U.S. PETROLEUM REFINING

MEETING REQUIREMENTS FOR CLEANER FUELS AND REFINERIES

NATIONAL PETROLEUM COUNCIL
AUGUST 1993

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NATIONAL PETROLEUM COUNCIL
1625 K Street, N.W., Washington, D.C. 20006 (202) 393-6100

August 30, 1993

The Honorable
Hazel R. O'Leary
Secretary of Energy
Washington, D.C. 20585

Dear Madam Secretary:

On behalf of the members of the National Petroleum Council, I am pleased to transmit herewith the Council's report entitled *U.S. Petroleum Refining*. This report was prepared in response to a request from the Secretary of Energy and presents a stark yet comprehensive portrayal of the U.S. petroleum refining industry over the next twenty years.

The U.S. refining industry is a vital link in the nation's industrial and economic health. During the 1980s, even though the industry earned a modest profit of about 2.5 cents per gallon and realized an average return on investment of 8.8 percent, 120 refineries shut down. Profits in 1991 and 1992 have been much lower and refineries have continued to shut down. To comply with environmental requirements, the total cost of supplying light products to consumers is projected to increase by 6 and 10 cents per gallon by 1995 and 2000, respectively. These cost increases far exceed the past profitability of the industry and will have to be reflected in the marketplace.

Investments in the 1990s to meet environmental requirements on refineries and products are projected to be 37 billion dollars. This is greater than the current 31 billion dollar book value of the refineries themselves. Even if profits return to the level of the 1980s, cash flow for the industry as a whole would be negative by about 30 billion dollars from 1991 through 1995 and remain negative through the year 2000. If profits improve significantly so as to recover the cost of capital on the new environmental investment, then cash flow would improve, although it would still be far short of covering cumulative cash flow requirements in the 1991-2000 period.

Many refiners expect refineries will be under-utilized in the 1990s. They are seriously concerned that margins in a very competitive market will be inadequate to recover large environmental investments and other regulatory costs and that refinery shutdowns will continue. Since this study considered average costs for all refineries in a refining region, no conclusions can be drawn relative to the financial health of individual refineries. Rationalization implies that poorer financial performers fail. However, the financial and legal barriers to shutting down facilities are large. Hence, continued overcapacity is possible.

Light product demand is a key determinant of the industry's health. In the optimistic, growing demand scenario, after the U.S. industry is fully utilized, the study projects that foreign product would be imported rather than new U.S. refining capacity being built. In the pessimistic, declining demand scenario, the U.S. industry backs out imports but suffers declining utilization. There is significant concern that various governmental policies will reduce demand while, at the same time, other policies require major new environmental investments. The industry also faces foreign competition and other major uncertainties; for example, the requirements for reformulated gasoline are not known, enforcement regulations could disrupt today's product distribution system, and large future environmental expenses are anticipated.

The U.S. industry is competing in a global marketplace. Foreign refined products presently have lower embedded environmental costs than U.S. products. This study projects that, over time, foreign refiners will have total cost increases, including those for capacity additions, similar to those in the United States. This projection is uncertain; if only the United States pursues an aggressive environmental agenda, it would not be valid. The ability of the U.S. industry to recover its large environmental investments and expenses would be severely hampered if foreign product cost increases were smaller or later than projected in this study. Imports of light products would increase, U.S. refinery utilization would decrease, and more refinery shutdowns could occur. Also, foreign refineries are not subject to the level of civil law suits, punitive damage awards, and joint and several liability exposures experienced by refiners in the United States.

To minimize costs to the consumer and help maintain the health of the industry, the National Petroleum Council recommends that you take the lead in implementing the following:

- Cost-effective reformulated gasoline regulations that are fully compatible with the existing distribution system.
- A constructive partnership process involving interested stakeholders to create cost-effective solutions to societal concerns related to the industry.
- Recognition by policy makers that the costs of regulation will ultimately be reflected in the marketplace and will affect rationalization, competitiveness, and the long-term financial health of the industry.

This report provides extensive data and analyses that underscore our concerns. We sincerely hope that it will be of value to you, to the Administration, and to Congress in agreeing on the appropriate actions to serve the interests of consumers and the nation.

Respectfully submitted,

Ray L. Hunt
Chairman

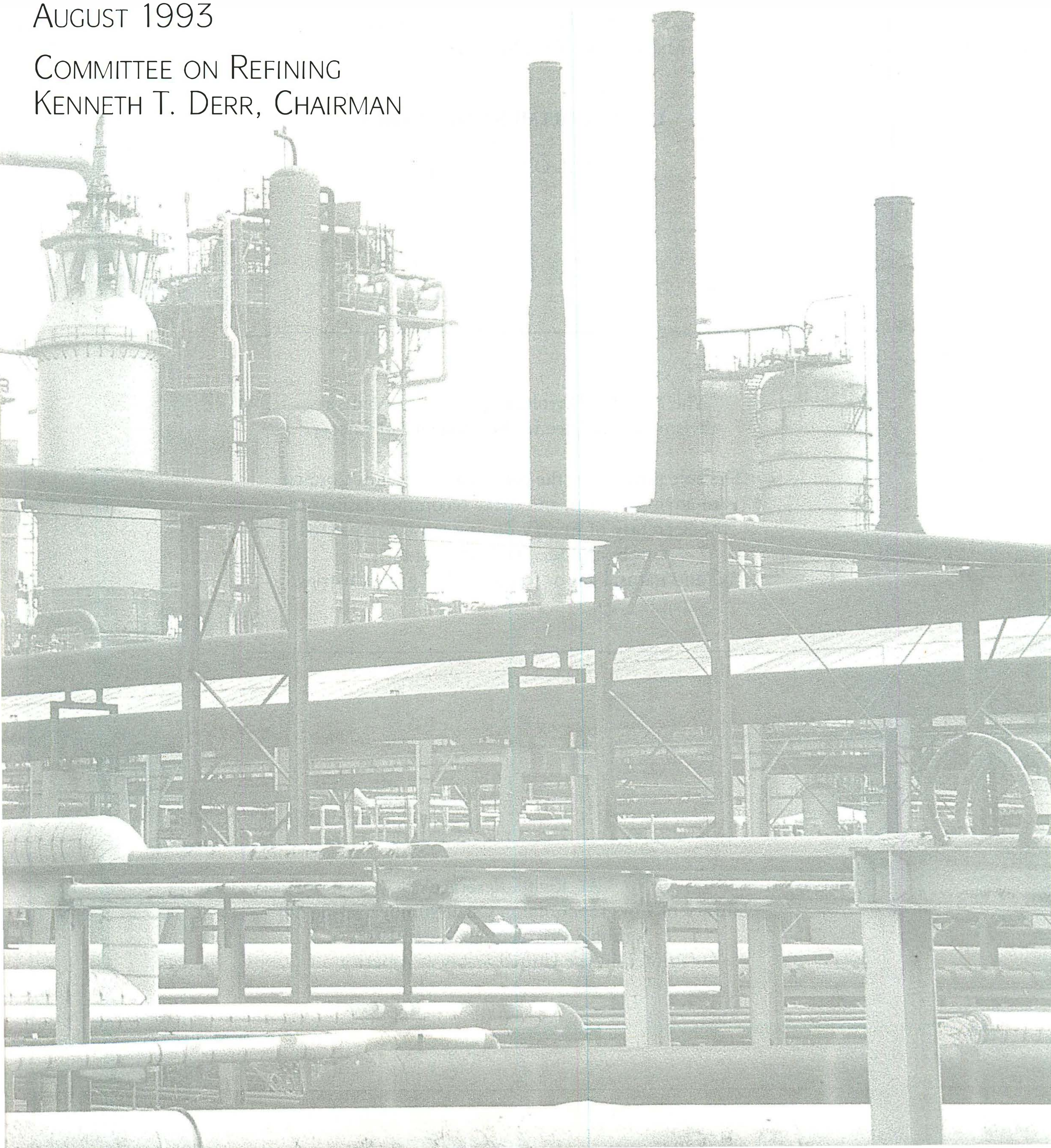
Enclosure

U.S. Petroleum Refining

Meeting Requirements for Cleaner Fuels and Refineries

National Petroleum Council
August 1993

Committee on Refining
Kenneth T. Derr, Chairman



NATIONAL PETROLEUM COUNCIL

U.S. DEPARTMENT OF ENERGY

The National Petroleum Council is a federal advisory committee to the Secretary of Energy.

The sole purpose of the National Petroleum Council is to advise, inform, and make recommendations to the Secretary of Energy on any matter requested by the Secretary relating to oil and natural gas or to the oil and gas industries.

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PREFACE

STUDY REQUEST

The National Petroleum Council (NPC), an advisory committee to the Secretary of Energy, has completed a two-and-a-half-year comprehensive study on the future of U.S. petroleum refining. In requesting the study, the Secretary asked that it focus on how environmental regulations impact refineries and petroleum products:

> I request that the NPC assess the effects of these changing conditions on the U.S. refining industry, the ability of that industry to respond to these changes in a timely manner, regulatory and other factors that impede the construction of new capacity, and the potential economic impacts of this response on American consumers.

The complete text of the Secretary's request letter and a description of the National Petroleum Council can be found in Appendix A.

STUDY ORGANIZATION

To assist in its response to this request, the NPC established a Committee on Refining chaired by Kenneth T. Derr, Chairman of the Board and Chief Executive Officer, Chevron Corporation. The Honorable William H. White served as Government Cochairman.[1] To provide study coordination and technical analyses, the Committee established a Coordinating Subcommittee, a Financial Analysis Subgroup, and four Task Groups: Refinery Facilities; Supply, Demand, and Logistics; Product Quality; and Survey. Rosters of the study groups are presented in Appendix B.

STUDY APPROACH

The NPC Committee on Refining decided on a two-phase study approach to respond to the Secretary's request. The first phase was to focus on the impact of Title II of the Clean Air Act Amendments (1990). The second phase was to be a broader and more detailed examination of the capabilities of the refining industry and the potential impact of the broad range of environmental initiatives and other issues facing refiners.

Phase I

Phase I of the study was conducted in a six-month time frame. The Phase I report, entitled *Petroleum Refining in the 1990s—Meeting the Challenges of the Clean Air Act*, was issued by the NPC in June 1991. In the report, the NPC presented advice on efficient and effective ways to implement the motor gasoline and diesel fuel requirements of Title II of the Clean Air Act Amendments (1990). The basis of the report was a series of interviews conducted for the NPC by McKinsey & Company, Inc. Twenty leading refining companies, and five major engineering and construction firms, were interviewed. To protect the confidentiality of the individual interviews, only aggregated results were provided to the study participants. The NPC analysis of the interview results led to conclusions and recommendations on several key Environmental Protection Agency regulatory actions necessary to enhance the chances for successful compliance with the Clean Air Act. These conclusions and recommendations are related to the 1992 program for oxygenated fuels in carbon monoxide nonattainment areas, to the 1995 program for reformulated gasoline

[1] The Honorable Linda G. Stuntz cochaired the Committee until January 1993.

in ozone nonattainment areas, to the 1993 program requiring ultra-low sulfur on-highway diesel fuel, to timely permits for required modifications or new construction, and to post-1995 concerns. See Appendix C for a discussion of the winter 1992-93 oxygenate supply situation. The complete report is available from the NPC.

Phase II

This report presents the findings and conclusions of Phase II of the study, as well as the supporting analyses and documentation. It assesses the ability of the U.S. oil industry, both physically and economically, to manufacture and supply the quantity and quality of products required in the 1990s and beyond. The competitiveness of domestic versus foreign supplies is analyzed. The investment requirements and other costs associated with meeting the new environmental legislation and regulations on both refinery products and the refineries themselves are addressed. In particular, the requirements and consequences of the 1990 Clean Air Act Amendments and other environmental, health, and safety initiatives, both current and prospective, are evaluated.

To support the analysis of the U.S. refining industry, the NPC conducted an extensive survey of all U.S. refineries, including refineries located in U.S. territories in the Caribbean, pipeline operators, terminal operators, motor gasoline blenders, and companies with U.S. offices doing business in foreign countries. The aggregated survey results were provided to the study groups for use in the industry modeling and analysis, particularly for the 1991-1995 time frame. The NPC retained SRI International to conduct the survey and protect the confidentiality of the survey data by collecting and tabulating the survey data and providing only aggregated data to the NPC study participants. All survey data were destroyed upon completion of the study.

The report includes analyses and costs from the refinery inlet to the marketing facility inlet. In general, state and local regulations are not addressed. However, certain California regulatory costs are included in some analyses. All costs in this report are presented in constant 1990 dollars except where otherwise specifically stated.

Detailed regulations on refineries as stationary sources and on reformulated gasoline are not final. The approach used in addressing regulatory uncertainty was:

- To premise regulations and resulting hardware requirements for the refineries based on available technology and equipment.
- To assume cost-effective product regulations for federal Phase II reformulated gasoline for the year 2000. This results in a much less severe reformulation than, for example, California Air Resources Board Phase 2 gasoline.

U.S. product demand uncertainty was covered by considering three scenarios representing growth (Foundation Case I), no growth (Foundation Case II), and decline (Foundation Case III). These scenarios are expected to encompass the range of the U.S. demand through 2010.

Phase II analyses were conducted by the National Petroleum Council study groups, supported by a number of contractors and outside experts, as shown in Figure 1.

The principal results of Phase II are highlighted in this Executive Summary. Chapters One through Five in Volume I of this report provide discussion of the study analyses. Further levels of detail are available in the report's Appendices Volumes and Working Papers, which can be obtained by contacting the NPC offices or by using the order form in the back of this report.

A brief review of the October 1986 NPC report, *U.S. Petroleum Refining*, is provided in Appendix D. General information concerning the U.S. refining industry can be found in Volume II of this report, covering Alternative Transportation Fuels, Summary of Environmental Legislation, History, Refining Operations, and Environmental Operations.

The appendices to the report chapters are available in Volumes III-VI.

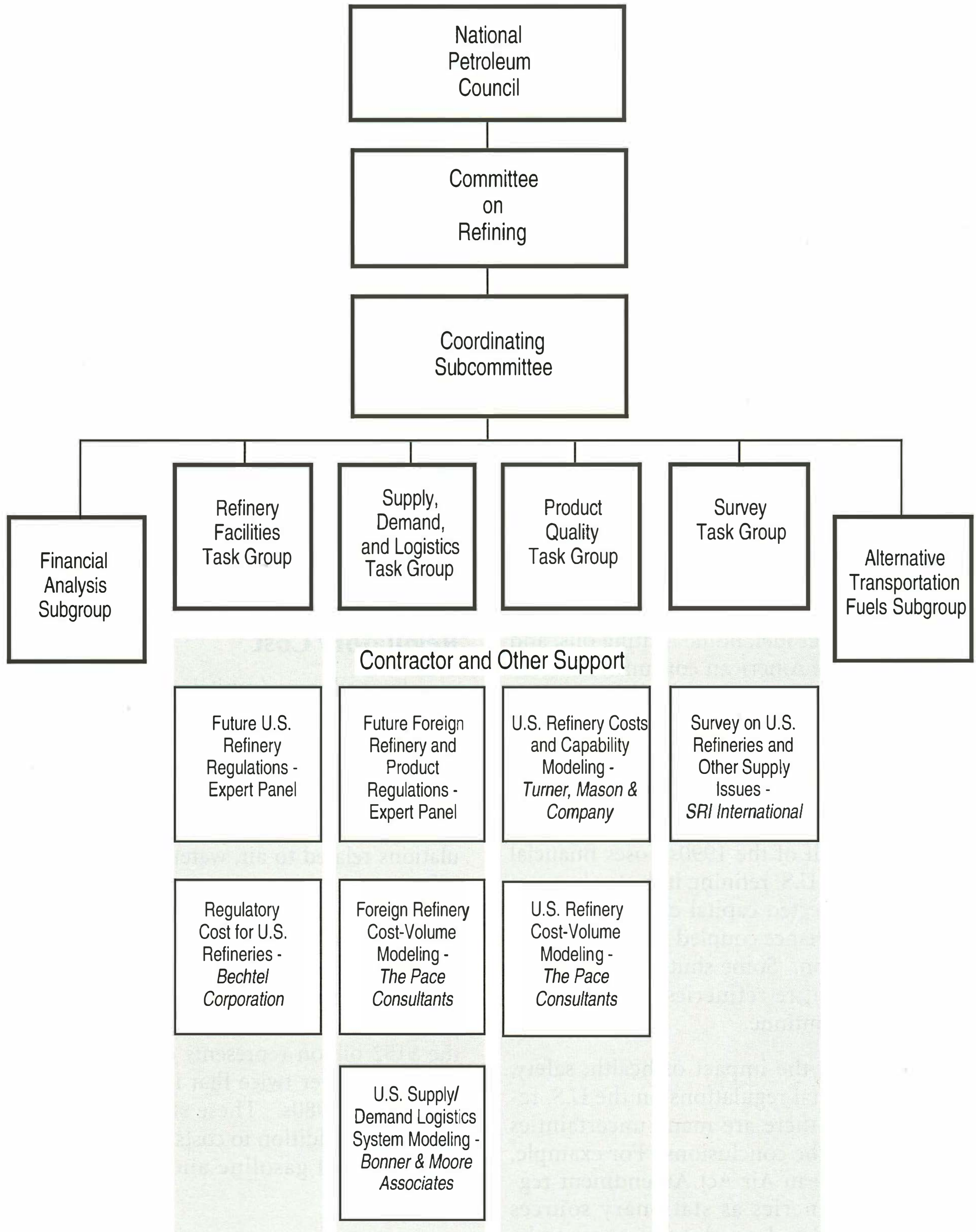


Figure 1. Study Organization.

Overview

The National Petroleum Council concludes that the U.S. refining industry can, with investment, meet foreseen consumer demand and environmental, health, and safety regulatory requirements. However, given the industry's recent low profitability and the uncertainties surrounding future regulations and product demands, it is by no means certain that companies will be willing and able to make the necessary expenditures for all facilities.

In the 1991-2000 decade, the U.S. refining industry will need to make capital expenditures of about $37 billion (1990 dollars) to meet refinery regulatory requirements and to manufacture reformulated gasoline and ultra-low sulfur diesel fuel. The additional cost of supplying gasoline, jet fuel, home heating oils, and diesel fuels to the American consumer to comply with these regulations will reach $18 billion per year by 2000, which is an increase of 10 cents per gallon of these products. Ultimately, the cost of meeting regulatory requirements will be reflected in the marketplace.

The first half of the 1990s poses financial difficulty for the U.S. refining industry because of the large projected capital expenditures for regulatory compliance coupled with declines in refinery utilization. Some shutdown of capacity, including entire refineries, has occurred and is likely to continue.

In studying the impact of health, safety, and environmental regulations on the U.S. refining industry, there are many uncertainties that could alter the conclusions. For example, detailed 1990 Clean Air Act Amendment regulations on refineries as stationary sources and on reformulated gasoline have yet to be promulgated. Another uncertainty is the future demand for petroleum products. The level of product demand affects U.S. refinery utilization, which directly impacts the ability to finance refinery modifications, the ability to recover costs, and the future structure of the refining industry. Demand is influenced by factors such as taxation, state of the economy, automobile efficiency, population growth, use of alternative fuels, and prices.

Based on this study, the National Petroleum Council suggests that the Department of Energy and other government policymakers and regulators carefully consider the following eight key conclusions and three general recommendations.

CONCLUSIONS

U.S. Refinery Stationary Source Regulatory Cost

Expenditures (capital, one-time expenses, and operating and maintenance expenses) of $106 billion (1990 dollars) are projected over the 20-year period 1991-2010 for new facilities and programs necessary for compliance with existing and anticipated stationary source regulations related to air, water, and waste and to safety and health requirements within U.S. refineries. In addition, $46 billion will be spent to operate and maintain similar facilities and programs now in place, for total stationary facilities environmental, health, and safety expenditures of $152 billion. As a comparison, the $152 billion represents average annual expenditures over twice that incurred in the last half of the 1980s. These stationary facilities' costs are in addition to costs for manufacturing reformulated gasoline and ultra-low sulfur diesel fuel.

Refining and Logistics Costs

Refining and logistics costs in the United States are projected to increase substantially. For example, relative to 1989 conventional gasoline, reformulated gasoline is projected to cost about 8, 12, and 14 cents (1990 dollars) per gallon more in 1995, 2000, and 2010, respectively. These include costs to the refineries for stationary emissions control improvements and additional health and safety regulations, costs due to more intensive processing and oxygenate addition to produce fuels, and costs of changes in the product logistics system to meet future regulations. Similarly, in 1995, 2000, and 2010, the cost to supply on-highway diesel fuel will be 7, 9, and 11 cents per gallon more than the cost to supply conventional diesel fuel in 1989.

The consumer using reformulated or oxygenated gasoline can expect to see an additional effective increase in cost of 2 to 3 cents per gallon because these gasolines have a lower energy content and hence give poorer mileage. The ultimate impact on the consumer would also include other factors, such as changes in raw material cost, taxes, marketing costs, as well as marketplace competition.

More stringent, costlier reformulations of gasoline might be required. For example, the refining cost to make California Air Resources Board Phase 2 quality gasoline for the entire United States would be 9 cents per gallon more than the study's estimated cost of making federal Phase II reformulated gasoline.

Financial

Projected U.S. refining capital expenditures of $37 billion (1990 dollars) in the 1991-2000 period for product quality (cleaner transportation fuels) and stationary source regulatory compliance exceed the total net fixed asset base of U.S. refineries of $31 billion at the start of this period. About two-thirds of the capital expenditures are projected to be made in the 1991-1995 period. Assuming all operating expenses (including depreciation) are recovered, cash flow generated during the 1991-1995 period is still on the order of $25 billion less than the required capital expenditures.

Product revenue increases will be necessary to recover operating expenses and to provide competitive returns on the capital employed. The projected cost increase in 2000 for regulatory compliance is more than twice the U.S. refining, marketing, and transportation industry's historical average net income in the 1980s. Given the projection of declining refinery utilization through 1995, recovery of these costs will be difficult until capacity and demand are rebalanced by further capacity shutdowns and/or increased product demand.

Product Compatibility

The logistics system will remain effective only if regulated product specification and enforcement procedures, including testing tolerances, allow product compatibility throughout. Product compatibility means being able to mix separate batches of a specific product as necessary for effective operation of the logistics system. If absolute batch segregation were required, the logistics system as it exists today would be inoperable.

Current product specifications and enforcement procedures allow effective use of the logistics system because commingling of similar products does not result in off-specification products at the final point of sale. Regulations such as those proposed by the Environmental Protection Agency on February 26, 1993 for reformulated gasoline could preclude any mixing of batch shipments of gasolines of the same grade in any degree, no matter how incidental. This would require isolating each batch from other batches of reformulated gasoline and therefore require many more segregations. If the number of segregations exceeds what can be practicably accommodated, the expected consequences would range from increased manufacturing and distribution costs and sporadic runouts to complete failure of some systems.

Refining Capability

With appropriate capital expenditures, sufficient volumes of on-highway diesel fuel and reformulated gasoline meeting requirements of the 1990 Clean Air Act Amendments can be manufactured in existing and anticipated process facilities using current technology and available engineering and construction resources. This assumes regulations, including enforcement and compliance provisions, for federal Phase II reformulated gasoline are set to provide cost-effective volatile organic compound reduction in ozone nonattainment areas.

Oxygenates

Assessment of worldwide existing capacity and announced expansion plans for producing oxygenates indicates adequate supply in 1995 for at least the legislated minimum requirements. By 2000, the potential supply is expected to cover essentially any situation permitted by the 1990 Clean Air Act Amendments. Needs in 2000 were estimated on the basis of all ozone nonattainment area opt-in to the federal reformulated motor gasoline program, the Northeast Ozone Transport Corridor using federal reformulated motor gasoline, and California using California Air Resources Board Phase 2 gasoline. Assuming all announced projects are built, the calculated supply for 2000 is close to the estimated requirements.

Foreign Product Supply Cost

Today, most foreign areas lag the United States in health, safety, and environmental regulations and, consequently, have lower embedded environmental costs than the United States. Over time, the total cost of foreign supply delivered to the United States is projected to increase as result of product quality changes outside the United States; foreign capacity additions needed to meet local demand growth; and foreign environmental, health, and safety regulations for stationary facilities. The study's projected foreign total cost increase is approximately the same as the corresponding U.S. cost increase. However, there is significant uncertainty in these cost increase estimates.

If future foreign environmental regulations are less severe than expected, or are not enforced, then the cost of foreign light product would be lower. Unlike the United States, where stationary facilities' environmental cost increases are the major factor, more of the foreign cost increases result from product quality and capacity addition factors. The financial ability of foreign refineries to meet these projected higher regulatory costs was not studied but could result in a situation similar to that projected for U.S. refineries.

Product Supply and U.S. Refinery Utilization

Evaluation of future oil product demand scenarios using expected foreign and U.S. product cost increases suggests that, if the required investments are made, the U.S. refinery complex will continue to supply most of the future U.S. light product demand. However, because of relatively flat U.S. demand through 1995 under all scenarios studied and increasing supply from oxygenate blending into gasoline, U.S. capacity utilization is lower in 1995 than in 1989, assuming no capacity shutdown. For later study years, capacity utilization changes consistent with projected demand conditions. Absent rationalization, the U.S. demand for light products is likely the most significant determinant of U.S. refinery capacity utilization.

However, the pace of foreign cost increases relative to those in the United States is important. Imports of light products would increase and U.S. refinery utilization would decrease if foreign refinery cost increases were smaller or later than premised. A sensitivity case with a foreign cost increase about two-thirds of the corresponding U.S. cost increase was evaluated. This cost differential was based on no increase in foreign stationary source environmental costs between 1989 and 2000 with corresponding U.S. costs only for those requirements supported by existing legislation. In this case, projected 2000, U.S. refinery output shifts from 94 percent of U.S. light product supply to 89 percent. The result is a light product import level of 1.24 million barrels per day, compared with 0.57 million barrels per day in the base case and a reduction in U.S. refining capacity utilization from 88 to 83 percent.

RECOMMENDATIONS

The National Petroleum Council requests that the Secretary of Energy take the lead in implementing the following recommendations.

Cost-Effective Regulations on Reformulated Gasoline

Reformulated gasoline certification and enforcement provisions should reflect the practical necessity to use the existing distribution system. Reformulated gasoline regulations that address product compatibility, fungibility, test tolerances, and enforcement should be developed on a cost-effective basis. The National Petroleum Council is especially concerned that the program for enforcement downstream of the refinery might remove much of the flexibility anticipated by refiners and raise the overall costs of the reformulated gasoline program beyond levels projected in this study.

Regulatory Resolution

U.S. refiners should be included in a constructive process with government and other interested stakeholders to plan strategies and develop cost-effective solutions to societal concerns related to the industry.

A more constructive process that involves all interested stakeholders—industry, government, and other affected parties—working in partnership could lead to more efficient cost-effective regulations and enforcement procedures for meeting a given environmental goal. Better overall solutions to problems such as meeting the federal air quality standards can be developed in a cooperative, multimedia approach rather than regulating individual pollutants from various sources. The recommended partnership should allow broader consideration of environmental goals and possible solutions, while sharing the burden of responsibility for cost-effective regulations and enforcement procedures and committing to proactive betterment of quality of life (i.e., reasonable reduction of health, safety, and environmental exposures).

The Environmental Protection Agency (EPA) ultra-low sulfur diesel fuel regulation is a good example of efforts that have been made to achieve negotiated, cost-effective solutions. Government, the oil industry, diesel engine manufacturers, and consumers were involved at an early stage. Since adequate time to comply was provided, the interactive process led to a level of diesel fuel desulfurization and engine modification that appears to be cost-effective and beneficial for the industries, the consumer, and the public. However, the process was not entirely satisfactory because ultra-low sulfur diesel fuel production had to begin before enforcement standards were final.

Other promising efforts to improve regulatory resolution are the Amoco-EPA Yorktown study of stationary source pollution prevention discussed in the full report, and the ongoing EPA industrial cluster concept.

Environmental Cost Recovery in the Competitive Marketplace

Government policymakers should recognize that in the competitive marketplace, product cost increases and some rationalization of the refining industry are probable outcomes of environmental and other regulation of refineries and petroleum products. Policies that reduce petroleum products demand also result in rationalization of the refining industry, with an attendant loss of jobs. Over the long term, refining expenditures will be reflected in the marketplace. In effect, the consumer pays an indirect tax for the mandated environmental improvements and, as with direct taxes, the public ought to receive commensurate benefits. Impacts of policy should be carefully and realistically evaluated prior to legislation or regulation.

Government policymakers should also recognize that the U.S. refining industry is competing in a global industry. If U.S. costs are significantly higher than those of foreign refineries, then U.S. source product is not as competitive, either for supplying U.S. customers or for export. The result could be a greater dependence on foreign source product and lower utilization of existing U.S. refining capacity.

FINDINGS

PROLOGUE

The U.S. refining industry enjoyed robust product demand growth in the post-World War II era into the early 1970s. Any excess capacity resulting from new plants or unit expansion was soon filled by demand growth. With the price shocks and periods of crude oil shortages in the 1970s, product demand growth slowed and in some periods declined. The refining industry changed in the 1970s from a growth industry to a mature industry. With the decline in U.S. crude oil production, imports of crude oil and other refinery feedstocks increased to meet refinery raw material requirements. However, light product (gasoline, jet fuel, and distillate) imports remained a small proportion of U.S. product supply. Figures 2 and 3 display the product demand as well as crude oil and product import levels from 1970 to 1992.

The number of refineries and distillation capacity grew steadily from 1970 through 1981. In 1979, crude oil runs started to decline, reflecting reduced product demand. With oil price decontrol in 1981, the total number of individual operating refineries dropped from a high of 315 in 1981 to 192 in 1986 as "crude oil entitlement" and other refineries became uneconomic, and shut down. Thereafter, slowly increasing light product demand resulted in increased downstream processing and conversion unit capacity and utilization, while rationalization of crude oil distillation capacity continued. Figure 4 shows the number of refineries, distillation capacity, and total crude oil runs from 1970 through 1992.

The U.S. refining industry is an important component of the U.S. economy and is especially vital to the transportation sector. The industry supplies 97 percent of the energy for the travel and freight needs of the nation. Fuel demands for more than 190 million automobiles, trucks, and buses as well as all aircraft are met by petroleum-based fuels.

U.S. refinery products have evolved over the last three decades and are not the same products bought by consumers in the 1960s. Although Los Angeles inaugurated gasoline regulation in 1959 in the form of a bromine number limitation (olefins content), federal regulation of gasoline quality began in the 1970s after the Clean Air Act of 1967. Significant use of oxygenates in gasoline for octane, volume, or emissions reduction began in the 1980s. The 1990 Clean Air Act Amendments mandated oxygenated gasoline in late 1992 and require reformulated gasolines (Phase I) in 1995. Oxygenates are expected to comprise 4 to 7 volume percent of U.S. gasoline in the year 2000 depending on the level of opt-in. Phase II reformulated gasoline performance standards require further emissions reduction in 2000. Lead will be completely eliminated by 1996, although very little lead is used even now. Gasoline quality has been further improved with enhanced additive packages that yield cleaner engines, improved efficiency, and lower emissions. In addition, ultra-low sulfur diesel fuel (0.05 weight percent sulfur) is required by the 1990 Clean Air Act Amendments for on-highway use beginning in October 1993.

The U.S. logistics system provides efficient distribution of light petroleum products to every part of the country. Terminals have been constructed at refineries, ports, and locations central to markets. Seventy-two thousand miles of major product pipelines cross the country connecting refineries and terminals. When economic, companies have joined together in pipeline and terminal ownership to seek efficiencies and economies of scale. Fleets of ships, barges, and rail tankcars serve the terminals. Trucks deliver products from terminals to retail outlets and wholesale customers.

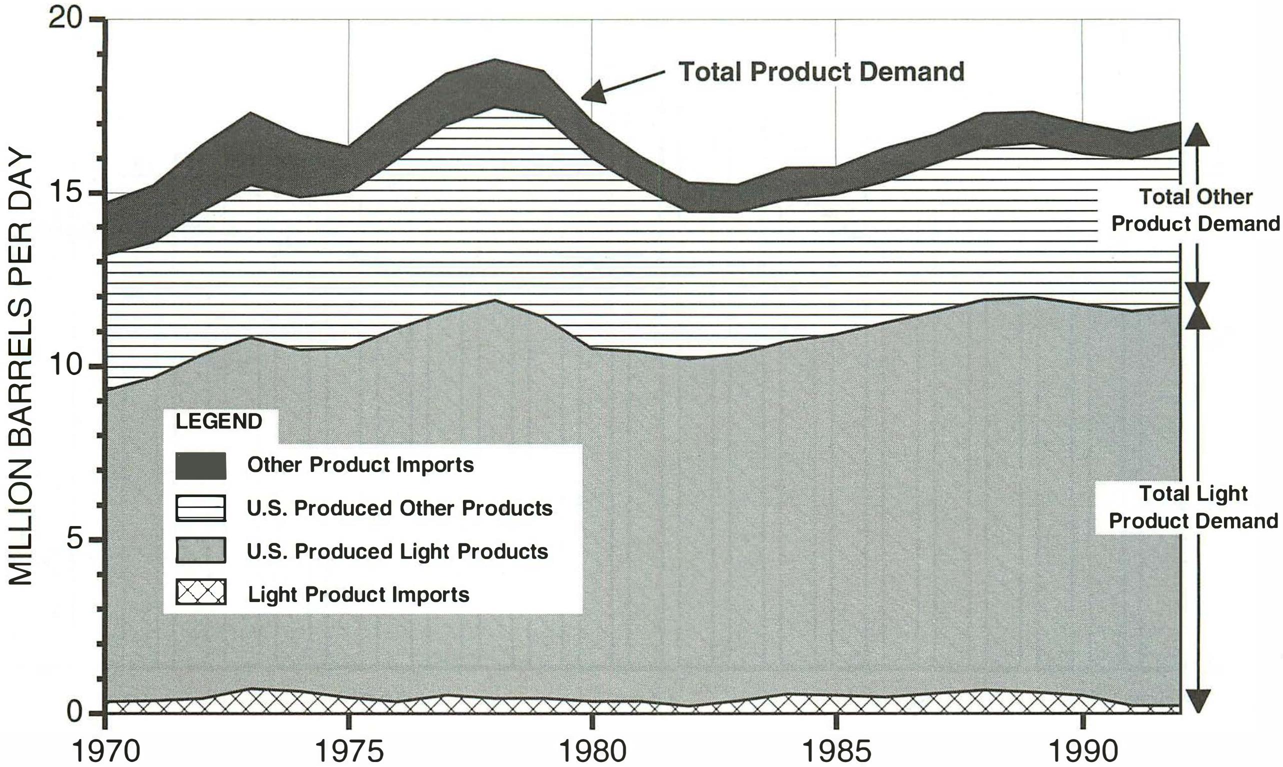


Figure 2. U.S. Petroleum Product Demand
Imports and Domestic Supply.

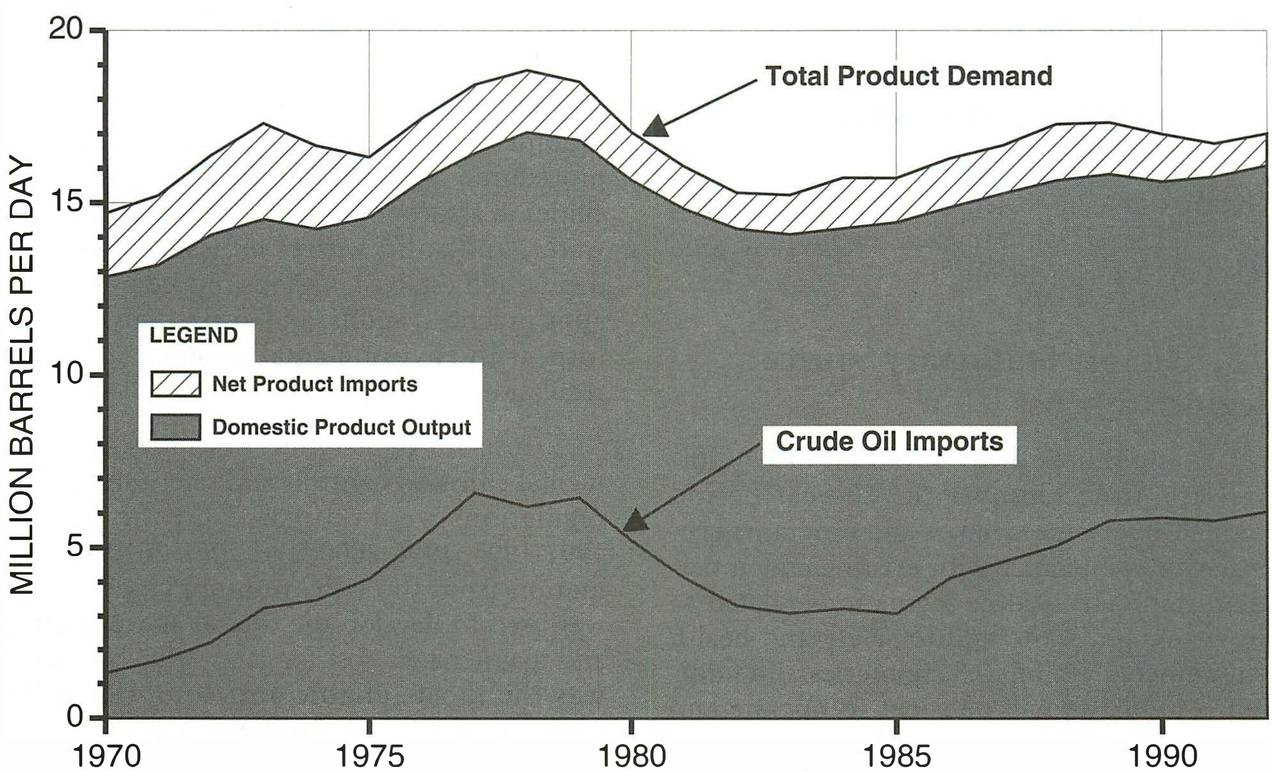
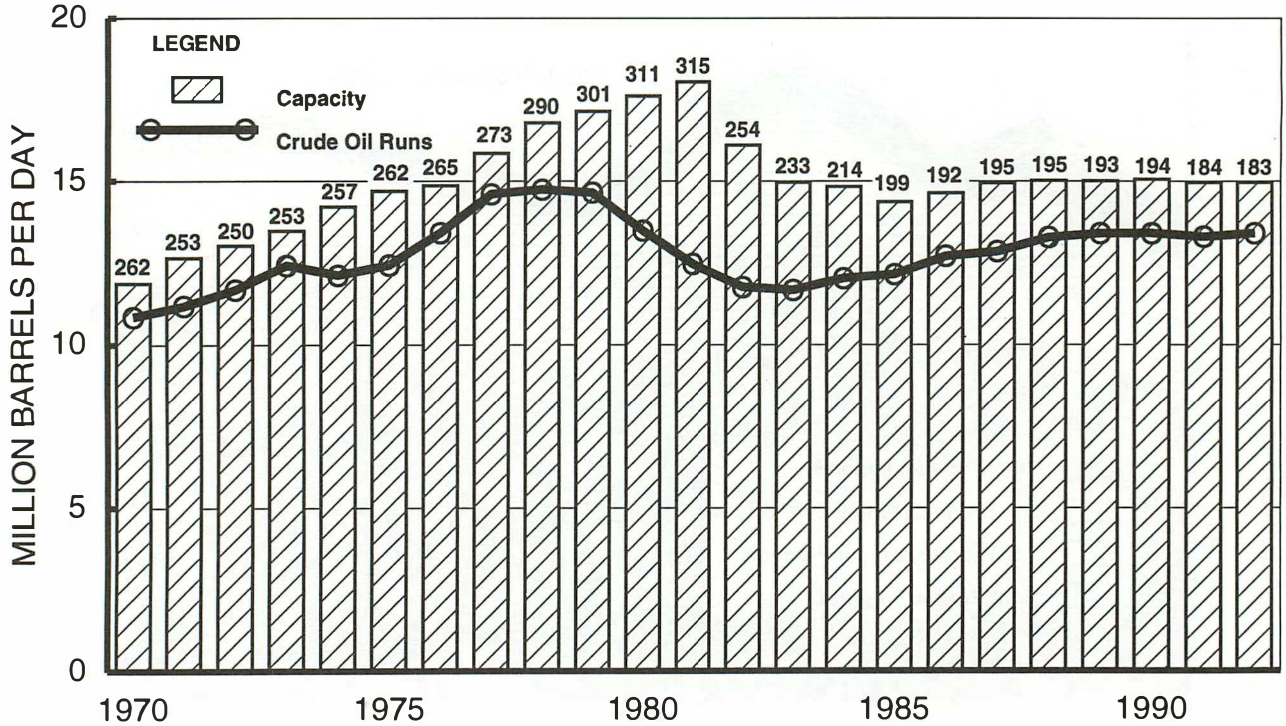


Figure 3. U.S. Product Demand
Relative to Refinery Input Source.



Source: U.S. Bureau of Mines (1970-1975), Energy Information Administration (1976-1992).

Figure 4. U.S. Operating Refining Capacity (With Number of Refineries and Crude Oil Runs).

Environmental regulations have affected the logistics system as well as the refineries.

DISCUSSION OF FINDINGS

The key conclusions presented in the Overview are supported by the findings of the study. This section discusses the findings pertinent to each conclusion.

U.S. Refinery Stationary Source Regulatory Cost

Expenditures of $106 billion (1990 dollars) are projected over the 20-year period 1991-2010 for new facilities and programs necessary for compliance with existing and anticipated stationary source regulations related to air, water, and waste and to safety and health requirements within U.S. refineries. In addition, $46 billion will be spent to operate and maintain similar facilities and programs now in place, for total stationary facilities environmental, health, and safety expenditures of $152 billion. As a comparison, the $152 billion represents average annual expenditures over twice that required in the last half of the 1980s.

Environmental regulations will impact the U.S. refining industry by requiring significant modifications and additions to facilities and procedures. Refiners must provide control facilities to assure compliance with all media (air, water, and solid waste) emissions requirements, and establish various procedures (operating practices, audits, and inspections) to conform with environmental, health, and safety regulations.

Costs for these refinery facilities' environmental emission controls and safety and health regulations were estimated for the periods 1991-1995, 1996-2000, and 2001-2010. Information from the NPC refining study survey was used to develop the capital and operating and maintenance cost for 1991-1995 because it was the most reliable and comprehensive source available. The following describes the approach for later periods:

- A panel of industry experts developed detailed premises defining current and anticipated air, water, waste, safety, and health regulations.

- The premises were used to define the hardware needed for specific emission sources and programs to meet procedural requirements. For this effort, compliance with specific regulations was the overriding criterion without consideration of cost-effectiveness.
- Use of best, maximum, or reasonable available control technology as applicable was assumed. Needs were not set by site-specific evaluation of risks and cost-effectiveness.
- Capital, one-time, and operating and maintenance costs required for implementation were separately estimated.

Table 1 summarizes the results, which show a 20-year cash requirement (capital expenditures, one-time expenses, and operating and maintenance expenses) of $152 billion for compliance with existing and anticipated regulations relative to air, water, waste, safety, and health within the refinery fence lines. These stationary facilities costs are in addition to the costs associated with manufacturing reformulated and oxygenated gasolines and ultra-low sulfur diesel fuels.

These regulatory capital expenditures, one-time expenses, and operating and maintenance expenses require an average annual cash outlay before tax of over $6 billion per year in the early period, increasing to over $8 billion per year. During the 1980s, similar expenditures were about $3.5 billion per year.

The premises considered only those regulatory items believed to have significant individual financial impact. As the costs of numerous small items were not quantified, the overall study cost estimates tend to be conservatively low. Further, the forecasted decline in capital expenditures toward the end of the study period is typical of any long-range evaluation. Undefined expenditures for site closures including cleanup, possible increased soil incineration, and further, less cost-effective regulations are not included in this analysis. The ability to project the pace and severity of future regulations diminishes the farther one looks into the future.

Figure 5 indicates that, on average, the 24 refineries with 100 to 150 thousand barrels per day of capacity (which is near U.S. average-size conversion refinery) will be required to expend $1.2 billion each between 1991 and 2010. Generally, refineries face costs proportionate to their size.

TABLE 1

STATIONARY SOURCE
ENVIRONMENTAL FACILITIES AND PROGRAM COST
(Billions of 1990 Dollars)

	1991-1995	1996-2000	2001-2005	2006-2010	Total
Capital Expenditures	12.6	10.2	6.8	6.7	36.3
One-Time Expenses	4.5	1.3	0.6	0.6	7.0
Operating and Maintenance Expenses (New)	4.1	14.2	20.7	23.6	62.6
Subtotal	**21.2**	**25.7**	**28.1**	**30.9**	**105.9**
Operating and Maintenance Expenses (Base)	11.5	11.5	11.5	11.5	46.0
TOTAL	**32.7**	**37.2**	**39.6**	**42.4**	**151.9**
Annual Average	6.5	7.4	7.9	8.5	

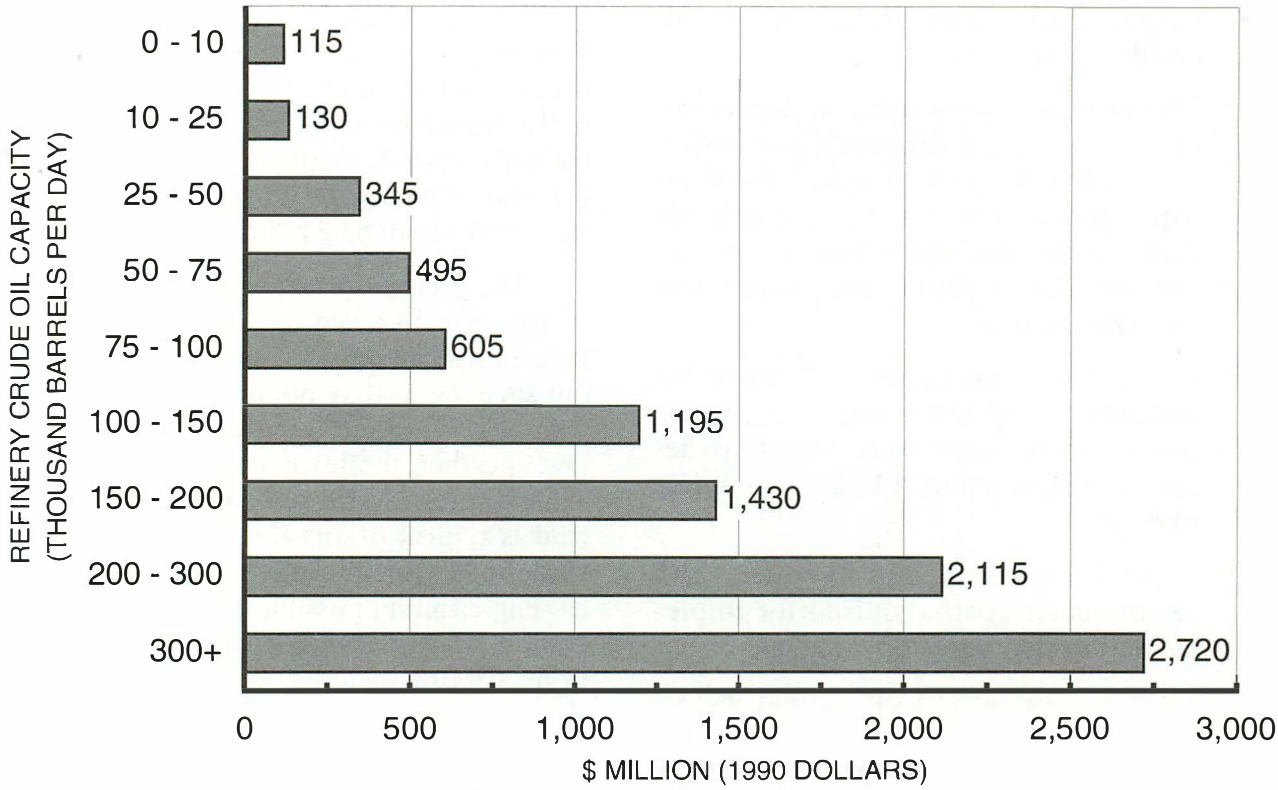


Figure 5. Environmental Facilities and Programs—
Average Total 1991-2010 Cost for Each Operating Refinery.

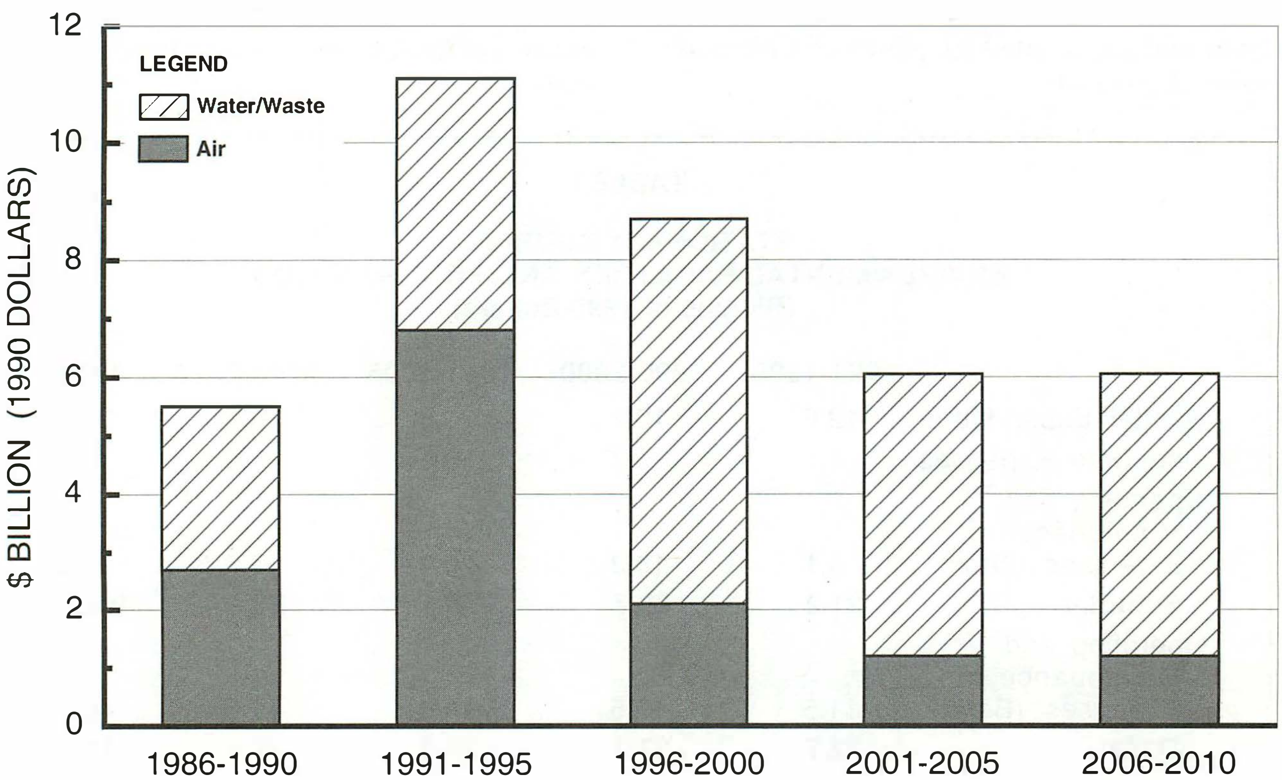


Figure 6. Regulatory Environmental, Safety, and Health Capital Expenditure
Requirements for Stationary Facilities.

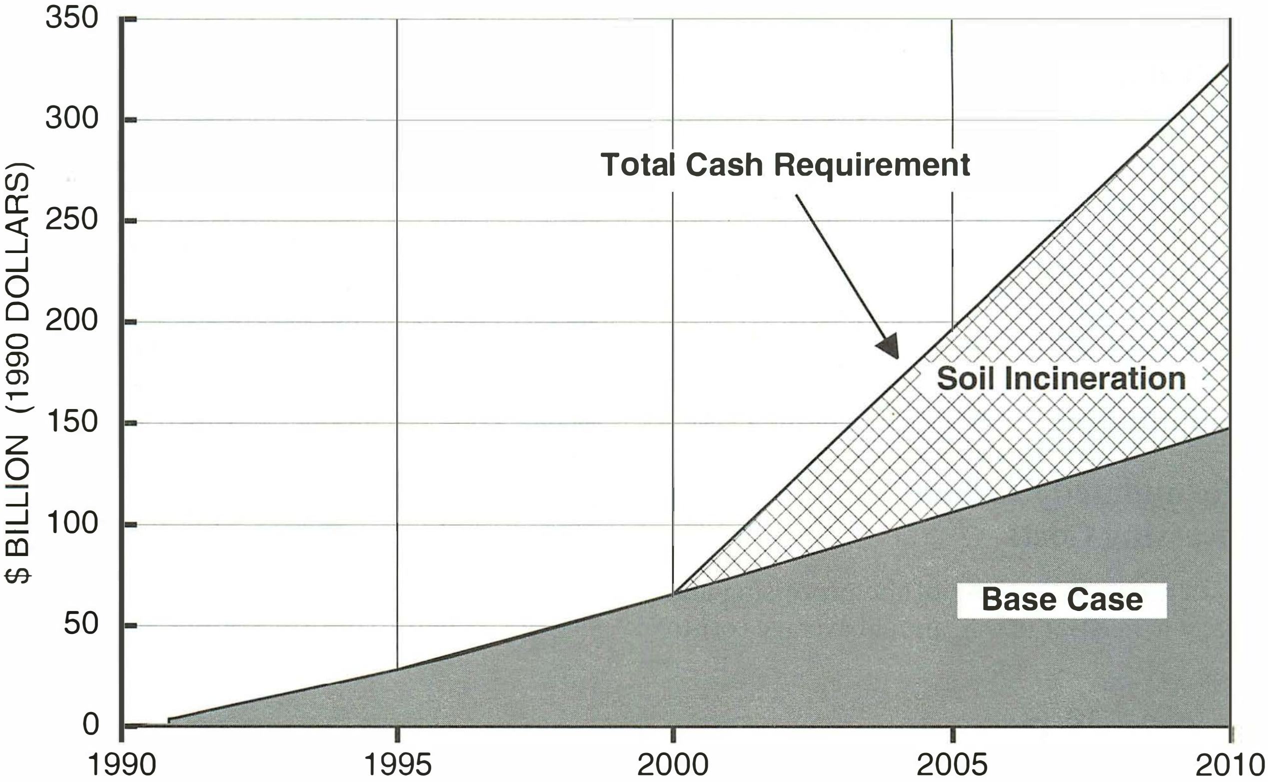


**Figure 7. Cost Sensitivity for Soil Remediation.
Incineration vs. Closure In-Place (Base)—Cumulative Cash Requirement.**

Another perspective (Figure 6) shows the shift of capital spending from air-related issues to a future dominated by water and solid waste. Figure 7 shows the cost sensitivity for potential regulation regarding remediation of contaminated soil. For example, incineration of removed soil could be required for remediation rather than the assumed in-place closure of contaminated sites. If so, the total cash requirements for refineries operating January 1, 1991 would increase from $152 billion to $330 billion. This $180 billion cost increase, if expended over ten years, would equate to 10 cents per gallon of light product and could cause a significant loss of U.S. refining competitiveness.

While no quantitative downside sensitivities are presented, such possibilities as lower expenditures due to technological advances, extensions of deadlines, or significant changes in political direction were considered but not quantified.

This report's refinery stationary source cost estimates do not include environmentally related expenditures that are not directly attributable to operating refineries such as costs for: remediation of closed refinery sites, remediation at crude oil and product terminal sites, litigation costs, and punitive damage settlements of civil suits arising from environmental issues. These required expenditures, which will be borne by industry, could be substantial.

Refining and Logistics Costs

Refining and logistics costs in the United States are projected to increase substantially. For example, relative to 1989 conventional gasoline, reformulated gasoline is projected to cost about 8, 12, and 14 cents per gallon (1990 dollars) more in 1995, 2000, and 2010, respectively. These include costs to the refineries for stationary emissions control improvements and additional health and safety regulations, costs due to more intensive processing and oxygenate addition to produce fuels, and costs of changes in the product logistics system to meet future regulations. The ultimate impact on the consumer would include other factors, such as changes in raw material cost, taxes, marketing costs, and fuel energy content, as well as marketplace competition.

Stationary Source Emissions Control Costs

New stationary source emissions controls and additional health and safety regulations, if their costs are evenly applied to light products, will add 2.6 cents per gallon in 1995, 4.5 cents per gallon in 2000, and 6.5 cents per gallon in 2010 to the 1989 cost (1990 dollars). It is assumed that light products will solely bear the cost increase because heavy products compete with close substitute fuels such as natural gas.

Reformulated Product Processing Costs

In addition, because of the processing and oxygenate needs, the U.S. annual average cost to produce federal Phase I reformulated gasoline in 1995 will add another 4.8 cents per gallon to 1989 conventional gasoline. The cost to produce the year 2000 Phase II reformulated gasoline premised by the NPC will add 6.4 cents per gallon to 1989 conventional gasoline. Because volatile organic compound (VOC) reduction is required in the summer high-ozone period, the cost of reformulating gasoline is about 1 cent per gallon higher in the summer than the annual average cost. A preliminary version (4/92) of the "complex model" was used to calculate vehicle emissions from gasoline properties.

Refining costs developed in this study for reformulated gasoline were determined using industry regional aggregate models, one for each Petroleum Administration for Defense

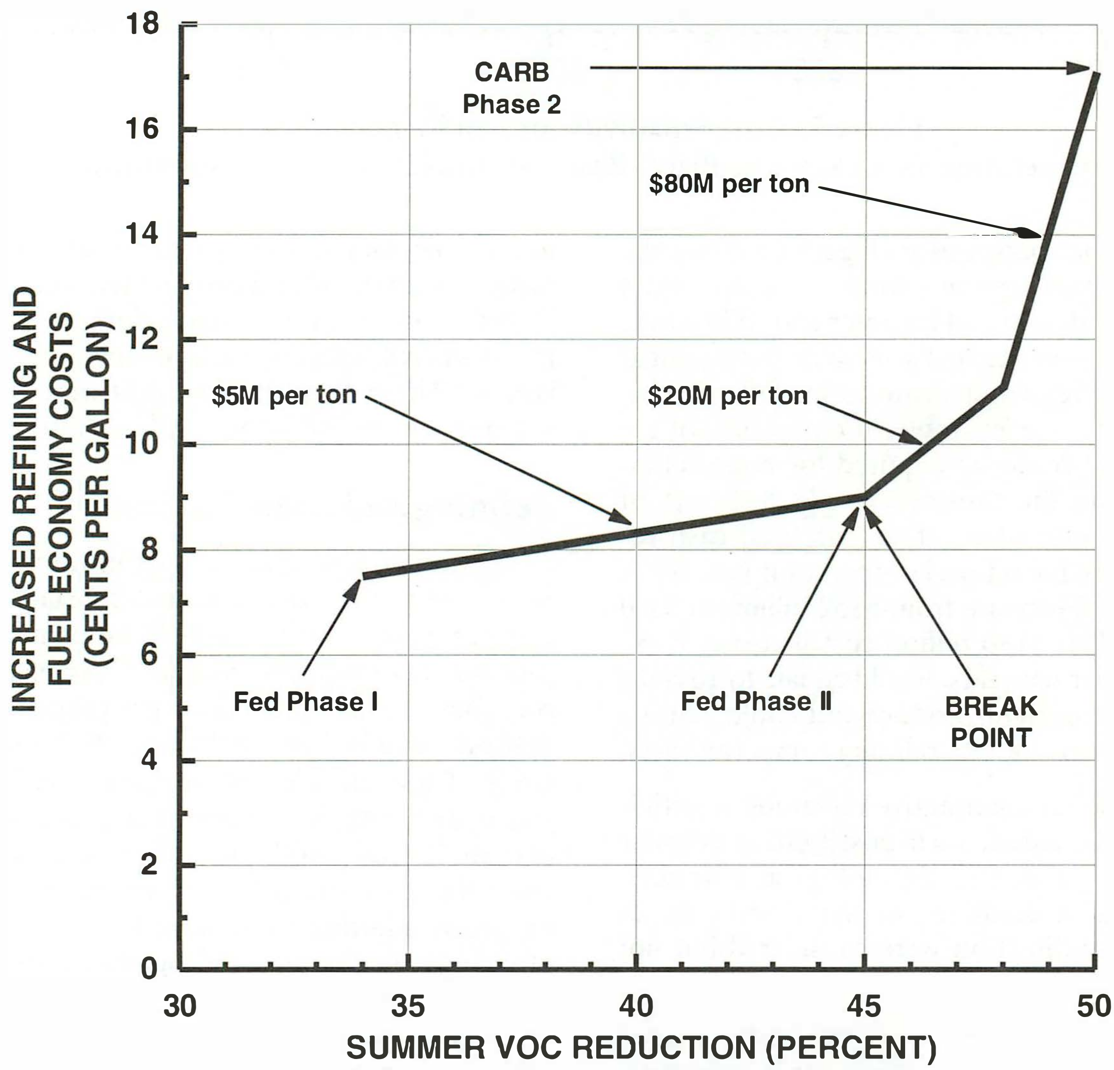


Figure 8. Incremental Cost-Effective Break Point Illustration for Reformulated Gasoline, PADD III, 4/92 Complex Model.

District (PADD). U.S. totals are volume averaged PADD results.

The reported cost corresponds to the cost curve break point (Figure 8), beyond which incremental refining and fuel economy costs for further reformulation severity are higher than the $10,000 per "6-months summer ton" assumed to be the upper limit of acceptable cost-effectiveness for VOC reduction. Refining cost and cost-effectiveness of reformulated gasoline vary from PADD to PADD. PADD III, the U.S. Gulf Coast, is shown as an example. This study's $10,000 per 6-months summer ton is equivalent to the EPA estimated upper limit for cost-effective VOC reductions of $5000 per annual ton (corresponds to the EPA definition of control decision benchmark).

Not including stationary source costs increases, refining cost for ultra-low sulfur diesel fuel starting in 1993 will average 3.8 cents per gallon in the United States (excluding California) above the 1989 cost of conventional product.

Logistics and Other Costs

Changes required to the logistics system are expected to add less than 1 cent per gallon to the cost of light products. Product quality enforcement is expected to add to the cost but was not estimated by this study.

The resulting increase in distribution cost from refinery to marketing location will vary by delivery location and source of product. For example, the cost increase to a New York service station from the U.S. Gulf Coast by pipeline or from Northwest Europe by tanker is about 3/4 cent per gallon for the 1989-1995 period.

Cost Summation

Product cost increases above 1989 levels along with retail marketing costs and lower fuel economy effects are shown in Table 2.

TABLE 2

FEDERAL EPA REFORMULATED PRODUCTS
ANNUAL AVERAGE COST INCREASE ABOVE 1989
(Cents per Gallon—1990 Dollars)

	Reformulated Gasoline			Ultra-Low Sulfur Diesel Fuel		
Costs Increases in Study	**1995**	**2000**	**2010**	**1995**	**2000**	**2010**
Stationary Source Controls	2.6	4.5	6.5	2.6	4.5	6.5
Refining Costs (and Oxygenate for Reformulated Gasoline)	4.8	6.4	6.4	3.8	3.8	3.8
Logistics and Other	1.0	1.0	1.0	1.0	1.0	1.0
Subtotal	**8.4**	**11.9**	**13.9**	**7.4**	**9.3**	**11.3**
Retail Marketing Regulations*	1.5	1.5	1.5	1.0	1.0	1.0
Total Increase	**9.9**	**13.4**	**15.4**	**8.4**	**10.3**	**12.3**
Lower Fuel Economy† (Indirect Increase)	2.5	2.5	2.5	–	–	–
Total Effective Consumer Increase	**12.4**	**15.9**	**17.9**	**8.4**	**10.3**	**12.3**

* No detailed NPC study; estimated from EPA and American Petroleum Institute data.

† Gasolines with oxygenate have less energy content per gallon; therefore, the consumer requires more gallons to travel the same distance.

Regulatory Uncertainty Cost Sensitivities

To keep the processing cost per ton of VOC removed within EPA suggested target levels with implementation of reformulated gasoline, emission performance standards should be set lower than the incremental cost-effectiveness break point previously mentioned so that any required allowances for blending, testing, and enforcement will not cause reformulated gasoline VOC reductions to become more costly than available alternative, non-fuel strategies for VOC reductions. To do otherwise could result in processing costs for reformulated gasoline much higher than reported here.

The cost of reformulating gasoline to meet the standards of the year 2000 was calculated based on a complex emissions model available in April 1992. With this model, the required VOC reduction was met primarily by reducing the Reid Vapor Pressure below that of 1995 Phase I reformulated gasoline.

Other complex model proposals have since been made public. Emissions calculations were made with three of these proposed complex models for comparison. For the cost-effective reformulated gasoline determined by the 4/92 model, all three of the other models give a lower calculated VOC reduction. The incremental VOC reduction and, therefore, the cost-effectiveness, calculated for the next VOC reduction step also depends on the complex model used. Hence, the complex model has to be established before a cost-effective performance standard for Phase II reformulated gasoline can be determined.

Aside from the effect of model choice, more costly gasoline reformulations than reported herein may be required of refineries to:

- Produce RFG that would provide reduced oxides of nitrogen (NOx) emissions
- Allow for enforcement standards and testing tolerances
- Be within specified limits and ranges permitted for fuel properties
- Provide for compatibility in the logistics system
- Allow for the increased VOC emissions from blending high-ozone period reformulated gasoline with ethanol.

In some cases, these requirements would not result in an emissions reduction, and in other cases the emissions reduction is not cost effective.

Additional VOC reduction for reformulated gasoline using methyl tertiary butyl ether (MTBE) has been proposed to accommodate the use of ethanol during the summer, high-ozone period in up to 30 percent of the total reformulated gasoline sold in an area. If this additional VOC reduction were required, the added cost would be about 1.4 cents per gallon.

More stringent EPA requirements for diesel fuel after 1993 and for reformulated gasoline after 2000 are possible. As an example of more stringent requirements, if California-specification low aromatics diesel fuel were made on a U.S. basis, it would cost 10 cents per gallon more than ultra-low sulfur diesel fuel. If California Air Resources Board Phase 2 reformulated gasoline were made on a U.S. basis, it would cost 9 cents per gallon more than the federal Phase II reformulated gasoline of this study.

Financial

Projected U.S. refining capital expenditures of $37 billion (1990 dollars) in the 1991-2000 period for product quality (cleaner transportation fuels) and stationary source regulatory compliance exceed the total net fixed asset base ($31 billion) of U.S. refineries at the start of this period. About two-thirds of the capital expenditures are projected to be made in the 1991-1995 period. Assuming all operating expenses (including depreciation) are recovered, cash flow generated during the 1991-1995 period is still on the order of $25 billion less than the required capital expenditures.

Product revenue increases will be necessary to recover operating expenses and to provide competitive returns on the capital employed. The projected cost increase in 2000 for regulatory compliance is more than twice the U.S. refining, marketing, and transportation industry's historical average net income in the 1980s. Given the projection of declining refinery utilization through 1995, recovery of these costs will be difficult until capacity and demand are rebalanced by further capacity shutdowns and/or increased product demand.

Historical and estimated future capital expenditures are shown in Table 3. Capital expenditures for environmental, health, and safety related to stationary source facilities were $10 billion in the 1980s. Capital expenditures for this category are estimated to be $23 billion for the 1990s and $14 billion for the period of 2001 to 2010. The projected stationary source expenditures for the 1990s are about 42 percent of the total capital expenditures expected to be made by the refining industry in 1991-2000, which is almost twice what it was in the 1980s. Refinery process facilities to manufacture products required by the 1990 Clean Air Act Amendments will cost another $14 billion.

The capital spending driven by environmental regulation will increase the amount of capital required by the industry per unit of product delivered with little change in capacity.

To assess the refining industry's ability to recover increased operating expenses and to fund this level of future capital expenditures, the NPC projected the industry's cash flow in then current dollars. The financial performance of the refining industry over the decade of the 1980s was, on average, below that of all U.S. industry, as represented by the Standard and Poor's 400 industrial firms (excluding energy firms). During the 1981-1990 period, U.S. petroleum refining, marketing, and transport operations realized an average return on investment (net income before interest, divided by net assets) of 8.8 percent, although

TABLE 3

U.S. REFINING CAPITAL EXPENDITURES
(Billions of 1990 Dollars)

	1981-1990	1991-2000	2001-2010
Environmental, Health, and Safety Stationary Source Facilities			
Pollution Abatement – Reported*	6.1	—	—
Stationary Facilities – NPC Estimates	3.9	22.8	13.5
Subtotal Stationary Source Facilities	**10.0**	**22.8**	**13.5**
Refinery Process Facilities			
Product Quality (Cleaner Fuels)	†	13.7	NS
Process Additions and Replacement	37.5	18.3	15.0
Total Capital Expenditures	**47.5**	**54.8**	**28.5**
Memo:			
Total Regulatory Compliance Expenditure	N/A	36.5	13.5
% Stationary Source Facilities	21%	42%	47%
Avg. Refining Capacity, Million B/SD	16.7	16.5	16.5
Capital Expenditures, $ per Daily Barrel of Capacity	$2,840	$3,320	$1,730

* From U.S. Department of Commerce, MA-200.

† 1981-1990 product quality facilities included in process additions and replacement.

Note: NS = Not Studied. N/A = Not Available.

cumulative net cash flow after capital expenditures was negative. In 1991 and 1992, profitability was lower than in the 1980s and cash flow continued to be lower than spending requirements.

Three cases were analyzed with alternative assumptions of net income to determine the impact on cumulative net cash flow and product costs (see Table 4). In the first case (A), net income in the 1993-2000 projection period was held equal to that of the historical levels of the 1980s; the resulting cumulative cash flow to 2000 is well short of requirements. If net income increases to recover the cost of capital on new environmental investment, as premised in the study (Case B), then the cash flow improves, although not sufficient to cover requirements in the 1991-2000 period. Only in the last case (C), where return on investment was held equal to that of the 1980s and net income is increased further, was cash flow sufficient to cover requirements.

The first half of the 1990s is a financially difficult period for the U.S. refining industry. Financial performance in the 1990s has been disappointing to date and shutdowns of refineries are on the increase. Even under the U.S. demand growth scenario, refinery utilization decreases in 1995 relative to 1990. If more refineries do not shut down, then an extended period of reduced profits can be expected.

If refiners perceive lower demand beyond 1995, then some may not be willing or able to make the required capital expenditures, and some refining capacity will be shut down. On the other hand, if refiners perceive demand growth after 1995, more may make these investments with the expectation of future recovery of the added costs of environmental and other regulations in the marketplace.

Product Compatibility

The logistics system will remain effective only if regulated product specification and enforcement procedures, including testing tolerances, allow product compatibility throughout. Product compatibility means being able to mix separate batches of a specific product as necessary for effective operation of the logistics system. If absolute batch segregation were required, the logistics system as it exists today would be inoperable.

Current product specifications and enforcement procedures allow effective use of the logistics system because commingling of similar products does not result in off-specification products at the final point of sale.

TABLE 4

SUMMARY OF CASES OF ALTERNATIVE NET INCOMES

	1981-1990	1991-2000 Case A	1991-2000 Case B	1991-2000 Case C
Return on Investment, %	8.8	5.7	7.1	8.8
Cumulative Net Cash Flow, billions then current dollars	(5)			
1991-1995		(31)	(28)	(22)
1991-2000		(37)	(19)	2
Net Income, cpg, all products,				
then current dollars	2.3	2.5	3.1	3.8
1990 dollars	2.7	2.0	2.4	3.0
Cost Increase in 2000 for Refinery Regulatory Compliance, cpg, all products, 1990 dollars		5.0	5.7	6.6

Commingling of new batches with some amount of the previous batch is inherent in the entire logistics system. Tanks are almost never empty because: (1) floating roof tanks fail to prevent evaporative emissions if allowed to become near empty; (2) reserve levels are needed to prevent product runout; and (3) batch sizes of shipments must meet individual system capabilities. The problem of mixing received product with the previous batch is not limited to tanks at terminals. Batches are loaded on top of small quantities of leftover product in barges and ocean-going tankers, in tank trucks, and in railcars. Blending with the previous batch occurs with every delivery to a retail service station where tanks are almost never empty. Finally, gasolines from multiple sources are blended in vehicle fuel tanks as consumers fill up at different service stations.

Regulations such as proposed by the Environmental Protection Agency on February 26, 1993 for reformulated gasoline could preclude any mixing of batch shipments of gasolines of the same grade in any degree, no matter how incidental. This would require isolating each batch from other batches of reformulated gasoline and require more segregations. The possible number of product segregations is limited by the physical characteristics of the logistics system. If the required number exceeds what can be practicably accommodated, the expected consequences would range from increased manufacturing and distribution costs and sporadic runouts, to complete failure of some systems. Regulations that effectively mandate complete segregation of individual batches would render the existing logistics system inoperable.

Environmental legislation and regulations require supply of more primary types of products. Several geographic and oxygenate-type variations of reformulated gasoline have been proposed. The additional product segregations will utilize more logistic system capacity relative to today's situation. The NPC refining study survey indicated that the industry is preparing to add a limited increased number of segregations. To satisfy regulatory requirements some refineries may find it preferable to produce a more costly common product (capable of meeting the most restrictive specification of two or more locations) instead of different products for each location.

Enforcement procedures should establish standards that include an adequate allowance for normal variation in testing — that is, to allow for testing tolerances. Otherwise, refineries and pipelines will target more stringent specifications to minimize the chance that complying products will be found to be out of compliance due to test result variations.

Refining Capability

With appropriate capital expenditures, sufficient volumes of on-highway diesel fuel and reformulated gasoline meeting requirements of the 1990 Clean Air Act Amendments can be manufactured in existing and anticipated process facilities using current technology and available engineering and construction resources.

Three significant areas relate to this finding and are discussed below.

Achievement of Reformulated Gasoline Emissions Reduction Performance

In 1995, under the simple emissions model proposed by the EPA, required reduction of emissions with reformulated gasoline will be produced with a lower Reid Vapor Pressure, a mandated oxygen content, and reduced benzene and aromatic content.

With Phase II reformulated gasoline in 2000, the level of emissions reduction calculated for a given processing cost is very dependent on the complex emissions model and the mobile source emissions inventory model used. The complex model is yet to be promulgated. However, calculations with various complex models indicate the 1990 Clean Air Act Amendments requirement of at least 20 percent volatile organic compounds reduction from the statutory baseline can be met. The processing costs for reformulation reported here reflect the use of an available model based on information published in the *Federal Register* in June and July 1991 and April 1992.

Availability of Resources

Refinery processes and stationary source emissions control requirements estimated in this study utilize current technology. No new technology is necessary to meet the future requirements studied.

A sampling of U.S. engineering and construction companies indicated ample availability of their resources as well as construction material and catalysts that may be required in the future for process facilities and stationary source emissions control equipment.

Oxygenates, as discussed in the Oxygenates Finding that follows, are expected to be available in quantities sufficient for the opt-in levels assumed for reformulated gasoline.

Availability of financial resources will depend on expectations for recovery of higher costs. Financial aspects are discussed in the Financial Finding, presented earlier in this Findings section.

Regulatory Concerns

The final complex emissions model performance standards and program enforcement regulations for reformulated gasoline were not known during this study. The study used an available complex emissions model. Cost-effective regulations and gasoline products compatibility were assumed. This resulted in relatively low-cost reformulations. More recent complex model proposals would require more costly gasoline reformulations. Use of some complex models in combination with proposed compliance enforcement would require all blends of gasoline to be segregated, which could severely limit refinery and distribution system flexibility, possibly causing occasional product runouts. Under conditions where options are limited, additional costs to supply reformulated gasoline could be substantial.

Refineries choosing to make reformulated products will need to maintain more segregations of products than in the past. This may require more tanks to retain operating flexibility, and tie up tanks with components and products for longer periods of time, adding to inventory costs.

The cost and strategy for reprocessing off-test reformulated gasoline to produce compliant or other gasoline will be highly dependent upon individual circumstances. All reprocessing strategies will incur increased costs compared to handling off-test gasoline currently and could result in the use of enough product tankage to restrict refinery output.

Oxygenates

Assessment of worldwide existing capacity and announced expansion plans for producing oxygenates indicates adequate supply in 1995 for at least the legislated minimum requirements. By 2000, the potential supply is expected to cover essentially any situation permitted by the 1990 Clean Air Act Amendments.

An analysis was made of the potential to produce oxygenates (methyl tertiary butyl ether [MTBE], tertiary amyl methyl ether [TAME], and ethanol) for blending into U.S. reformulated and oxygenated motor gasoline. The October 1992 survey of oxygenate producing capacity conducted by the U.S. Department of Energy's Energy Information Administration (EIA) was the primary source of information. Other surveys were used to supplement the EIA data, particularly beyond 1995. The capacity information was converted to potential supply assuming sufficient feedstock availability, and is shown in Table 5 as equivalent MTBE.

The demand assessment involved making assumptions concerning the number of nonattainment areas that would choose the reformulated gasoline program as a means of addressing the local ozone situation. The NPC refining study is based on the assumption that only the nine worst ozone nonattainment regions would use reformulated gasoline in 1995. It was assumed that all of the areas that could choose to use reformulated gasoline under the 1990 Clean Air Act Amendments would do so by 2000. In addition, it was assumed the entire Northeast Ozone Transport Corridor would choose to use reformulated motor gasoline by 2000. California is assumed to use California Air Resources Board Phase 2 reformulated gasoline beginning in 1996. These assump-

TABLE 5

U.S. OXYGENATE SUPPLY AND DEMAND
(Thousand Barrels per Day – MTBE Equivalent)

	1995			2000			2010		
	FC-I	FC-II	FC-III	FC-I	FC-II	FC-III	FC-I	FC-II	FC-III
U.S. Production*	442	442	442	566	566	566	566	566	566
Imports	81	90	90	21	71	79	0	57	80
Potential Supply	**523**	**532**	**532**	**587**	**637**	**645**	**566**	**623**	**646**
CAAA Demand	276	276	276	571	550	529	615	550	485
Gasohol Demand	69	69	69	43	43	41	47	43	37
Potential Demand	**345**	**345**	**345**	**614**	**593**	**570**	**662**	**593**	**522**
Potential Surplus	**178**	**187**	**187**	**(27)**	**44**	**75**	**(96)**	**30**	**124**

* January 1, 1993 production capability = 285 thousand barrels per day—MTBE equivalent.

Note: FC-I = Foundation Case I – Growth in U.S. demand.
FC-II = Foundation Case II –No growth in U.S. demand.
FC-III = Foundation Case III – Decline in U.S. demand.
CAAA = 1990 Clean Air Act Amendments.

tions add significantly to the demand assessments for the year 2000. The demand estimates are shown in Table 5.

One of the issues surrounding the use of oxygenates is geographic spillover. Geographic spillover of nonattainment area quality products into attainment areas is expected to be less than one percent. Higher costs for nonattainment area quality products provide a significant economic incentive to minimize the distribution of these products to areas where they are not required. Terminal and tankage capability near nonattainment-attainment areas interface locations appears sufficient to allow appropriate product segregations, through product exchanges between potential suppliers. In some situations, individual suppliers may find it economic to distribute oxygenated products to areas where they are not required.

As indicated on the last line of Table 5, the potential supply from already announced facilities is close to the estimated requirement for 2000-2010. There is ample time to build new capacity. Consequently, it does not appear likely that there would be a U.S. oxygenate supply shortfall under any of the situations evaluated.

Foreign Product Supply Cost

Today, most foreign areas lag the United States in health, safety, and environmental regulations and, consequently, have lower embedded environmental costs than the United States. Over time, the total cost of foreign supply delivered to the United States is projected to increase as result of product quality changes outside the United States; foreign capacity additions needed to meet local demand growth; and foreign environmental, health, and safety regulations for stationary facilities. The study's projected foreign total cost increase is approximately the same as the corresponding U.S. cost increase. However, there is significant uncertainty in these cost increase estimates.

Foreign product demands are expected to increase and demands for more environmentally acceptable products are also increasing. Input from experts on various foreign areas, review of foreign regulations, and the

NPC refining study survey indicates that there will be a significant effort in foreign refining centers to modify facilities from a health, safety, and environmental perspective. Waterborne transportation is also expected to bear increased costs as the result of health, safety, and environmental regulation. Extensive process facility additions are already underway or planned that will help meet foreign demand growth, which in many areas is outpacing growth in the United States.

Estimated existing and projected levels of health, safety, and environmental regulation of stationary facilities in foreign refining regions are shown in Table 6. The level is expressed as a percentage of the U.S. regulations in place as of 1990. The more industrialized areas such as Northwest Europe are shown on the table in 1990 as 75 percent of the U.S. regulation in the same year. Less industrialized areas such as the Middle East are assumed to have limited regulation in 1990. Local pressures are expected to result in all areas catching up to U.S. 1990 levels sometime in the next 20 years. There are diverse levels of regulations in each country in each area.

Foreign refineries are also expected to be required to adopt some of the future U.S. health, safety, and environmental standards over the next 20 years. Table 6 shows the percent adoption of premised future regulations by study year assumed for each foreign refining area. To illustrate, Latin America is expected to adopt the U.S. 1990 standards plus 75-100 percent of the future U.S. standards by the year 2010.

There is greater uncertainty surrounding the foreign health, safety, and environmental regulations and costs for stationary facilities than in the United States. Lacking detailed forecasts of anticipated foreign environmental regulations, the costs used for meeting the regulations in the foreign areas were derived from historical and projected U.S. costs. Foreign costs were discounted by 10 to 30 percent to reflect: (1) fewer environmentally sensitive processes; (2) greater cost sharing by foreign governments; (3) more "grandfathering;" and (4) in some lesser developed areas, lower levels of enforcement. There was no analysis of the financial ability of foreign refineries to meet regulatory costs. In some cases, the situation could be similar to that projected for U.S. refineries.

Oil product demand in some foreign regions is expected to grow. As a result, some new facilities will be required to meet increasing demand, which will result in higher cost for products that are exported to the United States. Table 7 shows the demands for the various for-

TABLE 6

HEALTH, SAFETY, AND ENVIRONMENTAL STANDARD COMPARISON
(Percent of U.S. Regulation)

	Canada	Northwest Europe	Mediter-ranean	Pacific Rim	Middle East	Latin America
			1990 Regulation			
1990	75	75	50	0	0	0
1995	100	100	75	35	35	35
2000	100	100	100	70	70	70
2010	100	100	100	100	100	100
			Future Regulation			
1995	75-100	75-85	65-85	35-60	25-50	25-50
2000	100	100	85-100	60-80	50-75	50-75
2010	100	100	100	85-100	75-100	75-100

TABLE 7

WORLD OIL DEMAND* – BY REGION
(Million Barrels per Day)

	1989	1995			2000			2010		
		FC-I	FC-II	FC-III	FC-I	FC-II	FC-III	FC-I	FC-II	FC-III
Canada	1.7	1.8	1.8	1.8	1.9	1.8	1.7	1.9	1.8	1.6
NW Europe	8.9	9.4	8.9	8.9	9.5	9.0	8.8	9.6	9.1	8.8
Mediterranean/ North Africa	5.2	5.7	5.4	5.4	5.9	5.5	5.4	6.3	5.7	5.5
Middle East	3.1	3.7	3.5	3.5	4.2	3.7	3.6	5.1	4.0	3.7
Latin America	5.2	6.5	6.0	6.0	7.3	6.3	6.2	8.9	6.9	6.4
Pacific Rim	10.7	12.6	11.6	11.6	13.8	12.0	11.7	15.4	12.9	12.0
Total Modeled Regions	**34.9**	**39.6**	**37.2**	**37.2**	**42.6**	**38.3**	**37.4**	**47.2**	**40.4**	**38.1**
Africa (excluding North Africa)	1.0	1.2	1.2	1.2	1.4	1.2	1.2	1.7	1.3	1.2
USSR (Former)/ East Europe/ Other	10.2	8.2	8.2	8.2	9.5	9.5	9.5	11.6	11.6	11.6
China	2.3	2.7	2.7	2.7	3.1	3.1	3.1	3.7	3.7	3.7
United States	17.3	17.3	17.1	17.0	18.5	17.1	16.1	20.2	17.1	14.7
Total World Demand	**65.7**	**69.1**	**66.3**	**66.2**	**75.1**	**69.2**	**67.3**	**84.4**	**74.1**	**69.3**

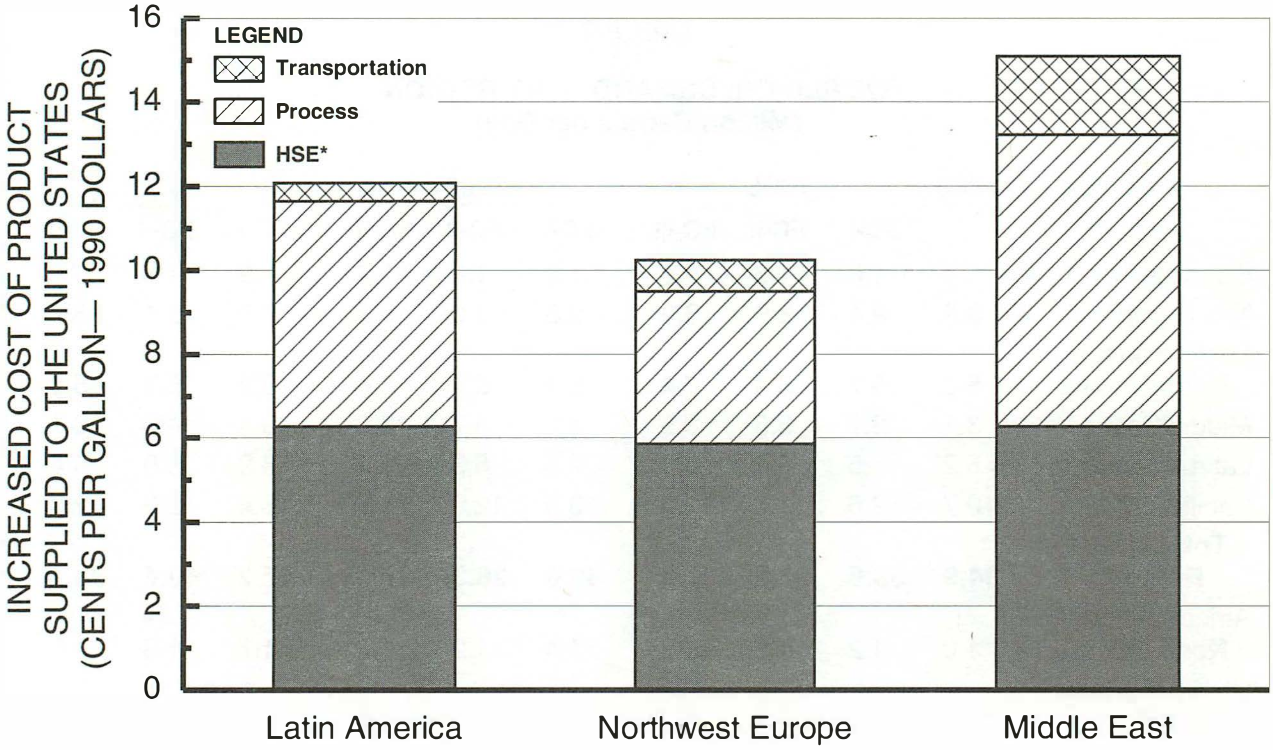
* Data may not add to totals due to independent rounding.

Note: FC-I = Foundation Case I – Growth in U.S. demand.
FC-II = Foundation Case II – No growth in U.S. demand.
FC-III = Foundation Case III – Decline in U.S. demand.

eign regions and the United States. Each foreign region is assumed to invest to maintain exports to the United States at 1989 levels. Thus, imports at historical levels reflect average cost increases rather than the higher cost increases associated with new capacity.

The total cost increase resulting from health, safety, and environmental regulation changes, process changes for capacity and product quality, and transportation impact each region differently. This analysis is based on both known laws and regulations and on projected environmental and product quality requirements. The EPA on-highway diesel fuel example shown in Figure 9 is indicative of the buildup of cost for every product in each foreign refining center for 2010. As can be seen in Figure 10, based on study assumptions, the sum of the foreign cost increases, excluding transportation costs, is similar to those expected in the United States. The U.S. cost increases are largely attributable to environmental requirements while foreign increases include a more significant capacity expansion component. The cost differences between the foreign regions and the U.S. regions vary in earlier study years, but the relationships are directionally the same.

The costs associated with unique California product qualities were not specifically analyzed on the assumption that the incremental costs of these products over EPA quality products would, on average, be the same



* HSE is health, safety, and environmental cost increase for fixed facilities.

Figure 9. Foreign Region Total Delivered Increase Cost
EPA On-Highway Diesel Fuel—1989 to 2010.

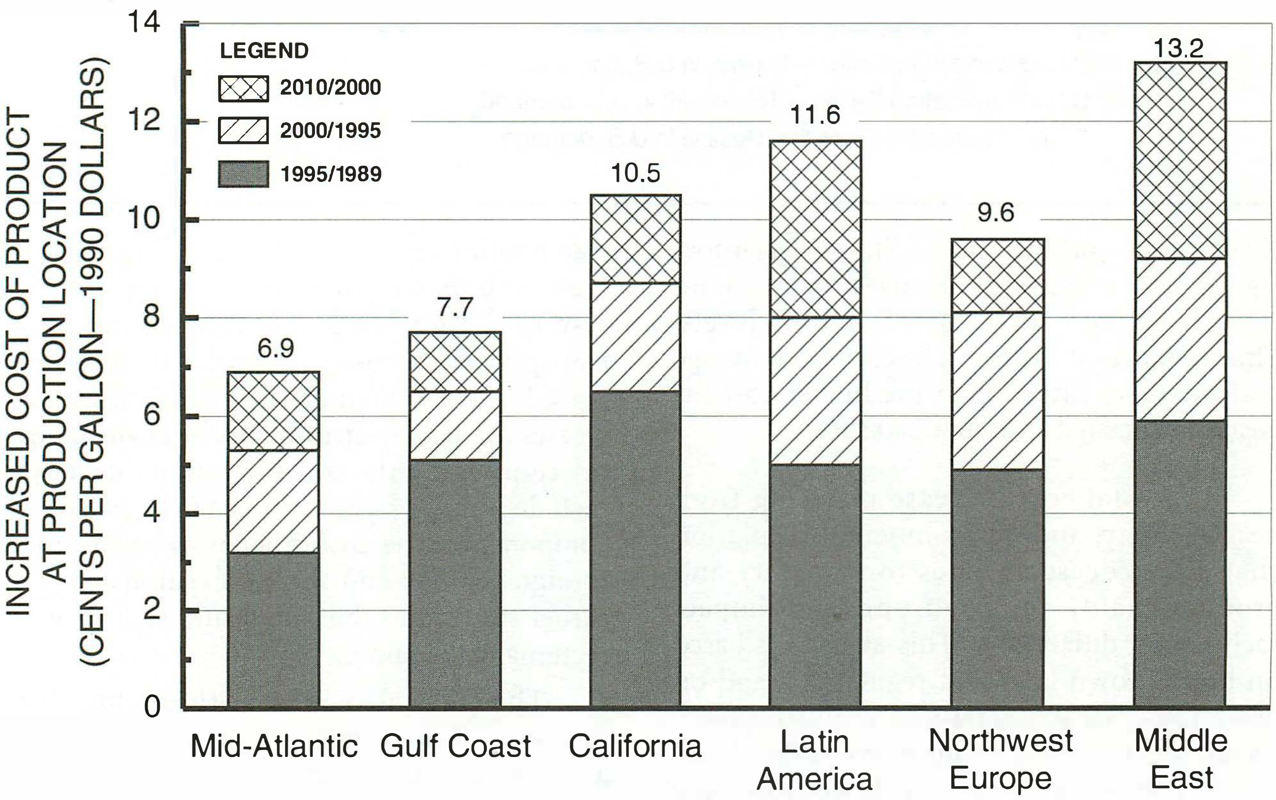


Figure 10. Regional Cost Increase
EPA On-Highway Diesel—1989 to 2010.

in all production locations. This means that some volume of California product could be produced at some locations at lower cost.

The costs shown are regional averages. As with all average analyses, some individuals in the average will have lower costs. Consequently, some individual light product producers might have cost advantages at a given time.

In addition, this analysis is based on full recovery of fixed operating costs and a capital charge on new capital expenditures. The study does not address incremental cost analysis frequently used for day-to-day operating decisions.

Product Supply and U.S. Refinery Utilization

Evaluation of future oil product demand scenarios using expected foreign and U.S. product cost increases suggests that, if the required investments are made, the U.S. refinery complex will continue to supply most of the future U.S. light product demand. However, because of relatively flat U.S. demand through 1995 under all scenarios studied and increasing supply from oxygenate blending into gasoline, U.S. capacity utilization is lower in 1995 than in 1989, assuming no capacity shutdown. For later study years, capacity utilization changes consistent with projected demand conditions. Absent rationalization, the U.S. demand for light products is likely the most significant determinant of U.S. refinery capacity utilization.

Future supply patterns were evaluated for the United States in the context of three future demand scenarios. The purpose of this effort was to assess the possibility that U.S. light product market supply would move toward imports and away from output from U.S. refineries relative to the situation in 1989.

The demand scenarios were called Foundation Case I (growth in U.S. demand), Foundation Case II (no growth in U.S. demand), and Foundation Case III (decline in U.S. demand). Three Foundation Cases were used because NPC refining study participants realized that evaluation of a single demand projection would not effectively deal with the uncertainty that surrounds the future. Therefore, none of the Foundation Cases represent a consensus view of future U.S. product demand. The three projections are thought to represent a reasonable range of possible futures. These U.S. projections are summarized in Table 8. Since the inception of the study effort, additional projections for 1995 U.S. product demand have been made public. These projections, if used, would increase the 1995 light product demand range by several hundred thousand barrels per day. For example, the Foundation Case I projection is from the 1991 EIA Annual Energy Outlook. The 1993 Annual Energy Outlook projection is 500 thousand barrels per day higher, which represents a 3 percent higher refinery utilization rate. The directional results of the U.S. supply/demand analysis would not be affected by an increase of this magnitude.

The U.S. light product supply sources for the various Foundation Cases were evaluated by utilizing a mathematical representation of the U.S. light product logistics system. This necessarily required the assessment of anticipated changes in the cost of supplying both U.S. produced and foreign produced light products to U.S. demand centers. The assessment included cost changes for transportation and refinery products.

Transportation cost changes, including tariffs, were estimated by evaluating NPC refining study survey results and U.S. regulations concerning ocean transport of product imports as well as assessing existing and expected free trade arrangements with North American countries. The transportation cost increase in both waterborne and overland North American imports is associated with the application of more restrictive environmental regulations (double hulls for tankers and increased pipeline product segregations to handle more environmental grades of product are examples) relative to 1989. The impact of the free trade philosophy is to lower North American import costs by removing tariffs. The total transportation cost change is expected to be relatively small (less than 1 cent per gallon).

While transportation cost increases are expected to be small, cost increases for light

TABLE 8

UNITED STATES OIL DEMAND
(Million Barrels per Day)

	FC-I	FC-II	FC-III
1989			
Light Products *	12.0	12.0	12.0
Other Products	5.3	5.3	5.3
Total Products	**17.3**	**17.3**	**17.3**
1995			
Light Products *	12.1	11.9	11.8
Other Products	5.2	5.2	5.2
Total Products	**17.3**	**17.1**	**17.0**
2000			
Light Products *	12.8	11.9	11.4
Other Products	5.7	5.2	4.7
Total Products	**18.5**	**17.1**	**16.1**
2010			
Light Products *	14.2	11.9	10.4
Other Products	6.0	5.2	4.3
Total Products	**20.2**	**17.1**	**14.7**

* Light products equal the sum of motor gasoline, jet fuel, and distillate.

Note: FC-I = Foundation Case I – Growth in U.S. demand.
FC-II = Foundation Case II – No growth in U.S. demand.
FC-III = Foundation Case III – Decline in U.S. demand.

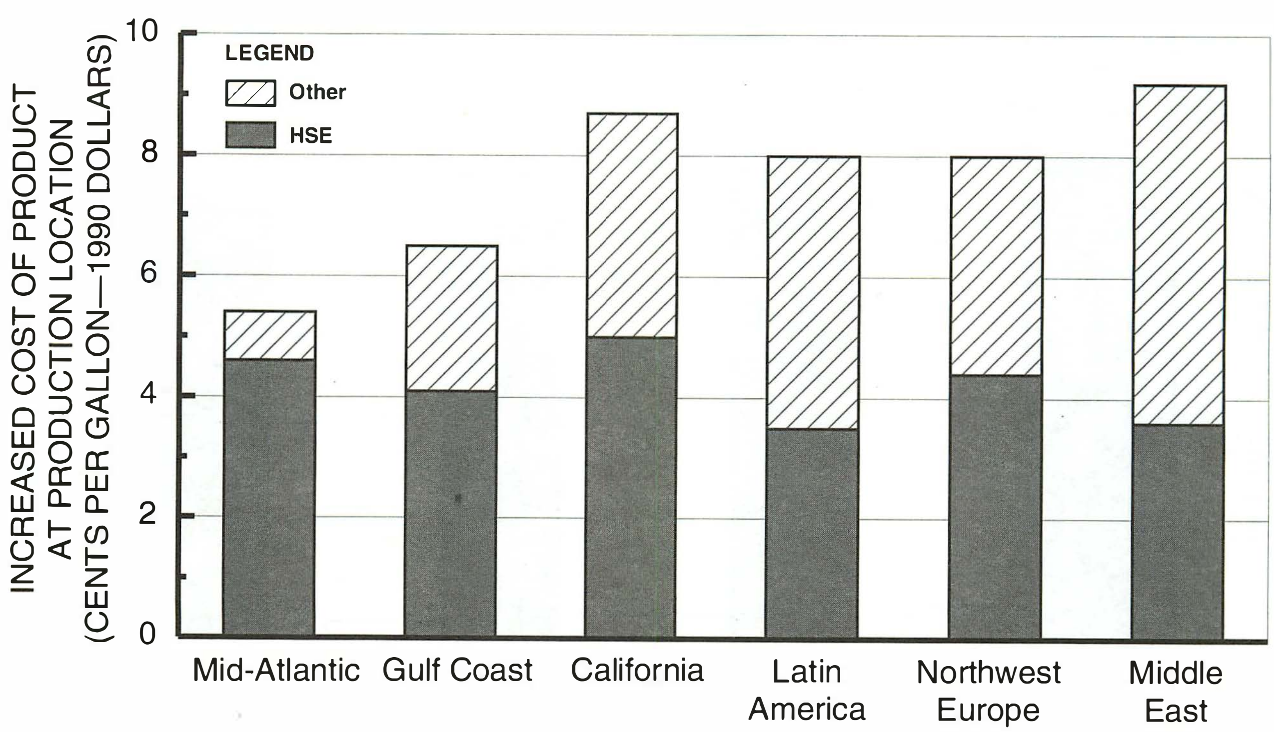
product from both U.S. and foreign refineries are expected to be substantial. Generally, this study projects that the total product cost increases for foreign refineries are of similar magnitude as those for U.S. refineries. This is true even though the health, safety, and environmental cost increases for refinery facilities are generally less than in the United States. Figure 11 indicates the magnitude of these effects for EPA on-highway diesel fuel (other products demonstrate similar cost impacts) for refineries in selected locations for 2000.

This study's assessment that the relevant calculated refinery cost increase by location coupled with the expectation that import transportation costs will be higher, leads to the realization that imports may be expected to play a decreasing role in U.S. light product supply. This is true assuming no significant change in the forces (other than future cost) that resulted in the balance in 1989 U.S. supply between imports and U.S. refinery output. The mathematical representation of the U.S. light product logistics system was used to verify this observation. The output from this effort is summarized in Figures 12 and 13. Exports were assumed to remain constant at 1989 levels. The depiction of imports shown in the figures should be viewed as a net import trend.

Figure 12 indicates that under Foundation Case I conditions, imports decline into the first decade of the next century as U.S. refinery output increases. After 2000, however, U.S. refinery capability reaches effective capacity in locations where imports compete directly with U.S. produced products. At this juncture, imports begin to increase to meet the increase in demand. The availability of products from foreign refineries under these conditions results from changing refinery operations. No new refining capacity is built in the United States. New capacity is built in foreign areas to accommodate demand growth in those areas and maintain the historical level of exports to the United States. Economics do not support construction of new refining capacity in foreign areas specifically to supply just the United States.

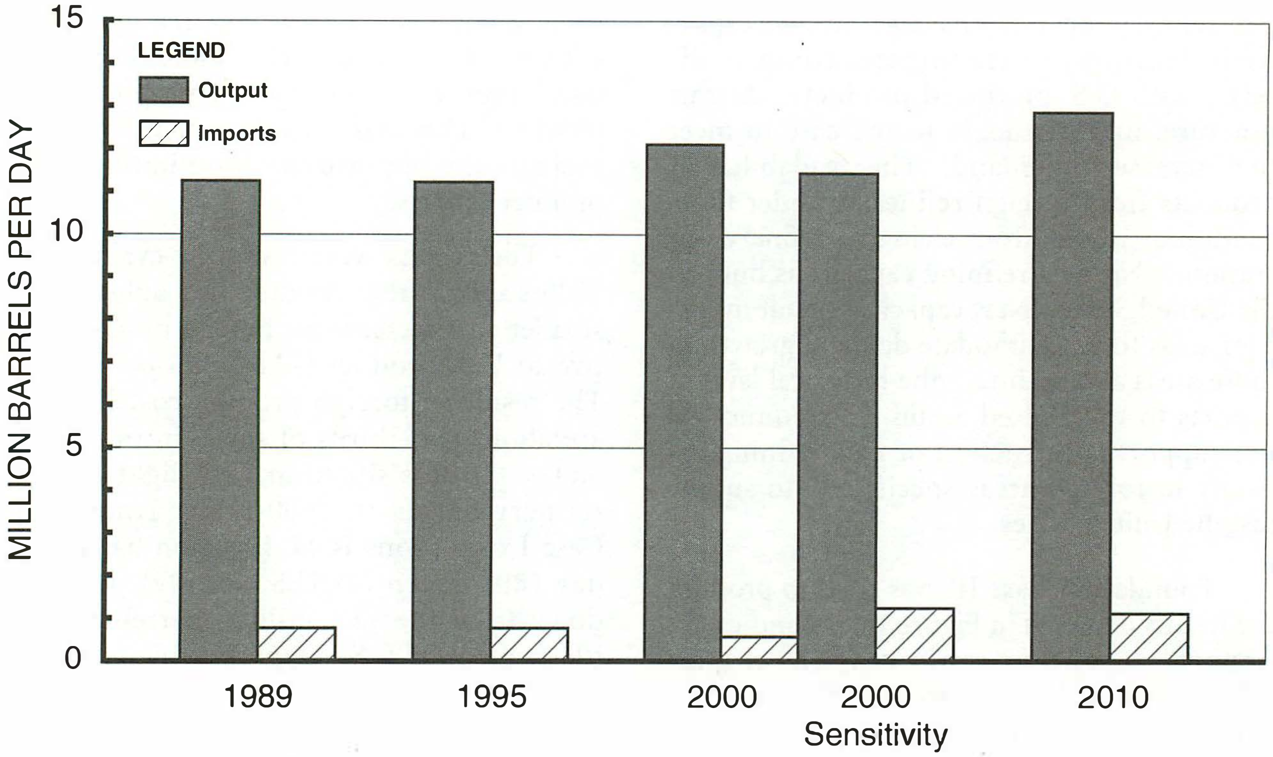
Foundation Case III was used to produce the results depicted in Figure 13. As indicated, imports decline to a minimum level after 2000. Ultimately there are insufficient product imports to be displaced as U.S. product demand declines and hence, U.S. refining output absorbs the decline with associated utilization reduction. There is no reason to believe that imports will cease altogether; rather it is expected that a minimum level will be reached. In this scenario, reduced light product utilization could lead to more than 2 million barrels per day of spare light product capability. The analysis was not structured to evaluate the opportunity for additional U.S. product exports.

The results were tested by evaluating a 2000 scenario that resulted in a substantially smaller cost increase for foreign product relative to U.S. product (-2.8 cents per gallon). The resulting foreign product cost increases are about two-thirds of those in the United States. In this situation, U.S. light product refinery output in 2000 under Foundation Case I conditions is 11.4 million barrels per day (89 percent of U.S. supply), which is down from the 12.1 million barrels per day (94 percent of U.S. supply) estimated under unadjusted Foundation Case I cost conditions. Similarly, U.S. refinery utilization drops from 88 percent to about 83 percent in 2000. These 2000 light-product output estimates compare with 1989 at 11.2 million barrels per day (94 percent of U.S. supply). This sensitivity case resulted in an indicated



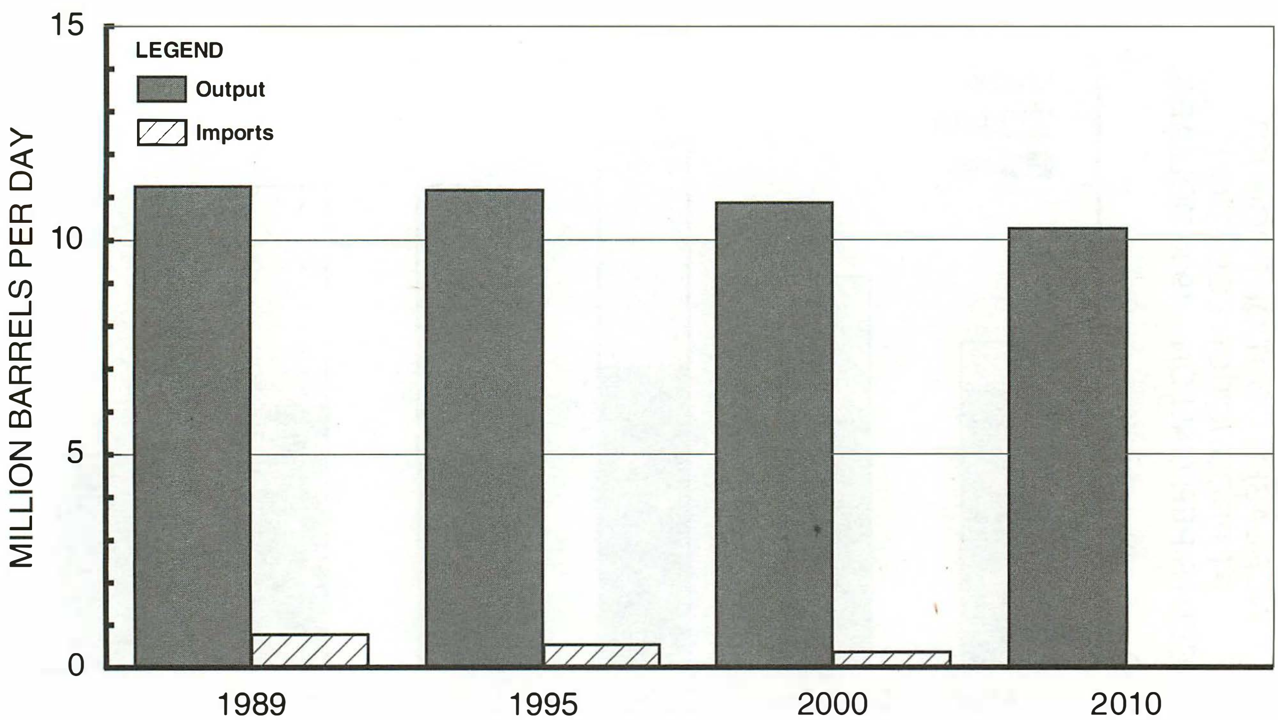
HSE is health, safety, and environmental cost change for fixed facilities.

Figure 11. Regional HSE and Other Cost Increases EPA On-Highway Diesel Fuel—1989 to 2000.



Light product is motor gasoline, jet fuel, and distillate.

Figure 12. U.S. Light Product Supply—Foundation Case I (Growth in Demand).



Light product is motor gasoline, jet fuel, and distillate.

Figure 13. U.S. Light Product Supply—Foundation Case III (Decline in Demand).

import increase of 700 thousand barrels per day. The results can be seen on Figure 12. The effects would have been similar under the other demand scenarios.

There is concern for the economic health of the U.S. refinery complex in that spare capability often leads to rationalization. No specific analysis of rationalization was undertaken. However, evaluating capability utilization can suggest the situations under which rationalization might occur.

The results of the analysis for the various Foundation Cases are shown in Table 9. Without rationalization, U.S. refinery utilization is expected to decline from 86 percent in 1989 to about 83 percent in 1995. In later years, 2000 and 2010, U.S. refinery utilization is strongly affected by U.S. light product demand.

In scenarios where U.S. refinery output decreases because demand declines (Foundation Case III) or where lower cost of foreign product increases imports, pressure will increase to rationalize refining capacity. If there is no growth in U.S. demand (Foundation Case II), the use of oxygenates to produce reformulated and oxygenated gasolines also reduces U.S. refinery utilization and increases the pressure for rationalization. In contrast, growth in U.S. demand (Foundation Case I) increases refinery utilization and reduces the pressure for rationalization.

TABLE 9

U.S. LIGHT PRODUCTS *
REFINERY OUTPUT — REFINERY CAPABILITY
(Million Barrels per Day)

	1989	1995			2000				2010		
		FC-I	FC-II	FC-III	FC-I	FC-IES	FC-II	FC-III	FC-1	FC-II	FC-III
Output	11.2	11.2	N/A	11.2	12.1	11.4	N/A	10.9	12.9	11.6	10.3
Capability†	13.1	13.5	13.5	13.5	13.8	13.8	13.8	13.8	13.8	13.8	13.7
Utilization	86%†	83%	N/A	82%	88%	83%	N/A	79%	93%	84%	75%

* Light Products = motor gasoline, jet fuel, and distillate.

† Operable capacity is derived from 1989 U.S. refinery operable crude oil capacity and crude oil input as reported by the Energy Information Administration equaling a utilization rate of 85.6 percent, which is rounded to 86 percent in the table. It is assumed that 1989 light product operable capability is directly related to this utilization and is calculated at 13.1 million barrels per day. Capability is increased in 1995 by 0.1 million barrels per day of announced U.S. refinery additions plus 0.3 million barrels per day of oxygenate blended in refineries. After 1995, capability changes reflect changes in refinery blending of oxygenate.

N/A = Not analyzed.

FC-IES = Environmental Sensitivity Case. Also represents other cost sensitivities.

APPENDICES

Appendix A

Request Letter and Description of the National Petroleum Council

The Secretary of Energy
Washington, DC 20585

June 25, 1990

Mr. Lodwrick M. Cook
Chairman
National Petroleum Council
1625 K Street, N.W.
Washington, D.C. 20006

Dear ~~Mr. Cook~~ Lod:

Through this transmittal, I am formally requesting that the National Petroleum Council (NPC) perform two studies that are currently of critical interest to the Department of Energy. These studies are described below.

Constraints to Expanding Natural Gas Production, Distribution and Use

I request that the NPC conduct a comprehensive analysis of the potential for natural gas to make a larger contribution, not only to our Nation's energy supply, but also to the President's environmental goals. The study should consider technical, economic and regulatory constraints to expanding production, distribution and the use of natural gas. In the conduct of this study, I would like you to consider carefully the location, magnitude and economics of natural gas reserves, and the projected undiscovered and unconventional resource; the size, kind and location of future markets; the outlook for natural gas imports and exports; and potential barriers that could impede the deliverability of gas to the most economic, efficient and environmentally sound end-uses.

This study comes at a critical time, given the increased interest in natural gas, for developing public and private sector confidence that natural gas can make a greater contribution to the energy security and environmental enhancement of our Nation. I anticipate that the results of your work will be able to contribute significantly to the development of the Department's policies and programs.

The U.S. Refinery Sector in the 1990's

U.S. refineries face significant changes to processing facilities in the next decade, particularly in response to new environmental legislation that will affect emissions and waste disposal from refineries and the composition of motor fuels. Substantial investments are likely to be required to comply with proposed Clean Air Act Amendments, including provisions dealing with air toxics and alternative fuels. There is concern about the U.S. engineering and construction industry's capability to design, manufacture, and install quickly the large number of new, sophisticated processing facilities that would be necessary to supply these fuels.

Product imports, which are projected to increase, may also have to be treated differently than in the past. For example, if U.S. refiners have different gasoline specifications (e.g., Reid Vapor Pressure, aromatics, olefins, oxygen content) than foreign refineries, imported products may require additional U.S. refining.

I request that the NPC assess the effects of these changing conditions on the U.S. refining industry, the ability of that industry to respond to these changes in a timely manner, regulatory and other factors that impede the construction of new capacity, and the potential economic impacts of this response on American consumers.

I look forward to receiving your results from these two studies and would like to be notified of your progress periodically.

Sincerely,

Jim

James D. Watkins
Admiral, U.S. Navy (Retired)

DESCRIPTION OF THE NATIONAL PETROLEUM COUNCIL

In May 1946, the President stated in a letter to the Secretary of the Interior that he had been impressed by the contribution made through government/industry cooperation to the success of the World War II petroleum program. He felt that it would be beneficial if this close relationship were to be continued and suggested that the Secretary of the Interior establish an industry organization to advise the Secretary on oil and natural gas matters.

Pursuant to this request, Interior Secretary J. A. Krug established the National Petroleum Council on June 18, 1946. In October 1977, the Department of Energy was established and the Council was transferred to the new department.

The purpose of the NPC is solely to advise, inform, and make recommendations to the Secretary of Energy on any matter, requested by the Secretary, relating to oil and natural gas or the oil and gas industries. Matters that the Secretary of Energy would like to have considered by the Council are submitted in the form of a letter outlining the nature and scope of the study. This request is then referred to the NPC Agenda Committee, which makes a recommendation to the Council. The Council reserves the right to decide whether it will consider any matter referred to it.

Examples of recent major studies undertaken by the NPC at the request of the Secretary of Energy include:

- *U.S. Arctic Oil & Gas* (1981)
- *Environmental Conservation—The Oil & Gas Industries* (1982)
- *Third World Petroleum Development: A Statement of Principles* (1982)
- *Enhanced Oil Recovery* (1984)
- *The Strategic Petroleum Reserve* (1984)
- *U.S. Petroleum Refining* (1986)
- *Factors Affecting U.S. Oil & Gas Outlook* (1987)
- *Integrating R&D Efforts* (1988)
- *Petroleum Storage & Transportation* (1989)
- *Industry Assistance to Government* (1991)
- *Short-Term Petroleum Outlook* (1991)
- *Petroleum Refining in the 1990s—Meeting the Challenges of the Clean Air Act* (1991)
- *The Potential for Natural Gas in the United States* (1992).

The NPC does not concern itself with trade practices, nor does it engage in any of the usual trade association activities. The Council is subject to the provisions of the Federal Advisory Committee Act of 1972.

Members of the National Petroleum Council are appointed by the Secretary of Energy and represent all segments of the oil and gas industries and related interests. The NPC is headed by a Chairman and a Vice Chairman, who are elected by the Council. The Council is supported entirely by voluntary contributions from its members.

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Appendix B

Study Group Rosters

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APPENDIX C

WINTER 1992-93 OXYGENATE SUPPLY/DEMAND FOR THE CARBON MONOXIDE NONATTAINMENT AREAS

The Phase I report of the NPC refining study, entitled *Petroleum Refining in the 1990s—Meeting the Challenges of the Clean Air Act*, expressed the view that an oxygenate shortfall would occur during the winter 1992-93 oxygenated fuel period. While there was a wide range of view expressed, the consensus of the refining industry interviewees in early 1991 was that there would not be enough oxygenate for all carbon monoxide nonattainment areas. An oxygenate shortfall did not occur, primarily because of changes in regulations which reduced the demand for oxygenates and a higher than anticipated supply of oxygenates from storage.

REGULATED OXYGENATE DEMAND

The ranges for NPC oxygenate demand estimates for the 1992-93 winter were based on the oxygen content and oxygenated fuel period rules written at the time, the cities involved, and an assumed 10 percent spillover.

Since completion of the Phase I study, the EPA decided to delay the start of the 1992-93 oxygenated fuel program to November 1 and made it a four-month program in most carbon monoxide nonattainment areas. Unexpectedly, some nonattainment areas did not participate in the 1992-93 oxygenated fuel program. Also, California adopted a 2 percent oxygen content level, rather than the federal 2.7 percent level. All these steps significantly reduced the winter 1992-93 oxygenate demand. Spillover appears to have been substantially less than 10 percent.

DELIVERIES FROM STORAGE

The availability of oxygenate from storage was cited by the Phase I study as one of the most uncertain factors in the oxygenate supply/demand balance. Because of lower than expected demand for gasoline, particularly premium gasoline, less MTBE was used for gasoline blending to meet octane requirements in 1991 and 1992 than expected. Thus, substantially more MTBE was available and there was a large buildup of MTBE and ethanol inventories.

OXYGENATE PRODUCTION AND IMPORTS

The study's estimate of domestic MTBE production in winter 1992-93 now appears to have been high. An adequate supply of MTBE was available from inventory without maximizing production. MTBE import data are not available. Ethanol production remained high throughout 1992.

OXYGENATE SUPPLY/DEMAND BALANCE

With the lower demand for oxygenates required by regulation, increased supply available from storage, and few compliance problems, the potential shortage did not occur.

Data on how much ethanol and MTBE were used in the oxygenated fuel program and how much in conventional gasoline blends during the 1992-93 winter season are not available. Extension of the ethanol subsidy to blends containing less than 10 percent ethanol increased the economic attractiveness of ethanol in the oxygenated fuel program. Ethanol supply and use in the oxygenated fuel program appears to have exceeded that anticipated in the Phase I study.

In summary, the reduced demands brought about by local actions and the shortened season for the oxygenated fuel program defined by the EPA have served to lower the oxygenate requirement such that industry was able to meet the demand without difficulty. The stable-to-declining spot price level for MTBE in the period preceding and during the compliance period suggests that most of the industry saw a supply/demand balance.

APPENDIX D

REVIEW OF FINDINGS FROM 1986 NPC REPORT

The 1986 National Petroleum Council report entitled U.S. Petroleum Refining was the last refining report produced by the NPC. The 1986 report reached three major findings and conclusions, which can now be examined with the vision of hindsight.

1986 Conclusion #1: Based on the 1988 data from the NPC Refinery Survey and modeling results, the U.S. refining industry is approaching maximum gasoline manufacturing capacity.

During the intervening years, gasoline production grew from 6.42 million barrels per day (B/D) in 1985 to 6.96 million B/D in 1988 and has remained almost constant since. During the same period, gasoline imports increased from 381 thousand B/D in 1985 to 405 thousand B/D in 1988, but declined to 294 thousand B/D in 1992.[1] The 1986 study estimated that at 6.8 million B/D gasoline production, downstream conversion units would be fully utilized, and hence increasing crude oil runs would provide very little additional gasoline.

Gasoline manufacturing capacity has remained adequate during the 7 years following 1985. During this same time frame, unleaded gasoline grades production increased from 4.14 million B/D in 1985 to 6.95 million in 1992 while leaded gasoline declined from 2.28 million B/D in 1985 to 0.11 million B/D in 1992[2] Thus, more than 95 percent of leaded gasoline was replaced by unleaded grades. Table D-1 shows the 1985-1992 U.S. refining industry gasoline production by leaded and unleaded volumes.

The 1986 report suggested that debottlenecking or minor additions to octane enhancement facilities could raise the annual gasoline production capability level above 6.8 million B/D. Octane changes in this period were in part accomplished through greater use of MTBE, a high-octane oxygenate.

1986 Conclusion #2: The operating rate of the U.S. refining industry is sensitive to the level of demand and product mix, both inside and outside the United States.

The 1986 report listed a series of premises that support Conclusion #2:

- An increase in world product demand with no change in the ratio of light to

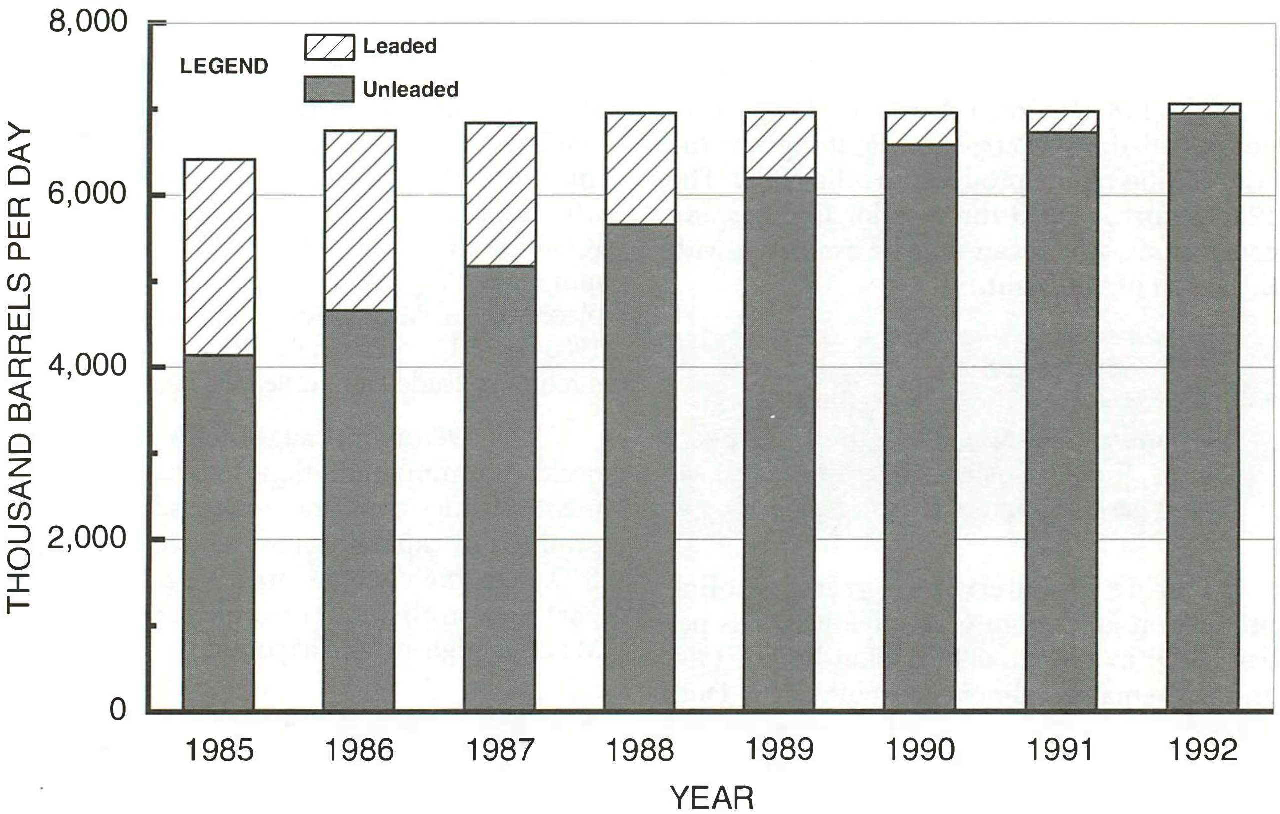
[1] *Petroleum Supply Annual 1992,* Volume 1 May 1993, Energy Information Agency, Office of Oil and Gas, U.S. Department of Energy, Washington, DC 20585, Table S4, page 17.

[2] *Petroleum Supply Annuals* 1985-1992, Table 3.

TABLE D-1

U.S. GASOLINE PRODUCTION — 1985-1992
(Thousands Barrels per Day)

Year	Unleaded	Leaded	Total
1985	4138	2281	6419
1986	4656	2096	6752
1987	5174	1668	6842
1988	5654	1302	6956
1989	6200	763	6963
1990	6590	369	6959
1991	6731	245	6976
1992	6951	112	7063



U.S. Gasoline Production.

heavy products should result in an increase in U.S. refinery throughput.

Table D-2 shows the demand for products within the United States and worldwide. World product demand for major products increased steadily from 59.7 thousand B/D in 1985 to 65.7 thousand B/D in 1989. During this same period, the U.S. refinery capacity utilization increased steadily from 77.6 to 86.3 percent. The light/heavy product ratio in the world dropped in the first year, but partially recovered in the following years.

- An increase in the worldwide ratio of light product to heavy product demand with

TABLE D-2

TOTAL APPARENT CONSUMPTION WORLDWIDE (Thousands Barrels per Day)

	1985	1986	1987	1988	1989
United States	15,726	16,281	16,665	17,283	17,325
North America	18,780	19,262	19,739	20,532	20,726
Central & South America	3,341	3,494	3,565	3,561	3,579
Western Europe	11,956	12,334	12,585	12,762	12,859
Eastern Europe and USSR	10,641	10,845	10,850	10,705	10,490
Middle East	2,682	2,724	2,798	2,969	3,126
Africa	1,862	1,819	1,836	1,905	1,991
Far East & Oceania	10,482	10,884	11,354	12,064	12,938
World Total	**59,745**	**61,363**	**62,727**	**64,499**	**65,709**

Source: Energy Information Administration/International Energy Annual 1986-1990.

UNITED STATES REFINERY UTILIZATION RATES (Percent of Calendar Day Capacity)

	1985	1986	1987	1988	1989
Crude Oil Distillation	77.6%	82.9%	83.1%	84.4%	86.3%
Cokers			92.3%	97.8%	95.5%
Catalytic Crackers			86.2%	88.4%	89.5%
Hydrocrackers			87.9%	84.8%	81.9%

Source: *Petroleum Supply Annual 1991*, Volume 1, pages 81-83. Downstream unit capacity. Utilization not available for 1985-86.

no change in total demand should result in an increase in U.S. refinery throughput and a decrease in imports.

Since the total worldwide demand did not hold constant and the light/heavy ratio declined slightly, this theory is neither confirmed nor refuted by the facts. Product imports did not show a steady trend.

- If the demand and mix changes take place only in the United States, the effect on U.S. refinery operations is greater than if these changes take place outside the United States. However, there is an impact on U.S. refinery operations even if the changes take place only outside the United States.

The demand and product mix changes did not occur only in the United States, but changed throughout the world as well.

1986 Conclusion #3: Political, economic, or social actions by exporting and importing nations can change industry economics and impact world product flow patterns and U.S. refinery operations.

In the 1986 study, it was concluded that foreign and U.S. governments can affect product flows through changing operating and importing incentives. Using the study model, various tariffs were imposed in the EEC and in the United States to determine how the product export/import flows would be affected.

- Middle East and North African refineries were run at estimated maximum throughput with the result of increased imports into Europe, the Far East, and the United States.

- European tariffs increases of $5 per barrel resulted in increased imports into the United States. A similar U.S. tariff increase would offset the European tariff.

- Imposed U.S. import tariffs on products that are not offset by foreign tariffs will cause:

  1. Reduction in product imports, with import shutdown at a tariff differential of $4 per barrel.

  2. Redistribution of U.S. imports to the rest of the world.

Major tariffs or other economic production incentives have not been imposed in the United States, the EEC, or other countries. Since the world crude oil price collapse of 1986, we have had a period of comparative price and supply stability with the exception of relatively short-term major interruptions such as the cold winter of 1990 and Iraq's invasion of Kuwait. However, major producing and consuming governments have not interfered in the petroleum product marketplace and thus the conclusion is still empirically untested.

In addition to the three major findings, the 1986 study noted several other findings and conclusions:

Measuring crude oil distillation capacity utilization may not fully describe the ability of U.S. refineries to produce light products.

As noted in major conclusion #1 above, when conversion capacity is nearing full utilization, increasing crude runs is not likely to increase gasoline production significantly. Under these circumstances, distillation utilization is not representative of how much more capacity is available for incremental production. Since the 1986 NPC study, the Energy Information Administration within the Department of Energy has started compiling statistics of utilization rates for major conversion units (Cokers, Catalytic Crackers, and Hydrocrackers).[3] The EIA reports Fresh Feed Inputs, Average Charge Capacity, and Percent Utilization Rates for the three major conversion unit types. With the new reported utilization, the industry no longer need speculate on whether the crude oil distillation utilization is reflective of refinery unit capacity utilization.

Regional refineries play an important and unique role in meeting U.S. product demands.

Regional refineries continue to play an important and unique role in meeting the petroleum requirements of their areas. Major pipelines and marine carriers move product from the major refining centers to the markets they serve. This is particularly true of Gulf Coast refining capacity serving East Coast and South East Markets. However, Mountain and Pacific refineries continue to be the primary source for products in their regions.

Los Angeles Basin refineries are subject to unique environmental regulations.

Los Angeles refineries continue to be subject to unique environmental regulations. Since the 1986 report, California and the Southern Coast Air Quality Management District have established the toughest environmental restrictions in the country.

- NOx emissions limitations were implemented in 1988 with a maximum of 0.14 pounds/million BTUs. At the end of 1992, the limit was further reduced to 0.10 pounds/million BTUs. An additional cut to 0.03 pounds/million BTUs will take place 1995. These emission levels apply to all boilers rated at more than 40 million BTUs per hour.

- Drainage systems must be sealed and a strict inspection program has been improved.

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[3] *Petroleum Supply Annual 1991*, Volume 1 Table FE4, page 83.

- Tank seals on floating roof tanks must be doubled for all products of greater than 0.5 psi vapor pressure. This includes all gasolines and military jet fuel (naphtha-jet). Kerojet and distillates do not require double sealed tankage.

In the California South Coast area, the RECLAIM program, under which emitters can buy and sell credits resulting from cutbacks which exceed standards, is being evaluated.

In addition, the California Air Resources Board will require more stringent gasoline specifications in 1996 through their Phase 2 program. Diesel specifications will also be more severe than the federal requirements.

Further environmental constraints on products or refining facilities increase industry's cost and/or reduce capacity to produce products.

The 1986 report was prophetic in arriving at this conclusion. The subsequent legislation and regulations stemming from the Clean Air Act Amendments of 1990, Oil Pollution Act of 1990, and the various state environmental legislation constitute the basis for this National Petroleum Council report on refining.

U.S. Petroleum Refining

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Working Papers

As input to the NPC refining study, a number of analyses were conducted on various topics. Copies of the following documents are being reproduced as NPC working papers in the public interest, and may be obtained from the National Petroleum Council. These documents were utilized by the NPC study participants in the course of the NPC study. The NPC **does not** necessarily endorse all of the specific information in these documents. These working papers **do not** constitute the advice and recommendation of the National Petroleum Council.

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