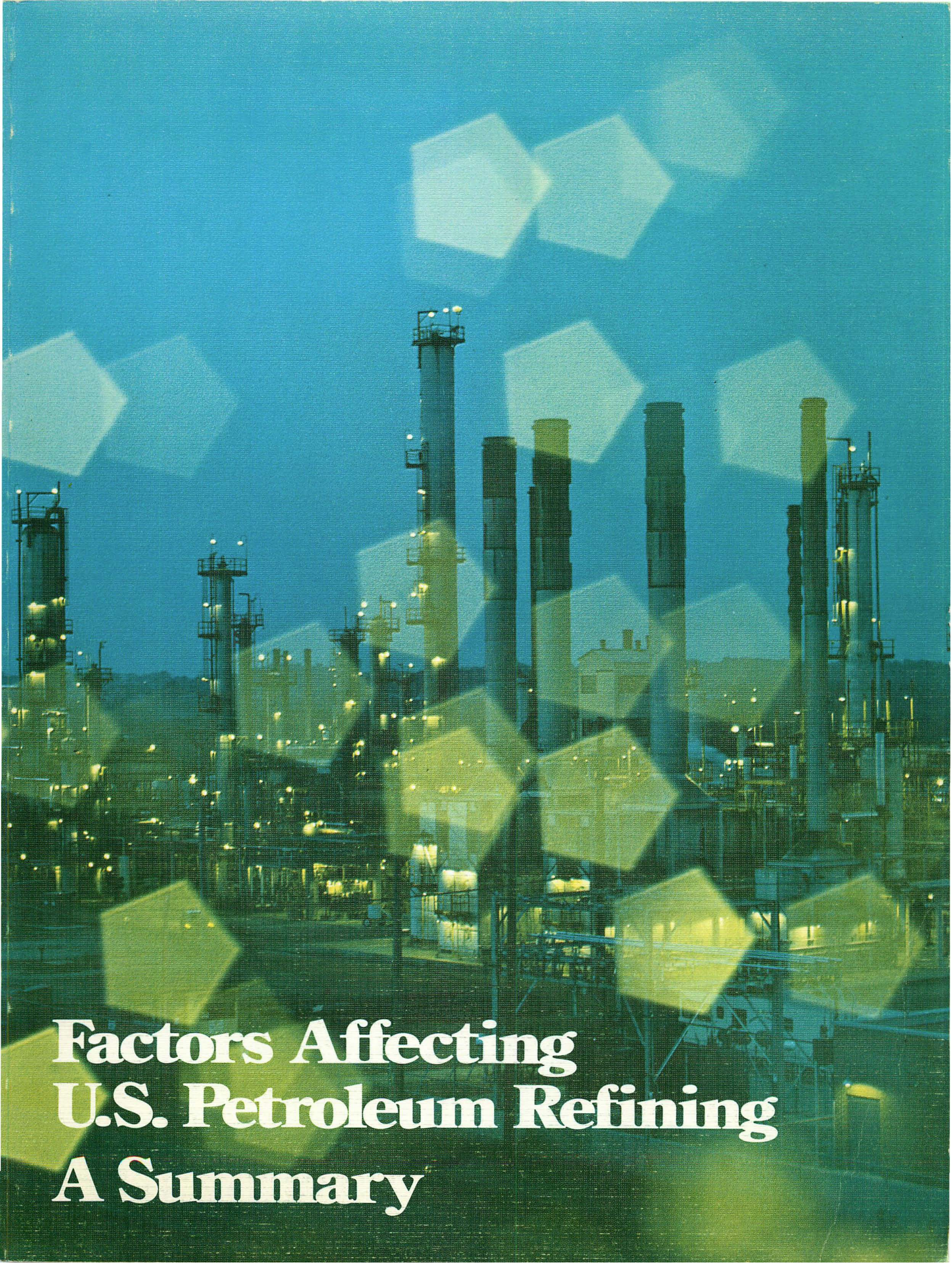

Factors Affecting U.S. Petroleum Refining A Summary

National Petroleum Council
(Established by the Secretary of the Interior)

May 10, 1973

My dear Mr. Secretary:

On behalf of the members of the National Petroleum Council, I am pleased to transmit to you herewith the summary report on *Factors Affecting U.S. Petroleum Refining* as approved by the Council at its meeting on May 10, 1973. The full report of the Main Committee, containing more detailed supporting information and data, will be submitted to you in the near future upon its completion and printing.

On February 9,1972, the Assistant Secretary of the Interior asked the National Petroleum Council to undertake a study of the factors-economic, governmental, technological and environmental-which may affect the domestic refining industry's ability to respond to demands for essential petroleum products.

In response to this request, the NPC Committee on Factors Affecting U.S. Petroleum Refining was established under the chairmanship of Orin E. Atkins, Chairman of the Board, Ashland Oil, Inc., with the assistance of a Coordinating Subcommittee, chaired by George Holzman, General Manager, Refining, Shell Oil Company.

This report was actually completed just prior to the issuance of the President's Energy Message to Congress on April 18, 1973, and does not take into account or evaluate any of these policy changes or recommendations.

The energy message addressed a range of key factors which directly affect U.S. energy supply and are important in assuring a healthy domestic petroleum refining industry. The enclosed report evaluates the various factors affecting the domestic refining industry and virtually all the basic factors mentioned are still relevant. This is particularly so from the point of view of future governmental policy.

Solutions to the present domestic refining problems will not be achieved easily or rapidly. We wish to point out that significant lead time is inherently involved in implementing any industry or government programs designed to enhance U.S. petroleum refining capabilities. The effects of any programs in terms of increased capacity and volumes of fuel could not be realized for 3 or 4 years.

The National Petroleum Council sincerely hopes that this study will be of benefit to the Government in the difficult decision-making process that lies ahead.

Respectfully submitted,

H. A. True, Jr.
Chairman

Honorable Rogers C. B. Morton
Secretary of the Interior
Washington, D. C.

Factors Affecting U.S. Petroleum Refining

A Summary

May 1973

Prepared by the
National Petroleum Council's Committee
on Factors Affecting U.S. Petroleum Refining
Orin E. Atkins, Chairman
with the Assistance of the Coordinating Subcommittee
George Holzman, Chairman

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Preface

On February 9, 1972, the National Petroleum Council, an officially established industry advisory body to the Secretary of the Interior, was requested by the Assistant Secretary of the Interior-Mineral Resources to undertake a survey of the factors-economic, governmental, technological and environmental- which affect the ability of domestic refining capacity to respond to demands for essential petroleum products. The Assistant Secretary asked that the Council's report discuss those elements which are considered essential to the development of domestic refining capacity. A copy of the request letter is included as Appendix I.

In response to this request, the National Petroleum Council established a Committee on Factors Affecting U.S. Petroleum Refining under the chairmanship of Orin E. Atkins, Chairman of the Board, Ashland Oil, Inc., and the cochairmanship of Hon. Stephen A. Wakefield, Assistant Secretary of the Interior for Energy and Minerals. The Committee was assisted by a Coordinating Subcommittee, chaired by George Holzman, General Manager, Refineries, Shell Oil Company. (For a listing of members of the Committee and its subcommittees, see Appendix 2.) This report is designed to call attention to those factors and issues which have affected domestic refining capacity.

The results of the investigation are presented in this report, *Factors Affecting U.S. Petroleum Refining-A Summary*. The more detailed findings of the Committee, which are the basis of this report, are contained in the full report of the Committee, published separately. In addition, the Committee undertook to supplement a previous NPC report entitled, *Impact of New Technology on the U.S. Petroleum Industry* (1946-1965). This review as regards refining technology is also published separately.

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Introduction

Refining is an integral part of the domestic petroleum industry. It is only through this process that crude oil can be transformed into the many varied products which have become the basis for the Nation's continued development. Refined petroleum products form the basis for heating oils, motor fuels, plastics, building materials, synthetic fibers, medicines, rubber, paint solvents, bio-degradable detergents, asphalt and lubricating oils, as well as many other products.

The petroleum industry, which has been called upon to supply the Nation's consumers with three-fourths of their energy needs, is a complex web of interrelated functions. In total, over 40,000 companies perform the primary functions of exploration, production, transportation, refining and marketing. This report is addressed primarily to the refining function.

The growth of the domestic refining segment of the petroleum industry is affected by the growth of the other segments. For example, domestic oil and gas production rates directly affect the amount and location of refining capacity requirements. Similarly, the development of transportation systems which allow the United States to realize the benefits of large modern tankers affect refiners' decisions regarding size and location of new refinery sites.

There are nearly 200 companies in the continental United States which are directly involved in the process of crude oil refining. These refineries are located in 40 states and range in capacity from 250 barrels per calendar day *(250 B/CD)* to over 400,000 barrels per calendar day (400 *MB/CD*).*

U.S. refiners have a highly diverse range of economic and industrial interests. Some refiners employ simple distillation techniques for the production of the most elemental refined products, while others are largely engaged in the manufacture of motor fuels and domestic heating oils. Still others produce a broad spectrum of petroleum products, including highly sophisticated petrochemicals. The various processing techniques and types of equipment employed in the manufacture of finished petroleum products are numerous. Because of the diversified interests, manufacturing techniques and raw materials base, different refining facilities have different interests and requirements.

This report attempts to delineate broad areas of concern to refiners and to suggest policy options which will help maintain the health and viability of the refining segment of the petroleum industry.

While numerous factors will be discussed in the body of the report, the single most influential factor on U.S. petroleum refining today—and indeed on the entire petroleum industry—is the current transition from operating in an era of stable and ample domestic crude and product supplies to operating in an era of instability and shortage. Refiners are no longer assured of the availability of needed raw materials of either the quantity or the quality for which their refineries were designed.

This NPC study addresses the past, present and future trends in domestic petroleum refining in relation to requirements, capacities and capabilities. In addition, technological factors that have contributed to the shortfall in domestic refining capacity are evaluated. To determine past, current and near-term refining capacity, an extensive survey was conducted, the composite results of which appear in the full report of the Committee.

In order to analyze the construction of new refining capacity, the study addresses the economic factors which indicate the advantages and disadvantages of building domestic refineries *vs.* building refineries in foreign perimeter locations such as eastern Canada and the Caribbean. Oil import policy, environmental considerations and other pertinent government policies are evaluated.

Due to the scope and complexity of the assignment, this study is presented in three volumes. This summary report contains the conclusions and recommendations of the National Petroleum Council and incorporates a summary of the second volume—the Committee's full report. The third volume is an update of the refining section of a previous NPC report entitled, *Impact of New Technology on the U.S. Petroleum Industry (1946-1965)*.

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* Since product demands are expressed as daily averages, daily average or calendar day refinery capacities are used throughout this report.

Part One
Conclusions and Recommendations

Conclusions

This study has determined that a number of factors involving supplyj demand, environmental and economic concerns have contributed to the shortfall of domestic refining capacity. It is important to realize that no single program or policy has caused nor will alleviate current and projected shortfall of domestic refining capacity. Any measures taken to attain short-term results must be cognizant of the effect of these measures upon long-term situations. Several of the more important factors which have an impact upon the refining situation and their implications are discussed in the following sections.

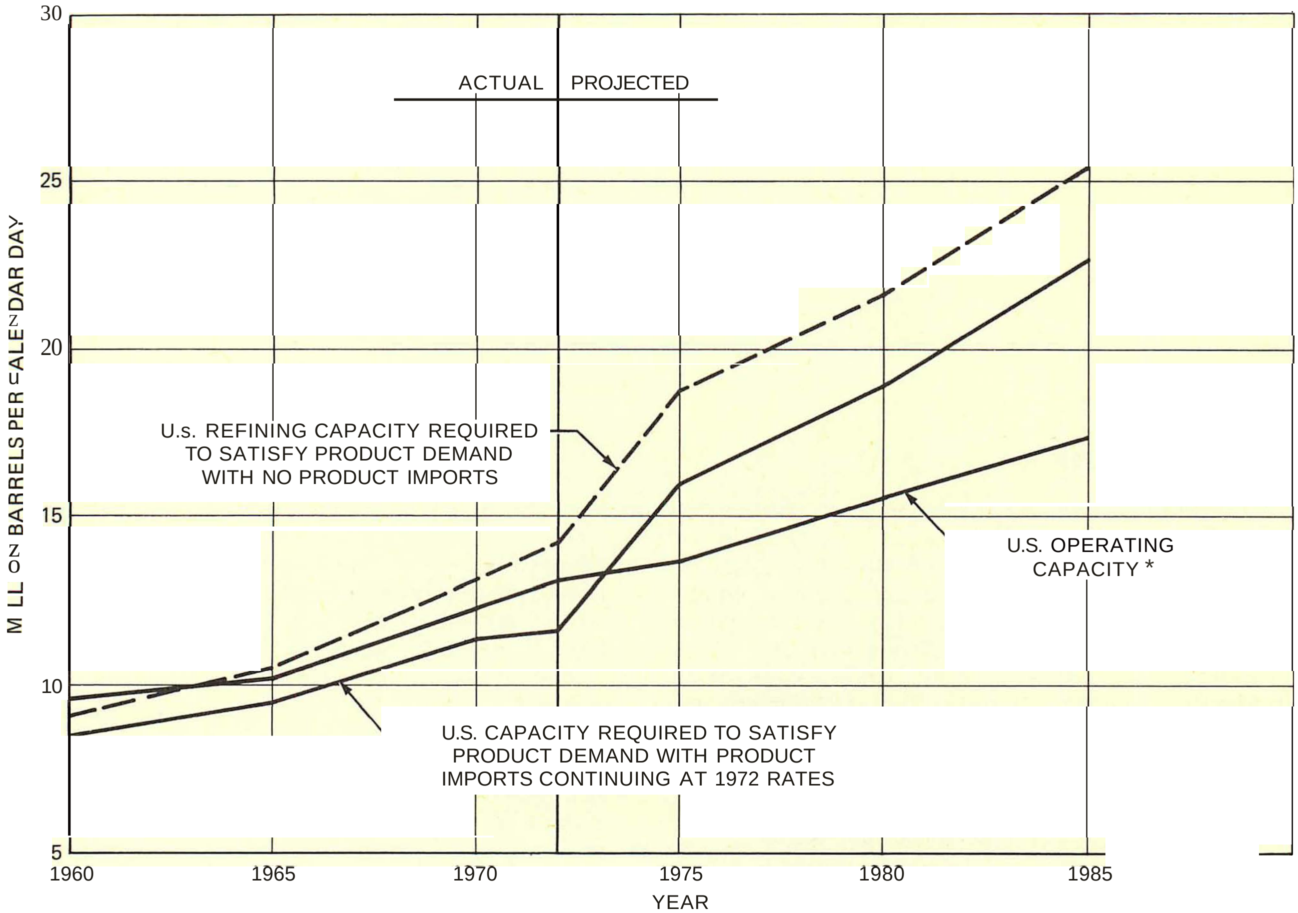
Supply and Demand

Product Demands Exceeding Capacity

The requirements for refining capacity are set by the demand for petroleum products, which is expected to grow at a rate of 5.7 percent per year from 1971 to 1975, 2.7 percent per year from 1976 to 1980, and 3.0 percent per year from 1981 to 1985. At these growth rates, demand for petroleum products will be nearly double the demand for the 1971-1985 period, increasing from 15 million barrels per day *(MMBjD)* in 1970 to over 26 *MMBjD* in 1985. The refining capacity necessary to satisfy 1985 demand will therefore exceed 25 million barrels per calendar day *(MMBjCD)*. Operating capacity of U.S. refineries on January 1, 1973, was 13.2 *MMBjCD*, with about 2.5 *MMBjD* of products being imported. Thus, if projected petroleum product requirements are to be met, it will be necessary to construct new refineries or expand existing refineries to add about 9 *MMBjCD* of capacity by 1985. The additional capacity will have to be built in the United States or come from existing or future offshore facilities in order to meet projected demand as shown in Figure 1. If these requirements were to be met solely from U.S. refineries with petroleum product imports completely eliminated, about 12 *MMBjCD* of new capacity will have to be constructed by 1985.

U.S. refining capacity was adequate to meet refined product demands until the 1960's. Since then, a shortfall in domestic refining capacity has developed, especially for residual fuel oil. Imports of such products have increased substantially, particularly into the East Coast. Until now, physical refining capacity has existed in the United States to meet the total demands for lighter fuel products-gasoline, jet fuels, etc. Now, however, demand for light products has also exceeded domestic capacity. By 1975, the total "shortfall" of domestic refining capacity is projected to be 25.9 percent of total refining capacity required or 4.8 *MMBjCD*.

The present shortfall of domestic refining capacity is the result of a series of emerging trends intensified by a surge in demand in 1972. For example, the current deficit of heavy fuel oil capacity developed over an extended period of time, while the shortfall in capacity to meet light product requirements is of more recent development. It takes several years for new plans to become operational, and lead time must be considered an important element of future planning. Because of the necessary lead time to plan and build new capacity and because no large increments of new capacity are now in the construction stage, it has been necessary to modify import controls to permit an increase in product imports in order that projected demand can be met. While this assumes that sufficient petroleum products are available in world markets, the Committee has not evaluated world refining capacity to determine the validity of this assumption. However, it is felt that, if large increases in U.S. demand continue, world capacity may be outstripped by demand, much as U.S. capacity was in 1972.



·Statistical projection of historical and survey capacity data-not a forecast.

Figure 1. Total U.S. Operating Refinery Capacity *vs.* Requirements-1960-1985.

Uncertainty Concerning Assurance of Supply and Quality of Crude Oil

The decline in exploration for and production of domestic crude oil has resulted in greater difficulties in obtaining assured crude supplies. This has had an inhibiting effect on the expansion of U.S. refineries. In 1975, crude oil and product imports are expected to be double the 3.4 MMB/D imported in 1970; imports in 1985 could be as high as 19.2 MMB/D, depending upon the degree of national commitment to domestic energy production.* Thus, domestic refineries are now compelled to rely increasingly upon foreign sources of crude supplies. In order to meet requirements-at least in the short term-the United States will also have to depend upon foreign refining capacity for increased amounts of product imports.

In addition to the uncertainty regarding long-term assurance of crude oil supply, the distinctive characteristics of the crude oil itself are important factors in the refining process. A given refinery cannot effectively process every type of crude oil. If a refinery processes a type of crude oil for which it was not designed, the effective throughput capacity of the refinery will in many cases be reduced substantially. Today there is a shortage of both domestic and foreign low-sulfur crude oil, and this is expected to continue in the near future. Many domestic refineries are designed, both from a metallurgical and from a processing viewpoint, to accommodate only low-sulfur crude oil. High-sulfur crude oil-the type most generally available from foreign supply sources- cannot be exclusively processed in a domestic refinery designed for 10'w-sulfur cl;ude oil without the installation of additional facilities and/or extensive modification of existing facilities to prevent corrosive damage and to meet product specifications.

* National Petroleum Council, *U.S. Enel°UY Outlook-A Summary Rep01·t of the National Petroleum Council* (December 1972).

Increased Demand for Refined Petroleum Products and Petrochemical and Substitute Natural Gas (SNG) Feedstocks

The demand for refined petroleum products could increase above projected requirements if demand is stimulated by such factors as the continuation of current shortages of natural gas, continuation of delays in bringing nuclear fueled electricity generating capacity on line, and a future decrease in the availability of environmentally and economically acceptable low-sulfur coal.

Although oil is not completely interchangeable with other fuels in existing equipment, it can .supplement the needs in any energy consummg sector of our economy. In effect, it can act as the "swing" fuel. If gas finding rates are disappointingly low in the future, oil can be used to fill the need. The same concept holds true for oil as an alternate to nuclear power and coal when necessary and where applicable.

The required specifications for individual products are affecting both the type and the amount of capacity required. The increasing demand for low-sulfur residual fuel oils (0.3-weight-percent sulfur) requires the installation of extensive treating facilities. Not all crude oils can be processed utilizing existing technology to. yield these fuels economically, and crudes WhICh are naturally low in sulfur are in short supply in world markets. Motor gasoline, representing nearly 40 percent of total U.S. oil demand, is also sensitive to environmentally enduced specification changes. Emission control equipment on new automobiles is reducing fuel efficiency, thus increasing gasoline demand. While this in itself is increasing refinery capacity requirements, the need for unleaded gasoline for these new vehicles is also significantly increasing the amount of crude capacity reqUIred to produce a given volume of gasoline.

In the last few years, the domestic manufacture of petrochemicals has become closely related .to domestic crude oil refining capacity. SupplIes of domestic natural gas liquids which are important petrochemical feedstocks, 'are declining, and petrochemical producers are having to turn more and more to refinery naphtha and gas oil. This shift in feedstock will result in a closer relationship between the refining and petrochemical industries as well as in increased need for integration of petrochemical and refining planning and operation.

The National Petroleum Council has projected petrochemical feedstocks to grow from less than 6 percent of total petroleum demand in 1970 to about 8 percent in 1985.* If refining capaCIty moves offshore, then petrochemical producers may have to use imports for their feedstock supplies. Conversely, if refining capacity is kept onshore, feedstock supplies can be expected to be more readily available.

An additional demand factor which will affect both petrochemical and refining operations is the planned reforming of naphtha and other petroleum liquids into SNG. Feedstocks for SNG manufacture could approach 1 *MMB/D* by 1985.

Environmental Concerns

Americans are becoming aware of the potential conflict between energy requirements and environmental goals. Both high energy consumption rates and satisfactory maintenance of environmental standards are possible but only through dealing effectively with the total environmental, social and economic system.

The principal environmental factors which have had inhibiting influences on the expansion of domestic refinery capacity are discussed in the following sections.

Availability of Refinery Sites

Requirements relating to construction and operating permits and other environmental considerations have seriously limited and delayed site development for new plants. Environmental issues and restrictive emission requirements have delayed or actually prevented new refining construction. Of more concern than the difficulty of complying with these requirements are the instances where proposed refinery construction-after complete compliance with federal, state and local requirements-is halted by citizen group court actions.

Despite the rigorous standards for both water and air quality that refineries must meet now and in the future, resistance still exists in many areas of the country to constructing plants, even with appropriate environmental equipment. It is hoped that, as the public becomes more aware of the excellent pollution control performance of modern refineries, such resistance toward plant location will disappear.

Availability of Deepwater Port Facilities for Crude Oil Imports

While domestic reserves need to be developed to their fullest extent, a need will still exist for supplemental quantities of crude oil from other countries. The most efficient and economical method of transporting these requirements to refinery centers is through the use of very large crude carriers (VLCC's). Effective use of VLCC's-tankers having greater than 150,000

* NPC, *U.S. Energy Outlook: An Initial Appraisal 1971-1985*, Volume Two (November 1971).

deadweight tons (DWT) displacement- will require the construction of deepwater ports located offshore, with pipelines delivering supplies from these superports to refineries.

Documented evidence shows that most spills from tankers occur during loading and unloading at ports now located on shorelines. Deepwater unloading terminals offer environmental advantages in that they would minimize such occurrences and effects of accidental spills on nearby shorelines by requiring less frequent ship movements and by allowing these movements to take place at more remote distances from land. Likewise, VLCC's with compartmented cargoes and highly trained crews, along with sophisticated new navigation equipment and safety developments, offer environmental advantages over smaller vessels.

Availability of Crude Oil

As mentioned earlier, basic to any refinery construction plans is the assurance of availability of suitable crude oil of known quality and assured stability of supply for a reasonable period of time. Environmental concerns have, at times, delayed the development of supplies of available or potentially available crude oil to refineries.

Perhaps the most important hinderance to refining construction is unreasonable interference with access to domestic crude oil resources after detailed studies have assessed the impact of environmental issues and demonstrated cost-benefit effectiveness. For example, reserves of crude oil on the North Slope of Alaska which were discovered in 1968 have been estimated to be over 10 billion barrels, a volume which is equivalent to about one-third of the known reserves of the lower 48 states. Billions of dollars of industry's capital have been rendered non-productive by citizen group court actions and other delays associated with environmental concerns. These dormant reserves have not only drained funds from uses in other ventures, such as expanding refinery capacity, but have increased our Nation's dependence on imports with attendant penalties on national security and balance of trade. The Nation cannot afford to allow these resources to remain unused indefinitely. Even under the most optimistic predictions, it will be several years before supplies of crude oil can be moved from the Alaskan North Slope to domestic refineries.

The potential for discovery of large quantities of crude oil and natural gas exists in offshore waters surrounding our continent. However, many areas of the continental shelf of the United States remain undeveloped or underdeveloped because of environmental concerns.

Economic Factors

Important changes are taking place in the economic environment in which refineries find themselves. Crude oil is being supplied in increasing amounts from foreign sources, and prices of foreign crude oil landed in the United States are rising sharply, exceeding delivered domestic prices in some cases. Refining facilities are becoming more complex in both design and materials requirements and are increasingly more expensive per barrel of capacity.

The principal economic factors affecting the expansion of domestic refining capacity are discussed in the following sections.

The Economic Outlook for New Refining Investment Has Become Uncertain

Refiners are having to compete for funds in capital markets at a time when investment dollars are becoming tight and are being attracted to those investments with a rate of return more commensurate with future risk and stability. Rates of return on refining investment must be adequate if financing is to be available for construction of new domestic refining capacity. Current economic conditions and the lack of encompassing US. policies on energy matters has made the outlook for new investments in new refineries quite uncertain.

Illustrative economic comparisons have been prepared concerning the cost of operating a refinery located in perimeter areas (Caribbean or eastern Canada) to the cost of the same refinery located in either Petroleum Administration for Defense (PAD) District I (US. East Coast) or PAD District III (US. Gulf Coast).* In all cases, the refineries were operated on the same Middle East crude. They were operated to produce a product mix comparable to the projected growth in District I product demand between 1970 and 1985, with the products ultimately delivered to the same market locations in District 1. These costs do not include any cost associated with acquiring the crude oil import quota but do include 1972 level import duties. They assume an application of current statutory income tax rates-zero for the Caribbean example, 48 percent for the United States and 49 percent for an eastern Canada refinery.

While these studies are only illustrative examples, they indicate that a refinery located in District III can expect average product costs

* *These illustrative economic comparisons we1'e prepared p1'ior to the issuance of the President's Energy Message to Congress of April* 18, 1973, *and do not take into account the oil import proclamation contained therein.*

which are on the order of $0.60 per barrel higher than the refinery located in the Caribbean. Assuming that such a refinery is built in District I, the economic advantage of the Caribbean refinery is reduced to approximately $0.40 per barrel. On the other hand, in eastern Canada, where the tax rates are comparable to those in the United States, the economic advantage tends to disappear-except in those instances where specific tax advantages and other benefits have been granted.

Recent Product Price Controls Will Lead to Increasing Supply Shortages

If the United States continues to impose price controls- direct or indirect-on petroleum and/or refined petroleum products in order to stabilize the economy, the full cost and financial risk of providing new supplies of petroleum products must be recognized, including higher costs of imported supplies. If they are not, refinery expansion will be discouraged, and shortages of domestically refined petroleum products will occur. To the extent available, products would have to be imported from world markets at prices which are not subject to U.S. price controls. This, in turn, could drive market prices for imported products landed in the United States higher than those of products refined domestically, a consequence currently being experienced.

Restrictive and Inflexible Import Regulations *

The relative inflexibility of the crude oil quota system, coupled with the decline in domestic crude oil production, has restricted the development of new refining capacity. While it is true that total U.S. import quotas would increase by the amount of new capacity built, there has been no direct mechanism to provide an existing refiner or a potential refiner with the necessary access to foreign crude oil supplies necessary to the operation of new refinery capacity in the United States. Limited and inadequate starter allocations were the only existing provisions for granting crude access for new refining capacity. The difficulties and costs of acquiring imported supplies from others were discouraging factors in refiners' decisions regarding new capacity construction.

The exemption of certain products from formal quota controls, however, has led to the construction of sizable refining capacity outside the United States. The ability to import these products into the United States, the ability to acquire long-term foreign crude oil supplies, and the economic advantage of offshore refining favor the buildup of refining capacity in these perimeter areas.

Requirements for Transportation and Storage Facilities

Increased requirements for petroleum will require the expansion of transportation and operational storage facilities. Most of the incremental crude oil supplies will be imported from the Middle East and Africa. For such long distances and large quantities, the most economical and environmentally safe system for receiving such oil is by direct shipment to the refining center utilizing VLCC's and properly designed deepwater crude unloading terminals. Considering the lowest cost logistical system for waterborne imports of crude oil, the capital required for the 1971-1985 period is substantial. Estimated investments for deepwater port facilities and for foreign construction of new 250,000 DWT vessels range from $14 to $16 billion. Total capital requirements may be higher depending on the extent to which U.S. shipyards must be used for vessel construction. Additionally, cargo preference legislation which would require the use of American flag vessels on direct shipments to the United States would substantially increase the transportation charge per barrel of delivered oil. Because of these increased costs, such legislation would act as a disincentive in the construction of U.S. refining capacity.

Storage requirements will also rise as imports increase. Domestic refineries running on domestic crude oil production need very little crude storage. With future receipts arriving in VLCC's, refiners will need facilities to store their large cargoes (almost 2 million barrels can be carried in a 250,000 DWT tanker) and to maintain a working inventory to ensure continuous operation in the event that shipments are delayed.

* *The P1'esident, in his ene1'gy message to Cong1'ess of A1Jril 18, 1973, has removed by proclamation all existing tariffs on imported c1'ude oil and products and has suspended direct control over the quantity of crude oil and refined p?'oducts which can be imported. In place of the control system, the P1'esident has initiated a license fee system. The President stated that, to encourage domestic ?'efinery const1'uction, crude oil in amounts up to th1'ee-fourths of new 1'efining capacity may be imported for a period of 5 yea1'S without being subject to any fees.*

Recommendations

U.S. Energy Policy Objectives

The National Petroleum Council recognizes that the primary energy industries, in cooperation with the Government, are responsible for meeting the energy needs of American society. This responsibility must be met while assuring free consumer choice at the lowest costs consistent with adequacy of long-term supply, preservation of the environment, and promotion of efficient use of energy and energy conservation. The impact of the effects of energy availability and costs on economic welfare and progress and, more importantly, the need to preserve national security underline the significance of this responsibility.

The NPC's recent U.S. Energy Outlook report includes recommendations for a U.S. energy policy.* This study reiterates some of those recommendations since petroleum refining is an integral part of the energy industries and, as such, is affected by overall U.S. energy policies. This report also contains additional recommendations which are more specifically related to domestic petroleum refining operations.

These recommendations are made with the belief that a healthy and viable domestic petroleum industry, in all its functional operations, is essential to the economic well-being and the national security of the United States. Increased "exportation" of petroleum refining capacity outside the United States results in the loss of domestic financial and manpower employment opportunities; reduces taxation revenue to federal, state and local governments; results in larger deficits in the U.S. balance of trade and payments; and adversely affects other types of manufacturing.

The United States Must Have a National Sense of Purpose to Solve the Energy Problems

A long-term national sense of purpose must evolve to meet the social and economic issues related to energy problems similar to the national dedication to environmental conservation and full employment. It is this dedication and the cooperation among government, industry and private citizens that must be expanded if the issues relative to locating and siting future refining facilities are to be resolved. Environmental issues and aesthetic considerations must be balanced against the socio-economic benefits of developing adequate sites for refining facilities to meet public requirements. The need to provide our Nation with adequate energy at a reasonable cost is a matter of such vital concern that it will necessitate rational resolution of the inconsistencies and conflicts emerging in federal, state and local planning involved in siting and other considerations.

The Federal Government Should Encourage an Economic and Fiscal Climate Conducive to Energy Development

It has been projected that meeting U.S. energy requirements during the 1971-1985 period will require capital outlays of between $450 and $550 billion. For such vast sums of money to be generated by U.S. energy suppliers, several conditions must exist:

- *Competition:* Competitive markets are a particularly effective mechanism for determining price levels necessary to balance energy demand and supply. The complex operation of market forces will best serve consumers and the national interest by providing energy in amounts needed and in forms preferred for environmental reasons. Market forces, if unfettered, would promote efficient use of energy and allocate

* NPC, *U.S. Energy Outlook-A Summary Rep01't of the National Petroleum Council* (December 1972), pp. 75-80.

resources among energy activities on an economical basis.

Vigorous competition requires unrestricted entry into the various energy fuels markets, subject to applicable antitrust laws. Competition is stimulated when a supplier of one fuel can provide additional capital investment, technology and management skill for the development of other fuels.

- *Free Market Prices:* A favorable economic climate enabling companies to generate internal sources of capital as well as to compete in capital markets is essential to the long-term development of energy resources. Profitability is essential to free enterprise, and prices must be permitted to reflect costs and provide an adequate return on invested capital.

Because of the deep and inseparable relationship between domestic refining and the world petroleum industry, it is very unlikely that the problem of new refining capacity will be met without restoring the free play of an open domestic market. In recent years, product prices have been inadequate to provide sufficient return on new investments commensurate with the risks involved. Any external forces such as price controls which hold prices below market clearing levels will continue the trend of insufficient returns of the industry. Flexibility to adjust prices based on market supply and demand forces within the United States should be sufficient to permit realization of an adequate return on present and future investment.

- *Fiscal Policies:* Fiscal policies, such as the investment tax credit and accelerated depreciation rates, should be utilized to foster the availability of capital requisite for the construction of new refineries. Such policies should be designed to encourage growth of domestic refining, petrochemical and SNG facilities.

Whatever policies are adopted should be clear and firm. If investors believe that government inducements to build onshore refineries are temporary, the economic attractiveness of onshore refineries will be weakened. For example, turning the investment tax credit on and off to control the economy is not an effective inducement to refinery construction.

Import Policies Should Be Designed to Encourage the Growth of Domestic Refining Capacity *

Increasing product imports at the expense of domestic refining capacity would place the United States in a position of having to depend on foreign sources for a growing part of its crude oil supply. It would also, to an increasing degree, result in U.S. dependence on foreign processing capacity. This would appear to be contrary to U.S. national security and national defense as defined by Section 232 of the Trade Expansion Act of 1962.

In order to be effective, any system of import controls, whether quota restrictions or variations thereof, should at the very least consider-

- More favorable provisions for importation of crude oil than refined products
- Provisions to ensure a market for all domestic crude production
- Policies that provide the domestic refiner assurances of an adequate and long-term supply of crude oil from domestic as well as foreign sources and, in so doing, assure maximum utilization of existing refining capacity
- Incentives to offset the disadvantages faced by domestic refiners when manufacturing products currently exempt from formal quota control
- Provision for maintenance of the U.S. petrochemical industry's competitive position in world markets
- Consistency and stability in order to provide refiners the basis for establishing long-term planning objectives
- Emergency reserve oil storage capability †
- Compatibility with overall objectives of national energy policy.

The Construction of Modern Transportation Facilities Should Be Encouraged

Unloading facilities for VLCC's, built as close as practical to the coastal refining centers, result in the lowest cost transportation system. This would ideally place the unloading facility just offshore, with onshore distribution made by pipeline. The site must have sufficiently deep water, uncongested approaches from the sea

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* *The President, in his energy message to Congress of April 18, 1978, has removed by proclamation all existing tariffs on imported crude oil and products and has suspended direct control over the quantity of crude oil and refined products which can be imported. In place of the control system, the President has initiated a license fee system. The President stated that, to encourage domestic refinery construction, crude oil in amounts up to three-fourths of new refining capacity may be imported for a period of 5 years without being subject to any fees.*

† An in-depth analysis of this subject is currently being made by the NPC's Committee on Emergency Preparedness.

and minimum potential for environmental disruption. With the equipment possible under the existing technology, near pollution-free operation is attainable. In addition, if it is not at an existing terminal or refinery, the site should have an onshore area suitable for oil storage facilities and access to a sufficient infrastructure for support of the facility. Specific site locations for deepwater terminals are currently under study by government and industry groups. Because offshore refineries can take advantage of the lower unit costs associated with VLCC's and deepwater ports, the lack of such facilities has in the past and will continue in the future to act as a disincentive to the construction of domestic refining capacity.

An additional cost to a domestic refiner of foreign crude oil would be incurred by legislation requiring receipt in American flag tankers. Any benefits of such legislation to the economy must be weighed carefully against the added costs incurred.

A Rational Balance Must Be Achieved Between Environmental Goals and Energy Requirements

The goals of a cleaner environment and increased domestic refining capacity are not incompatible. Both are important to the Nation's well-being, and both can be accommodated. It is not necessary to export refining capacity to maintain a reasonably clean environment.

Recent experience has shown that many of the present refineries can be expanded and the necessary new refineries can be built while achieving a satisfactorily clean environment. In this effort to expand our energy supply, it is essential that the emission standards imposed be realistic. As zero emission levels are approached, costs and operating problems tend to become excessive, often without measurable benefit to the environment and often with attendant waste of resources.

Economically viable refineries have certain requirements for their location. These include land space, access to raw material supply, product distribution systems and adequate labor. While local communities should be concerned with environmental protection, they must recognize the Nation's need for essential plants and facilities. Regulations regarding the official sanction of refinery sites should be revised to speed up the approval process while maintaining proper environmental protection for the communities involved.

The cost benefit of the following features of environmental improvement must be weighed carefully. In particular, it should be noted that, as environmental standards are made more restrictive, costs and the use of irreplaceable resources go up at an increasing rate.

- Consumption of petroleum products will be increased by the substitution of low-sulfur residual fuel oil, liquefied petroleum gas (LPG) and distillate fuels for natural gas and non-petrOleum fuels (such as coal) as well as by the use of less efficient automobile engines.
- Refining costs and crude oil requirements will be increased substantially in order that fuels meet Environmental Protection Agency (EPA) proposed lead regulations and the required auto emission standards established by the 1970 amendments to the Clean Air Act.
- Transportation costs will be increased by banning deepwater port construction and construction of refineries in the most economical locations.
- The magnitude of expenditures for environmental needs are significant as even large refineries (over 100 MB/CD) report costs in excess of 10 percent of all refinery investment to meet environmental regulations.

Both Government and Industry Should Continue to Promote Energy Conservation and Efficiency of Energy Use in Order to Eliminate Waste of Our Resources

Energy producers and the U.S. Government should exert positive leadership in advocating energy conservation measures. However, forced reductions in energy consumption should be employed only on an emergency basis.

A reduction in future petroleum requirements can be achieved if the Nation takes timely and vigorous steps to use petroleum products and natural gas more prudently than it has in the past. To the extent that conservation results in reduced consumption, the strain on domestic refining capacity will be lessened. Additionally, the burden of either crude oil or product imports will be reduced.

Federal Policies Should Encourage Domestic Crude Oil and Natural Gas Production and Development of Synthetic Fuels

Assurance and stability of crude oil supply is necessary to plans and programs for expanding or building refining facilities. Increased availability of domestic crude oil supply offers the greatest assurance against future supply interruptions and provides a stable economic climate which would attract and encourage private investment capital for the construction of refining facilities. Utilization of the Nation's vast resources of coal, oil shale and tar sands to manufacture synthetic oil and gas for fuels and feedstocks will also have a stabilizing effect on the assurance of supply and the stability of the economic climate.

Similarly, additional domestic supplies of natural gas should be encouraged in order to decrease the burden placed on refining capacity to manufacture those additional products which are now required due to current shortages of natural gas.

The artificially low price for gas established by the Federal Power Commission (FPC) has influenced the consumer in both choice of energy source and the amount used. The competitive price established for alternate fuels, such as coal, fuel oils and heating oils, has affected production and the economics of producing these alternate sources of energy. Rapidly increasing consumer demands for natural gas-the "cheap" fuel-coupled with insufficient supplies have contributed to the overall energy shortage.

The Federal Government Should Coordinate the Many Competing and Conflicting Agencies Dealing with Energy

Much of the confusion and delay that now plagues energy suppliers stems from conflicts among government agencies. All too often one agency may encourage an action while another agency prohibits it. Consistent guidelines and stability of policy on energy matters are necessary to ensure that the Nation's vital needs are met.

Part Two
Summary of the Full Report of the Committee

Chapter One

Trends in Petroleum Refining Requirements, Capacity and Capabilities

Introduction

In this report, refining capacity is defined as the capacity to process crude oil, i.e., crude oil throughput for the purpose of manufacturing refined products. The processing of crude oil to finished products requires many varied steps. These steps or unit processes are determined primarily by two considerations: (1) the type and quality of crude oil to be processed and (2) the type and volume of finished products desired. Each refinery in the United States processes a mixture of crude oils different from that being processed in any other refinery, has a different configuration of processing units to convert the crude oil to refined products, and produces a different mixture of refined products. Therefore, reported refining capacity is based on a certain type of crude oil being processed and the manufacture of a premised mixture of refined products having defined characteristics or meeting certain specified requirements.

A change in the type of crude oil available to a refinery will affect the capacity of the refinery to process crude oil. Many refineries are designed to process low-sulfur crude oils and would soon become inoperable if significant volumes of high-sulfur crude oils were processed. Appendix 3, "Fundamentals of Refining Operations and Product Use," is a brief explanation of basic information and interrelationships concerning crude oils, refining operations and refined products.

In order to develop data for a study of domestic refining capacity, it was considered important to have not only historical data but also data concerning the current status and future plans for additional refining capacity. For this purpose, a survey questionnaire was submitted to all companies operating refineries in the United States. The respondants represented over 90 percent of U.S. capacity. Key conclusions and data derived from the questionnaire are used throughout this volume, and a summary of the survey results is included as an appendix in the full report of the Committee. It should be noted that the survey data reflect present and future plans as of the fall of 1972. The results serve as a background against which effects of recent economic and governmental changes can be evaluated.

Historical and Projected Product Demands

The requirements for refining capacity are related to and dependent upon petroleum product demands. The NPC has recently made a comprehensive long-term projection of petroleum demand in the United States through 1985.* These projections were used with some near-term adjustments, and the future requirements for refining capacity were estimated from these projections. That report projected the energy outlook through 1985, assuming that government policies and regulations and the economic climate for the energy industries existing at that time would continue without major changes.

In the Initial Appraisal, an assessment was made of total U.S. energy consumption by market sectors. The various fuel subcommittees applied their respective judgments in deciding what factors would affect demands for the particular fuel examined and took into account the probable supply of other fuels. The resulting U.S. energy balance for the Initial Appraisal is shown in Figure 2. From this balance, final

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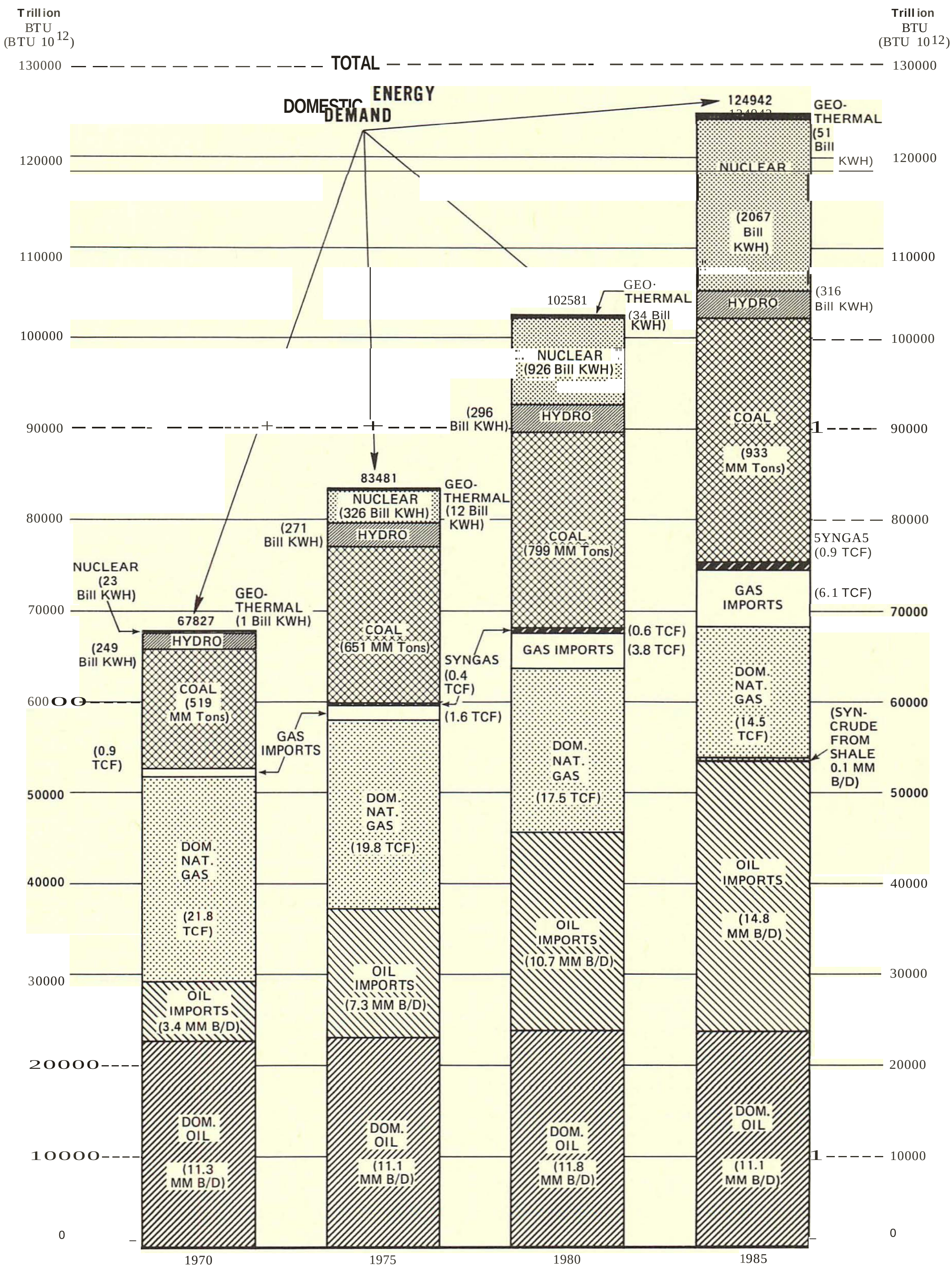
* NPC, *U.S. Energy Outlook: An Initial Appraisal 1971-1985*, Volume Two (November 1971).



Source: NPC, "U.S. Energy Outlook: An Initial Appraisal 1971-1985," *Volume One (JUly* 1971), *p. 15.*

Figure 2. U.S. Energy Balance-Initial Appraisal.

projections of future demand for refined products were made.

Examination of Figure 2 shows that the demand for energy is expected to almost double during the 1971-1985 period. In order to meet these energy requirements, a tremendous investment program is required to find and produce more oil and gas; to build the refineries that are needed to process the additional volumes; and, at the same time, to expand the distribution systems that will deliver the additional products to the consumer. Other energy suppliers will also have to expand, and they will require additional funds to develop new coal and uranium mines, to build nuclear and conventional power stations, and to develop technology to commercialize new sources of energy. Substantial investments will also be required so that existing as well as new facilities can meet environmental standards.

The historical growth rate for refined products shows an average increase of 3.2 percent per year from 1961 to 1965 and 5.1 percent per year from 1966 to 1970. Future demand for petroleum products is expected to grow at a rate of 5.7 percent per year from 1971 to 1975, 2.7 percent from 1976 to 1980 and 3.0 percent per year for the 1981-1985 period. The historical data and the projected growth rates are shown in Table 1.

The historical demand for petroleum products and the Committee's projection of future demand for these products are plotted in Figure 3. However, there are many factors which can alter future demand for products. Already, environmental concern over pollution from high-sulfur fuels has reduced or eliminated the use of traditional fuels such as coal and high-sulfur residual oils in many areas. Since reserves of natural gas and supplies of low-sulfur residual oils are insufficient to fill the void, many industrial consumers have had to switch to distillate fuels. This situation, plus the swing by big consumers on interruptible gas service to the use of propane, butane or distillates, further compounds the problem of projecting demand.

Historical and Projected Domestic Refining Capacities

Prior to making projections of future refining capacity, historical data concerning past capacity, additions or abandonments and refinery condition were considered. In the 10-year period, January 1, 1962, to January 1, 1972, additions to capacity totaled 5.4 MMB/CD while reductions to capacity totaled 2.1 MMB/CD. Nearly 78 percent of the added capacity was accomplished through expansion of or additions to existing facilities. Grass roots refineries were also constructed during the period, but they accounted for only 1.2 MMB/CD of capacity additions. The concurrent reductions in capacity included partial or total shutdowns of 73 refineries.

Comparisons between Bureau of Mines and NPC questionnaire data indicate that only minor changes in total refinery operating capacity occurred in 1972. Based on historical performance, it would be reasonable to expect

TABLE 1

TOTAL U.S. DEMAND FOR REFINED PETROLEUM PRODUCTS-1960-1985

	Total U.S. Demand* (MMB/CD)	Average Annual Growth over Previous Period	
			MMB/CD
1960	10.0		
1965	11.7	3.2	0.32
1970	15.0	5.1	0.66
1975	19.8	5.7	0.96
1980	22.6	2.7	0.54
1985	26.2	3.0	0.73
1970-1985 Average		3.8	0.77

* Includes adjustments of Figure 2 data for export demands and more recent 1975 projections.

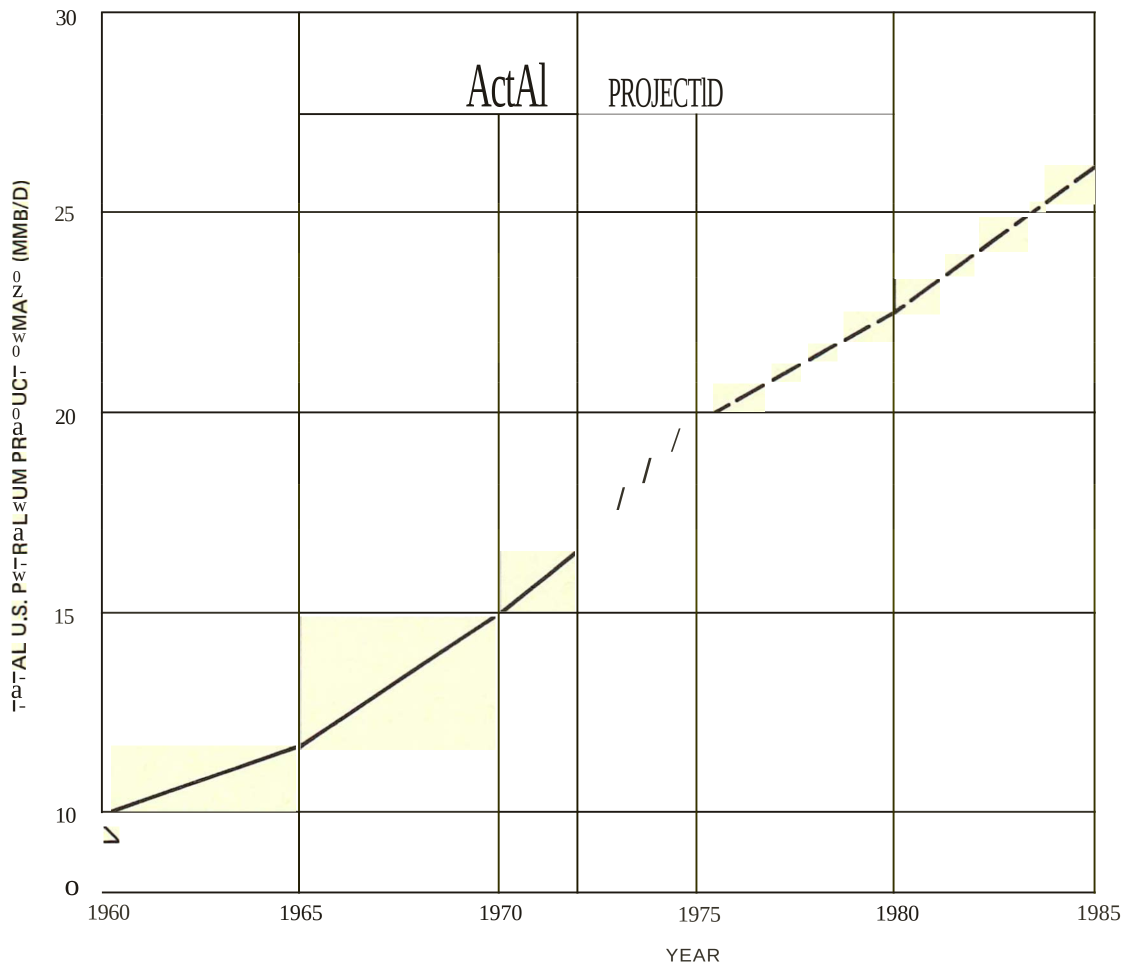


Figure 3. Total U.S. Demand for Refined Products-1960-1985.

that, in the future, about 2 percent of the Nation's refining capacity (or about 0.3 MMB/CD) will be abandoned each year. These shutdowns reflect obsolescence due to a combination of logistic, technological, environmental and economic considerations. The fact that little operating capacity was reported to be shut down during 1972 probably reflects the current and growing shortage of U.S. refining capacity, and there may be a temporary deviation from the historical abandonment trend. However, it should also be pointed out that the refineries not responding to the survey generally are small. Historically, small refineries have had the highest abandonment rate, with the average size of shutdowns during the 10-year period beginning January 1, 1962, being under 30 MB/CD.

An additional factor which leads to a reduction of capacity is the type of crude oil processed. As discussed in detail in Appendix 3, if a refinery is forced to process certain types of crude oil for which it was not designed, its effective throughput capacity will, in many cases, be reduced substantially. For example, a refinery designed to process a crude oil with a high gravity cannot process equivalent volumes of low-gravity crude oil. Both domestic and foreign low-sulfur crude oils are in short supply, and many refineries are designed to process only this type of crude oil, both from a metallurgical and from a processing viewpoint. High-sulfur crude oils, the type generally available from foreign supply sources, cannot be processed in a refinery designed for low-sulfur crudes without the installation of additional facilities and/or extensive modification of existing facilities to prevent corrosive damage and to meet product specifications.

Based on the results of the industry questionnaire, the operating capacity of U.S. refineries as of January 1, 1973, was 13.2 MMB/CD. This total represents nearly 12.3 MMB/CD of reported operating capacity and slightly under 1.0 MMB/CD of capacity operated by companies not responding to the NPC questionnaire. This capacity compares with the 13.0 MMB/CD of total U.S. operating capacity as reported by the Bureau of Mines as of January 1, 1972.

Results of questionnaire responses were also tabulated for planned refinery expansions, abandonments and grass roots construction through 1978 and are shown in Table 2. These changes to capacity and the resulting total capacity based on survey results reflect plans as of late 1972. Recent changes in the political and economic climate are not reflected.

Figure 4 and Table 3 show the historical data, the response to the questionnaire, and a projection of the data-not a forecast-to the year 1985.

Also shown in Figure 4 are historical and projected crude oil throughput rates to refineries. In Figure 4, and in all projections of required refining capacity, a 92-percent refinery utilization factor has been used (i.e., 92 barrels of actual crude throughput for each 100 barrels of crude oil distillation capacity). Historical experience shows that this represents the highest rate which has been sustained by the industryon a year-in, year-out basis. The question of the industry being unable to run at 100 percent of rated crude distillation capacity arises from the anomoly in the definition of a "crude distillation capacity." It does not take into account the fact that other materials, such as natural gas liquids, unfinished oils and partially refined oils, are often run in the crude distillation unit. A refinery is a continuous flow operation, and any imbalances in the capacity of essential downstream units, such as catalytic cracking and catalytic reforming units, can restrict the overall refinery input volume. Operating capacity cannot be recovered if problems occur when operating at maximum rates. Variations in crude oil supply, type and transportation, as well as unexpected process unit downtime, etc., make the use of an overall industry utilization factor necessary.

Refining Capacity Shortfall

Until recently, the shortfall in U.S. refining capacity has been primarily confined to heavy oil capacity. This deficit developed over many years and was essentially attributable to the underlying economics of fuel use patterns and domestic refining. As the real price of industrial fuels fell, domestic refiners became increasingly unable to compete. Foreign refiners with unlimited access to low cost foreign crude could build relatively simple and inexpensive refineries to supply the U.S. heavy fuel oil market at a cost competitive with gas and coal. Import policies recognized the prevailing economics affecting the manufacture of residual fuel oil in the United States and provided accordingly for liberal importation of heavy oils.

Under these circumstances, refinery capacity to meet demand for heavy oils in the United States was increasingly built in the offshore areas adjacent to the U.S. markets, and U.S. capacity was designed to increase light product yields. The economics for an offshore refinery to produce fuel oil are, however, changing. Low

TABLE 2

U.S. OPERATING REFINING CAPACITY
QUESTIONNAIRE RESPONSE
(MMB/CD)

	1973	1974	1975	1976	1977	1978
Beginning-Year Capacity	13.2	13.2	13.5	13.9	14.6	14.6
Add: Grass Roots		0.1	0.1	0.4		0.3
Expansion		0.2	0.4	0.4	0.1	0.1
Less: Abandonment			0.1	0.1	0.1	
Year-End Capacityt	13.2	13.5	13.9	14.6	14.6	15.0
Mid-Year Average Capacity	13.2	13.3	13.7	14.3	14.6	14.8

* Less tnan 0.1.

t Includes 1.0 MMB/CD capacity not reported to questionnarie.

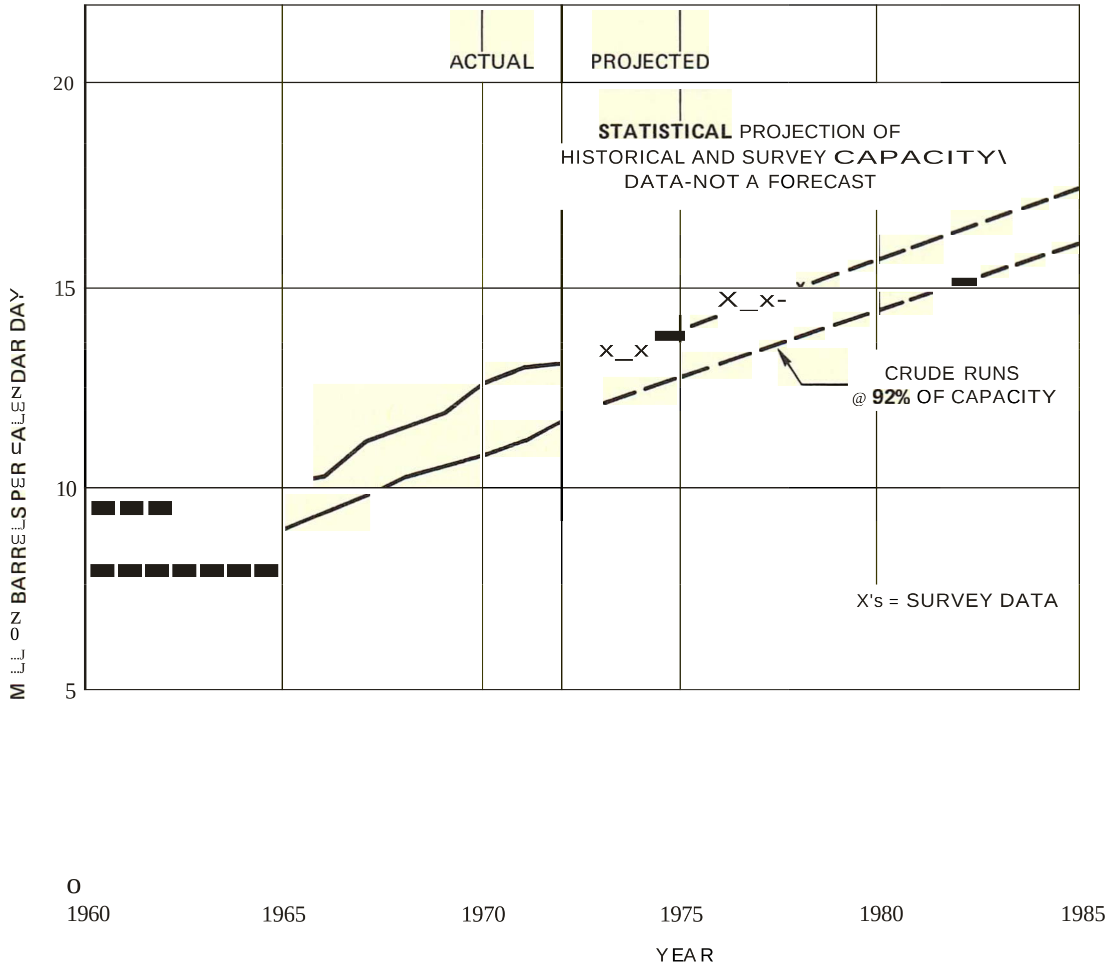


Figure 4. Total U.S. Operating Refining Capacity and Crude Runs (Year-End Capacity)-1960-1985.

TABLE 3

TOTAL U.S. REFINING CAPACITY-
ACTUAL AND PROJECTED*

	Number of Operating Refineries	Total U.S. Mid-Year Average Refining Capacity (MMB/CD)
1960	290	9.6
1965	273	10.2
1970	262	12.3
1975		13.7
1980		15.6
1985		17.4

* Not a forecast.

TABLE 4

COMPOSITION OF U.S. IMPORTS OF REFINED PETROLEUM PRODUCTS*
(MB/CD)

Product Group	1960	1965	1970	1972
Light Products				
Gasoline	27	27	67	68
Jet Fuels	34	81	144	195
Middle Distillates (Ex. No. 4 Fuel Oil)	35	36	81	97
LPG	4	21	52	89
Petrochemical Feedstocks		1	15	8
Solvent Naphthas		8	6	2
Total Light Products	100	174	365	459
Heavy Products				
Residual Fuel Oil	637	946	1,528	1,742
No.4 Fuel Oilt			70	85
Asphalt	17	17	17	25
Lubricants and Wax			1	3
Total Heavy Products	654	963	1,616	1,855
Natural Gasoline and Plant Condensate			6	86
Unfinished Oils	45	92	108	125
Total NGL‡ and Unfinished Oils	45	92	114	211
Total Product Imports	799	1,229	2,095	2,525
Bonded Products Included Above				
Light Products	20	51	144	179
Heavy Products	104	136	117	125
Total Bonded	124	187	261	304
Imports for Consumption				
Light Finished Products	80	123	221	280
Heavy Finished Products	550	827	1,499	1,730
Total Finished Products Imported for Consumption	630	950	1,720	2,010
NGL and Unfinished Oils	45	92	114	211
Total Imports for Consumption	675	1,042	1,834	2,221

* Data from U.S. Department of Commerce, as reported by Bureau of Mines.

t Census classified No.4 fuel oil as distillate fuel and industry as a heavy fuel.

‡ Natural gas liquids.

cost and low-sulfur foreign crude oil supplies which provided incentives for offshore manufacture of heavy fuel oil are in tight supply. Additionally, demand for low-sulfur fuel oil has increased substantially and, in order to increase production levels, refiners may have to install costly desulfurization equipment when appropriate crudes can be obtained.

Generally, however, U.S. domestic refining capacity was adequate to meet refined product demand until the 1960's. Since that time, a shortfall in refining capacity has been developing, and total product imports have been increasing sharply as shown in Table 4. It should be noted that a large share of the total imports were heavy fuel oils and that a large share of the light product imports were bonded fuels. Also, a large portion represented unfinished oils imported for final processing in U.S. refineries. Table 5 shows the trend in refinery capacity utilization over the last 12 years. As a rule, the physical capacity has existed to meet total light product demands. In 1972, U.S. product demand increased more than 1.1 MMB/CD, or 7.4 percent. Domestic capacity plus authorized imports became insufficient to meet demand and, as a result, large draw-downs of inventories occurred. Current industry projections for 1973 show that another large increase in demand may be expected, and therefore even higher levels of product imports will be required to meet demands.

Figure 5 provides a graphic demonstration of the widening spread between refinery capacity required to satisfy total demand for products and the estimated refining capacity to be available. For 1975, the shortfall of refining capacity is projected to be 4.8 MMB/CD or 25.9 percent. By 1980, this may increase to 26.7 percent, and in 1985 product demand is projected to exceed U.S. capacity by 30.7 percent or 7.7 MMB/CD. A tabulation of these data is included in Table 6. Tables 7 and 8 show basic data and derivations of capacity requirements.

Oil imports must rise rapidly in the short term in order to covel' the growing gap between total requirements and domestic porduction. Oil import policies, comparative economics of U.S. and offshore refineries, and environmental concerns bear importantly on how much oil refining capacity will be built in the United States during the next 15 years. This in turn will determine the ratio between crude and product imports. Unless sufficient refinery capacity is added to meet growing consumer needs for nonresidual products, the United States will be forced into reliance on imported light products (e.g., motor gasoline, aircraft fuels and home heating oils) and will continue to be dependent on imports of heavy fuel oil.

TABLE 5

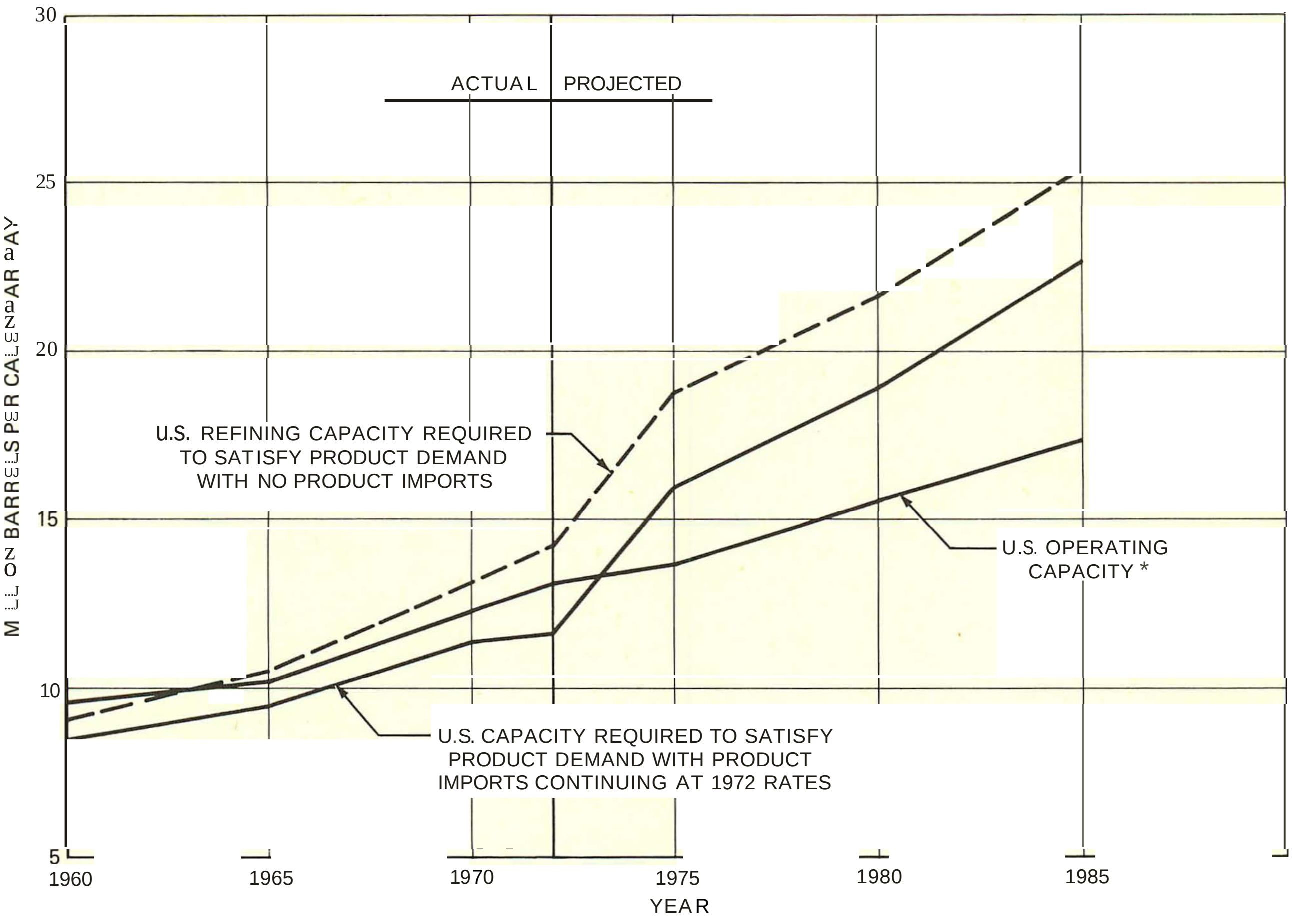
TRENDS IN U.S. REFINING CAPACITY UTILIZATION*
(MB/CD)

	1960	1965	1970	1972
Crude Runs to Stills	8,067	9,043	10,869	11,699
Estimated NGL and Unfinished Oils Processed in Crude Units	403	452	546	586
Estimated Total Throughput in Crude Units	**8,470**	**9,495**	**11,415**	**12,285**
Average Crude Distillation Capacity (Mid-Year)	9,587	10,166	12,270	13,134
Apparent Spare Crude Distillation Capacity	1,117	671	855	849
Finished Products Imported for Consumptiont				
Light Oils	80	123	221	280
Heavy Oils	550	827	1,499	1,730
Total Finished Products Imported for Consumption	**630**	**950**	**1,720**	**2,010**
Refinery Capacity Equivalent‡	685	1,033	1,870	2,185
Apparent Shortfall in U.S. Refining Capacity to Meet Total Requirements	(432)	362	1,015	1,336

* U.S. Bureau of Mines data.

t Excluding imports in bond and fuels imported for military offshore use.

‡ Imports converted to capacity equivalent using 92-percent utilization factor.



* Statistical projection of historical and survey capacity data-not a forecast.

Figure 5. Total U.S. Operating Refining Capacity vs. Requirements-1960-1985.

TABLE 6

PROJECTION OF TOTAL U.S. REFINING CAPACITY SHORTFALL 1960-1985

	Mid-Year Average Refining Capacity (MMB/CD)	Total Refining Capacity Required to Satisfy Product Demand (MMB/CD)	Shortfall MMB/CD	Shortfall %
1960	9.6	9.1	(0.5)	(5.2)
1965	10.2	10.5	0.3	2.9
1970	12.3	13.2	0.9	6.8
1972	13.1	14.3	1.2	8.4
1975	13.7	18.5	4.8	25.9
1980	15.6	21.3	5.7	26.7
1985	17.4	25.1	7.7	30.7

TABLE 7

U.S. PETROLEUM SUPPLY AND DEMAND-1970-1985
(MB/CD)

	1970 Actual	1972 Actual	1973 Estimated	Projection 1975	1980	1985
Total U.S. Product Demand	14,942	16,589	17,600	19,800	22,550	26,200
Refinery Capacity (Mid-Year Average)	12,270	13,134	13,234	13,735	15,614	17,359
Refinery Crude Runs*	10,869	11,699	12,175	12,636	14,365	15,970
Unfinished Oil Reruns (Net)	105	141	150	200	250	300
Process Gain	359	388	400	415	500	550
Product Output	11,333	12,228	12,725	13,251	15,115	16,820
Supply Factors						
NGL Transfers	1,663	1,827	1,860	1,700	1,600	1,500
Other Hydrocarbon Inputs	17	28	30	48	75	150
Crude Transfers to Fuel Oils	14	12	12	12	12	12
Finished Product Imports						
Bonded Fuels	261	304	325	375	500	625
Imports for Consumption†	1,720	2,010	2,648	4,414	5,248	7,093
Decrease in Product Inventories	-66	180				
U.S. Refinery Output	11,333	12,228	12,725	13,251	15,115	16,820
Total Supply	14,942	16,589	17,600	19,800	22,550	26,200

* Refinery crude runs calculated at 92 percent of refinery capacity-1973-1985.

† Imports for consumption assumed to balance supply/demand-1973-1985.

TABLE 8

APPARENT SHORTFALL IN U.S. REFINING CAPACITY 1973-1985
(MB/CD)

	1973 Base	1975	1980	1985	1985 over 1973*
Average Crude Capacity	13,234	13,735	15,614	17,359	4,125
Finished Products for Imports Required to Balance Supply/Demand	2,648	4,414	5,248	7,093	4,445
Capacity Equivalent of Product Imports†	2,878	4,798	5,704	7,710	4,832
Capacity Required to Meet Total Product Requirements	16,112	18,533	21,318	25,069	8,957

* To meet demands and replace all product imports by 1985, capacity required:

1985 - 25,069
1973 - 13,234
11,835 MB/CD or approximately 1 MMB/CD per year growth in capacity required.

† At 92-percent utilization factor.

Chapter Two

Factors Affecting Refining Shortfall and Environmental Considerations

Factors Affecting Demand for Capacity

There are four major factors affecting the need for individual petroleum products and crude oil. These are-

- The demand for energy in the United States which is projected to grow at an average rate of 4.2 percent per year through 1985
- The supply of natural gas which has become very short due to decreasing discoveries and increasing demands
- Environmental concerns which have greatly contributed to the delay in many nuclear power plants being constructed or going on-stream
- Environmental legislation which is causing, or will cause, the displacement of high-sulfur coal and fuel oil and leaded motor gasoline by low-sulfur fuel oil and low-lead or unleaded motor gasoline.*

Fluctuations in total oil demand and in demand for individual products stem from the fact that, although oil is not completely interchangeable with other fuels in existing equipment, it can supply the needs in any energy sector of our economy. In effect, it can act as a "swing" fuel. If natural gas finding rates are disappointingly low in the future, oil can be used to fill the need. The same concept holds true for oil as an alternate to nuclear power and coal when appropriate.

The power industry's efforts to utilize nuclear power plants have been delayed by construction lead time problems, cooling water discharge standards and environmental court actions. There are not sufficient production facilities for low-sulfur coal, and there are not sufficient reserves of low-sulfur coal within reasonable distances to satisfy the demand. Thus, many power plants have been, or will be, converted to run on low-sulfur fuel oil. This conversion has increased the demand for fuel oil over normal rates, thus contributing to the current low-sulfur fuel oil shortages.

Additionally, the supplies of low-sulfur crude oil are limited, and their worldwide availability will tighten as countries compete more vigorously in the world market for a limited resource. Also, low exploration finding rates and limited lease sales have led to few new domestic sources of oil being developed.

On January 10, 1973, the EPA published its regulations requiring the general availability of unleaded gasoline by July 1, 1974. These regulations were issued on the premise that a catalytic device was necessary to control auto emissions, that a suitable device (50,000 mile life) could be developed, and that lead would poison the catalyst. EPA also proposed that leaded grades of gasoline be limited to 2.0 grams per gallon of lead by January 1, 1975, and 1.25 grams per gallon by January 1, 1978.

One direct effect of the techniques used to control these emissions is that a vehicle's fuel efficiency is lowered. As a result, it is necessary to process more crude oil in order to produce the additional gasoline that is required. Restricting the use of lead additives in gasoline will require refiners to use more crude oil in order to produce more high-octane gasoline components. If the volatility of today's gasoline

In his April 18, 1973, energy message, the President affirmed EPA's call to use the most environmentally desirable fuels only for attainment of "Primary" air quality standards (those related to health) as outlined by the 1970 Clean Air Act Amendments and allow orderly attainment of the more stringent "Secondary" standards (those related to general welfare).

has to be changed to accommodate emission control objectives, which was proposed at one time by a major automotive manufacturer, the use of more crude oil will be required. The cumulative effect of all these requirements could cause an increase in our need for crude oil distillation capacity by 1985 beyond that shown in Figure 5.

Factors Affecting Expansion of Refining Capacity

Within today's economic climate, there are uncertainties and technological problems which contribute to the shortfall of refining capacity, as described in the following:

- There is difficulty in economically providing flexibility in capacity to accommodate the varying characteristics of the crude oil resulting from uncertain supply sources. During the latter part of 1972 and the early part of 1973, inland refineries have operated at reduced rates due to a lack of crude oil. Some Gulf Coast refineries have operated at reduced rates both due to a lack of crude oil and due to the type of crude oil available to them. When considering refinery expansion or the addition of new refineries, it is necessary, for proper design of the type and size of process conversion units, to know the characteristics of the crude oil to be processed.
- When considering the expansion of current refineries or the addition of new refineries, there are uncertainties as to how to process the heavier portion of the crude oil. Low-sulfur residual can be produced directly from low-sulfur crude oils. However, additional low-sulfur domestic crude oils are not available, and low-sulfur crude oils from North and West Africa, the Middle East and Indonesia are not available in sufficient quantities due to limited production and the competition for these crude oils by other countries. The coking process can be used on high-sulfur residuals, but disposing of the high sulfur-content coke presents a problem due to environmental restrictions.

  Direct desulfurization of high-sulfur residuals can presently be accomplished only on certain low metal-content residuals. Low-sulfur residuals can be produced from high metal-content residuals by the indirect route of desulfurizing the gas oil and then blending the desulfurized gas oil with the residual. This operation, however, offers only limited reduction in sulfur levels and, as a result, is not capable of producing enough of the high volumes of 0.3-percent-sulfur heavy fuel oil required in certain areas.

  Flue gas desulfurization which would allow the use of high-sulfur fuels has received widespread attention, but full scale commercial flue gas desulfurization processing for large installations is still not fully operable. Progress has been slow due to the magnitude and complexity of the problem. These processes are not likely to be in wide use in time to meet existing and proposed environmental targets. Establishing regulations beyond available technology may increase research and development efforts but, at the same time, the growth of the industry can be seriously affected.

Refinery Requirements Responsive to Environmental Needs

Nationwide, the contribution of refineries to atmospheric pollution is relatively small, as shown in Table 9. In local situations, however, control of refinery emissions is required and can be achieved as is shown by the example in Table 10.

The situation with regard to aqueous effluents from refineries is similar in that the national contribution of refineries is not large. Also, reliable technology is available to make refinery effluent water fully suitable for discharge into sensitive aquatic environments.

Among the many steps the petroleum industry has taken to reduce pollution are–

- *Air:* (1) Greater use of low-sulfur fuels and sulfur recovery plants, increased capacity to desulfurize products, development of new processes for removing sulfur oxides from stack gases; (2) control of hydrocarbon emissions and odors by floating roofs on storage tanks, mechanical seals on pumps, closed systems to recover vented vapors; (3) reduction of particulate emissions by smoke controls, electrostatic precipitators and cyclone separators; (4) special furnaces to burn gases containing carbon monoxide; and (5) air quality monitoring instruments.
- *Water:* (1) Expansion of water reuse systems and increased use of air cooling; (2) multiple-stage effluent treating to remove oil and other wastes, biological treatment to remove organic material which might be harmful to marine life; and (3) design and remodeling of facilities to minimize the possibility of oil spillage, closer surveillance of oil transfer operations.
- *Noise and light:* (1) Use of silencers and other devices to reduce noise emissions and (2) use of low-level, shielded and smokeless

TABLE 9

ESTIMATED NATIONWIDE EMISSIONS-1969*
(Million Tons per Year)

	Sulfur Oxides	Particulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Petroleum Refining	2.0	0.1	2.6	2.3	< 0.1
Total Emissions	33.4	35.2	151.4	37.4	23.8

* *Cumulative Regulatorv Effects on the Cost of Automotive Transportation* (RECAT), Final Report of the Ad Hoc Committee Prepared for the U.S. Office of Science and Technology (February 28, 1972).

incinerators to reduce smoke, glare and noise from flares.

Future new refineries will incorporate many of the current emission and effluent control systems together with newly developed processes. Environmental studies at the site will begin before construction to establish and document the preconstruction conditions. These studies will also serve to anticipate any potential adverse impact of the facilities and to permit revisions of the design to minimize or eliminate this impact. These studies will be continued through the initial period of operation to document the suitability of the pollution control facilities as they are designed. Where appropriate, buffer zones will be provided to isolate operating units from surrounding residential or recreational areas. Peripheral landscaping will be used to improve the refinery's appearance.

Existing refineries either are already in conformance with ambient air quality standards or will be under legally binding schedules for installing the necessary equipment. Further, rational evaluations have shown that many of the present refineries can be expanded and the necessary new refineries can be built while achieving a satisfactorily clean environment. In order for the goal of expanded energy supply to be met, it is essential that the emission standards imposed be realistic. As zero emission levels are approached, costs and operating problems tend to become excessive, often without measurable benefit to the environment and often with attendant waste of resources.

TABLE 10

REFINERY AIR CONTAMINANT EMISSIONS
LOS ANGELES COUNTY-JANUARY 1971*
(Tons per Day)

	Sulfur Oxides	Particulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Without Control Program	1,320	15	1,635	1,495	130
With Control Program	55	10	5	295	95

* *Profile of Air Pollution Control* (Air Pollution Control District, County of Los Angeles, Calif., 1971).

Chapter Three

Storage and Transportation Requirements

The NPC U.S. Energy Outlook report projects that future oil demands will increase greatly from present requirements. In addition, it is possible that domestic production will not expand significantly above current levels, necessitating an increase in the importation of crude and/or products. The logistics system, including transportation and storage facilities, to handle increased crude as well as potential product imports will impact upon the consumer as well as upon the construction of U.S. refining capacity.

Added importation of large quantities of oil will require substantial expansion of transportation and storage facilities both to receive the oil and subsequently to transport it to the consuming locations. Considering only the lowest cost logistical system for importing crude oil to onshore refining centers, the amount of capital required for the increase in imports during the 1970-1985 period is very large. Estimated investments for the facilities, including new vessels, range from $14 to $16 billion depending upon whether PAD District I increases are delivered directly to PAD District I or-as reflected in the higher number-whether they are supplied from PAD District III. Figure 6 shows a map of the United States outlining the five PAD districts.

Marine Transportation

Import of petroleum into the United States can be accomplished either with waterborne or with overland transportation systems. Current projections indicate that the majority of import increases will come from the Persian Gulf. Results from the NPC survey show that refiners are planning increased marine receipts of crude. PAD Districts III and V show the largest percentage increases (see Table 11). However, these numbers may understate the problem because, as pointed out previously in this report, U.S. refinery capacity as reported in the 1972 NPC questionnaire will be unable to meet near-term demands. For long-distance hauls, e.g., Persian Gulf to the United States, the most economical and environmentally safe system to receive the oil is via direct shipment from the supply source to the refining center using a combination of VLCC's and properly designed deepwater crude unloading terminals.

Economies of size enable VLCC's to transport crude more economically on longer hauls than can smaller vessels, providing port facilities are available to handle the VLCC's. In order to handle such vessels, ports must have berths of sufficient capacity and length and tankage of sufficient volume for unloading full cargoes. For shorter moves, other transportation systems provide various levels of economy.

In 1970, there were approximately 4,000 ship unloadings to handle petroleum imports to the United States. These ships averaged 30,000 DWT. If projected 1985 imports use this same average ship size, then traffic would increase to approximately 18,000 annual ship calls. Port

TABLE 11

REFINERY RECEIPTS OF CRUDE OIL DIRECTLY BY WATER

(Percent of Total Crude Oil Receipts)

	PAD Districts			Total
		III	V	U.S.
1972	85	15	45	27
1978	87	30	59	38

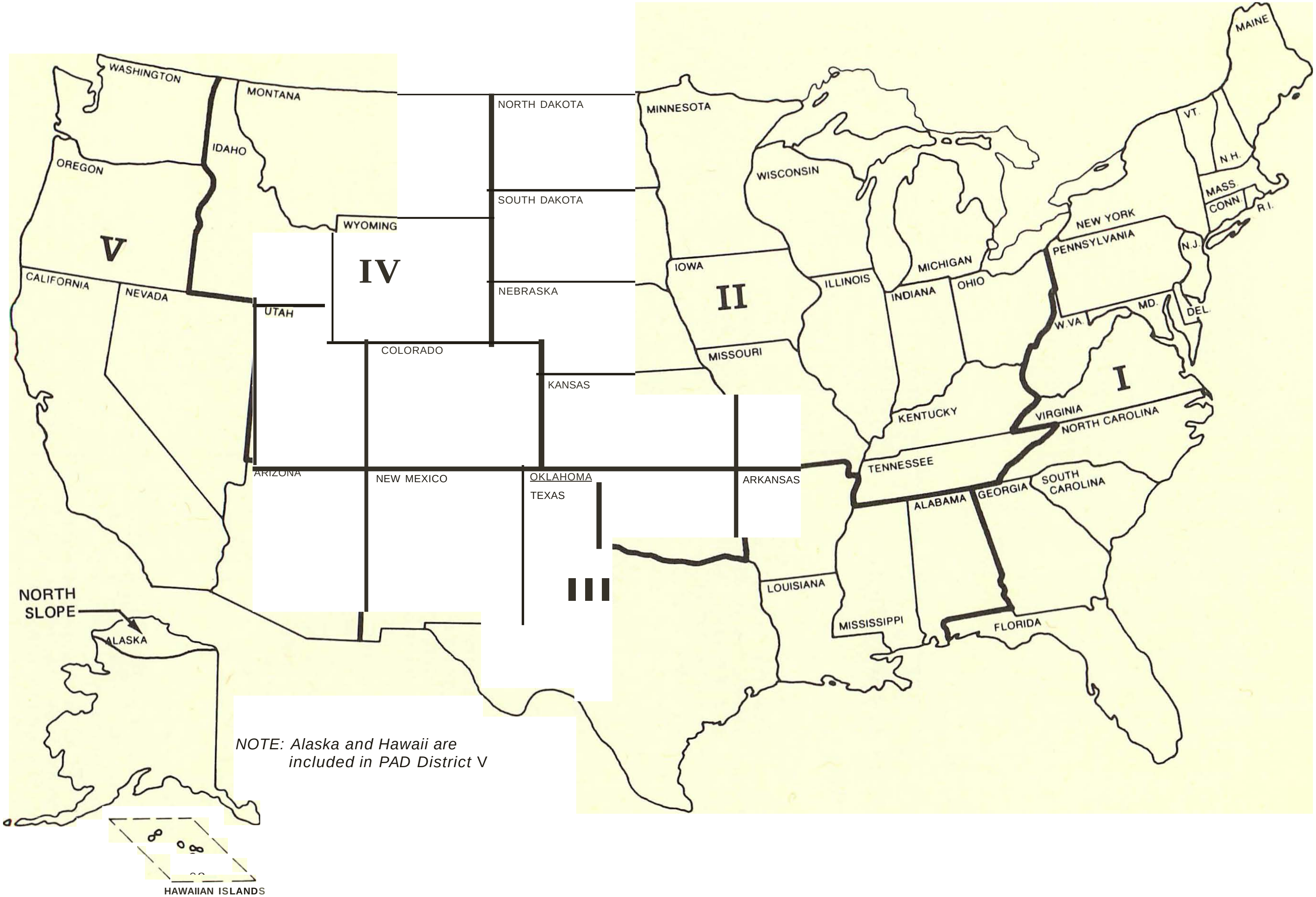


Figure 6. Petroleum Administration for Defense (PAD) Districts.

congestion from these ships will substantially increase the opportunity for accidents and perhaps increased ,vater pollution. If, on the other hand, the imports arrive in optimally sized ships (including VLCC's averaging 250,000 DWT), total activity could be reduced to about 3,000 annual ship calls- a level below 1970 calls.

VLCC's reduce the total number of ships required and thereby reduce the chance of collisions. Furthermore, since VLCC's require 70 to 100 feet water depths (which is more than existing terminals have), new deepwater unloading sites can minimize the intrusion of tankers into existing inner harbors, thus reducing the risk of groundings. Historical data on collisions and groundings demonstrate that most oil spilling accidents occur where harbor congestion is great and when the maneuvering of the ships is restricted by narrow, winding channels.*

There is a great disparity between what refiners plan to do about marine facilities as indicated in the survey and what would have to be done to maximize use of existing sites. Only a net of four berth additions (1972 to 1978) were reported in the survey as planned, a split between Districts I, III and V. Thus, the total reported berths go from 233 in 1972 to 237 in 1978. Most of these berths (138 in 1978) have a water depth of less than 35 feet. Only two locations exist with 60 feet or more water (both in PAD District V). Results of the refinery survey reveal that, if existing refineries were to expand to make maximum use of existing refining sites, over 60 marine facilities would need to be constructed or developed, and 9 of these would require over 60 feet of water.

Unloading facilities for VLCC's, built as close as practical to the coastal refining centers, result in the lowest cost system of operation. This would ideally place the unloading facility just offshore, with onshore distribution made by pipeline.† The site must have sufficiently deep water, sufficient shelter from storms, uncongested approaches from the sea, and minimum potential for environmental disruption. With the equipment possible under the existing technology, near pollution-free operation is attainable. In addition, if it is not at an existing terminal or refinery, the site should have an onshore area suitable for oil storage facilities and access to a sufficient infrastructure for support of the facility. Specific site locations for deepwater.terminals are currently under study by government and industry groups. Much work has been done by the Corps of Engineers which is responsible for development of harbors.‡ The Council on Environmental Quality is making extensive studies of seven locations.§ The Maritime Administration has commissioned a study of a multipurpose terminal off the Delaware Coast.|| Jointly owned terminals have been studied in the lower Delaware Bay area, off Louisiana, and the Texas Gulf Coast, and individual projects have been discussed for many additional sites.**

Cargo Preference Legislation

Cargo preference bills such as those which have recently been before Congress would, if enacted, directly and negatively affect the economic feasibility of U.S. refining. While the most recent bill before the Senate was defeated, there will undoubtedly be continuing attempts to impose U.S.-flag vessel preferences for the shipment of imported oil.

The justification for cargo preference legislation, which would require that a certain percentage of oil imports be carried in U.S.-flag vessels, is the creation of incentives to build up and maintain a healthy and viable U.S.-flag fleet. Although such legislation is intended to improve and benefit distressed conditions in the American Merchant Marine fleet, it raises far more serious problems and complications with regard to (1) U.S. relationships in international trade, (2) the economics of the domestic refining industry, and (3) future cost of energy to American consumers.

There are a great number of substantive reasons why the cargo preference bills are contrary to national economic interests, national security objectives, consumer objectives and, specifically, the oil refining industry.

- The cargo preference legislation would invariably raise costs to the refiner which can be expected to lead to higher retail prices. Thus there is a direct and negative impact on consumer interests. Moreover,

* "Tankers and Ecology," Paper Presented by Joseph D. Porricelli. Virgil F. Keith and Richard L. Storch, at the Annual Meeting of the Society of Naval Architects and Marine Engineers, New York, N.Y., November 11-12, 1971.

† For illustrative calculations comparing deepwater offshore oil terminals with and without pipeline service, see Soros Associates, Inc., *Offshore Terminal System Concepts (1972)*.

‡ For extensive environmental and cost/benefit analysis of use of VLCC's for U.S. imports, see U.S. Department of Army, Corps of Engineers, *U.S. Deepwater Port Study*, IWR 72-8 (Institute for Water Resources, August 1972).

§ U.S., Congress, Senate, Committee on Interior and Insular Affairs, *Deep Water Port Policy Issues*, Serial No. 92-26, April 25, 1972, p. 28.

|| Soros, *Offshore Terminal System Concepts*.

** *The President, in his energy message to Congress of April* 18, 1973, *proposed legislation for Congressional consideration granting the Department of the Interior authority to license deepwater terminals in federal waters.*

the cost will continue to rise as the United States becomes more dependent upon oil imports.

- Narrowing these "flag questions" to the oil industry, and specifically to the refining industry, this study reflects a need for about 9 MMB/CD of additional refining capacity in the United States by 1985. Cargo preference legislation would have a serious adverse effect on new refinery construction to meet this growing demand for products. Such legislation would force refineries to import a portion of their crude in U.S. vessels. This would mean that, as foreign crude accounts for a larger and larger share of total refinery crude inputs, the landed cost of the average barrel of crude would be higher. To the extent that refineries would have to draw crude increasingly from the Middle East, the long haul would raise costs substantially.

  Cargo preference legislation would also severely affect the economics of any incentive plan designed to locate new heavy fuel-oriented refineries in the United States. These plants would run primarily, if not exclusively, on foreign crude. Such new U.S. plants would, however, be competing with existing heavy fuel-oriented refineries located offshore. If these U.S. refineries must use U.S.-flag vessels to import a large portion of their crude, they may well not be competitive with existing foreign heavy fuel refineries. Under such circumstances, it is most likely that refiners would continue to see an incentive to locate heavy fuel refineries in the Caribbean and other adjacent areas.

- Any increase in foreign petroleum import costs would also adversely affect the competitiveness of U.S. petrochemical manufacturers who rely upon imported crude for a portion of their feedstocks.

  If indeed there is a case for a strong U.S.-flag fleet from the standpoint of national security, then the subsidies required to build and operate such a fleet should be covered by the Merchant Marine Act. In fact, a comprehensive Merchant Marine Act providing construction and operation subsidies is already in effect. Under this Act, U.S. Government grants, financed loans and direct federal operating differential subsidies are offered. However this Act is based on dry cargo and liner transportation concepts which are not readily applicable to tanker and dry bulk trading. Consideration should be given to modifying and liberalizing the Merchant Marine Act to apply to the special needs generated by the bulk segment of the U.S. maritime industry.

Pipeline Transportation

In addition to marine transportation, pipelines are a major mode of transportation for petroleum. In 1971, some 64 percent of movements between PAD districts were made by pipeline. The increasing dependence on foreign oil will necessitate additional pipeline systems designed both to move crude from offshore unloading terminals as well as to transport adequate supplies to the many refineries in the country which do not have direct marine access. Additionally, should major expansions of refining capacity occur on the Gulf Coast, it is logical to assume that there will be increasing numbers of product pipelines for moving products from the Gulf Coast to both the Midwest and the East Coast. The need for pipeline capacity to the inland refiner is underlined by the survey results which indicate that the 1978 PAD District II crude running capacity is not matched by crude receipts, with a deficit of 0.4 MMB/CD.

Rail and Truck Transportation

Rail and truck movement of crude is planned to decrease as a percent of crude capacity. Survey results indicate 1972 rail/truck receipts at 1.1 percent of capacity *vs.* 0.9 percent in 1978. Product movements by rail/truck from refineries are projected to remain at the same level (13 percent of capacity).

Storage Requirements

Future requirements for crude tankage volume will be affected by the increased percentage of imported crude and movement of crude over greater distances as well as the increase in average vessel size. At the same time, product tankage requirements will also increase due to increased demand levels. The optimum amount of tankage at a refinery is a function of the size and frequency of crude arrivals and product shipments. The trade-offs are excess tankage on the one hand or tanker delay, commingled stocks or refinery downtime on the other. Number, types and relative amounts of stocks also affect the absolute volume of tankage required.

Refinery tankage, described in terms of days of crude running capacity, has historically tended to decrease over time. The results of the refinery survey show this trend continued relative to reported planned refining capacity. Reported 1972 crude intermediates and product storage capacity available was 87.5 days of crude run, declining to 82.1 days in 1978. This is about the same rate of decline as estimated for actual inventory (as opposed to capacity) from Bureau of Mines data.* This would indi-

* NPC, *Petroleum Storage Capacity* (1970), p. 10.

cate a trend towards higher utilization (Le., inventory level divided by capacity) at the end of the period. Higher utilization is in line with historical trends.* However, if the refining shortfall is to be met with onshore capacity, proportionate volumes of tankage must be added. Alternatively, tankage will be required in the United States for increased product import volumes to meet the refining capacity shortfall. Much of increased product imports may be expected to go directly to consumers (such as shore-located power plants) or distribution terminals. For example, in PAD District I, the largest importing district, significant volumes of storage are located at terminals not associated with refineries. These storage capacities were not included in the refinery storage of the 1972 NPC survey. Hence no statement can be made on the adequacy of tankage to receive imported products. The overall adequacy of tankage including that of refineries, terminals and consumers will be considered in the forthcoming NPC Emergency Preparedness study.

* NPC, *Petroleum Storage Capacity,* p. 6.

Chapter Four

Petroleum Refining Economics*

Important changes are taking place in the economic environment surrounding U.S. refiners. Crude oil supplies are coming from new sources, and prices of foreign crude oils are rising sharply; new environmental regulations are causing changes in product characteristics, making refineries more costly; domestic crude oil supplies are declining; both crude oil and product prices are subject to controls; and a recent sharp surge in oil demand has strained domestic refinery production capabilities. These conditions and the lack of a consistent government approach with respect to matters affecting refineries-particularly long-term access to foreign supplies of crude oil and product import policies-have made the outlook for investments in new refineries in the United States much more uncertain than it was in the 1960's.

A continuation of these conditions will create an increasing shortage of domestic refining capacity between now and 1985. Furthermore, there could be a future worldwide shortage of refining capacity available to supply U.S. markets, depending on economic and political conditions both here and abroad. While the Committee has not evaluated the ability of world refining capacity to meet the growth in both U.S. and non-U.S. world demand, the assumption is made that sufficient refining capacity will be built. However, it is felt that, if petroleum product demands continue the rapid growth which occurred during the last 1 to 2 years and if U.S. policies are not sufficiently responsive to the refining situation, adequate worldwide capacity may not exist. Some of the capacity to meet U.S. demand has already been constructed just outside the perimeter of the United States for the specific purpose of supplying U.S. demand for selected products.

A number of key factors have dictated the decisions made by some companies to establish refining facilities in perimeter locations. Some of these factors are as follows:

- *To accommodate revisions in U.S. import quota restrictions:* Foreign crude oil could be imported without limitations into perimeter locations. Products could be manufactured that were exempted from formal U.S. quota controls, such as residual fuel oil for District I, and exported to the United States.
- *Fo?' logistical consider'ations:* Natural deep-water harbors were available to accommodate larger, more efficient and economical tankers.
- *To minimize the risks associated with acquiring crude oil supply:* Foreign refinery locations frequently provided greater long-term access to necessary foreign crude oil supplies than did refinery locations in the United States.
- *To avoid environmental delays:* In recent years, environmental constraints in. the United States have made foreIgn locations more attractive. Environmental obstacles have been less severe in the foreign perimeter locations in terms of building or expanding refining capacity compared to alternative U.S. locations. These offshore areas have low-density populations and less port siting problems.
- *To minimize overall costs:* EconomIC advantages favored refining operations in some perimeter locations compared to on-shore U.S. locations. These included lower crude oil handling, transportation and operating costs and advantageous tax pro-

* *This chapter was prepared prior to the issuance Of the P1"esident's Energy Message to Congress of April 18, 1973, and does not take into account the oil import proclamation contained therein.*

visions and other industrial development incentives.

Relative Economics

As part of this study, illustrative relative economics of refining foreign crude oil domestically as compared to offshore locations were prepared. A crude supply, transportation and manufacturing "model" was constructed to show the order of magnitude of the differential costs of producing petroleum products between the areas studied.

The illustrative case studies indicated that a new refinery located on the East Coast designed to meet a balanced growth in product demand between 1970 and 1985, with full provisions for envIronmental considerations, would experience average costs of between $5.58 and $6.07 per barrel of product produced assuming a crude oil cost of $2.50 per barrei f.o.b. the Persian Gulf (see Appendix 4). A refinery located in the Caribbean, using the same crude price and producing the same product slate, would have an average cost of $5.42 to $5.68 per barrel of products after paying 1972 level product duties and transportation costs to the East Coast. Therefore, the Caribbean location shows an advantage of $0.16 to $0.39 per barrel over an East Coast site. Each cost is inclusive of a 10-percent and 15-percent rate of return, respectively, on invested capital. In the instance of the Caribbean location, the product cost has no income tax cost.

These cost comparisons are illustrative rather than typical, but they do display that the overall economic climate was more favorable offshore than onshore and that income tax accounted for a significant portion of the difference. However, these relationships may not necessarily be a consistent compelling business or economic motivation for offshore locations. Whether the magnitude of the difference is $0.16 per barrel or $0.39 per barrel, there was an economic incentive to locate refineries offshore where overall costs are lower than onshore and where there was a greater access to long-term crude oil supplies.

A refinery location in eastern Canada displayed a less favorable economic climate than one in either the Caribbean or District 1. If statutory tax rates are applied in eastern Canada, costs would have ranged between $5.76 and $6.16 per barrel. However, special concessions and incentives are available in the Canadian tax laws and make generalized comparisons difficult.

Income Taxes

Income taxes paid by offshore refineries vary conSIderably. Several Caribbean countries offer tax concessions to new industry in order to stimulate economic development. These concessions can range from a total exemption from income tax for several years (tax holiday) to no income tax at all. In several Caribbean countries, a graduated fee is charged which increases the cost of refining operations progressively over time. In eastern Canada the statutory income tax rate is currently at'49 percent along with a pollution tax of $0.04 per barrel. In contrast, the U.S. tax rate is 48 percent. The aspect of taxes can be a very important factor in the decision to locate a refinery onshore *vs*. offshore.

Price Controls

If the United States continues to impose price controls-direct or indirect-on petroleum and/or refined petroleum products in order to stabilize the economy, the full cost and financial risk of providing new supplies of petroleum products. must be recognized, including higher costs of Imported supplies. If they are not, refinery expansion will be discouraged, and shortages of domestIcally refined petroleum products WIll occur. To the extent available, products would have to be Imported from world markets at prices which are not subject to U.S. price controls. This, in turn, could drive market prices for imported products landed in the United States higher than those of products refined domestically, a consequence currently being experienced.

Crude Oil Supply

Based on the projections in the NPC U.S. Energy Outlook report, a growing share of domestic demand for oil products will have to be satisfied by imports of crude oil or products. Incremental. crude oil supplies will come largely from the MIddle East and North Africa where the greatest resources are located. Technology to produce potential future sources of petroleum liquids, such as oil shale and Canada's tar sands, is not yet able to provide economical supplies in competition with Middle Eastern and North African .crude oils. However, at the present time, pnces of foreign crude oil and products landed in the United States are, in some cases, higher than prices for conventional domestic supplies.

Uncertainties .with respect to crude supply fall into two major categories-volumetric and economic. Potential political actions in the producing countries raise the spectre of possible interruptions of crude oil deliveries. Also, actions by the producing countries could result in large, unilateral increases in prices. Transportation costs add another dimension of economic uncertainty.

Whether crude oil and/or refined products come directly to U.S. coastal regions or indirectly through an offshore refinery, very large shipping and terminalling facilities and investments will be required.

As domestic dependence on imported supplies of crude oil and refined products increases, U.S. policies must be adjusted to safeguard against the uncertainties surrounding assurance of supply.

Construction Costs and Limitations

Refinery construction costs for domestic and foreign locations can vary widely. Lower foreign costs for a refinery to supply a particular region of the United States could influence offshore refinery construction as opposed to domestic construction.

Regardless of whether capacity is built onshore or offshore, the capability of the worldwide heavy construction industries will be strained to provide the new refining capacity needed to meet the rapid growth in demand for petroleum products. The availability of technical manpower and construction labor and the capacity for equipment fabrication appear critically short. In addition to the demands for manpower and equipment for the refining, chemical and power generating industries, total construction requirements are increased by the needs for SNG and synthetic fuel facilities.

Petrochemical Feedstocks

In the last few years, the domestic manufacturing of petrochemicals has become closely related to domestic crude oil refining. Supplies of domestic natural gas liquids, which are important petrochemical feedstocks, are no longer growing, and petrochemical producers are having to turn more and more to refinery naphtha and gas oil for new feedstock supplies. The NPC has projected that petrochemical feedstocks are expected to grow from less than 6 percent of total petroleum demand in 1970 to about 8 percent in 1985.* If refining capacity moves offshore, then petrochemical producers may have to use imports for their feedstock supplies, which would adversely affect the U.S. balance of trade. Conversely, if refining capacity is kept onshore, feedstock supplies can be expected to be more readily available.

As one element in the overall petrochemical economic equation, the availability of ample feedstock supplies at internationally competitive prices will have an important bearing on future decisions to build petrochemical plants in the United States or overseas.

Financing

The capital required for providing for the Natiort's oil demands will be much greater than it has been in the past. Indeed, the capital required for new petroleum refining and transportation facilities needed by the Nation to supply 1985 demand is in the range of $60 to $70 billion, including capital to comply with environmental standards.

In spite of the magnitude of this capital requirement and the increasing competition for funds in capital markets, refining investments will be made as long as rates of return are adequate relative to other opportunities in world financial markets. However, if rates of return on investment are not deemed adequate by investors, difficulties in financing will restrict construction of new domestic refining capacity.

Environmental Considerations

Environmental considerations increase the demand for and cost of petroleum products in numerous ways. For example:

- Consumption of petroleum products will be increased by the substitution of low-sulfur fuel oil, LPG and distillate fuel for alternative high-sulfur petroleum, natural gas and non-petroleum fuels (such as coal) and by the use of less efficient automobile engines.
- Refining costs and crude oil requirements will be increased sharply in order to produce environmentally acceptable fuels and to meet environmental standards.
- Transportation costs will be increased if refinery construction continues to be delayed or banned in the more economical locations.
- The magnitude of expenditures for environmental needs are significant as even large refineries (over 100 MB/CD) report costs exceeding 10 percent of all refinery investment to meet environmental regulations.

Estimates of expenditures to meet existing and proposed environmental regulations were obtained from the refining survey. Over the 6-year period 1973-1978, costs in terms of constant 1970 dollars are expected to total $3.3 billion for the 12.3 MMB/CD capacity covered by the survey response. This is equivalent to an expenditure of $266 per daily barrel of capacity, of which $112 will be required for manufacturing unleaded gasoline, $54 for control of refinery water effluent, $89 for control of ambient air, and $11 for control of refinery

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* NPC, *U.S. Energy Outlook: An Initial Appraisal 1971-1985*, Volume Two (November 1971).

noise and light. These environmental expenditures will be required over the next 6 years and are in addition to substantial expenditures already made by the industry. For perspective, this $3.3 billion expenditure is equivalent to the expenditures required to construct between 1.3 and 2.2 MMB/CD of additional refinery capacity, based on refinery construction costs of $1,500 and $2,500 per daily barrel of capacity, respectively.

In addition, the facilities necessary to effect the reduction of sulfur content in heavy fuel oil are estimated to cost $400 per barrel of fuel oil output to lower the content from 1.4 percent to 0.3 percent. Reduction of the sulfur level from 1.4 percent to 0.7 percent would cost $320 per barrel, whereas reducing sulfur from 1.4 percent to 1.0 percent would cost less than $100 per barrel of fuel oil output capacity.

Refinery Fuel

Unlimited gas supplies will not be available for new or expanded domestic refining capacity. New refining capacity will increasingly depend on internally produced low-sulfur fuel at substantially higher costs than has been the case in the past when natural gas was available at artificially low prices or when high-sulfur fuel could be used. Foreign refineries will also burn internally produced fuel, but less stringent sulfur emission standards in certain countries usually result in lower fuel costs than at domestic refineries.

Chapter Five

Oil Import Policy and Other Related Issues of Government Policy*

Introduction

Government policies, legislation and regulations at the federal as well as state and local levels have become an increasingly more important factor to be considered in building and operating refineries in the United States. It is critical, therefore, that (1) existing policies and regulations be evaluated in terms of their impact on the shortfall of refining capacity, (2) current policies and regulations be modified as necessary to facilitate sufficient supply of imported crude oil and products to meet the short-term growth in demands, and (3) new policy guidelines be implemented within a reasonable period of time in order to maximize long-term domestic refining capabilities.

The decline in production of domestic crude oil and the near-term shortages in domestic refining capacity have been contributing factors in the emerging shortages of crude oil and products in the United States. Long-term planning by the oil industry to provide for increased domestic production of crude oil and adequate refining capacity for processing both domestic and foreign crude supply has become increasingly more difficult. Uncertainties and inconsistencies in government policies and the lack of consistent and cohesive long-term policy guidelines aggravated the planning environment. Sound government policy guidelines at federal as well as state and local levels are necessary if the oil industry is to maximize supply for domestic sources.

The relative inflexibility of the crude oil quota system, coupled with the decline in domestic crude oil production, has restricted the development of new refining capacity. While it is true that total U.S. import quotas would increase by the amount of new capacity built, there has been no direct mechanism to provide an existing refiner or a potential refiner with the necessary access to foreign crude oil supplies necessary to the operation of a new refinery in the United States. Limited and inadequate starter allocations were the only existing provisions for granting crude access for new refining capacity. The difficulties and costs of acquiring imported supplies from others were discouraging factors in decisions regarding new capacity construction.

Oil Import Policy-1959-1973

The principal element of government policy affecting the petroleum refining industry and the petrochemical industry has been the Mandatory Oil Import Program. This program was instituted by Presidential Proclamation in 1959 in order to restrict imports of petroleum to a level which would not threaten the national security and to provide a basis for preserving

* *The President, in his energy message to Congress of April 18, 1973, has removed by proclamation all existing tariffs on imported crude oil and products and has suspended direct control over the quantity of crude oil and refined products which can be imported. In place of the control system, the President has initiated a license fee system. The President stated that, to encourage domestic refinery construction, crude oil in amounts up to three-fourths of new refining capacity may be imported for a period of 5 years without being subject to any fees.*

This chapter was prepared prior to the issuance of the President's Energy Message and does not take into account or evaluate any of the policy changes or recommendations contained therein. The chapter does, however, evaluate various factors which affected refinery operations prior to April 18, 1973. Many of these factors are still relevant, particularly from the point of view of future governmental policy decisions and are presented in that light.

a vigorous and healthy petroleum industry in the United States. These restrictions and limitations on imports of petroleum were considered necessary to prevent a surplus of low cost foreign production from displacing higher cost domestic supplies. It was evident that, unless a reasonable limitation on imports were imposed, the following might occur:

- Oil imports would flow into this country in increasing quantities, entirely disproportionate to the quantities needed to supplement domestic supply.
- There would be a resultant discouragement of, and a decline in, domestic production.
- There would be a substantial reduction in domestic exploration and development.
- In the event of a serious emergency, this Nation would find itself years away from attaining the level of petroleum production necessary to meet national security needs.

The Mandatory Oil Import Program has been in operation for more than 14 years. During this time period, it has maintained the total level of imports "controlled" within the framework of the President's Proclamation and has provided procedures for allocating imports among eligible domestic companies. As the import program has evolved, the volume restrictions on certain imports have been removed. For purposes of this study, these imports are designated as "decontrolled." At the same time, certain procedures for distributing the quota for "controlled" imports have been revised in order to accommodate changing conditions and circumstances in the oil and petrochemical marl{ets. Without elaborating in detail, the Mandatory Oil Import Program established-

- A system of quota-regulated imports in three separate geographic areas- east of the Rockies (Districts I through IV), West Coast (District V) including quota drawbacks for production of low-sulfur fuels, and Puerto Rico
- A system of licenses for decontrolled imports of petroleum products from foreign refineries, principally residual fuel oil
- An allocation system for distribution of quota licenses to petroleum refiners, petrochemical companies and, to a limited extent, marketers without raw material processing facilities
- Preferential status for overland imports from Canada and Mexico in recognition of their proximity to the U.S. market and their inherent security advantages
- Special exceptions for promoting and encouraging exports of petrochemicals and development of new industries in Puerto Rico, the Virgin Islands, etc.

Quota-Controlled Imports

Imports subject to quota limitations and allocations have been primarily limited to crude and unfinished oils requiring further processing in U.S. refineries and petrochemical plants. The allocation of licenses to refiners has been based on an applicant's refinery input prorated by a predetermined graduated scale for different levels of input. Basically, the sliding scale system provides smaller refiners a proportionately larger volume of import licenses relative to their eligible inputs than larger refiners. Quota allocations for the manufacture of petrochemical derivatives have been included in the quota system since the mid-1960's. The quota licenses for petrochemical feedstocks are allocated to both eligible petroleum refiners and chemical companies on a fixed percentage of plant input. The petrochemical import regulations for allocation of feedstock quota permit the licensee, with proper certification, to import up to 100 percent of such allocations in the form of unfinished oils. The import regulations permit the exchange of import licenses for domestic feedstock.

The total level of quota-controlled imports east of the Rocky Mountains is shown in Table 12. Until recently, this level was set at a fixed percentage of domestic crude and natural gas liquids production. Imports on the West Coast (District V), also shown in Table 12, have continually been derived as the difference between domestic supply and total demand. Overland

TABLE 12

CONTROLLED IMPORTS
(MB/CD)

	1960	1970	1973*
	Districts 1-IV†		
Finished Products	76	171	130
Crude and Unfinished Oil‡	776	1,138	2,600
Total	852	1,309	2,730
	District V†		
Finished Products	7	18	8
Crude and Unfinished Oil‡	292	464	942
Total	299	482	950

* As authorized prior to April 18, 1973.

† Includes overland imports from Canada and Mexico.

‡ Includes petroleum refiners and chemical companies.

imports from Canada into Districts I through IV are included in the "controlled" level of imports.

Crude and natural gas liquids production has failed to increase since 1970 (remaining at about 10 *MMB/CD)*. As a result, quota imports into Districts I through IV have increased substantially since 1970 in order to meet the growing shortfall in domestic production. Quota-controlled imports will have more than doubled during this time.

Decontrolled Imports

Since 1966, imports of residual fuel oil on the East Coast (District 1) have been exempt from formal quota limitations. Very little residual fuel is imported into the other districts and is generally subject to quota restrictions. The growth in residual fuel demand since the inception of the Mandatory Oil Import Program has been met entirely from offshore sources. Production of heavy fuel oil in U.S. refineries actually declined during this period.

Imports of LPG from the Western Hemisphere, asphalt, overland imports of finished products from Canada processed from Canadian origin oil, No. 4 fuel oil imports, and more recently No. 2 fuel oil imports (the first 4 months of 1973) have been excluded from quota restrictions. In addition, a small but growing bonded fuel market has continually been exempt from import restrictions. This is fuel loaded in the United States on vessels and aircraft engaged in foreign commerce.

Imports formally exempt from quota restrictions increased from about 700 *MB/D* in 1960 to almost 2.5 *MMB/D* in 1972. The increase of almost 2.0 *MMB/D* has been primarily supplied from refining capacity located in areas adjacent to the U.S. mainland, but in effect represents refining capacity that might otherwise have been built in the United States.

The ability of refiners to supply this market by processing foreign crude oil in areas adjacent to the U.S. East Coast has been the primary factor contributing to the export of refining capacity from the U.S. mainland. Increasing requirements for imported naphtha to meet petrochemical feedstock demands and potential requirements for manufacture of SNG could accelerate this trend. The U.S. refiner, because of import restrictions and economic considerations, is at a disadvantage in supplying this market. Until recently, the economics of the domestic refining industry necessitated minimizing the yield of the lower value heavy fuel oils. The increased demands for higher value low-sulfur fuels has modified comparative product economics to some extent.

Oil Policy Considerations

Import controls alone have not achieved the desired levels of exploration for new oil and gas reserves in the United States over the last 10 to 15 years. Furthermore, it is evident that certain features of the import control system have contributed to the export of some types of refining capacity. Nevertheless, it is fair to conclude that, in the absence of the oil import program, domestic crude oil production would be less than current levels, and substantially more refining capacity to supply the U.S. market might have been built in foreign locations. It should be recognized, however, that the circumstances and conditions leading to the adoption of formal quota controls in 1959 have changed considerably, as discussed in the following:

- The domestic oil industry has moved from a period of "surplus" productive capacity (Districts I through IV) to a period of developing shortages of crude oil as well as refined products.
- The surplus of foreign productive capacity has been reduced significantly with developing shortages of low-sulfur crudes.
- The landed price of foreign crude oil and products has increased and in some cases now exceeds the price of equivalent domestic petroleum.
- The ownership of petroleum reserves in foreign producing areas is reverting to the host country governments by reason of recent agreements between international oil companies and host governments. These recent agreements have resulted in advancing the return of reserves to the host countries from the original terms of the concession agreements.

In evaluating the impact of these changing circumstances on oil import policy and the import control system, it is quite evident that other policy considerations should complement the oil import control system as a means for developing an economic climate favorable to long-term development of domestic productive capacities as well as refining capacity. These considerations include but are not limited to the following:

- Recognition by the Federal Government that petroleum prices in the United States must be adequate to provide sufficient return on the new investments necessary to develop domestic resources. Flexibility for prices to adjust based on market supply and demand within the United States should provide sufficient incentive to develop a relevant degree of self-sufficiency in raw material supply and processing capabilities.

- The need to reevaluate certain aspects of environmental regulations in order to ensure that benefits are commensurate with cost.
- The need to establish standards for orderly siting of new energy producing facilities in order to prevent the serious delays now realized in almost all facets of the energy industries.

Oil Import Policy and Refining Capacity

At present, the petroleum industry is operating near or at maximum refining capacity in the United States, with every indication that persistent shortages of capacity will exist for at least the next several years. The lag in development of new refining capacity in the United States, coupled with the extent of capacity already exported to the Caribbean and other adjacent areas, is cause for serious concern. These trends involve a number of complex considerations, the more important of which are discussed in the following sections.

The National Security

In evaluating the relationship of oil imports to requirements of national security, the Trade Expansion Act of 1962 (Sec. 232-Safeguarding National Security) provides that the President and the Office of Emergency Preparedness shall give consideration to–

> . . . domestic production needed for projected national defense requirements, the capacity of domestic industries to meet such requirements, existing and anticipated availabilities of the human resources, products, raw materials, and other supplies and services essential to the national defense, the requirements of growth of such industries and such supplies and services including the investment, exploration and development necessary to assure such growth, and the importation of goods in terms of their quantities, availabilities, character, and use as those affect such industries and the capacity of the United States to meet national security requirements.

> . . . further recognize the close relation of the economic welfare of the Nation to our national security, and shall take into consideration the impact of foreign competition on the economic welfare of individual domestic industries; and any substantial unemployment, decrease in revenues of government, loss of skills or investment or other serious effects resulting from 'the displacement of any domestic products by excessive imports shall be considered, without excluding other factors, in determining whether such weakening of our internal economy may impair the national security.

An expanding domestic refining industry capable of meeting primary product demands is essential to the economic structure of the U.S. oil industry and the considered requirements of national security. Although the U.S. oil industry will require substantially larger volumes of foreign oil to supply the anticipated growth in demands, maximizing domestic refining capacity to the fullest extent possible provides a greater degree of flexibility in meeting basic national security requirements. Increasing product imports at the expense of domestic refining capacity would place the United States in a position of having to depend on foreign sources for a growing part of its crude supply. It would also force the United States to rely, to an increasing degree, on foreign processing capacity. This would appear contrary to the national security and the national defense as defined by Section 232 of the Trade Expansion Act of 1962.

Political and Economic Risks

One of the more critical issues to be considered in evaluating an onshore *vs.* an offshore location of future refining capacity to meet domestic requirements is the uncertainty created by political and economic instability in various areas of the Free World. The growing rate of expropriation and nationalization of American and other foreign investments in various areas of the world must be considered in evaluating the advantages and disadvantages of import policies which would substantially increase product supply from foreign refiners.

Short of actual expropriation and/or nationalization is the threat or risk of host government control of part or all of the operations of a particular facility. This could affect a company's operation in any number of ways, including the availability of supply, price and possibly control of finished product sales in consuming areas. These are risks which must be weighed in evaluating the long-term security of such facilities.

Foreign Host Country Demands

Notwithstanding the political and economic risks involved in the export of refining capacity to supply the U.S. market, there is the real possibility that, in the long run, the U.S. Government may not be in a position to effectively implement policies designed to maximize construction of refining capacity in the United States.

The participation agreements negotiated with foreign producing countries have raised the possibilities of future participation by these producing countries in the downstream refinery operations of the oil industry. The extent to which this may materialize in the construction of new capacity in either the consuming markets or producing areas could have far-reaching significance in regard to long-term import policies.

Balance of Trade

The NPC U.S. Energy Outlook report concludes that oil imports could increase from 3.4 *MMB/D* in 1970 to as much as 19 *MMB/D* by 1985 and that the deficit in balance of trade in petroleum liquids could increase from almost $3 billion in 1970 to almost $30 billion annually by 1985.* Deficits of this magnitude would obviously have serious consequences on the Nation's overall balance of payments by 1985. Increasing product imports to meet the growing domestic shortfall of refining capacity would further aggravate the already unfavorable balance of trade estimated for 1985.

Employment in the United States

In a recent study, the Department of the Interior indicated that the "export" of refining capacity since 1961 has eliminated employment opportunities in the United States not only in refining but also in other allied and supporting industries.†

The study by the Department of the Interior indicates that more than 100,000 jobs may have been lost as a result of the increase in product imports of almost 2 *MMB/CD* over the last 10 years. The loss of about 25,000 of these jobs is directly attributable to refinery employment and the balance to allied industries. This is a serious loss of employment opportunities which would undoubtedly be accelerated if the United States commits itself to greater dependence on foreign processing capacity.

Modification of the Import Control System

Oil import policy and the implementing control system can be effective and instrumental in promoting the long-term growth of domestic refining capacity, providing sufficient and adequate economic incentives prevail to encourage refinery investment in the United States.

The Mandatory Oil Import quota system alone is no longer an effective means for ensuring an adequate supply of petroleum to meet requirements in the United States. Uncertainties concerning the future direction of import policy, uncertainties with respect to allocations within the existing system, and quota restrictions limiting access to foreign supply have made it increasingly difficult for any refiner to realize an assured and adequate long-term supply of crude oil necessary for large scale expansion of refining capacity. The resulting lag in development of new refining capacity, coupled with the deficit in domestic raw material supply and the rapid increase in requirements for foreign crude oil, has created an urgent need for modification of existing import controls.

Short-Term Considerations

Short-term considerations within the import control system have become critical in the last 6 to 12 months as evidenced by the growing shortages of both crude oil and products, by the necessity to eliminate controls on light heating oils for the first 4 months in 1973, and by the fact that the refining industry is operating at or close to maximum effective capacity.

With no substantial additions to capacity scheduled to come on-stream over the next several years, the growth in petroleum demand, at least through 1975, will have to be supplied increasingly by imports of finished products, assuming sufficient foreign refining capacity is available to meet these requirements. Lead time of at least 3 years to construct new large increments of refining capacity preclude any other possibilities at the present time to meet the normal short-term growth in petroleum demands.

It is important to recognize, however, that product imports discourage the development of domestic refining capacity. At the same time increased petroleum product imports are essential to meet demand over the near term. Changes in the import program to accommodate additional product imports have been necessary, but it is important that any such change or changes be compatible with long-term goals and priorities of import policy. Adequate incentives to phase out the short-term increase in product imports will be necessary as additional domestic refineries are brought on-stream.

Long-Term Considerations

The NPC U.S. Energy Outlook report recommended that import policies be designed to encourage the growth of domestic refining capacity by assuring refiners adequate access to long-term crude oil supplies. The extent to which product imports may be required to meet

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* NPC, *U.S. Energy Outlook—A Report by the National Petroleum Council's Committee on U.S. Energy Outlook* (December 1972).

† U.S. Department of the Interior, Office of Oil and Gas, *Trends in Capacity and Utilization* (December 1972).

short-term considerations should not obviate the need for long-term policy guidelines to encourage the development of domestic refining capabilities.

Various proposals and recommendations to revise the import control system and make it more responsive to refinery requirements have been studied and considered. These proposals include but are not limited to—

- Modification of the existing quota system with special incentives for development of U.S. refining capacity
- Elimination of formal quota controls on crude oil, a phaseout of product imports, or alternatively a tariff on product imports, with provision for standby controls in the event that foreign productive capacity threatens the well-being of the domestic producing industry
- A tariff system with a phaseout of formal quota controls
- A quota-auction system or quota-tariff system
- Elimination of crude quota controls by requiring each refiner to run a predetermined percentage of U.S. produced petroleum liquids.

It is not the intent of this study to evaluate the advantages or disadvantages of any of the specific proposals suggested, but to consider those guidelines essential to the long-term development of crude processing facilities. In order to be effective, any system of import controls, whether quota restrictions or variations thereof, should at the very least consider-

- More favorable provisions for importation of crude oil than refined products
- Provisions to ensure a market for all domestic crude production
- Policies that provide the domestic refiner with assurances of an adequate and long-term supply of crude oil from domestic as well as foreign sources and, in so doing, assure maximum utilization of existing refining capacity
- Incentives to offset the disadvantages faced by domestic refiners when manufacturing products currently exempt from formal quota control
- A degree of consistency and stability in order to provide refiners with the basis for establishing long-term planning objectives
- Compatibility with overall objectives of energy policy.

Natural Gas Policies

Federal control of wellhead prices of natural gas at artificially low ceilings has contributed to (1) an inflated demand for gas relative to other energy fuels, (2) a reduction in exploration activity for new gas reserves, and thus (3) an accelerated depletion of existing reserves.

As a result, shortfalls in natural gas supplies have become more frequent in recent years. With a continuance of the existing economic and policy environment, the projected shortage in domestic supply is almost directly proportional to the increase in future requirements.

Because of environmental considerations and other factors, oil has been and will continue to be required in increasing quantities to meet this shortfall in domestic gas supply. To this extent, the current shortage of gas, attributable to past federal policy, has contributed to inflating the demand for oil and attendant refining capacity.

Permitting field prices of natural gas to reach their competitive levels with other energy fuel sources would expand exploration efforts for new oil and gas reserves and future domestic supplies to meet market requirements. The extent to which additional domestic supplies of natural gas can effectively reduce the Nation's overall energy shortfall, there would be an equivalent reduction in the demand for oil and a reduction in required refinery capacity.

Refinery Siting and Land Use

Local environmental restrictions and a growing antagonism on the part of some state and local governments and privately organized citizen groups to the location of heavy industry, such as refineries and electric power plants, have created serious problems for locating new facilities in the major energy markets of the East and West Coasts. For example, California and Delaware have legislated coastal land use laws that place major restrictions on the industrial use of coastal zones.

The NPC refinery survey revealed that very few companies were planning new refineries-eight refineries with a total of only 900 MB/CD capacity are in the planning stage industry-wide. Other companies reported that land was available, but that environmental considerations have forced them to defer any firm plans.

With today's political, social and environmental climate, there are many restrictions imposed by regulatory authorities which are contributing to the shortfall of refining capacity.

Survey data from the industry indicate that, in general, refinery expansion can take place at existing locations. These expansions are subject to the lengthy process of obtaining permits under local zoning and environmental ordinances and in accordance with all federal regulations. However, new grass roots refinery sites are difficult to obtain, particularly on the East and West Coasts where additional refining capacity is most needed. In these areas, local ordinances and state regulations, such as coastal zone acts, restrict construction within specified distances of the coastline and make the possibility of development of marine facilities very unlikely.

The East Coast (PAD District I) has the largest population and is in the least favorable position of any area with respect to energy self-sufficiency. In 1971, crude capacity was only 25.1 percent of product demand. About *2.0 MMB/D* of products were imported from offshore (89 percent of U.S. total product imports), and about 3 *MMB/D* were brought in from the South and Southwest by ship and pipeline. There has been essentially no significant growth in the refining capacity on the East Coast since import controls were adopted. Projections of petroleum product requirements indicate an increase between 1970 and 1985 of *4.8 MMB/D*. This represents 41.1 percent of the total growth for the United States during that time period.

If it is necessary to ship foreign crude oil to the Gulf Coast for refining and then back to the East Coast, there will be added costs. In view of the impending shortfall of refined products, the usual product allocation procedures or the attempt to fulfill the shortfall from foreign supply sources will impact more heavily on the East Coast consumer.

Several legislative bills before the Congress are specifically related to land use planning of both private and federal lands. These bills would provide for–

- Land use planning and management by the states
- Planning in terms of population growth, expanding urban development, industrial diversifications, etc.
- A means of overriding conflicting patterns of land use and lack of uniformity among governmental entities
- Exercising authority on the location and siting of key facilities by assuming local regulations do not unreasonably restrict land use.

Legislation of the type now under consideration would have little impact on the energy industry until at least 1980 because of procedures which essentially provide the states with lead time of at least 5 years to develop land use plans. Even then, there is no assurance that such legislation would enable industry to develop adequate refining facilities.

Traditionally the United States has placed primary reliance on the private sector for the production, generation, distribution and marketing of energy and energy fuels. This reliance necessarily implies the availability of land for energy-related facilities.

Proper land use planning at both the state and federal levels is recognized as an important governmental function. However, such planning, in addition to meeting preservation, conservation and environmental goals, must make specific provisions for energy-related facilities for both public utilities and private business.

Construction Lead Time

Refinery equipment is, by its nature, large, complex and costly. Even under the best of circumstances, it takes a long time to plan for, design and construct a new process facility. For example, the construction of an alkylation plant with known technology and proved engineering takes 1.5 to 2.0 years. The lead time for a process using new technology can be 5 or more years when research is required.

Lead times are being lengthened by the need to file impact statements, obtain permits, hold public hearings and attend to all the complex administrative procedures established by federal, state and local agencies. It is estimated that the current lead time for a major process facility is 3 to 6 years.

Long lead times accentuate the importance of long-range planning. The lack of a national energy policy to establish goals, set priorities and help coordinate the interested federal, state and local agencies makes it difficult for the petroleum industry to effectively plan how to supply its share of the U.S. growing energy needs.

Coordination of Agencies Dealing with Energy

Prompt action should be taken to develop a comprehensive national energy policy and a coordinated, consistent program to accomplish national energy goals. The chief role of the Government should be to establish priorities and guidelines and to eliminate the delays, conflicts and confusion that presently prevail among the many different federal, state and municipal agencies involved in energy matters.

Appendices

Appendix I

United States Department of the Interior
Office of the Secretary
Washington, D.C. 20240

February 9, 1972

Dear Mr. True:

The increasing dependency of this Nation on imported supplies of petroleum, both crude and refined products, the sources of which vary considerably in reliability, is a cause for serious concern. At the same time the United States appears to be increasing its dependence on refining facilities and capabilities located outside this country. This growing proportion of foreign manufactured petroleum products which are necessary for the economic well-being and security of this Nation is also a matter of increasing concern.

I therefore request that the Council undertake, as a matter of urgency, a survey of the factors-economic, governmental, technological and environmental-which may affect the domestic refining industry's ability to respond to the demands for essential petroleum products that are made upon it. The Council should discuss those elements which are deemed essential to a healthy domestic refining industry. To the extent that petroleum belonging to other phases of petroleum supply and consumption impinge upon growth and technological capabilities of the refining segments, these should be included in the analysis.

Representatives of the Department of the Interior will consult with you in the near future to arrive at a detailed outline of the matters relative to this general request.

Sincerely yours,

/S/ HOLLIS M. DOLE
Assistant Secretary of the Interior

Mr. H. A. True, Jr.
Acting Chairman
National Petroleum Council
1625 K Street, N.W.
Washington, D.C. 20006

Appendix 2

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Factors Affecting U.S. Petroleum Refining

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Appendix 3

Fundamentals of Refining Operations and Product Use

Past History of Product Use

The demand for petroleum products has grown enormously in the past 25 years in both volume and complexity. During this period, demand for all products has increased from less than 5 MMB/D to over 16 MMB/D in 1972. The most spectacular growth has been in the use of aviation fuels, where consumption has increased over 30 times the amount used at the end of World War II.

The quality of virtually all petroleum products has been improved significantly during this period, resulting in more efficiency with less polluting emissions such as those caused by sulfur.

Petroleum products are the major source of energy for transportation and are the raw materials for many of the products throughout our economy. They also provide a substantial part of the energy for the production of electrical power. They provide the mobility required for national security and contribute greatly to the economic welfare of our society.

The chief factors contributing to the rapidly growing demand for petroleum are the increasing population and the rapid growth in the demand for energy. The U.S. per capita demand for petroleum products has more than doubled since World War II.

The United States has become a nation on wheels. Four out of five workers use an automobile for commuting to and from work Over 80 percent of the vacationing public use their own automobiles for transportation.

Air travel developed rapidly after World War II, causing rapid growth in the demand for aviation gasoline. The jet age began in the 1950's, creating a demand for an entirely new fuel. Faster and larger planes were required to supply the very rapidly increasing demand for air travel. Although Americans travel more than the rest of the world combined, air travel in the United States is still in the early stages of growth.

The demand for oils for space heating increased sharply after World War II, chiefly because of the switch from coal for home use. In 1946, 2.7 million homes in the United States were centrally heated with oil, increasing to 11.2 million by 1969.

The demand for residual fuel oils for heating large buildings rose substantially after World War II because of the large increase in new construction of such buildings. In the past few years, the demand for residual fuel oils has taken a sharp increase as a result of industrial and electrical power plant usage. Nuclear power generation has not developed as rapidly as previously anticipated, and coal has not been able to fill the increasing demand for low-sulfur fuels. During the 1946-1970 period, residual fuel oil experienced an overall growth rate of 2.2 percent per year. However, annual growth for this fuel increased 4.2 percent in 1971 and over 8.9 percent in 1972.

LPG is a large-volume product which has experienced an overall growth rate since World War II of approximately 10 percent per year and has continued at a rate of about 5 percent per year since 1960.

Product Development-Characteristics and Improvements

Motor Fuels

Motor Gasoline

Since World War II, gasoline has changed in hydrocarbon composition and is now a product made by careful blending of refinery stock prepared by involved new processes and special additives developed in extensive research programs. The most outstanding change in gasoline during this period has been a vast improvement in antiknock quality. Although the past benefits enjoyed by the consumer in terms of high-efficiency, high-performance automobiles are being eliminated in order to meet automobile pollution regulations, this octane quality not only is needed but will have to be increased to supply unleaded fuels of the future. Higher octanes have been obtained largely by new refining technology and processing, including better desulfurization of gasoline blending stocks which has made the lead antiknock additives more effective. During this same period, the control of gasoline volatility has improved, contributing to better engine performance.

Special detergent or dispersant additives are now available to help maintain a clean carburetion system, resulting in improved engine performance, better mileage in city driving, reduced carburetor maintenance and reduced exhause pollutants.

At present, there are proposed regulations limiting the lead alkyl content of future motor gasolines. In addition, one grade of unleaded gasoline must be available for public use by mid-1974. The primary reason for these considerations is the expectation that low-lead or unleaded fuels will permit operation of proposed pollution control systems on automobiles. Voluntary action on the part of the oil industry has already resulted in general availability of low-lead and unleaded gasolines. This trend will undoubtedly continue, bringing about increasing supplies of these types of fuels, and will result in major investments for proper process facilities. Further changes in motor fuel characteristics may be required. Such characteristics as sulfur content, volatility and boiling range may require further modifications to satisfy automobile pollution control system requirements.

Diesel Fuels

Like gasoline, distillate diesel fuels for use in automotive diesel engines have been improved during the past several years to meet requirements imposed by changes in engine design and operation. The most significant change in diesel fuels has been the use of hydrogen treating in refineries, primarily to reduce sulfur content. In addition, fuels have been gradually improved, resulting in decreased engine deposits, smoke and odor. Railroad diesel fuels have not changed significantly since the large diesel engines used in railroad service operate satisfactorily on fuels with less exacting specifications.

The use of additives in diesel fuels has become more common to provide improvements such as lower pour points, ignition quality and storage stability. Recent air pollution regulations have generated an increased interest in antismoking additives.

Other Petroleum Motor Fuels

LPG has been used as a motor fuel since the 1920's in bus, truck and taxi fleet operations which have central servicing centers. The use of compressed natural gas (CNG) and liquefied natural gas (LNG) as motor fuels is a recent development proposed for urban use in service vehicle fleets.

Aviation Fuels

Aviation Gasoline

Quality control is particularly important in aviation gasoline production. Antiknock control is especially critical because, unlike the motorist, the pilot is not able to hear an engine knock over the noise level. Other important quality factors are volatility, freezing point, heat of combustion and oxidation stability. Quality control surveillance and close process control have enabled the industry to produce a uniform-quality premium product.

Jet Fuels

Commercial kerosine was first used as a fuel in early development on jet aircraft since it provided the necessary volatility and was a readily available commercial product of rather uniform characteristics. Jet fuels are exposed to both high and low temperatures in use. Therefore, these fuels must have very low freezing points and must be stable when exposed to high temperatures. The JP-4 and JP-5 military jet fuels and equivalent commercial fuels have thermal stability properties satisfactory for operations up to speeds of Mach 2.

Industrial and Heating Fuels

Liquefied Petroleum Gas

LPG has taken on increased importance during the past few years. The extensive use of catalytic cracking and catalytic reforming processes and the growth in hydrocracking have resulted in the production from natural gas processing. Prior to the start of the tremendous growth in the use of LPG in ethylene production, its major use was in household and industrial fuel, although LPG has long been used to a limited extent as a motor fuel.

Distillate Fuel Oil

Distillate fuel oil can be defined as Nos. 1, 2 and 4 heating oils, diesel oil and industrial distillates. Grade No.2 fuel oil is the designation given to the heating or furnace oil most commonly used for domestic and small commercial space heating.

The period since World War II has seen marked changes in both the quality of home heating oils and the manufacturing techniques employed in producing them. Domestic heating oil should form no sediment in storage and leave no measurable quantity of ash or other deposits on burning. It should be fluid at storage conditions encountered during the winter months. The composition of the product must be controlled to assist in reducing smoke emission. Low sulfur content has become quite important. The fuel must have a light color, an attractive appearance and an acceptable odor. It is these properties, along with sulfur removal, which have undergone the greatest change in the past 20 years.

In the early 1950's, hydrogen treating was adopted as a means of reducing the sulfur and nitrogen compounds content of distillate fuel oil. Through the use of this process, carbon residue is reduced to less than 0.10 percent. Hydrogen-treated products are of excellent quality from the standpoint of a change in both color and sludge formation during storage.

The superior processing techniques used in producing distillate fuel oils today, coupled with the improvements and developments in additives, result in a cleaner-burning product. The reduction in sulfur has contributed to the improvement of air quality.

Residual Fuels

Residual fuel oil can be defined as Nos. 5 and 6 heating oils, heavy diesel, heavy industrial and Bunker C fuel oils. Typically, these fuels are used to provide steam and heat for industry and large buildings, to generate electricity and to power ships.

Since World War II, refining processes in the United States have continued to favor the breaking up of the heavier residuum into lighter petroleum products until residual fuel amounts to less than 8 percent of the crude refined.

Methods of desulfurizing low metal-content residual oils have been developed and are being utilized as stringent air pollution regulations become more widespread. The oil industry and boiler manufacturers have stepped up their research and development efforts considerably in the areas of desulfurizing high metal-content fuel oil and stack gas desulfurization.

Other Petroleum Products

Petrochemical Feedstocks

Petrochemical feedstocks, such as benzene, toluene, xylene, ethane and propane, are used in such diverse products as synthetic rubber, synthetic fibers and plastics. Tremendous growth in the petrochemical industry over the last 10 years has resulted in many new and improved uses for petrochemicals.

Lubricants

Lubricants fall generally into three categories: automotive oils, industrial oils and greases. Engine oils, gear oils and automatic transmission fluids are three major lubrication products used in automotive operations. These products function to lubricate, seal, cool, clean, protect and cushion. Industrial oils are formulated to perform a broad range of functions under a variety of operating conditions. The major functions provided include lubrication, friction modification, heat transfer, dispersancy and rust prevention. Greases are basically gels and are composed of lubricating oil in a semirigid network of gelling agents such as soaps, clays and, more recently, totally organic substances.

Petroleum Solvents

A variety of petroleum solvents are produced, and critical specifications are largely a function of the end product use. For example, rigid specifications are required for petroleum solvents used in the paint industry. These products must contain no materials that would discolor pigments. They must possess low odor for interior paints. Control devices make it possible to maintain consistent product quality even under the most rigid specifications.

Asphalt

The heaviest fractions of a great many crude oils include natural bitumens or asphaltenes and are generally called asphalt. Actually this material is the oldest product of petroleum and has been used throughout recorded history. However, new uses and new demands for asphalt are continually being developed. The industry has satisfied these demands by changing processing and types of crudes and by improving storage, transportation and blending facilities.

A Crude **Oil** Refinery *

Crude oil is a substance comprised of a very complex mixture of hydrocarbons, which are molecules consisting almost solely of carbon and hydrogen atoms in various arrangements. Crude oil contains thousands of different molecules of varying sizes, their size being determined by the number of carbon and hydrogen atoms aggregated together. As a result of the different sizes and configurations, the molecules

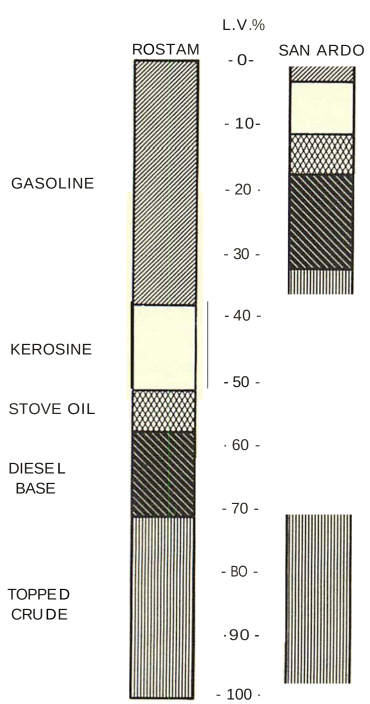
* Terms used in this section are defined in the Glossary.

boil at different temperatures. It can be assumed that most of the molecules boil between 100°F and something in excess of 1,500°F. Due to the complexity of the hydrocarbon mixtures, only a few of the smaller, lower boiling molecules are named.

Paraffinic type crude oil is generally of high °API gravity and low in sulfur content and contains a lesser amount of other contaminants such as metals and nitrogen. The straight-run gasoline derived from this type of crude oil is low in octane quality. The naphtha fraction is a poor reformer charge stock but an excellent SNG feedstock and cracking stock for olefms. The heavy naphtha and kerosine fractions give problems in meeting product freeze point specifications, and the diesel fuel fractions have problems in meeting pour point specifications. The residual fuel oils also have high pour points, and the asphalt quality is often poor. However, the heavy naphtha and kerosine have good smoke point characteristics, and the heavy naphtha, kerosine and light gas oil have high cetane indices. The volumes of residuals are low and often can be cracked without too much penalty.

The physical properties of naphthenic crude oils vary widely between different producing fields. They are generally of low °API gravity, may be either high or low in sulfur content, and are often high in nitrogen and metals. The straight-run gasolines from this source are higher in octane but often of lesser volume. The naphtha is excellent reforming charge stock. The heavy naphtha has a poor smoke point and cetane index and should be reformed. The kerosine and light gas oils have very poor cetane indices and are not suitable for domestic distillates. Pour points and freeze points of this latter fraction are very low. The residual fuel oil may be of high or low volume and high or low sulfur and may be high in metals content. The metals are corrosive to boiler tubes, and the use of high-sulfur fuel oils is becoming more restrictive. These crudes are the source of naphthenic lubricating oils, and the asphalt quality is often good.

Intermediate type crude oils are, as their



CRUDE	ROSTAM	SAN ARDO	REMARKS
Gravity (OAPI)	38	13	
Sulfur (wt. %)	1.5	2.0	
Type	**Intermediate**	Naphthenic	
Gasoline (60-400°F)			
Octane	69_1	79.3	
Naphthenes	20%	74%	
Aromatics	16%	12%	**San Ardo gasoline is only 3 percent of crude and high in sulfur content.**
RVP	4.9	1.0	
Sulfur (wt. %)	0.05	0.33	
Kerosine (400-500°)			
Gravity (oAPI)	42	31	
Viscosity @ 100°F	33SUS	35 SUS	
Sulfur (wt. %)	0.30	0.57	
Stove Oil (400-550°)			
Gravity (oAPI)	40	29	
Viscosity @ 1000F	35SUS	43 SUS	**San Ardo distillate is not salable due to failure to meet API, sulfur and cetane specifications because of the naphthenic nature of the crude.**
Sulfur (wt. %)	0.47	0.76	
Pour	-27°F	-45°F	
Diesel Base (500-650°)			
Gravity (oAPI)	36	26	
Pour	+25°F	-25°F	
Cetane	53.5	41.5	
Sulfur (wt. %)	0.92	1.01	
Viscosity @ 100°F	39 SUS	54 SUS	
Topped Crude (650° H)			
Gravity (oAPI)	16	9	
Sulfur (wt_ %)	3.3	2.2	
Viscosity @ 122° F	99SFS	1800 SFS	
Pour	70°F	80°F	

Figure 7. Crude Oil Characteristics.

name implies, somewhere in between the paraffinic and naphthenic type crudes. These crudes generally will fall in the medium to high gravity range. Sulfur content may fall between 0.1- and 2.5-weight-percent sulfur. Distillate generally may be expected to be of sufficient quality. Figure 7 illustrates the differences between a typical intermediate crude oil and a typical naphthenic crude oil.

Although we have discussed briefly the paraffinic, naphthenic and intermediate types of crude oils, there exist many combinations of these crudes. The Bureau of Mines categorizes oils in the following classifications:

- Paraffin-Paraffin
- Paraffin-Intermediate
- Paraffin-Naphthenic
- Intermediate-Paraffin
- Intermediate-Intermediate
- Intermediate-Naphthenic
- Naphthene-Intermediates
- Naphthene-Paraffin.

Crude oils are also classified as low sulfur content (below 0.5-weight-percent sulfur), intermediate sulfur content (between 0.5- and 1.0-weight-percent sulfur) and high sulfur content (over 1.0-weight-percent sulfur). In general, the definition of a sweet crude oil is that the crude oil does not contain hydrogen sulfide and has below 0.5-weight-percent sulfur content, with only a minor portion of the sulfur content being present as mercaptans. Mercaptans (sulfur compounds) are one of the most undesirable contaminants of crude oil and petroleum products.

Each refinery processes a different mixture of crude oils, and over a period of time a processing sequence has been developed which converts these particular crude oils into the products required by consumers in the marketing area served. Therefore, since it is not meaningful to attempt to describe the operation of an "average" refinery, the following discussion chooses a simple-example refinery rather than an average or typical refinery for its illustrative purposes. Figure 8 graphically shows the flow within the example refinery.

When the crude oil is charged into this refinery, the first processing equipment it reaches is called a crude oil distillation unit. The purpose of the crude unit is to separate the crude oil into at least four different boiling range fractions. The first fraction contains the lower boiling materials and is termed straight-run gasoline. This lower boiling fraction is then further processed into a finished gasoline blend stock. The next fraction boils between 400°F and 650°F and is called the straight-run distillate fraction. This distillate fraction is the material that is primarily sold as kerosine, jet fuel, heating oil (No.1 and No.2 fuel oil), and diesel fuel.

The next and heavier fraction, which boils between 650°F and 850°F, is called the gas oil fraction. It is somewhat difficult to define gas oil, except to say that it is usually the material that is heavier than the distillate fraction and is not a black residual fuel oil. There is no consumer market for gas oil, and, since it is too high boiling to be sold as distillate and too valuable to be sold as residual fuel oil, it is necessary to convert this fraction into something that can be utilized in the marketplace. Generally speaking, the molecules are cracked (molecular rupture) into smaller-size molecules boiling in the gasoline and No. 2 fuel oil boiling range.

The heaviest fraction from the crude unit is usually referred to as the residuum and includes materials that boil at 850°F to the heaviest material in the barrel of crude which boils in excess of 1,500°F.

After the crude has been separated into these four fractions, each fraction is further processed to yield a product slate that can be accommodated in the market. The actual refined product distribution varies considerably, depending upon the exact nature of the crude oil that is available and the demands in the marketing area surrounding the refinery.

Many years ago, the straight-run gasoline fraction was used directly as automotive gasoline. Technological developments have now made this material, as it is contained in the crude oil, unsuitable for modern day engines. Today, it is necessary to process the straight-run gasoline by molecular rearrangement and by making certain changes in the molecules that will increase the octane number. This is usually accomplished by sending the straight-run gasoline to a fractionator and separating it into two fractions. The lower boiling fraction, boiling between 100°F and 200°F, is called light, straight-run gasoline and has ordinarily gone directly into automotive gasoline. Although the octane number is not extremely high, light, straight-run gasoline can be included in finished gasoline. However, under proposed no lead regulations, additional processing will be required to increase the clear (no lead) octane rating of the straight-run gasoline.

The remaining portion of the straight-run gasoline boiling between 200°F and 400°F is sent to a catalytic reformer. The catalytic reformer uses a very expensive catalyst containing platinum. The heavy gasoline is first mixed with hydrogen and the temperature increased to over 900°F. When it is passed over the platinum catalyst, hydrogen is removed from some of the compounds, greatly increasing the

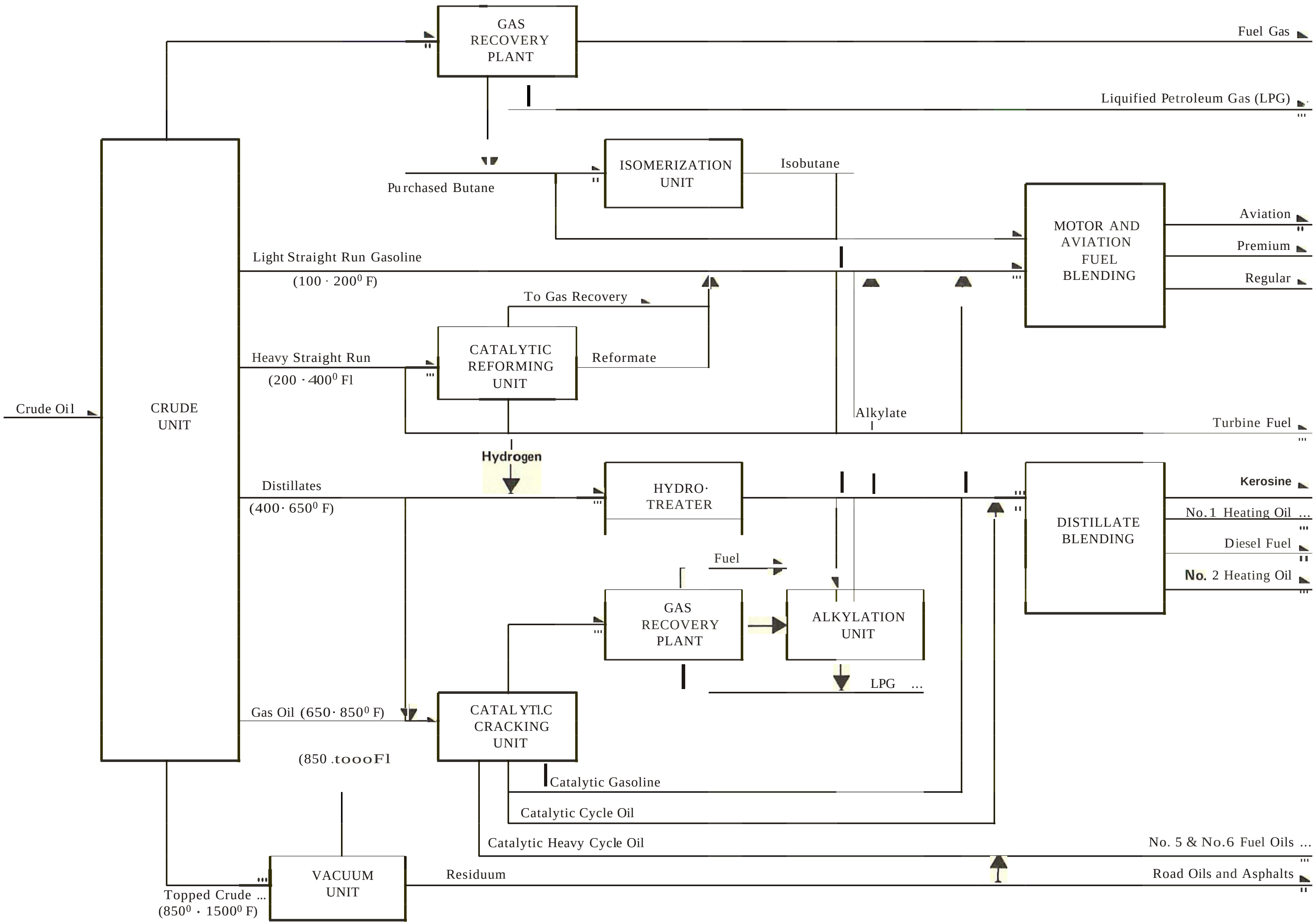


Figure 8. Process Flow-Example Refinery.

octane number. When performing this operation, some of the molecules rupture, producing propane and butane which are then sold as liquefied petroleum gases. After adding 3 grams per gallon of lead alkyl, the usual range of octane numbers in gasoline resulting from this process is 90 to 103. Once the platinum catalyst has been used for a considerable length of time, it becomes economically unusable and must be rejuvenated or replaced.

The next heavier fraction from the crude still is the distillate fraction. Ordinarily, the distillates are treated to improve color stability and reduce the sulfur content to very low levels. The process whereby this treatment is accomplished is called hydrodesulfurization. This process consists of mixing hydrogen with the distillate at an elevated temperature of between 600°F and 700°F, then passing the hydrogen-distillate mixture over a catalyst usually containing the metals cobalt and molybdenum. The sulfur contained in the distillate reacts with the hydrogen to form hydrogen sulfide gas. This gas is then collected with various other refinery gases and sent to a central unit where the sulfur is removed as elemental sulfur. This elemental sulfur is a basic raw material used in many industrial applications. The treated distillates are fractionated to specifications for space heating oil, industrial heating oil and diesel fuel.

Gas oil, the next higher boiling range fraction from the crude still, is converted into marketable products by processing in a unit called a catalytic cracking unit. The catalyst used in most installations is a finely divided material that is about the consistency of fine sand. It is generally composed of silica and alumina, the principal components of naturally occurring clay. The newer catalyst used today is modified into particular crystalline structures, greatly enhancing the value of the catalyst to a refiner by improving the yields of gasoline, which in turn increases the value of the total products from the catalytic cracking unit. The objective of this unit is to reduce the molecular size of the gas oil by rupturing or cracking the molecules and thereby lowering their boiling points into the gasoline and distillate boiling range. The gasoline from the catalytic cracking unit goes directly to the motor gasoline pool and has quite a high octane number-between 96 and 99 after adding 3 grams of tetraethyl lead per gallon. As a result of this process, the unit makes a considerable amount of fuel gas that can be used as refinery fuel and a rather large volume of propane and butane fractions which also contain the olefins propylene and butylene.

Olefins are molecules from which a part of the hydrogen has been removed. These olefins are reacted with isobutane (a four-carbon molecule where the carbon atoms are not in a straight line but are what is termed "branched hydrocarbons"). This isobutane may be made to react with hydrogen deficient molecules of butylene to make isooctane or with propylene to make isoheptanes. The isoparaffin mixture processed from this reaction is termed alkylate and is used for blending premium gasoline. It has also been used for many years as the principal high octane component of aviation gasolines. The octane number of the alkylate usually ranges from 103 to 107 with 3 grams of tetraethyl lead per gallon.

Not all of the gas oil is converted into gasoline and alkylation unit feed in the fluid catalytic cracker. Part of the gas oil feed is only reduced in boiling range to a range comparable to that of the distillate fraction from the crude oil, and this material is the principal base stock for No. 2 heating oil. A small amount of very heavy fuel oil is made, which is a distillate fuel, but this is usually blended in with residual type fuel oil for sale.

The fourth and highest boiling fraction from the crude oil-topped crude–is processed in several different ways, depending upon geographic location of the refinery and the market demands of the area. This extremely high boiling fraction of the crude oil can be further processed through a vacuum distillation unit. The purpose of the vacuum unit is to allow vaporization of more of the heavier gas oil molecules from the crude residue without thermal disintegration of the molecules. The hydrocarbons vaporized can be included in the fluid catalytic cracker as additional gas oil feedstock. The heavier residual bottoms can be further processed into various kinds of fuel oil, primarily No.6 or bunker fuel oil, and/or asphalt.

The refinery described above is of the simplest form. Many specialty products-such as solvents-can be made in a refinery. Special processing can be performed to recover a variety of aromatics, including benzene, toluene and xylenes, for which there is a demand in the petrochemical markets. Typical boiling ranges for the major petroleum products are shown in Figure 9.

Several gasoline streams of varying quality can be produced from this refinery which can be blended in various proportions for making the different grades of gasoline and achieving desirable characteristics in each of the marketable grades.

Each petroleum refinery processes a different type of crude oil, and each refinery uses different amounts and types of conversion units. The conversion units are designed on the basis of converting the particular hydrocarbons in the available crude oil to the volume and type of products required by the consumer.

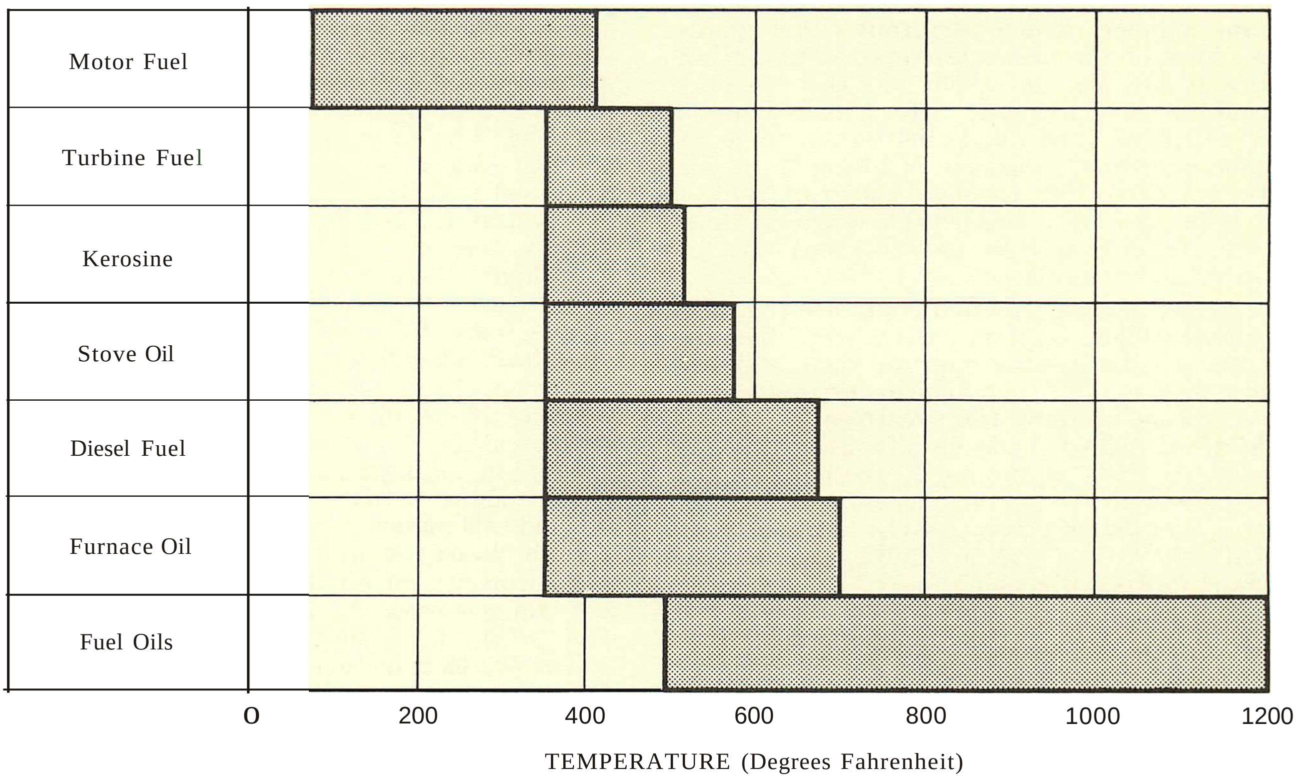


Figure 9. Typical Product Boiling Ranges.

Appendix 4

nlustrative Economic Model Studies*

To illustrate the relative economics of refining foreign crude oil domestically and offshore, an economic model was constructed and studies were made to evaluate different situations that might arise between now and 1985. Many of the cases concentrated on the situation in District I (due to the critical refinery shortage in that area) and on the likely refining combinations for meeting the demand. Other districts were also examined to determine the cost of meeting the demand district by district. Comparisons between District I onshore refineries and offshore refineries were made, and the costs of supplying environmentally acceptable fuels were examined.

In addition to direct refinery-to-refinery comparisons illustrating the basic onshore/offshore cost differences, three energy scenarios were postulated to determine the overall effect on Districts I, II and III: (1) a product import scenario in which import quota controls continue and the growth of domestic capacity is projected from the responses to the survey questionnaire with foreign capacity making up the difference; (2) a national security scenario which brings all new capacity onshore; and (3) a zero growth scenario, an unlikely situation where all new capacity moves offshore. The full report of the Committee details the methodology of the model as well as numerous other combinations studied. This Appendix is designed to summarize those data.

Principal assumptions used in the economic models are as follows:

- Growth in product demand is based on the Initial Appraisal.t
- Demand growth is to be satisfied in new 200 MB/CD refineries. (Actually, a substantial amount of product will be produced by expanding existing refineries.)
- Iranian light crude oil is representative of future crude oil supplies. The crude oil price is an assumed price for 1985. Recent dollar devaluation and negotiated changes between international oil companies and Middle Eastern countries indicate that this price ($2.50 per barrel) might be reached by the 1975-1977 period. If this price is exceeded, the effect will be to increase the per barrel cost of products from both onshore and offshore refineries. This increase will be almost the exact amount of the per barrel crude oil price increase.
- Crude oil import quotas are available at no cost.
- Crude oil is delivered to offshore (Caribbean) refineries in VLCC's, and products are barged to the United States.
- Import duties on all products are assumed to be at 1972 levels.
- For domestic refineries, crude oil is delivered in VLCC's to an offshore deepwater transshipment port and thence by barge to the United States or (in the case of District III) in VLCC's to an offshore receiving terminal.
- Construction costs will increase 3 percent per year to reflect anticipated real cost increases in the construction industry.

* *The illustrative economic model studies p1'esented in this Appendix were prepa1'ed prior to the issuance of the President's Energy Message to Congress of April* 18, 1973, *in which the President removed by proclamation all existing tariffs on imported crude oil and products and suspended direct control over the quantity of crude oil and 1"efined product imports. In place of the cont1'ol system the President has initiated a license fee system. This Appendix does not attempt to evaluate or comment on the P1'esident's Energy Message and is based solely on policies in effect prior to Ap1'il18, 1.973.*

t NPC, *U.S. Energy Outlook: An Initial Appraisal* 1971-1985, Volume Two (November 1971).

- All dollar costs are expressed in constant 1972 dollars.
- Manpower cost is assumed to be effectively 28 percent higher in the United States than offshore (Caribbean).
- Expected product costs include interest on working capital and an assumed return on investment required on fixed assets. Although costs were computed for rates of return from 4 percent to 20 percent, costs are displayed at 10-percent and 15-percent rates of return for illustrative purposes. Rate of return is based on the discounted cash flow (DCF) method or internal rate of return method commonly used in the economic analysis of business projects.
- Future effects of inflation are not included.
- An income tax rate of 48 percent applies to onshore locations. No income tax is assumed for an offshore Caribbean location on the premise that refiners would be in a position to use tax concessions commonly available. However, the full report of the Committee shows offshore Caribbean costs with tax rates up to 28 percent for purposes of comparison. In Eastern Canada, the 49-percent statutory tax rate is assumed to be in effect.

These studies do not attempt to give finite answers on preferable locations either onshore or offshore. Each refinery location, of course, presents a special case, with its own particular site, transportation, labor, environmental and other related operating situations. However, the studies do adequately show the order of magnitude of the differential costs of producing petroleum products between the general areas studied.

On the basis of these assumed data, it would be expected that, to a large degree, the necessary refineries will be constructed offshore (except in the cases of Districts IV and V where suitable offshore locations are not readily available, but refineries supplying the U.S. West Coast from a Pacific Island or the West Coast of Latin America are not inconceivable). However, the Government may conclude that other considerations-military and economic security, balance of trade, and provision of jobs for U.S. citizens-provide greater overall benefits for the national economy than the cost savings from using foreign refineries. If overriding benefits require that new refining capacity be located in the United States, some differential incentives will be required to induce the domestic construction. Whatever policy is adopted, it should be clear and firm. If investors believe that government inducement to build onshore refineries is temporary, the economic attractiveness of doing so will be weakened. A program aimed at the lowest possible current product prices is not compatible with having ample domestic refining capacity. Policies that try to accomplish both of these objectives are ambiguous and are not likely to be effective.

The national implications of refining cost differences between offshore and onshore locations under various policy conditions are clearly illustrated in terms of District I supply. (The same principles apply to a lesser degree in Districts II and III.) Table 13, which summarizes the studies in the full report of the Committee, provides a basis for studying the patterns of refinery construction that are likely to result under various sets of circumstances. It shows illustrative expected costs, including return on invested capital, for supplying District I's product demand by several different methods, assuming no cost for crude oil import tickets and no price controls.

The assumptions and data in Table 13 can be summarized as follows:

- *Assuming refineries can be built in District I and imports of light products are prohibited:* New balanced refineries will be built in District I and will save consumers about $0.42 to $0.50 per barrel over bringing heavy fuels from offshore (item d minus item b of Table 13). The term "balanced refinery" refers to a refinery with a product slate of both light and heavy products proportional to the project-

TABLE 13

ILLUSTRATIVE RELATIVE COSTS
FOR SUPPLYING DISTRICT I*
($/Bbl of Product in 1985)

Origin of Supply	10% DCF Rate of Return	15% DCF Rate of Return
a. Offshore Balanced Refinery (Full Range of Products)	5.42	5.68
b. District I Balanced Refinery	5.58	6.07
c. District III Balanced Refinery	5.85	6.28
d. Combination of a Light Products Refinery in District I and a Heavy Fuel Oil Refinery Offshore	6.08	6.49
e. Combination of a Light Products Refinery in District III and a Heavy Fuel Oil Refinery Offshore	6.10	6.56

* These cost data include 1972 level U.S. import duties. For a detailed explanation of these data and other cases studied, see the full report of the Committee.

ed growth in product demands. To assure the production of low-sulfur heavy fuel oil in District I, it might also be necessary to limit its import from specialized units, such as low-sulfur crude oil topping plants.

- *Assuming refineries can be built in District I and imports of light products are permitted:* Balanced refineries will be built offshore to supply District I demands at a saving of $0.16 to $0.39 per barrel over an onshore, balanced refinery (item b minus item a). In other words, a cost disadvantage of $0.16 to $0.39 per barrel over and above the crude oil import quota cost must be overcome if the refineries are to be built in the United States.
- *Assuming refineries cannot be built in District I and light product imports are prohibited:* There would be a slight advantage of $0.25 to $0.28 per barrel to supplying District I from balanced refineries in District III instead of from light product refineries in District III and heavy fuel oil refineries offshore (item e minus item c). As previously noted, it might also be necessary to prevent fuel oil imports from low-sulfur crude oil topping plants.
- *Assuming refineries cannot be built in Dis-*

TABLE 14

ILLUSTRATIVE COSTS OF ONSHORE VS. OFFSHORE REFINERIES TO SUPPLY DISTRICT I GROWTH IN DEMAND
($/Bbl of Product in 1985)

	Origin of Supply		
	Onshore		
	District I	District III	Offshore*
Crude Oil in Persian Gulf†	2.65	2.63	2.69
Transportation and Terminalling‡	1.28	1.21	1.00
Duty	0.11	0.11	0.29
Operating Costs	0.48	0.45	0.38
Product Transportation		0.51	0.27
Interest on Working Capital	0.08	0.08	0.10
Marketing Expense	0.05	0.05	0.05
Income Taxes§	0.52	0.45	
Return on Refinery Investment ‖	0.90	0.79	0.90
Total (15% DCF Rate of Return)	6.07	6.28	5.68
Total (10% DCF Rate of Return)	5.58	5.85	5.42

* The tabulation of costs shown in this table for an offshore refinery is not based on any particular location, nor are there currently any offshore refineries making the assumed "balanced" District I slate of products. Current offshore refineries are of the hydroskimming type, feeding mixtures of low-sulfur and high-sulfur crude, primarily producing fuel oil for the U.S. market. Consequently, these costs are not intended to display actual circumstances of current offshore conditions.

† Prices of crude oil in the Persian Gulf are the same. Figures in the table differ because they are expressed in dollars per barrel of product, and product yields vary from location to location. Costs include butane purchases and exclude cost of acquiring import quota.

‡ Shipping at Worldscale 70 rates. Oil moves to District I by VLCC to a Caribbean terminal and thence by barge to the United States. District III uses VLCC's and a man-made deepwater port.

§ 48-percent tax rate onshore and zero offshore. It is assumed that a refiner offshore will make full use of tax concessions.

‖ 15-percent rate of return. Return is related to estimated refinery investments. Offshore refinery investments include a power plant which onshore refineries do not have.

trict I and light product imports are permitted: Balanced refineries would be built offshore to supply District I at $0.43 to $0.60 per barrel saving over an onshore, balanced refinery in District III (item c minus item a). In other words, a cost disadvantage of $0.43 to $0.60 must be overcome if the refineries are to be built in the United States in the event that they are prohibited in District 1.

Offsetting the cost disadvantages of onshore refineries the Nation's economy would benefit from the'creation of U.S. jobs, savings in the balance of trade, and a more secure refining system.

AO'ain in terms of District I supply, Table 14 illustrates where the differences between expected offshore and onshore costs occur.

It can be seen that several cost variations exist between onshore and offshore refineries. In general, the lower crude oil handling costs and lower operating costs offshore just about offset the duty on products imported into the United States. In addition, offshore refineries frequently enjoy tax advantages.

Because of the assumption that crude oil import licenses are available at no cost, these studies show that providing refiners with free access to foreign crude oil will not, by itself, be enough of an incentive to cause new grass roots refinery construction onshore. Supplemental incentives or programs, such as firm restrictions on product entry, are required to ensure onshore construction.

If foreign taxes are assumed to be higher, or if the rate of return is assumed to be IO'wer, the $0.39 per barrel advantage of foreign refineries shown in Table 14 will be less. These effects are illustrated in Table 15.

The illustrative economics of a refinery located in eastern Canada (as shown in Table 16) show quite a different set of economics than the cases previously described. In eastern Canada, the current income tax rate is 49 percent and, in addition, there is a statutory $0.04 per barrel environmental tax now applicable. As indicated by Tables 15 and 16, when the perimeter location income tax rates are comparable to domestic U.S. tax rates the economic advantage of offshore locations'tends to disappear *vis-a-vis* an onshore location.

As an indication of the relationship between current product prices and current costs, one illustrative case was prepared to show the cost associated with a 200 MB/CD District I balanced refinery using 1973 construction and operating costs. The results are that the product value is $5.67 per barrel and $5.30 per barrel at 15-percent and 10-percent DCF rates of return, respectively. The comparable average product price (as of December 1972) for an East Coast location was $4.85 per barrel. Hence, if a refinery could be built overnight, the refineries could expect a rate of return of 3 percent relative to December 1972 product prices.

Not all new U.S. refinery capacity will move offshore in response to these economic forces. The projection of domestic refinery capacity expansion, based on the NPC suryey, indicates that some new domestic constructIon wIII occur.

TABLE 16

ILLUSTRATIVE COSTS
OF EASTERN CANADA REFINERY*

	$/Bbl of Product in 1985
Crude Oil in Persian Gulf	2.63
Transportation and Terminalling	1.10
Duty Crude and Products	0.29
Operating Costs	0.31
Product Transportationt	0.20
Interest on Working Capital	0.10
Marketing Expense	0.06
49% Income Tax	0.52
Return on Investment (15% DCF Rate of Return)	0.91
Total	6.12
Pollution Tax	0.04
Total (15% DCF Rate of Return)	6.16
Total (10% DCF Rate of Return)	5.76

• Estimated from existing operations; hence the product slate is not wholly consistent with the product slate projections used to develop Table 14.

t At Worldscale 125 rates.

TABLE 15

SENSITIVITY OF PRODUCT COST
TO INCOME TAX RATE AND RATE OF RETURN
($/Bbl of Product in 1985)

	Advantage of Offshore Refinery over District I	
	10% DCF Rate of Return	15% DCF Rate of Return
0% Tax Rate Offshore	0.16	0.39
28% Tax Rate Offshore	0.05	0.17
48% Tax Rate Offshore	(0.02)	(0.02)

In the event that cost differences remain (coupled with crude oil availability and government policy uncertainties), exported capacity will increase by about 5 *MMBjCD* by 1985 to supply District I and part of District II.

The illustrative cost of supplying this 5 *MMBjCD* from domestic refineries instead of from offshore refineries was reached not by comparison of individual refineries, but by pairing two scenarios, each of which would provide the growth in demand for Districts I, II and III. One scenario is based on domestic construction as projected from the survey and on crude oil and product import quota controls. The other is based on effective programs to bar additional product imports over current levels and to solve environmental siting problems. In this latter scenario, all new refining capacity is built in the United States. The difference between these two scenarios in the costs of supplying the growth in demand is $0.17 per barrel of product (average cost of $6.07 per barrel for the product-import scenario *vs. $6.24* per barrel for the no-product-import scenario). This figure should be regarded as a rough measure of the cost to keep refining capacity in the United States when the three districts are considered as a whole. The cost difference for actual refinery construction in a single district could be higher.

Glossary

Glossary

°**API** gravity-American Petroleum Institute gravity is an expression of the density or the weight of a unit volume of material when measured at a temperature of 60° Fahrenheit.

alkylate-a synthetic gasoline of high octane number used in aviation and motor gasoline produced from an olefin and isoparaffin.

alkylation-a refinery process for chemically combining an isoparaffin and olefin in the presence of a catalyst. Sulfuric acid and hydrofluoric acid are the most commonly used catalysts.

alumina-a natural occurring type of clay containing a high percent of hydrated aluminum oxide commonly referred to as bauxite. Also a synthetically produced hydrated aluminum oxide of high purity. Used in refining processes as a drying agent and as a support for certain catalysts.

aromatic hydrocarbons-hydrocarbons characterized by the presence of a six-membered, unsaturated ring structure of carbon atoms. Examples include benzene, toluene and xylenes.

benzene-clear, colorless, extremely flammable liquid of molecular weight 78.11 found as a high octane component of catalytic reformate. Used in organic synthesis and as a solvent.

butane—a hydrocarbon of the paraffin series, consIsts of 4 carbon atoms and 10 hydrogen atoms. A naturally occurring component of crude oil and natural gas as produced at the well. A gas at room temperature and atmospheric pressure. Used in motor fuel, as petrochemical feedstocks, and as LPG (bottle gas).

butylene—a hydrocarbon of the olefin series, consIsts of four carbon atoms and eight hyd.rogen atoms. A product of a cracking operation and a gas at ambient temperature and atmospheric pressure. May be used as a component of motor fuel, feed to an alkylation unit, or in petrochemical operations.

carbon monoxide-colorless, odorless, very toxic gas formed as a product of incomplete combustion of carbon (as in water gas and producer gas, exhaust gases from internal combustion engines).

catalyst-a substance capable of changing the rate of a reaction without itself undergoing any net change.

catalytic cracking unit-a refinery process unit that converts a high boiling range fraction of petroleum (gas oil) to gasoline, olefin feed for alkylation, distillate, fuel oil and fuel gas by use of a catalyst and high temperature.

catalytic reforming-a catalytic process used to improve the antiknocl< quality of low octane gasoline by conversion of naphthenes (such as cyclohexane) and paraffins into higher octane aromatics such as benzene, toluene and xylenes.

cetane index or cetane number-a term indicating quality of diesel fuel as octane number indicates a quality of gasoline.

cobalt-a tough, lustrous, silver-white metal related to iron and nickel. In refinery use, cobalt oxide is combined with molybdenum oxide to make a catalyst used in hydrodesulfurization units.

crude unit-first processing equipment which crude oil reaches after it enters a refinery. Separates the crude oil into at least four different boiling range fractions. The four boiling ranges would be gasoline, distillate, gas oil and topped crude.

cyclone separator-a mechanical device for separation of liquid or solid particles from a gas stream by use of centrifugal force.

desulfurization-the process for removal of undesirable sulfur or sulfur compounds from petroleum products, usually by chemical or catalytic processes.

downtime-time during which a machine, department or factory is inactive during normal operating hours.

effluent-material discharged or emerging from a process or from a specific piece of equipment.

electrostatic precipitator-a device used to separate particulate materials from a vaporous stream. Separation is made by electrically charging the solid particles which are then attracted to an electrode of the opposite charge while the vapors pass through without change. This device is commonly used to remove particulates from catalytic cracking unit flue gases.

floating roof storage tank-a type of storage tank having a specially designed roof that floats on the surface of the product in the tank. The floating roof essentially eliminates evaporation loss experienced with fixed roof tanks.

flue gas-the products of combustion consisting principally of nitrogen, steam and carbon dioxide with small amounts of other components such as oxygen and carbon monoxide.

freeze point-the temperature at which a liquid changes to a solid.

gas oil-a petroleum product produced either from the distillation of crude oil or synthetically by a cracking process. The boiling range may vary from 500°F to 1,100°F.

hydrocarbon-any of a large class of organic compounds containing only carbon and hydrogen, comprising paraffins, olefins, acetylenes, alicyclics and aromatic hydrocarbons. Crude oil, natural gas, coal and bitumens are primarily hydrocarbons.

hydrodesulfurization-the removal of sulfur from hydrocarbons by reaction with hydrogen in the presence of a catalyst.

hydrofluoric acid-a colorless liquid boiling at 67°F soluble in all proportions in water. The water mixture is extremely corrosive to metals. Adequate safety precautions must be used when working with either liquid or vapor hydrofluoric acid. The use in the oil industry is as a catalyst in alkylation units and in acidizing oil wells.

hydrogen sulfide-a poisonous, colorless, flammable gas, which may be prepared by the direct combination of hydrogen and sulfur. Hydrogen sulfide can be reacted with caustic to form sodium sulfide or charged to a sulfur plant to produce sulfur. A component of sour crude oils.

intermediate crude oil-a crude oil containing both naphthenes and paraffins. Usually of intermediate sulfur content and in the medium gravity range.

isobutane-a hydrocarbon containing 4 carbon atoms and 10 hydrogen atoms, the same as normal butane. Different arrangements of the molecular structure result in different physical properties. Isobutane with olefin(s) is the feed to an alkylation unit to produce high octane gasoline.

isooctane-a hydrocarbon composed of 8 carbon atoms and 18 hydrogen atoms, a liquid at normal temperatures and a highly desirable component of gasoline. Although found in crude oil, the principal source is from synthetic processes such as alkylation.

liquefied natural gas (LNG)-natural gas which has been liquefied at a temperature of minus 258°F for ease of storage and transportation.

liquefied petroleum gas (LPG)-as a rule, it is a mixture of natural and/or refinery gases, compressed until a liquid and contained under pressure in steel cylinders. It is used as fuel for many different purposes, such as tractors, buses, trucks and stationary engines; for domestic and industrial purposes; and for power generation where commercial natural gas is not available. New uses are constantly being found. A recent development is the use of LPG as a direct quick-freezing agent in the frozen foods industry. It is also known and marketed as butane, propane, bottled gas, etc.

mercaptans-organic compounds possessing a thiol group (-SH). The simpler mercaptans have a strong, repulsive, garlic-like odor which becomes less pronounced with increasing molecular weight. Small amounts are intentionally added to LPG so that even small leaks will be readily noticeable.

molybdenum- silvery-white, very hard, metallic element with physical properties similar to those of iron and chemical properties similar to those of a non-metal. The oxide of molybdenum with the oxide of cobalt is used to make hydrodesulfurization catalyst.

naphtha-liquid hydrocarbon fractions, generally boiling within the gasoline range, recovered by the distillation of crude petroleum. Used as solvents, dry cleaning agents and charge stocks to reforming units to make high octane gasoline.

naphthenic crude oil-a crude oil that contains a large amount of naphthenic type compounds. A source of naphthenic lubricating oils. Characteristics vary widely between the different producing fields.

natural gas liquids (NGL)-a mixture of liquid hydrocarbons naturally occurring in suspension in natural gas and extracted by various means to yield a liquid product suitable for refinery and petrochemical feedstocks.

nitrogen oxide-any of several oxides of nitrogen, some of which are formed in a mixture as toxic fumes by the action of nitric acid on oxidizable material or by the decomposition of metal nitrates used as catalysts in refineries and the combustion of gasoline in internal combustion engines.

octane number-a term numerically indicating the relative antiknock value of a gasoline. It is based upon a comparison with the reference fuels isooctane (100 octane number) and normal heptane (0 octane number). The octane number of an unknown fuel is the volume percent of isooctane with normal heptane which matches the unknown fuel in knocking tendencies under a specified set of conditions.

olefins-a class of unsaturated (hydrogen deficient) open-chain hydrocarbons of which butene, ethylene and propylene are examples. Propylenes and butylene olefins with isobutane are used in an alkylation unit to produce high octane gasoline. Ethylene is the feedstock used by chemical plants to produce polyethylene plastic

paraffin-a white, tasteless, odorless, waxy substance obtained from some petroleum oils.

paraffinic type crude oil-a crude oil containing predominantly paraffinic hydrocarbons. Some types of this crude oil are used to produce high quality motor oils.

petrochemical feedstock-a fraction of crude oil or hydrocarbons which are used as a charge to process units in the production of petroleum based chemicals.

platinum-a silvery-white metallic element closely related to silver and gold. Used in the manufacture of catalysts used in catalytic reforming and isomerization units.

pour point-temperature at which an oil commences to flow under stated condition. Lowest temperature at which an oil can be poured. Reported in increments of 5°F.

propane-a saturated hydrocarbon containing three carbon atoms and eight hydrogen atoms, gaseous at normal temperature and pressure, but generally stored and transported as a liquid under pressure. Used for domestic heating and cooking and for certain industrial purposes, such as metal cutting.

silica-dioxide of silicon. Used in the manufacture of glass and refractory materials.

smoke point-the maximum height a flame can be extended without smoking the lamp chimney when testing kerosine under specified test conditions.

straight-run distillate-fraction of crude oil which boils between 400°F and 650°F. Primarily sold as kerosine, heating oil (No. 1 and No.2 fuel oil), and diesel fuel.

straight-run gasoline-low boiling fraction of crude oil which, after further processing, is used as a finished motor gasoline blending stock.

substitute natural gas (SNG)-a gas having similar chemical and use properties to natural gas. Manufacturable from petroleum liquids, coal and other hydrocarbons.

sulfuric acid-a heavy corrosive oily dibasic strong acid that is colorless when pure and is a vigorous oxidizing and dehydrating agent. Composed of sulfur, oxygen and hydrogen. Used in the chemical refining of petroleum products. One of the two commonly used catalysts for alkylation units.

sweet crude oil-a crude oil having so little sulfur that it requires no special treatment for the removal of sulfur compounds.

tetraethyl lead (TEL)-an organic lead compound which usually is added in concentrations up to 3 grams per gallon to motor and aviation gasoline to increase the antiknock properties of the fuel.

toluene-an aromatic solvent having a specific gravity ranging between 0.8690 and 0.8730. Has many chemical uses and may be a component of aviation gasoline or motor gasoline.

topped (reduced) crude-a residual product remaining after the removal, by distillation or other processing means, of an appreciable quantity of the more volatile components of crude petroleum.

vacuum unit-a unit operated below atmospheric pressure which allows vaporization of more of the heavier gas oil molecules from the crude residue without thermal disintegration of the molecules.

vapor recovery system-system for controlling hydrocarbon vapor losses from a refinery.

volatility-that property of a liquid which denotes its tendency to vaporize.