRC to employ U.S. and Japanese assistance.

Substantial exports by the PRC are not expected. This is due to

political as much as geological assumptions. Self-reliance is considered extremely important in China and it is debatable whether the Chinese would find exports desirable if this would jeopardize their failure to meet growing future domestic needs.

Summary of the Effect of Communist Countries

If the CIA is correct, we estimate an import potential for the Communist countries of O to 1.9 MBD in 1985 and O-2 MBD in 2000. As stated above, however, there is considerable uncertainty about this and further analysis is necessary. For example, Exxon* projects net Communist exports of 1 MBD in 2000 arising principally from increased production by the People's Republic of China.

PROJECTIONS OF NON-COMMUNIST WORLD OIL SUPPLIES

Based upon the OTA analysis of non-communist world oil production and the possibility of net imports by the Communist countries, a range for non-Communist world oil supply of 47-60 MBD for 1985 and 40-62 MBD for 2000 is projected. These ranges should be compared with the 1979 non-Communist world oil supply of 52.4 MBD.

It is thus possible that non-Communist world oil supply (and more importantly the developed countries oil supply) will experience no increase and will, in fact, decline over the next three decades. Moreover, even under optimistic assumptions non-Communist world oil supply will not experience the level of increase that had been anticipated by earlier studies.

Exxon, World Energy Outlook, December 1979.

** Several studies made before the Iranian revolution are analyzed in the next section.

TABLE 16
PROJECTIONS OF FUTURE NON-COMMUNIST WORLD OIL SUPPLIES (MBD)

	1979	1985	2000
Developed Countries	14.9	13-15.5	7.5-13
OPEC	31•4	28.5-35	27-37
Non-OPEC LDC's	501	7.5-9	705-11.5
Net Communist Trade**	1*	(-1 .9)-o	(-2)-o
TOTAL ***	52.4	47-60	40-62

* Estimate

** Negative number indicates Communist imports. As indicated in the text, there is considerable uncertainty in the estimates for the years 1985, 2000.

***May not add due to rounding.

Source: OTA based upon assumptions stated in text.

4. COMPARISON WITH OTHER FORECASTS

Forecasts Made After January 1979

Two oil companies (Exxon and British Petroleum) have made projections for production through the year 2000 since the Iranian revolution. Few details are given in either the Exxon or British Petroleum forecasts.

Conservable care must be made in directly comparing these estimates with the OTA estimates. The Exxon forecast includes synthetics and unconventional oil in its projection, which are not included in the OTA study. The British Petroleum forecast is for non-Communist world crude oil production. This study does not consider natural gas liquids production or the effect of the Communist countries.

The British Petroleum estimate falls into the lower half of our production range while the Exxon forecast is at the upper end of our projection range. The primary difference in the Exxon and BP forecasts appears to be the projection of new discoveries outside of OPEC. This difference reflects the subjective judgments that are necessary in long term petroleum production forecasts.

British Petroleum (BP)*

BP forecasts non-Communist world crude oil production peaking in 1985 in the range 54-61 MBD and then steadily declining to a level of 40-48 MBD in the year 2000. The higher levels assumed Saudi Arabian production at 12 MBD, Iran at 4 MBD, and the removal of conservation limits imposed by some other OPEC countries.

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* British Petroleum Ltd., Oil Crisis Again, September 1979. (Note numbers are read from graphs and not tables.)

After adding approximately 3 MBD of natural gas liquids (today's current rate) to the above estimate, one obtains a range of 43-51 MBD for non-Communist world oil production. This range is in the lower half of the OTA range of production estimates for the year 2000.

Exxon*

Exxon projects conventional free world liquid petroleum supply rising to 58 MBD in 1990 and 60 MBD in the year 2000.** This estimate for 2000 is near the higher estimate of supply possibilities listed in this OTA report.

A breakdown by region is compared with the OTA estimate for the year 2000 in Table 17. Exxon's estimates for the U.S., Canada, and OPEC production fall with the range of OTA estimates for the year 2000. Their estimate for Europe, other non-OPEC countries, and Communist exports are slighter higher than the OTA range of production possibilities. The regional Exxon estimates have been compared to the OTA estimates in each section of the report.

Table 17

Liquid Petroleum Supply in the Year 2000 (MBD)

	Exxon	OTA
OPEC	33	27-37
U.S. and Canada	8	5-9
Europe	4	2.0-3.5
Other Non-OPEC	14	8-12
Subtotal	59	42-62
Communist exports	1	(-2) to 0
Total	60	40-62

(May not add due to rounding)

* Exxon, World Energy Outlook to 2000, December 1979.

** Unconventional and synthetic production, estimated by Exxon to be 6 MBD in the year 2000, has been deleted in the description here.

Congressional Budget Office

Concurrently with the preparation of this report, the Congressional Budget Office (CBO) prepared a report The World Oil Market in the 1980s: Implications for the United States which was released in may 1980. This report has point projections of future oil supply through this decade. Their estimates of production in the US and in the non-OPEC LDC's are somewhat higher than those in this OTA report. These higher estimates are based upon assumed, new discovery rates which are higher than those given in this report.

The CBO study projects world petroleum availability in 1985 to be 54.5 MBD. This estimate falls within the range of OTA estimates (47-60 MBD) for 1985. The corresponding regional estimates are compared in the table below.

Table 18

1985 Non-Communist World Oil Supply (MBD)

	OTA	CBO
Developed countries		
United States	7.2-8.6	9.4
Canada	1.6-108	1.5
North Sea	2.8-4	3.7
Other	.8	1*
	13-15.5	15.6
OPEC	28.5-35	30.1
Non-OPEC LDC	7.5-9	9.8*
Communist trade	(-2)-o	-1
Totals... (May not add due to rounding)	47-60	54.5

* Australia was classified with the non-OPEC LDC category in the CBO report. OTA estimated its production at .5 MBD and included it in the other category of the developed countries in this description of the CBO report.

SOURCE: OTA, CBO.

Forecasts Prior to January 1979

It is difficult to compare the analysis here with other forecasts made prior to the disruption in Iran. Prior to the Iranian revolution, many projections had assumed that oil exporters would produce at *(or close* to) their maximum production rates. However, as was discussed in Section 3, the events in Iran have made it clear that many oil exporters would prefer to lower production rates.

In the analysis here OTA has attempted to take into consideration the political, economic, technical, and geological factors that determine production in each country. Several studies (including the Energy Information Agency of DOE and Electrical" Power Research Institute studies discussed below), working with data prior to the Iranian revolution, had ignored the importance of the non-geological factors. Consequently, these studies have estimated non-Communist world oil supply to be significantly higher than the OTA estimates in this report.

Energy Information Agency

The Energy Information Agency (EIA) of the Department of Energy made an estimate of future non-Communist world oil supply in its Volume 3 of the 1978 Annual Report to the Congress which was released in 1979. The EIA has projected free world oil supply to range between 56.2-63.1 MBD in 1985 and 70.3-90.4 MBD in 1995.

These estimates are considerably higher than the projections for non-Communist world oil supply made in this report. The EIA estimates for 1995 estimates are even 10 to 30 MBD above the OTA high estimate for

production in the year 2000. However, the EIA has recently testified* that the disruption in Iran has significantly altered their projections and that their production rates will be modified.

It is important to understand the EIA methodology which caused these high projections. EIA does not make a country by country analysis of the production possibilities of the major producers. Instead EIA relies heavily on econometric modelling resulting in the their supply estimates of petroleum being price driven. This does not imply that all other factors are totally ignored but only that the price of oil is the major factor in determining the available supply of petroleum. A range of production estimates is then made under varying assumptions on price.

The EIA uses different price analyses for determining the production ranges for foreign non-OPEC, OPEC, and the U.S. For foreign non-OPEC production (Mexico, North Sea, etc.), the EIA first obtained ranges of foreign supply potential (at constant prices) provided by the International Affairs Division of DOE. The future production rates for these countries are then determined using a long-term supply elasticity of 0.2. This assumption means that any 10% in price would lead to a 2% increase in production after ten years have elapsed. Thus price determines supply in the EIA model.

OPEC production is determined by EIA to be a function of world demand for oil, capacity expansion plans, and price. This process can be briefly described as follows:

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c. Roger LeGassie, EIA before the Permanent Select House Committee on Intelligence, October 17, 1979.

OPEC expands capacity from its current level of 34 MBD to a level of 39 MBD in 1995 if oil prices remain constant or decline in real dollars (approximately .3 MBD a year).

If prices rise, OPEC would increase its annual rate of capacity an additional .65 MBD a year after 1985 with capacity increasing until the level of 45.8 MBD is obtained.

Future U.S. petroleum production is determined based on a combination of geologic, price and cost of production assumptions. Increases in price are assumed to have a direct effect on the rate of exploration for and development of our current undiscovered resources. Estimates of the U.S. undiscovered resource are taken from 1975 U.S.G.S. estimates. (Most experts consider these estimates inflated based upon recent disappointing drilling experience.)

The EIA approach is of limited value in making supply projections, since in their analysis supply is primarily price determined. In reality the supply of oil is price-driven for only a limited range of circumstances. The first circumstance is where the cost of production is close to the market price. This is true in some places but these places would produce only small amounts because they are in small (high-cost) fields. The second circumstance is where known reserves are viewed as the only national asset able to generate economic development, and the rate of development is limited by foreign exchange. This was true in the Shah's Iran (and may be true of Iran in the future) and is perhaps true of Nigeria. But this circumstance does not apply to most known reserves. For most of the world's production of oil, increases in supply will be determined either by geology (U.S., U.S.S.R., North Sea) or by political factors (Persian Gulf).

The EIA model gives little consideration to the conservation objectives that have been explicitly stated by several governments. Saudi production is projected to range between 14-16.4 MBD despite official Saudi statements that sustainable capacity would not be extended beyond levels to support production of 12 MBD and that actual production may be held to 10 MBD. Kuwait and the UAE are projected to increase production by 1995 a minimum of 1.2 MBD despite statements by these two governments that they will not increase production.

The EIA price analysis also leads to some extremely high estimates for future U.S. production from new (post 1978) additions to reserves. In 1978 the U.S. added only 1.3 billion barrels to reserves, and the average annual addition since 1973 has been approximately 1.5 billion barrels despite a five-fold price increase since 1973. The continued addition of 1.5 billion barrels per year to reserves would result in a production of approximately 3 MBD from this source by 1995. However, EIA estimates that between 4.34 and 10.73 MBD will come from production from reserve additions.

Electrical Power Research Institute (EPRI), Outlook for World Oil into the 21st Century, May 1978

EPRI published a forecast of future non-Communist world oil supply excluding U.S. production will rise to a maximum level of 72 MBD, occuring at the earliest by 1995-96. OPEC production will account for 51 MBD of this production.

It is important to note that EPRI had assumed that political considerations by exporting countries will not cause production to be limited. This assumption is based upon an analysis by Professor D.A. Rustow.

As stated by EPRI in this report,

> "very brief 1 y, Professor Rustow believes that the governments of the major oil exporting countries, regardless of political orientations, Will find it expedient to sell oil to the non-Communist world within the limits of their technical capacity and economic needs. Thus , in most situations purely political considerations are unlikely to determine the long term glob al avail ability and price of oil."

Events following the disrupt ion in Iran have made this assumption untenable.

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