United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park, NC 27711

EPA-453/D-94-052
July 1994

Air

EPA

Economic Impact Analysis for the Petroleum Refineries NESHAP

DRAFT

Office of Air Quality
Clean
Air
OAQPS
Planning and Standards

CONTENTS

CONTENTS (continued)

Page

CONTENTS (continued)

TABLES

TABLES (continued)

FIGURES

ACRONYMS AND ABBREVIATIONS

API	American Petroleum Institute
ASM	Annual Survey of Manufactures
bbl	One barrel; equal to 42 gallons
bbl/d	Barrels per day
BCA	Benefit Cost Analysis
BWON	Benzene Waste Operations NESHAP (NESHAP is defined below)
CAA	Clean Air Act
CERA	Cambridge Energy Research Associates
DOC	Department of Commerce
DOE/EIA	Department of Energy/Energy Information Administration
EIA	Economic Impac Analysis
EPA	Environmental Protection Agency
HAP	Hazardous Air Pollutant
HON	Hazardous Organic NESHAP (NESHAP is defined below)
LPGs	Liquefied Petroleum Gases
MACT	Maximum Achievable Control Technology
Mg	Megagram
MRR	Monitoring, reporting, and recordkeeping
MTBE	Methyl tertiary butyl ether
NAAQS	National Ambient Air Quality Standard
NESHAP	National Emission Standard for Hazardous Air Pollutants
NSPS	New Source Performance Standard
NO_x	Nitrogen oxide
OGJ	Oil and Gas Journal
OMB	Office of Management and Budget
PADD	Petroleum Administration for Defense District
RFA	Regulatory Flexibility Act; also Regulatory Flexibility Analysis
RIA	Regulatory Impact Analysis
SIC	Standard Industrial Classification
SO_2	Sulfur dioxide
VOC	Volatile Organic Compound

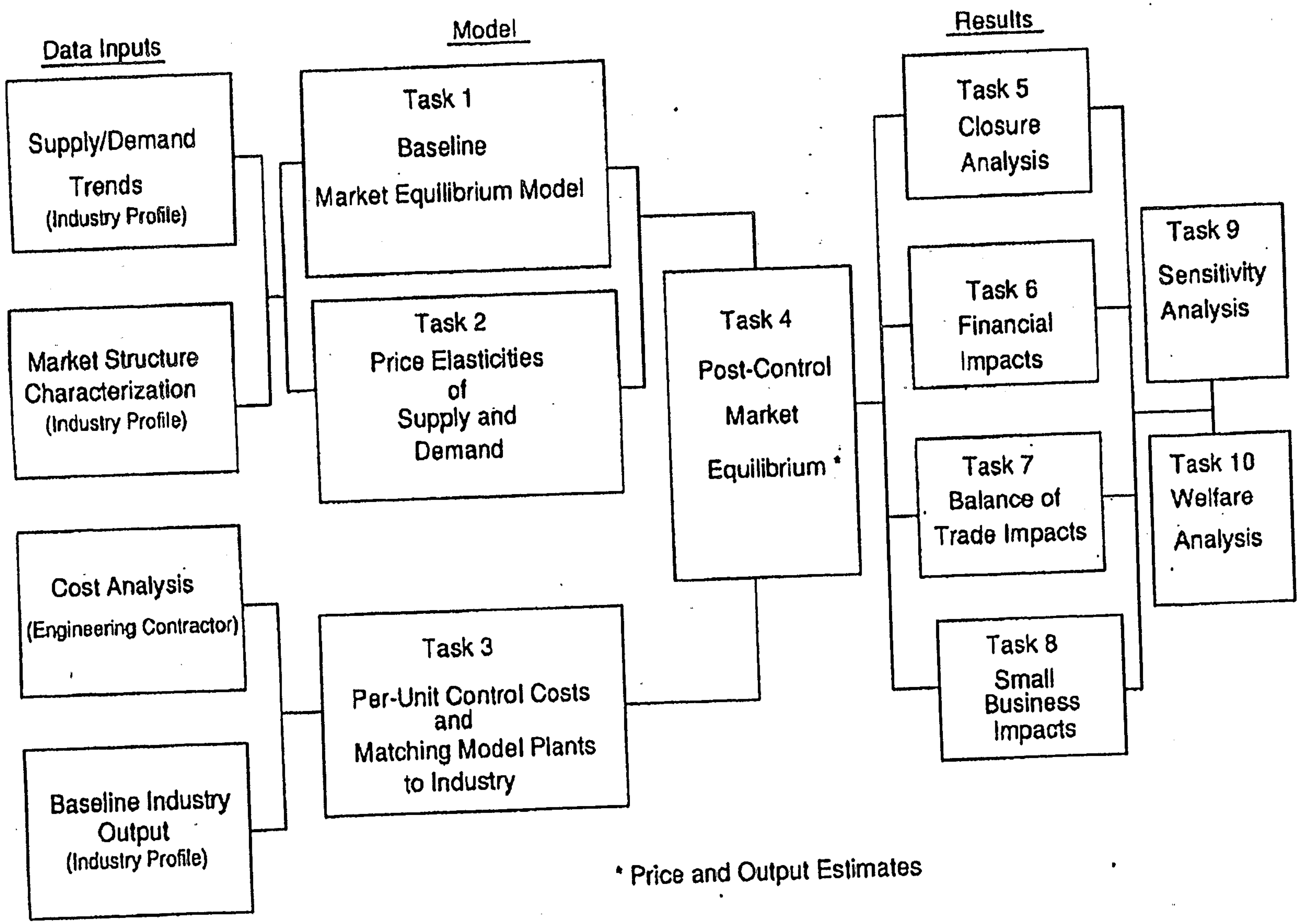
EXECUTIVE SUMMARY

ES.1 ECONOMIC IMPACT ANALYSIS OBJECTIVES

The purpose of this economic impact analysis (EIA) is to evaluate the effect of the control costs associated with the Petroleum Refining National Emission Standard for Hazardous Air Pollutants (NESHAP) on the behavior of the regulated petroleum refiners. The EIA was conducted based on the cost estimates for one hybrid regulatory option above the maximum achievable control technology (MACT) "floor" (or minimum standard). This analysis compares the quantitative economic impacts of regulation to baseline industry conditions which would occur in the absence of regulation. The economic impacts of regulation are estimated for the industry, using costs which were supplied on both a national and a refinery level.

Section 112 of the Clean Air Act (CAA) contains a list of hazardous air pollutants (HAPs) for which the U.S. Environmental Protection Agency (EPA) has published a list of source categories that must be regulated. To further meet this requirement, EPA is evaluating NESHAP alternatives for the regulation of the petroleum refining industry, based on different control options for the emission points within refineries which emit HAPs. This EIA was completed to fulfill CAA requirements and an Executive Order. Section 317 of the CAA requires EPA to evaluate regulatory alternatives through an EIA. Executive Order 12866 requires EPA to assess major regulations through a regulatory impact analysis (RIA). In addition to other analyses, an RIA must include an EIA. Accordingly, this EIA has been prepared to

Figure ES-1
Model Development for Economic Impact Analysis



* Price and Output Estimates

satisfy the requirements of the CAA and to partially fulfill the requirements of Executive Order 12866.

The objective of this EIA is to quantify the impacts of NESHAP control costs on petroleum refinery output, price, employment, and trade. The probability of refinery closure is also estimated, in addition to potential effects on the financial conditions of affected firms. To comply with the requirements of the Regulatory Flexibility Act (RFA), special attention is focused on the potential effects of control costs on smaller refineries.

ES.2 INDUSTRY CHARACTERIZATION

The firms affected by the Petroleum Refinery NESHAP are classified in SIC code 2911. The U.S. refining industry uses crude oil as an input to refine petroleum products for use as fuels, lubricants, waxes, asphalt materials, and other miscellaneous products. The five main refinery output categories are (1) motor gasoline, (2) jet fuel, (3) residual fuel oil, (4) distillate fuel oil, and (5) liquefied petroleum gases (LPGs). These five products accounted for 93 percent of total refinery output in 1992. The economic model used for this analysis focuses on these five product categories. The four economic sectors which are the source of demand for these five petroleum product categories are (1) residential and commercial, (2) industrial, (3) transportation, and (4) electric utilities.

During the past decade, the number of operating refineries in the United States has declined by 40 percent. As of January 1, 1992, there were 192 operable petroleum refineries in the United States owned by 109 firms. Firms that operate petroleum refineries are characterized as vertically integrated if they own and operate segments responsible both for exploration and production of crude oil (which supplies the input for refineries) and for marketing the finished petroleum products after refining occurs. The crude capacity of the major, vertically integrated firms in the petroleum refining industry represents almost 70 percent of nationwide production. Of the 109 firms in the industry, 73 operate only one refinery each. These are the

TABLE ES-1. SUMMARY OF COSTS IN THE FIFTH YEAR BY EMISSION POINT[4]

		Annual Fifth Year Costs ($1,000/yr) (1992 Dollars)			Annual Emission Reduction (Thousand Mg/yr)		Cost-Effectiveness ($/Mg)	
Emission Point	Option	Existing Sources	New Construction	Total	VOC	HAP	VOC	HAP
Equipment Leaks	Floor	$69,000	$0	$69,000	130	35	$531	$1,971
	Option 1[1]	$66,000	$(210)	$65,790	160	44.6	$411	$1,475
Miscellaneous Process Vents	Floor[1]	$11,000	$370	$11,370	180	8.4	$63	$1,353
Wastewater Systems	Floor[1]	$0	$0	$0	0	0	0	0
Storage Vessels	Floor[1]	$3,700	$98	$3,798	11	0.7	$345	$5,425
TOTAL FOR OPTIONS CHOSEN		$80,700	$258	$80,958	351	53.7	$231	$1,508

NOTES:
[1]Designates chosen alternative.
[2]Brackets indicate negative values.
[3]1992 dollars.
[4]Costs reflect compliance costs excluding monitoring, reporting, and recordkeeping costs.

newly constructed emission points, which were prepared by the engineering contractor for use in the EIA. All costs are in first quarter 1992 dollars. Costs are provided by emission point for the MACT floor level of control and Option 1 for equipment leaks. The total national annualized cost for the chosen option is approximately $81.0 million (excluding monitoring, reporting, and recordkeeping costs).

Table ES-1 also shows the HAP and VOC emission reductions associated with control at three of the four emission points and the calculated cost-effectiveness of each control method. The cost-effectiveness of VOC emission reduction ranges from $63 to $411 per megagram, and the cost-effectiveness of HAP reductions ranges from $1,353 to $5,425 per megagram. No control costs or emission reductions are associated with the control of wastewater streams.

To allocate the costs among the five petroleum product categories in the analysis, a national average production mix was applied to individual refinery production data found in the *Oil and Gas Journal's* (OGJ) "Survey of Operating Refineries for 1992." This calculation assumes that all refineries have the same product mix as the national average. Costs were then allocated in a two-step process: (1) by assuming that all storage vessels control costs were associated with the production of motor gasoline, and (2) costs associated with equipment leaks and miscellaneous process vents were distributed among the product categories based on the national product mix ratios.

ES.4 MONITORING, RECORDKEEPING, AND REPORTING COSTS

In addition to provisions for the installation of control equipment, the proposed regulation includes provisions for monitoring, recordkeeping, and reporting (MRR). EPA estimates that the total annual cost for refineries to comply with the MRR requirements is $30 million. After incorporating MRR costs, the total cost of compliance of the Chosen Regulatory Alternative is $111 million.

ES.5 ECONOMIC METHODOLOGY OVERVIEW

In this study, data inputs are used to construct a pre-control baseline equilibrium market model of the petroleum refining industry. This baseline model of the petroleum refining market provides the basic framework necessary to analyze the impact of proposed control costs on the industry. The *Industry Profile for the Petroleum Refinery NESHAP* contained industry data, including estimates of price elasticities of supply and demand measures which are inputs to the baseline model. The industry profile characterizes the market structure of the industry, provides necessary supply and demand information, and identifies market trends. Engineering control cost studies provide the final major data input required to quantify the potential impact of control measures on the market. These profile and engineering cost data inputs are evaluated within the context of the market model to estimate the impacts of regulatory control measures on the petroleum refining industry and on society as a whole. The potential impacts include the following:

- Changes in market price and output.
- Financial impacts on firms.
- Predicted closure of refineries.
- Welfare analysis.
- Small business impacts.
- Labor market impacts.
- Energy use impacts.
- Foreign trade impacts.
- Regional impacts.

The progression of steps in the EIA process is summarized in Figure ES-1.

ES.6 PRIMARY REGULATORY IMPACTS

Primary regulatory impacts include estimated increases in the market equilibrium price of refined petroleum products, decreases in the market equilibrium domestic output or production, changes in the value of domestic shipments, and plant closures. The analysis was conducted for the five petroleum products of interest. The primary regulatory impacts are summarized in Table ES-2.

As shown in Table ES-2, the estimated price increases for the petroleum products range from an increase of $0.03 per barrel for residual fuel oil to $0.14 per barrel for jet fuel. These predicted price increases represent a less than 1 percent increase in the price of each product and range from 0.24 percent for residual fuel oil to 0.53 percent for jet fuel. Domestic production is expected to fall for the five petroleum products combined by approximately 12.52 million barrels annually. This estimated decrease in production for each of the petroleum products varies from annual decreases of 0.65 million barrels for jet fuel to 5.67 million barrels annually for motor gasoline.

The predicted change in the dollar value of domestic shipments or revenue to producers in the industry is actually anticipated to increase for the five petroleum products combined by approximately $107.41 million annually ($1992). Annual revenues for each of the petroleum products are anticipated to increase with the exception of residual fuel oil. Price increases for products with inelastic demand generally lead to

TABLE ES-2. SUMMARY OF PRIMARY ECONOMIC IMPACTS OF PETROLEUM REFINERY NESHAP

Refined Product	Estimated Impacts[4]: Price Increases[1]	Production Decreases[2]	Value of Domestic Shipments[3]
Motor gasoline			
Amount	$0.09	(5.67)	$55.63
Percentage	0.29%	(0.22%)	0.07%
Jet fuel			
Amount	$0.14	(0.65)	$53.22
Percentage	0.53%	(0.13%)	0.41%
Residual fuel			
Amount	$0.03	(1.62)	($11.92)
Percentage	0.24%	(0.50%)	(0.26%)
Distillate fuel			
Amount	$0.08	(2.78)	$8.06
Percentage	0.29%	(0.26%)	0.03%
LPGs			
Amount	$0.07	(1.80)	$2.42
Percentage	0.26%	(0.25%)	0.01%

NOTES: [1]Prices are shown in price per barrel ($1992).
[2]Annual production quantities are shown in millions of barrels.
[3]Values of domestic shipments are shown in millions of 1992 dollars.
[4]Brackets indicate decreases or negative values.

8, etc.

revenue increases for producers. This result holds for each of the petroleum products studied except residual fuel oil. The resulting decrease in predicted revenues for this product results from the large quantity of this product that is imported. As the price of domestic residual fuel oil rises, greater amounts of this product are imported leading to revenue decreases for domestic producers.

Approximately 7 refineries are predicted to close as a result of the regulation. Plant closure estimates and other regulatory impacts are likely to be overestimations for the following reasons:

- The model assumes that all refineries compete in a national market. In reality, some refineries are protected from market fluctuations by regional or local trade barriers and may therefore be less likely to close.
- It is assumed that the plants with the highest control cost per unit of production also have the highest baseline production costs. This is a worst- case assumption and may not be true in every case.
- Control costs are assigned exclusively to the five products of interest which collectively represent 93 percent of the total quantity of petroleum products produced.
- Refineries with the highest per-unit control costs have compliance costs that are significantly higher than the average costs. This could be the result of the manner in which control costs were estimated or the method used to allocate costs by product category based on production data.

ES.7 SECONDARY REGULATORY IMPACTS

Secondary impacts of the Petroleum Refinery NESHAP include the potential effects of the regulation on the labor market, energy use, foreign trade, and regional effects. The effects on the labor market, energy use, and foreign trade are summarized in Table ES-3.

Labor market losses resulting from the NESHAP are estimated to be approximately 114 jobs for the domestic petroleum refining industry. This estimate reflects the reductions in jobs predicted to result from the anticipated reduction in annual production of refinery products. No effort has been made to estimate the number of jobs that may be created as a result of the regulations, however, so this estimate of job losses is likely to be overstated.

Annual reductions in energy use as a result of the regulation are expected to amount to a savings of approximately $10.85 million (1992 dollars) annually. Net annual exports are predicted to decrease by 2.26 million barrels for the five products, with the range of reductions varying from 0.21 million barrels for LPGs to 0.91 million barrels for residual fuel oil.

Regional effects are expected to be minimal, since the predicted plant closures are dispersed throughout the United States, rather than concentrated in specific geographic regions.

ES.8 ECONOMIC COST

Air quality regulations affect society's economic well-being by causing a reallocation of productive resources in the economy. Resources are allocated away from the production of goods and services (refined petroleum products) to the production of cleaner air. Economic cost are associated with the reallocation of resources.

The economic costs of regulation incorporate costs borne by all of society for pollution abatement. The social or economic costs reflect the opportunity cost or economic cost of resources used in emission control. Consumers, producers, and all of society bear the costs of pollution controls in the form of higher prices, lower quantities produced, and possible tax

TABLE ES-3. SUMMARY OF SECONDARY REGULATORY IMPACTS

	Estimated Impacts[1]		
Refined Product	Labor Input[2]	Energy Input[3]	Foreign Trade (net exports)[4]
Motor gasoline			
Amount	(52)	($5.79)	(0.43)
Percentage	(0.22%)	(0.22%)	(0.54%)
Jet fuel			
Amount	(6)	($0.52)	(0.23)
Percentage	(0.13%)	(0.13%)	(1.41%)
Residual fuel			
Amount	(15)	($0.71)	(0.91)
Percentage	(0.50%)	(0.50%)	(0.81%)
Distillate fuel			
Amount	(25)	($2.27)	(0.48)
Percentage	(0.26%)	(0.26%)	(40.92%)
LPG			
Amount	(16)	($1.56)	(0.21)
Percentage	(0.25%)	(0.25%)	(0.54%)
Total five products			
Amount	(114)	($10.85)	(2.26)

NOTES: [1]Brackets indicate decreases or negative values.
[2]Indicates estimated reduction in number of jobs.
[3]Reduction in energy use in millions of 1992 dollars.
[4]Reduction in net exports (exports less imports) in millions of barrels.

revenues that may be gained or lost. Annual economic costs of $132.35 million ($1992) are anticipated for the chosen alternative and are shown in Table ES-4. Economic cost are a more accurate estimate of the cost of the regulation to society than emission control cost estimates to the directly affected industry.

TABLE ES-4. ANNUAL ECONOMIC COST ESTIMATES FOR THE PETROLEUM REFINING REGULATION
(Millions of 1992 dollars)

Social Cost Category	Net Costs[1]
Surplus Losses for Chosen Alternative:	
Change in Consumer Surplus	$ 476.19
Change in Producer Surplus	$ (242.11)
Change in Residual Surplus to Society[2]	$ (101.73)
Total Social Cost of Alternative[3]	$ 132.35

NOTES: [1]Negative net costs or benefits are shown in brackets
[2]Residual surplus loss to society includes adjustments necessary to equate the relevant discount rate to the social cost of capital and to consider appropriate tax effect adjustments.
[3]The Chosen Alternative includes floor controls for all emission points except equipment leaks. Option 1 is preferred to the floor for equipment leaks because it is a less costly option than the floor.

ES.9 POTENTIAL SMALL BUSINESS IMPACTS

The RFA requires that a determination must be made as to whether or not the subject regulation would have a significant economic impact on a substantial number of small entities. (A *significant* number is generally considered to be more than 20 percent of the small entities identified.) There were approximately 63 small petroleum refineries in the United States producing less than 50,000 barrels of refined petroleum products per day in 1992. Although the proposed regulation may result in the closure of *some* firms in the industry – with small business entities at the greatest risk – this study indicates that the number of closures would be limited to approximately 7, or less than 20 percent of the small businesses in the industry. This estimate is likely overstated for reasons previously outlined. An alternative criterion of determining if small businesses will be adversely affected by a regulation is to compare control costs to sales revenues for small businesses relative to all other firms in the industry. According to the RFA, impacts are "significant" if costs as a percentage of sales for small entities is at least 10 percent higher than compliance costs as a percentage of sales for large entities. The cost to sales ratio for small refineries for the study period was 0.191 percent, compared to 0.082 percent for all other refineries in the industry. Since the differential in these ratios exceeds 10 percent, the conclusion that small domestic petroleum refineries will experience a significant economic impact as a result of the proposed emission controls is warranted.

1.0 INTRODUCTION AND SUMMARY OF CHOSEN REGULATORY ALTERNATIVE

1.1 INTRODUCTION

This report evaluates the economic impact of proposed standards on the petroleum refining industry. Section 112 of the CAA contains a list of HAPs for which EPA has published a list of source categories that must be regulated. To further this requirement, EPA is evaluating alternative NESHAPs for the petroleum refining industry, because several emission sources within refineries emit HAPs. Section 317 of the CAA requires EPA to evaluate regulatory alternatives through an EIA. Executive Order 12866 requires EPA to assess major regulations through a Regulatory Impact Analysis (RIA). In addition to other analyses, an RIA includes an EIA. Accordingly, this EIA has been prepared to satisfy the requirements of the CAA and to partially fulfill the requirements of Executive Order 12866.

This chapter presents a discussion of the NESHAP alternative under analysis in this report. Chapter 2 of this report is a compilation of economic and financial data on the petroleum refining industry. Included in this profile are an identification of affected refineries, a characterization of market structure, separate discussions of the factors which affect supply and demand, a discussion of foreign trade, a financial profile, and the quantitative data inputs for the EIA model. Chapter 3 outlines the economic methodology used in this analysis, the structure of the market model, and the process used to estimate industry supply elasticities.

Chapter 4 presents the control costs used in the model, the estimated emission reductions expected as a result of regulation, and the cost-effectiveness of the regulatory option. Also included is a quantitative estimate of economic costs and a qualitative discussion of conceptual issues associated with the estimation of economic costs of emission controls. Chapter 5 presents the estimates of the primary impacts determined by the model, which include estimates of price, output, and employment impacts. A capital availability analysis is included as well as a discussion of the limitations of the model. Chapter 6 presents the secondary economic impacts, which are the estimated quantitative impacts on the industry's labor market, energy use, foreign trade, and regional markets. Lastly, Chapter 7 specifically addresses the potential impacts of regulation on small refineries.

1.2 SUMMARY OF CHOSEN REGULATORY ALTERNATIVE

The CAA stipulates that HAP emission standards for existing sources must at least match the percentage reduction of HAPs achieved by either (1) the best performing 12 percent of existing sources, or (2) the best five sources in a category or subcategory consisting of fewer than 30 sources. For new sources, the CAA stipulates that, at a minimum, the emission standard must be set at the highest level of control achieved by any similar source. This minimum level of control for both existing and new sources is referred to as the MACT floor.

A source within a refinery is defined as "the collection of emission points in HAP-emitting petroleum refining processes within the source category. The source comprises several emission points. The definition of source is an important element of this NESHAP because it describes the specific grouping of emission points within the source category to which this standard applies. An emission point is a piece of equipment or component of production which produces HAPs. Based on Section 112(c) of the CAA, controls are required on the following emission points in refineries: storage vessels, equipment leaks, miscellaneous process vents, wastewater collection and treatment systems, and catalytic reformer process vents. EPA chose one regulatory alternative for detailed economic impact analysis which combines MACT floor level controls for storage vessels, wastewater collection and treatment systems, and miscellaneous process vents, with an option more stringent than the MACT floor for equipment leaks.

2.0 INDUSTRY PROFILE

2.1 INTRODUCTION

The petroleum industry can be divided into five distinct sectors: (1) exploration, (2) production, (3) refining, (4) transportation, and (5) marketing. *Refining*, the process subject to this NESHAP, is the process which converts crude oil into useful fuels and other products for consumers and industrial users. All affected facilities are classified under Standard Industrial Classification (SIC) code 2911. Although petroleum refineries produce a diverse slate of products, the five primary output categories are (1) motor gasoline, (2) jet fuel, (3) residual fuel, (4) distillate fuel, and (5) liquefied petroleum gases (LPGs), which in total accounted for 93 percent of all domestically refined petroleum products in 1992. This analysis focuses on the markets for these five main product categories.

Section 2.2 through Section 2.6 of this chapter provide an overview of the activities of the petroleum refining industry. The economic and financial information in this chapter characterizes the conditions in the refining industry which are likely to determine the nature of economic impacts associated with the implementation of the alternative NESHAPs. The information contained in this chapter represents the inputs to the economic model (presented in Chapter 3) which were used to conduct the economic impact analysis. The general outlook for the industry is also discussed in this chapter.

Section 2.2 describes the refining process and refined petroleum products, and identifies the unique market characteristics of each product. Section 2.2 also identifies affected refineries, presents trends in refining capacity, and addresses the range in complexity among refineries. Section 2.3 characterizes the industry structure in terms of market concentration, integration, and product differentiation. Also included in Section 2.3 is a financial profile of a sample of firms. Section 2.4 characterizes the supply side of the market in terms of production trends, supply determinants, and export levels. Section 2.5 presents demand-side characteristics, including end-use markets, consumption trends, and import levels. Lastly, Section 2.6 presents quantitative estimates of supply, demand, and price projections.

A wide range of references were relied upon in the development of this industry profile. Data from the U.S. Department of Energy/Energy Information Administration (DOE/EIA) are relied upon most extensively, since DOE/EIA provides the most comprehensive production and consumption data by refined petroleum product. In cases of conflicting or differing information, preference is given to the most current and complete data source.

2.2 PROFILE OF AFFECTED FACILITIES

This section reviews the products and processes of the refining sector of the industry, and identifies any differences among product markets. The affected refineries are identified by location, capacity, and complexity.

2.2.1 *General Process Description*

The refining process transforms crude oil into a wide range of petroleum products which have a variety of applications. The refining industry has developed a complex variety of production processes used to transform crude oil into its various final forms, many of which are already subject to some CAA controls. EPA's source category list (57 FR 31576, July 16, 1992) required by Section 112(c) of the CAA, identified two source categories within refineries for which NESHAPs are to be established. These two categories are: (1) catalytic cracking (fluid and other) units, catalytic reforming units and sulfur units, and (2) other sources not distinctly listed. During development of the proposed standard, EPA determined that some of the emission points from these two categories can be controlled by the same control techniques, and as a result, the emission points within these source categories will be regulated by a single NESHAP. Upon revision of the source category list, all emission points regulated by the subject NESHAP will be in a single source category.

There are numerous refinery processes from which emissions occur. *Separation processes* (such as atmospheric distillation and vacuum distillation), *breakdown processes* (thermal cracking, coking, visbreaking), *change processes* (catalytic reforming, isomerization), and *buildup processes* (alkylation and polymerization) all have the potential to emit HAPs. HAP emissions may occur through process vents, equipment leaks, or from evaporation from storage tanks or wastewater streams. The NESHAP will address emissions from all of these refinery processes.

2.2.2 *Product Description and Differentiation*

Most petroleum refinery output consists of motor gasoline and other types of fuel, but some non-fuel uses exist, such as petrochemical feedstocks, waxes, and lubricants. The output of each refinery is a function of its crude oil feedstock and its preferred petroleum product slate. The five main petroleum product markets which are analyzed in this EIA are motor gasoline, residual fuel oil, distillate fuel oil, jet fuel, and LPGs.

Motor gasoline is defined as a complex mixture of relatively volatile hydrocarbons that have been blended to form a fuel suitable for use in spark-ignition engines. Residual fuel oil is a heavy oil which remains after the distillate fuel oils and lighter hydrocarbons are distilled away in refinery operations. Uses include fuel for steam-powered ships, commercial and industrial heating, and electricity generation. Distillate fuel oil is a general classification for one of the petroleum fractions produced in conventional distillation operations. It is used primarily for space heating, on- and off-highway diesel engine fuel (including railroad engine fuel and fuel for agricultural machinery), and electric power generation. Jet fuel is a low freezing point distillate of the kerosene type used primarily for turbojet and turboprop aircraft engines. LPGs are defined as ethane, propane, butane, and isobutane.

Product differentiation is a form of non-price competition used by firms to target or protect a specific market. The extent to which product differentiation is effective depends on the nature of the product. The more homogenous the overall industry output, the less effective differentiation by individual firms becomes. Each of the five petroleum products in this analysis are by nature quite homogenous -- there is little difference between Exxon premium gasoline and Shell premium gasoline -- and, as a result, differentiation does not play a major role in the competitiveness among petroleum refineries.

2.2.3 *Distinct Market Characteristics*

The markets for refined petroleum products vary by geographic location. Regional markets may differ due to the quality of crude supplied or the local product demand. Some smaller refineries which produce only one product have single, local markets, while larger, more complex refineries have extensive distribution systems and sell their output in several different regional markets. In addition, because refineries are the source of non-hydrocarbon pollutants such as individual HAPs, volatile organic compounds (VOCs), sulfur dioxide (SO_2), and nitrogen oxide (NO_x), many Federal, State, and local regulations are already in place in some locations. Differences in the regional market structure may also result in different import/export characteristics.

The United States is segmented into five regions, called Petroleum Administration for Defense Districts (PADDs), for which statistics are maintained. PADDs were initiated in the 1940s for the purpose of dividing the United States into five economically and geographically distinct regions. Relatively independent markets for petroleum products exist in each PADD, and much of the data available from DOE and other sources is segmented by PADD. Figure 2-1 illustrates the geographic breakdown for each PADD.

Table 2-1 shows both State- and PADD-level capacity totals for a variety of refinery processes. Several industry trends are evident from the PADD-level totals in Table 2-1. First, PADD III has more than twice the capacity of any other single PADD, mainly because much of the domestic crude oil supply is located in this region. Conversely, PADDs I and IV have very little capacity. Given the large population and correspondingly large petroleum demand in PADD I and the small population and lower demand in PADD IV, it is likely that the market for petroleum products is in some way fundamentally different in each district. The availability of petroleum products in each PADD plays a role in the import/export characteristics of each region.

In addition to differences in regional markets, each of the five product categories in this analysis possesses its own individual market segment, satisfying demand among different end-use sectors. The substitutability of one of the products — motor gasoline, for example — is not possible with another refinery output, such as jet fuel. Thus, each of the products in this analysis is treated as a separate product with its own share of the market. From a refinery standpoint, however, if the production of one refined product were to become less costly after regulation, production of this product may increase at the expense of a product with a more costly refining process.

FIGURE 2-1. PETROLEUM ADMINISTRATION FOR DEFENSE DISTRICTS (PADDs)

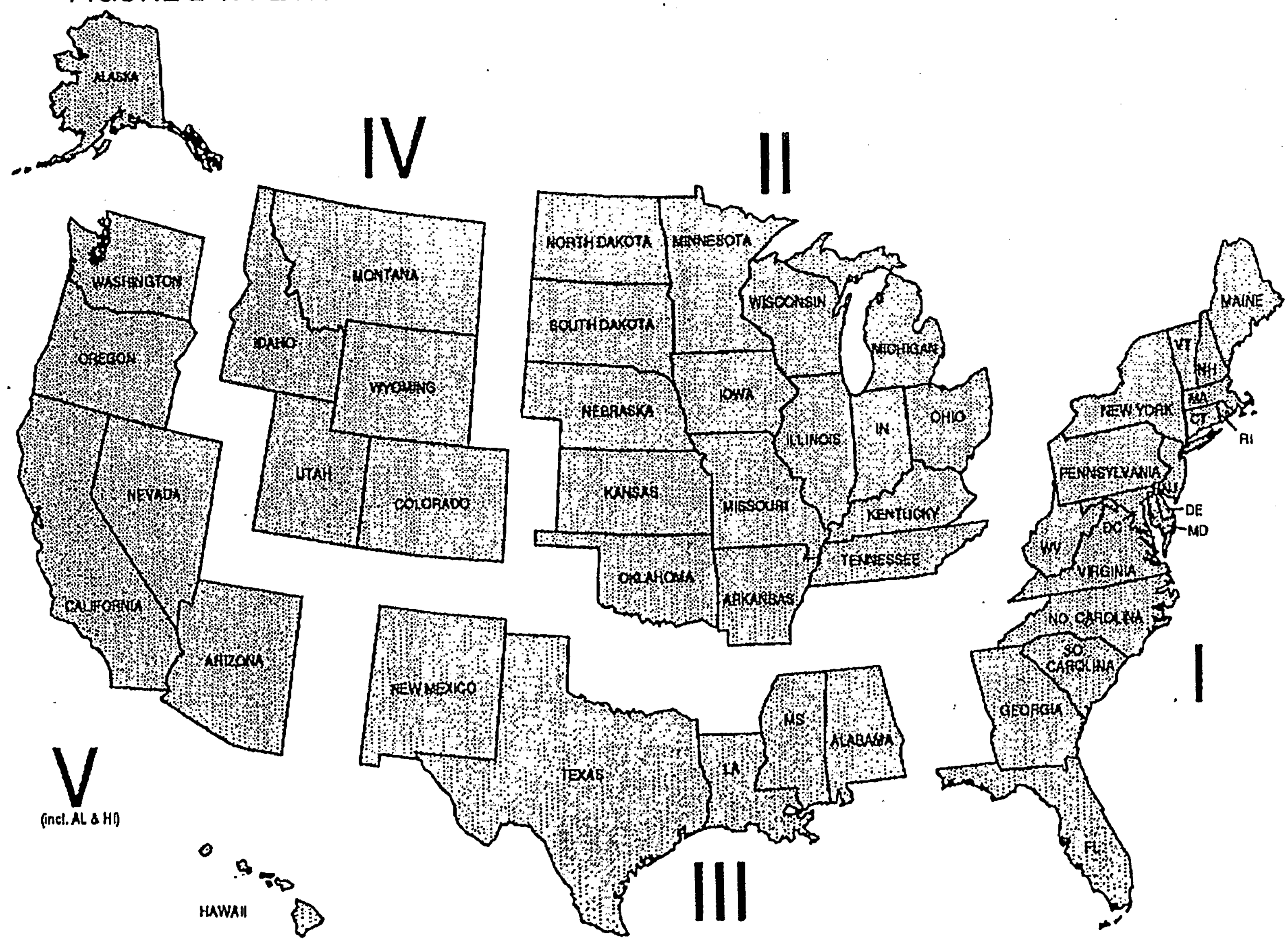


TABLE 2-1. PRODUCTION CAPACITY OF OPERABLE PETROLEUM REFINERIES 3 (AS OF JANUARY 1, 1991)

PAD District State	Number of Operable Refineries			Atmospheric Crude Oil Distillation Capacity			
				Barrels per Calendar Day		Barrels per Stream Day	
	Total	Operating	Idle	Operating	Idle	Operating	Idle
PADD I Totals	22	19	3	1,338,405	152,400	1,403,000	162,400
Delaware	1	1	0	140,000	0	152,000	0
Georgia	2	1	1	5,540	28,000	6,000	30,000
New Jersey	6	4	2	334,500	124,400	352,000	132,400
New York	1	1	0	41,850	0	45,000	0
North Carolina	1	1	0	3,000	0	3,000	0
Pennsylvania	8	8	0	744,315	0	772,500	0
Virginia	2	2	0	56,700	0	60,000	0
West Virginia	1	1	0	12,500	0	12,500	0
PADD II Totals	40	39	1	2,975,902	1,250	3,496,303	2,500
Illinois	7	7	0	937,600	0	994,000	0
Indiana	5	4	1	429,900	1,250	443,100	2,500
Kansas	8	8	0	2	0	374,483	0
Kentucky	2	2	0	218,900	0	226,300	0
Michigan	3	3	0	118,600	0	129,000	0
Minnesota	2	2	0	267,100	0	279,220	0
North Dakota	1	1	0	58,000	0	60,000	0
Ohio	4	4	0	457,100	0	477,000	0
Oklahoma	6	6	0	395,500	0	416,200	0
Tennessee	1	1	0	60,000	0	62,000	0
Wisconsin	1	1	0	33,200	0	35,000	0
PADD III Totals	72	64	8	6,766,807	440,150	7,121,307	507,500
Alabama	3	2	1	113,500	26,600	116,300	28,000
Arkansas	3	3	0	53,900	5,800	57,000	6,000
Louisiana	22	19	3	2,286,707	340,500	2,388,900	395,000
Mississippi	6	5	1	362,400	6,000	383,000	7,900
New Mexico	4	3	1	74,800	4,000	79,107	6,100
Texas	34	32	2	3,875,500	57,250	4,097,000	64,500
PADD IV Totals	18	17	1	539,875	15,200	566,250	16,000
Colorado	3	2	1	76,000	15,200	85,000	16,000
Montana	4	4	0	139,650	0	145,500	0
Utah	6	6	0	154,500	0	160,000	0
Wyoming	5	5	0	169,725	0	175,750	0
PADD V Totals	50	45	5	2,986,090	107,850	3,165,100	118,154
Alaska	6	6	0	239,540	0	254,700	0
Arizona	1	1	0	10,000	0	12,000	0
California	32	29	3	2,094,150	91,450	2,217,400	98,700
Hawaii	2	2	0	146,300	0	150,000	0
Nevada	1	0	1	0	4,500	0	4,700
Oregon	1	1	0	0	0	0	0
Washington	7	6	1	496,100	11,900	531,000	12,754
U.S. Totals	202	184	18	14,607,079	716,850	15,751,960	804,554

TABLE 2-1 (CONTINUED).

PAD District State	Downstream Charge Capacity (barrels per stream day) Vacuum Distillation	Thermal Cracking	Catalytic Cracking Fresh	Catalytic Cracking Recycled	Catalytic Reforming	Catalytic Hydro-cracking	Catalytic Hydro-treating	Fuels Solvent Deasphalting
PADD I Totals	737,150	80,000	697,600	50,800	345,800	90,440	917,260	0
Delaware	95,000	45,000	67,000	5,000	54,000	18,000	123,000	0
Georgia	0	0	0	0	0	0	2,940	0
New Jersey	258,900	21,000	256,000	37,000	77,600	17,000	289,000	0
New York	28,000	0	0	0	0	0	0	0
North Carolina	0	0	0	0	0	0	0	0
Pennsylvania	320,250	0	247,000	6,800	200,400	51,000	471,820	0
Virginia	29,000	14,000	27,500	2,000	10,200	0	26,500	0
West Virginia	6,000	0	0	0	3,700	4,440	4,000	0
PADD II Totals	1,407,500	382,600	1,294,800	52,300	928,600	162,890	1,995,400	39,800
Illinois	383,900	126,300	378,000	10,000	302,300	67,500	617,600	0
Indiana	235,450	28,000	173,000	4,200	99,800	0	267,800	5,000
Kansas	124,650	52,500	123,800	9,000	93,800	3,190	211,000	5,500
Kentucky	92,000	57,600	100,000	0	46,000	0	172,300	10,000
Michigan	38,000	0	47,000	1,000	33,000	0	61,800	0
Minnesota	182,000	60,000	83,000	1,000	59,500	0	227,000	0
North Dakota	0	0	26,000	3,600	12,100	0	19,100	0
Ohio	172,000	31,700	174,000	17,500	162,600	87,200	196,500	9,000
Oklahoma	147,000	26,500	149,000	5,000	101,500	5,000	177,500	10,300
Tennessee	12,000	0	30,000	0	10,000	0	30,000	0
Wisconsin	20,500	0	11,000	1,000	8,000	0	14,800	0
PADD III Totals	8,208,075	1,050,000	2,670,900	149,275	1,832,150	554,500	4,817,260	143,000
Alabama	45,000	12,000	0	0	26,000	0	59,300	0
Arkansas	23,300	0	19,100	775	11,200	0	30,000	5,500
Louisiana	1,132,200	580,700	895,500	11,500	530,300	172,000	1,267,500	35,000
Mississippi	274,775	83,500	80,000	7,000	96,000	68,000	254,000	0
New Mexico	13,900	0	38,800	4,500	21,050	1,000	29,800	[illegible]
Texas	1,718,900	373,800	1,642,500	125,500	1,147,600	313,500	3,176,650	102,50
PADD IV Totals	216,430	29,400	200,200	30,350	123,480	12,300	248,740	16,50
Colorado	43,000	4,200	27,500	1,000	22,900	5,000	35,700	
Montana	58,450	7,700	55,900	6,250	37,730	4,900	119,340	11,50
Utah	46,980	8,500	54,800	10,600	30,500	2,400	41,200	5,00
Wyoming	73,000	9,000	62,000	12,500	32,350	0	52,500	
PADD V Totals	1,706,350	615,900	795,200	21,000	695,800	487,800	1,697,680	71,50
Alaska	6,000	0	0	0	12,000	9,000	0	
Arizona	7,000	0	0	0	0	0	0	
California	1,347,600	530,900	656,700	14,000	542,300	408,800	1,475,180	50,0
Hawaii	74,250	13,000	20,000	0	13,000	18,000	3,500	
Nevada	0	0	0	0	0	0	0	
Oregon	16,000	0	0	0	0	0	0	
Washington	255,500	72,000	118,500	7,000	128,500	52,000	219,000	21,5
U.S. Totals	7,275,505	2,157,800	5,558,600	303,725	3,925,830	1,307,830	9,676,330	270,8

2.2.4 *Affected Refineries, Employment, and Location*

There are currently 192 operable petroleum refineries in the United States.[2] Though refineries differ in capacity and complexity, almost all refineries have some atmospheric distillation capacity and additional downstream charge capacity, such as the processes described above in Section 2.2.1.

The most recent employment data source is the 1987 Census of Manufactures for petroleum and coal products, which lists data on employment and the number of establishments for SIC code 2911.[3] Table 2-2 provides an indication of the frequency distribution of small facilities in the petroleum refining industry. An adjustment to the U.S. Department of Commerce data was necessary because of the estimation process used by DOC.[4] Column 3 lists the number of plants which can be attributed to overestimation by DOC. This conclusion was determined based on information from DOE. Column 4 lists the actual number of refineries. Some disparity still exists between column 4 and DOE data, but the totals (219 and 213, respectively) are comparable. According to the adjusted data set (column 6), slightly fewer than 4 percent of refinery employees work in establishments of fewer than 100 people. The remaining 96 percent of the labor force in the industry works at establishments of 100 employees or more.

On a firm level, 1990 employment data were available for several of the larger petroleum refining companies. Table 2-3 lists employee and sales data for a sample of companies in SIC 2911. In addition to these large firms, there are numerous small firms which typically operate one refinery. For the smallest firms in this industry, employment data was not available.

TABLE 2-2. EMPLOYMENT IN THE PETROLEUM REFINING INDUSTRY[3] [4]

	1	2	3	4	5	6
Establishments with average number of employees:	E[a]	Number of Refineries	Over-estimation[c]	Net Number of Refineries	Net Total Employees	Percentage of Total
1 to 4	9[a]	46	41	5	11	0.0
5 to 9	7[a]	22	15	7	64	0.1
10 to 19	7[a]	20	14	6	90	0.1
20 to 49	4[a]	53	21	32	966	1.3
50 to 99	2[a]	27	5	22	1,630	2.2
100 to 249	b	51	0	51	9,100	12.4
250 to 499	b	43	0	43	15,000	20.4
500 to 999	b	31	0	31	21,400	29.2
1,000 to 2,499	b	16	0	16	25,100	34.2
All establishments		309	97	213	73,361	100.0

TABLE 2-3. 1990 EMPLOYMENT FOR SELECTED REFINING FIRMS[5 6]

Company	Number of Employees
Amoco	54,524
ARCO	27,300
Ashland Oil	33,400
Chevron	54,208
Citgo	3,300
Diamond Shamrock	84[1]
Exxon	104,000
Mobil	67,300
Occidental Petroleum	12,500
Phillips Petroleum	21,800
Sun Co.	20,926
Texaco	39,000

NOTES: [1]Diamond Shamrock had 1990 sales in excess of $1 billion, and therefore cannot be considered a small entity.

2.2.5 *Capacity and Capacity Utilization*

Refineries have many different specialties, targeted product slates, and capabilities. Some refineries produce output only by processing crude oil through basic atmospheric distillation. These refineries have very little ability to alter their product yields and are deemed to have low complexity. In contrast, refineries that have assorted downstream processing units can substantially improve their control over yields, and thus have a higher level of complexity. Because of their differences in size and complexity, refineries can be grouped by two main structural features: (1) atmospheric distillation capacity (which denotes their size) and (2) process complexity (which characterizes the type of products a refinery is capable of producing).

Capacity is the characteristic most often used to categorize petroleum refineries in market analyses. Throughout this report, capacity will be used as a measure of production and output. National refining production capacity was summarized on a regional and State basis in Table 2-1. Appendix A, at the end of this report, lists the production capacity for all firms and refineries in the petroleum refining industry.

Capacity utilization rates of petroleum refineries have been rising in recent years, reaching a high of 87.1 percent in 1990.[7] This indicates that existing refineries are operating closer to full capacity, and will have limited opportunity to enhance production by increasing utilization.

During the past 23 years, the entire domestic refining industry has been affected by crude oil quality changes, shifting petroleum demand patterns, and evolving regulations, resulting in a more complex, more flexible refining industry. Ownership of U.S. refiners changed through consolidation and foreign investments. Throughout the 1970s, the number of U.S. refineries rose rapidly in response to rising demand for petroleum products. In the early 1980s, the petroleum refining industry entered a period of restructuring, which continued through 1992. A record number of U.S. refineries were operating in 1981. A decline in petroleum demand in the early 1980s caused many small refineries and older, inefficient plants to close. The refinery shutdowns resulted in improved operating efficiency, which enabled the refinery utilization rate to increase, despite lower crude oil inputs. As of January 1, 1992, there were 192 operating refineries, compared with 324 in 1981. Trends in the nation's operable refining capacity and capacity utilization are presented in Table 2-4. Note that operable capacity has remained relatively constant since 1985, while capacity utilization has risen steadily.

2.2.6 *Refinery Complexity*

Complexity is a measure of the different processes used in refineries. It can be quantified by relating the complexity of a downstream process with atmospheric distillation, where atmospheric distillation is assigned the lowest value, 1.0. The level of complexity of a refinery generally correlates to the types of products the refinery is capable of producing. Higher complexity denotes a greater ability to enhance or diversify product output, to improve yields of preferred products, or to process lower quality crude oil. By defining refinery complexity, it is possible to differentiate among refineries having similar capacities but different process capabilities. In theory, more complex refineries are more adaptable to change, and are therefore potentially less affected by regulation.

TABLE 2-4. AVERAGE ANNUAL OPERABLE AND CAPACITY UTILIZATION RATES[8] (THOUSAND BARRELS PER DAY)

Year/Element	PADD I	PADD II	PADD III	PADD IV	PADD V	Total U.S.
1985						
Operable Capacity	1,538	3,367	7,199	558	3,010	15,671
Utilization Rate	75.4	81.5	77.2	77.6	75.6	77.6
1986						
Operable Capacity	1,456	3,296	7,106	534	3,065	15,459
Utilization Rate	84.3	85.9	83.5	81.0	78.2	82.9
1987						
Operable Capacity	1,450	3,282	7,174	535	3,202	15,642
Utilization Rate	86.6	86.9	82.5	81.7	79.1	83.1
1988						
Operable Capacity	1,464	3,302	7,449	537	3,176	15,927
Utilization Rate	88.5	88.7	81.8	84.7	84.2	84.4
1989						
Operable Capacity	1,452	3,267	7,377	552	3,054	15,701
Utilization Rate	87.2	89.2	84.2	83.4	88.4	86.3
1990						
Operable Capacity	1,505	3,307	7,165	555	3,091	15,624
Utilization Rate	83.5	92.0	85.6	83.4	87.9	87.1

As Table 2-5 indicates, the complexity of a refinery usually increases as its crude capacity increases. (Lube plants are the exception to this rule.) As Table 2-5 indicates, well over 50 percent of the operable capacity (50,000 to 100,000 bbl/d) can be found at refineries with above-average complexity (above 7.0). Likewise, the smaller refineries are apt to be less complex.

2.3 MARKET STRUCTURE

The purpose of this section is to characterize the market structure of the refining industry. Market structure has important implications for the resultant price increases as a result of controls. For example, in a perfectly competitive market, the imposition of control costs will shift the industry supply curve by an amount equal to the per-unit control costs and the price increase will equal the cost increase. A perfectly competitive market is characterized by many sellers, no barriers to entry or exit, homogeneous output, and complete information. In other words, a perfectly competitive market is one in which producers have small degrees of market power and pricing is determined by market forces, rather than by the producers. An indication of the market structure of the petroleum refining industry is provided by an assessment of the number of firms operating refineries, market concentration, vertical integration, and diversification. Each of these factors is discussed separately.

TABLE 2-5. 1990 REFINERY COMPLEXITY DISTRIBUTION: OPERABLE CAPACITY

Complexity Range	Size Range (thousand barrels per day) 0-10	10-30	30-50	50-100	100-175	175+	Total Capacity	% of Total
0-2	113,990[1]	274,290	204,600	80,000	112,800	0	785,680	5.0%
3-5	24,200	134,500	119,900	300,500	0	0	579,100	3.7%
5-7	0	90,105	355,370	415,700	119,600	300,000	1,280,775	8.2%
7-9	6,700	163,100	313,950	1,047,500	872,500	1,765,000	4,168,750	26.6%
9-11	12,500	28,800	258,200	176,100	1,116,500	1,990,300	3,582,400	22.9%
Over 11	28,822	73,800	0	525,900	1,777,100	2,873,300	5,278,922	33.7%
Total Capacity	186,212	764,595	1,252,020	2,545,700	3,998,500	6,928,600	5,675,627	100.0%
Percentage of total	1.2%	4.9%	8.0%	16.2%	25.5%	44.2%	100.0%	

[1] These numbers represent total refinery capacity for each size range and corresponding complexity range.

2.3.1 *Market Concentration*

Market concentration is a measure of the output of the largest firms in the industry, expressed as a percentage of total national output. Market concentration is usually measured for the 4, 8, or 20 largest firms in the industry. A firm's concentration in a market provides some indication of the firm's size distribution. For example, on one extreme, a concentration of 100 percent would indicate monopoly control of the industry by one firm. On the other extreme, concentration of less than 1 percent would indicate the industry was comprised of numerous small firms.

The American Petroleum Institute (API) has compiled a time-series set of market concentration data for the petroleum refining industry.[9] Concentration is measured based on refining capacity, which, in turn, is based on information developed from DOE/EIA data on operable refining capacity per calendar day. Table 2-6 summarizes refinery concentration for selected years in the past decade. Until recently, the top four firms have consistently comprised over 30 percent of the market share, but most market concentration ratios have marginally decreased in recent years.

API also gauges market concentration by using the Herfindahl-Hirschman index, which is defined as the sum of the squared market shares (expressed as a percentage) for all firms in the industry. If a monopolist existed, with market share equal to 100 percent, the upper limit of the index (10,000) would be attained. If an infinite number of small firms existed, the index would equal zero. An industry is considered *unconcentrated* if the Herfindahl-Hirschman index is less than 1,000. Ratings are also developed for moderately concentrated (between 1,000 and 1,800) and highly concentrated (greater than 1,800) industries. As Table 2-6 shows, the petroleum refining industry has always been considered unconcentrated.[9]

TABLE 2-6. CONCENTRATION IN REFINING CAPACITY[9]

Refinery Industry Concentration	Percentage of Market Concentration						
	1980	1985	1986	1987	1988	1989	1990[a]
4-firm	29.0	34.4	33.2	32.2	32.3	31.6	31.4
8-firm	49.0	54.4	53.0	52.0	53.3	50.0	50.1
15-firm	67.0	73.0	71.6	70.5	72.8	68.9	67.7
20-firm	74.5	80.3	79.0	77.2	80.4	77.9	76.7
30-firm	82.3	88.8	87.9	86.3	89.0	88.2	87.0
Herfindahl-Hirschman Index	381.5	494.6	471.2	448.2	465.4	431.9	[b]

NOTES: [a]Calculated independently.[2]
[b]Not available.

2.3.2 *Industry Integration and Diversification*

Vertical integration exists when the same firm supplies input for several stages of the production and marketing process. Firms that operate petroleum refineries are vertically integrated because they are responsible both for exploration and production of crude oil (which supplies the input for refineries) and for marketing the finished petroleum products after refining occurs. To assess the level of vertical integration in the industry, firms are generically classified as *major* or *independent*. Generally speaking, major energy producers are defined as firms that are vertically integrated.

A definition of major energy producers, *majors*, was originally developed by DOE/EIA in 1976.[10] Selection criteria for the list of publicly owned major firms included those which had either at least 1 percent of the production or the reserves of oil, gas, coal, or uranium, or 1 percent of the refining capacity or petroleum product sales. DOE's current list contains 20 major energy companies. Table 2-7 lists the 20 firms (with refining capacity) that are currently considered to be major energy producers. The table also shows the percentage of refining capacity operated by each of the firms. The crude capacity of the major, vertically integrated firms represents almost 70 percent of nationwide production.

For the major oil companies, horizontal integration exists because these firms operate several refineries which are often distributed around the nation. Seventy-three of the 109 firms in the industry operate only one refinery each. These are the smaller independent firms. The major firms operate several refineries, and the largest, Chevron, operates 13. Fourteen firms operate four or more refineries each.

Diversification exists when firms produce a wide array of unrelated products. In the short run, diversification may indirectly benefit firms that engage in petroleum refining, since the costs of control in petroleum refining may be dispersed over other unaffected businesses operated by the firm. Over the long term, however, firms will not subsidize petroleum product production with profit from other operations, but will shut down unprofitable operations instead.

TABLE 2-7. MAJOR ENERGY FIRMS WITH REFINING CAPACITY[11 12]

Company	Barrels per Calendar Day (Operating)	Percentage of National Total
Amerada Hess	30,000	0.2%
Amoco Oil	974,000	6.5%
Ashland Oil	346,500	2.3%
Atlantic Richfield	415,740	2.8%
BP Oil	733,500	4.9%
Chevron U.S.A.	1,495,100	10.0%
Coastal Corp.	248,700	1.7%
E.I. Du Pont	406,500	2.7%
Exxon	1,147,000	7.7%
Fina Oil & Chemical	165,000	1.1%
Kerr-McGee Corp.	156,800	1.0%
Mobil Oil	838,000	5.6%
Pacific Resources	93,500	0.6%
Phillips 66	305,000	2.0%
Shell Oil	1,082,900	7.2%
Sun	515,000	3.4%
Texaco	320,000	2.1%
Total Petroleum	197,600	1.3%
U.S. Steel	604,500	4.0%
Unocal	226,000	1.5%
Total	10,301,340	68.9%

2.3.3 *Financial Profile*

This subsection examines the financial performance of a sample of the petroleum refining industry's major firms. In order to evaluate the financial condition of the refinery operations of firms, annual reports to stockholders were used as a source of data for a small sample of firms. While this sample is too small and diverse to be considered representative of the aggregate industry, the data presented are more recent and more refinery-specific than API's data. The compilation of financial data for this small sample is presented at the end of the chapter.

The sample of annual report data presents refinery-specific data in order to provide a preliminary assessment of the condition of the refinery segments of firms in the industry. The firms included in this sample are listed in Table 2-8. This 12-firm sample as a whole operated 59 refineries in 1991, and represented 45.3 percent of the industry's total refining capacity. Refining capacity in the sample ranges from 165,000 bbl/d to 2,139,000 bbl/d. Refinery-specific data obtained from annual reports are presented in Table 2-9. Over the 5-year period from 1987 to 1991, operating income per dollar of revenue increased from 1 percent to 4 percent. Capital expenditures increased steadily, while refined product sales continued a period of decline. The consolidation taking place in the refining industry is reflected in the decreasing crude oil capacity and refinery runs shown in the table.

According to DOE, refined product margins are a good indicator of overall refinery financial performance.[13] The difference between refined product costs and refined product revenues is the refined product margin. During the 1980s, refined product margins were affected by a shift in product slates to gasoline and jet fuels, the decrease in crude oil prices, fluctuations in demand, and an increase in refinery utilization rates.[14] Refined product margins for the years 1977 through 1988 are shown in Table 2-10. In constant 1982 dollars, the refined product margin fluctuated over this time frame, decreasing between 1985 and 1987 and then increasing significantly in 1988. The fluctuations in the refined product margins reflect the volatility of the market and the degree to which refineries' revenues are often subject to significant change over short time periods. In the early half of 1990, the margin between overall U.S. refined product prices and crude oil import costs rose to record levels, given falling crude oil prices and stable gasoline prices.[15] After the invasion of Kuwait, U.S. refined product prices did not keep pace with crude oil prices for the remainder of the year. This negatively impacted refinery revenues for 1991.

TABLE 2-8. FIRMS IN SAMPLE FOR REFINERY-SPECIFIC FINANCIAL DATA

Amoco Oil Inc.
Ashland Petroleum
Chevron U.S.A.
Coastal Corporation
Diamond Shamrock
Kerr-McGee Corporation
Mobil Oil Corp.
Murphy Oil
Phillips 66 Co.
Shell Oil Co.
Sun Co. Inc.
Texaco Refining and Marketing

TABLE 2-9. OPERATING STATISTICS OF REFINERY SAMPLE 1987-1991

	(millions of 1990 $)				
	1991	1990	1989	1988	1987
Refining Operations Segment					
Production Revenues	142,794.8	155,221.9	134,624.9	135,752.0	140,422.1
Operating Income	6,346.9	10,026.2	8,669.5	10,096.7	1,516.4
Income per Dollar of Revenue (%)	4.4%	6.5%	6.4%	7.4%	1.1%
Assets	97,774.6	100,073.7	96,833.1	67,799.4	72,308.3
Additions to Property, Plant, & Equipment	7,703.4	6,463.7	5,991.0	6,120.9	4,885.7
Capital Expenditures as a Percentage of Revenue	5.4%	4.2%	4.5%	4.5%	3.5%
Depreciation, Depletion, and Amortization	3,813.2	3,777.9	3,715.0	4,351.1	4,999.3
Crude Oil Capacity (thousand bbl/d)	9,567.3	9,941.2	10,417.4	11,329.8	11,918.2
Refinery Runs (thousand bbl/d)	8,545.4	8,885.879	9,277.5	10,093.7	10,285.0
Utilization Rate	89.3%	89.4%	89.1%	89.1%	86.3%
Refined Product Sales (thousand bbl/d)	11,618.8	11,926.2	12,493.2	13,427.1	13,374.5
Operating Income per Thousand Barrels Sold	$0.53	$0.84	$0.73	$0.83	$0.13
Average U.S. Product Price per Gallon	$0.61	$0.72	$0.62	$0.61	$0.62
Available Lines of Credit (as of 12/31/91)	12,919.2				
Average Credit per Firm	1,076.6				

TABLE 2-10. REFINED PRODUCT MARGINS[14]
1977-1988

Year	Refined Product Margin	
	Current Dollars	Constant Dollars
1977	0.64	0.95
1978	0.75	1.04
1979	0.85	1.08
1980	1.00	1.17
1981	0.83	0.88
1982	0.85	0.85
1983	0.71	0.68
1984	0.01	0.01
1985	1.09	0.98
1986	0.67	0.59
1987	0.15	0.13
1988	1.78	1.46

Firms have three sources of funding for the capital available for purchasing emission control equipment to comply with the NESHAP. These sources include (1) internal funds, (2) borrowed funds, and (3) stock issues. Typically, firms seek a balance between the use of debt and stock issues for financing investments. Debt-to-equity ratios reflect a measure of the extent to which the firm has balanced the tax advantages of borrowing with the financial safety of stockholder financing. Based on information obtained in the annual reports of the 12 companies in the refinery sample, firms anticipate that internally generated funds will fund most of their capital expenditures. Other firms recognize the need to also draw on available credit lines and commercial paper borrowing. As indicated in Table 2-9, the total amount of credit available to these 12 firms as of December 31, 1991 was $13,462.9 million, or an average of $1,121.9 million per firm. DOE has published annual capital expenditures by domestic refiners.[16] This trend is presented in Table 2-11. Overall, capital expenditures have doubled since 1977, although spending peaked in 1982 and has since been in a period of decline.

Planned uses of investment funds by the 12 firms in the financial sample over the next few years include construction of diesel desulfurization units, expansion of existing units, and construction of units to manufacture methyl tertiary butyl ether (MTBE) and oxygenated fuels. In a 1991 study, Cambridge Energy Research Associates (CERA) surveyed refiners and oxygenate producers to evaluate the ability of the refining industry to meet CAA provisions.[17] Among the firms in the CERA survey, the majors and some large independents plan to fund their investments primarily or entirely from internally generated cash flows, while most of the small refineries surveyed are planning on resorting to the debt market for funds.

TABLE 2-11. CAPITAL EXPENDITURES BY DOMESTIC PETROLEUM REFINERS[16] 1977-1988

Year	Current Dollars	1982 Constant Dollars
1977	1,029	1,529
1978	1,430	1,981
1979	2,221	2,826
1980	2,547	2,972
1981	4,041	4,299
1982	4,973	4,973
1983	3,695	3,556
1984	3,681	3,418
1985	2,380	2,148
1986	1,752	1,538
1987	1,920	1,631
1988	3,675	3,020

2.4 MARKET SUPPLY CHARACTERISTICS

This section analyzes the supply side of the petroleum refining industry. Historical production data are presented, and the factors which affect production are identified. The role of foreign competition in this industry is also assessed.

2.4.1 *Past and Present Production*

The domestic supply of refined petroleum products and its components for the past decade are shown in Table 2-12. A significant increase in domestic demand in 1984 stimulated domestic refinery production. Refiners have increased production almost every year since 1984. Historically, motor gasoline has been the product that is supplied in the greatest quantities to meet increased demand. Most of the other petroleum products show a net increase in supply over the past few years. The lack of change in the yield for most refined petroleum products indicates a relatively stable supply slate, but significant regulatory costs could force some reshuffling of product yield.

Refinery production of motor gasoline has increased each year, with the exception of periods of economic recession. Production remained relatively steady from 1988 to 1992. Distillate fuel oil output peaked at 3.3 million barrels per day in 1977, then fell through 1983. Output has increased slightly almost every year since, reaching 3 million barrels per day in 1992. Jet fuel production grew during the 1970s and 1980s, and almost doubled by 1990 before declining to 1.4 million barrels per day in 1992. Residual fuel oil production generally declined from 1980 through 1985, and was 1 million barrels per day in 1992, compared with 0.7 million barrels per day in 1970.

2.4.2 *Supply Determinants*

The most important short-run production decision for an oil refinery is to decide how much crude oil to allocate for the production of each of the refinery's products. The production decision depends on the profit each of the oil products can generate for the firm. Profits, in turn, depend on the productivity of the oil refinery -- its ability to obtain each

TABLE 2-12. U.S. PETROLEUM PRODUCTS SUPPLIED, 1980-1992[18]
(MILLION BARRELS PER DAY)

Year	Motor Gas	Jet Fuel	Distillate Fuel Oil	Residual Fuel Oil	Liquified Petroleum Gases	Other Products	Total
1980	6.58	1.07	2.87	2.51	1.47	2.57	17.07
1981	6.59	1.01	2.83	2.09	1.47	2.08	16.07
1982	6.54	1.01	2.67	1.72	1.50	1.86	15.30
1983	6.62	1.05	2.69	1.42	1.51	1.94	15.23
1984	6.69	1.18	2.84	1.37	1.57	2.07	15.72
1985	6.83	1.22	2.87	1.20	1.60	2.01	15.73
1986	7.03	1.31	2.91	1.42	1.51	2.09	16.27
1987	7.21	1.38	2.98	1.26	1.61	2.22	16.66
1988	7.34	1.45	3.12	1.38	1.66	2.33	17.28
1989	7.33	1.49	3.16	1.37	1.67	2.31	17.33
1990	7.24	1.52	3.02	1.23	1.56	2.42	16.99
1991	7.19	1.47	2.90	1.16	1.69	2.27	16.68
1992	7.27	1.45	2.98	1.09	1.76	2.47	17.02

NOTES: Other products include kerosene, petrochemical feedstocks, wax, lubricants, petroleum coke, asphalt, road oil and miscellaneous.

oil product as effectively as possible from a barrel of crude oil. The quantity of crude oil a refinery will refine depends on the capacity of the refinery and the cost of production. The marginal costs of production of each product will determine any future changes in production. Crude oil is the primary material input to the refining process; as a result, the production of refined products is vulnerable to fluctuations in the world crude oil market.

In the long run, production decisions are based on the cost of capacity expansion relative to existing and anticipated future price levels. A refinery uses different processing units to turn crude oil into finished products, so when a particular processing unit reaches capacity, output can be increased only by substituting a more expensive process. Firms will typically utilize sufficient crude oil to fill the appropriate processing unit until the price increases substantially. At this point, the firm would calculate whether the increased price warrants using an additional, more expensive processing unit.[19]

2.4.3 *Exports of Petroleum Products*

Some measure of the extent of foreign competition can be obtained by comparing exports with domestic production. Table 2-13 presents export levels and domestic refinery output for the past decade. Exports as a percentage of domestic refinery output steadily increased from 1984 to 1991, and then fell slightly to 5.6 percent in 1992. Distillate oil, residual fuel oil, motor gasoline, and petroleum coke are exported in the highest volumes. The combined export volumes of these products represent 75 percent of domestic refinery output shipped overseas.

2.5 MARKET DEMAND CHARACTERISTICS

The purpose of this section of the profile is to characterize the demand side of the petroleum refining industry, to identify the end-use markets of each petroleum product in this analysis, evaluate the extent to which price determines demand levels, and define the role that imports play in satisfying domestic demand.

TABLE 2-13. EXPORTS AND DOMESTIC REFINERY OUTPUT [20]
(MILLION BARRELS PER DAY)

Year	Exports	Domestic Refinery Output	Exports As a Percentage of Domestic Output
1981	0.37	13.99	2.6%
1982	0.58	13.39	4.3%
1983	0.58	13.14	4.4%
1984	0.54	13.68	4.0%
1985	0.58	13.75	4.2%
1986	0.63	14.52	4.3%
1987	0.61	14.63	4.2%
1988	0.66	15.02	4.4%
1989	0.72	15.17	4.7%
1990	0.75	15.26	4.9%
1991	0.88	15.20	5.8%
1992	0.86	15.30	5.6%

2.5.1 *End-Use Markets for Refined Products*

In this analysis, the end-use sectors that contribute to demand for refined petroleum products are classified in the following four economic sectors: (1) residential and commercial, (2) industrial, (3) transportation, and (4) electric utilities. Figure 2-2 shows a more detailed breakdown of the 93.2 percent petroleum product demand attributed to fuel users for the years 1970 through 1990. Petroleum products used as transportation fuel include motor gasoline, distillate (diesel) fuel, and jet fuel, and accounted for an estimated 64 percent of all U.S. petroleum demand in 1990. Since mobile source emissions will be regulated by Title II regulations, this output from petroleum refineries will be most affected by the CAA. The industrial sector constitutes the second highest percentage of demand for petroleum products, followed by household and electric utility demands.

Petroleum is used most widely in the transportation sector. In the household and commercial sector, light heating oil and propane are used for heating and energy uses, and compete with natural gas and electricity. Petroleum fuels in the industrial sector compete with natural gas, coal, and electricity. In the industrial sector, residual and distillate heating oils are used for boiler and power fuel. In the electric utility sector, petroleum products satisfy demands for heavy residual fuel oil and in smaller amounts, bulk light distillate fuel oil.[21]

In terms of refined products, the motor gasoline and jet fuel markets are associated with the transportation sector. The markets for distillate fuel oil are associated with the transportation sector (diesel-powered trucks), household (space heating), industrial (fuel for commercial burner installations), and electric utilities (power generation). The sectors that are sources of demand for residual fuel oil include the commercial and industrial sectors (heating), utilities (electricity generation), and the transportation sector (fuel for ships). Nonutility use of residual fuel has been decreasing due to interfuel substitution in the commercial and industrial sectors.

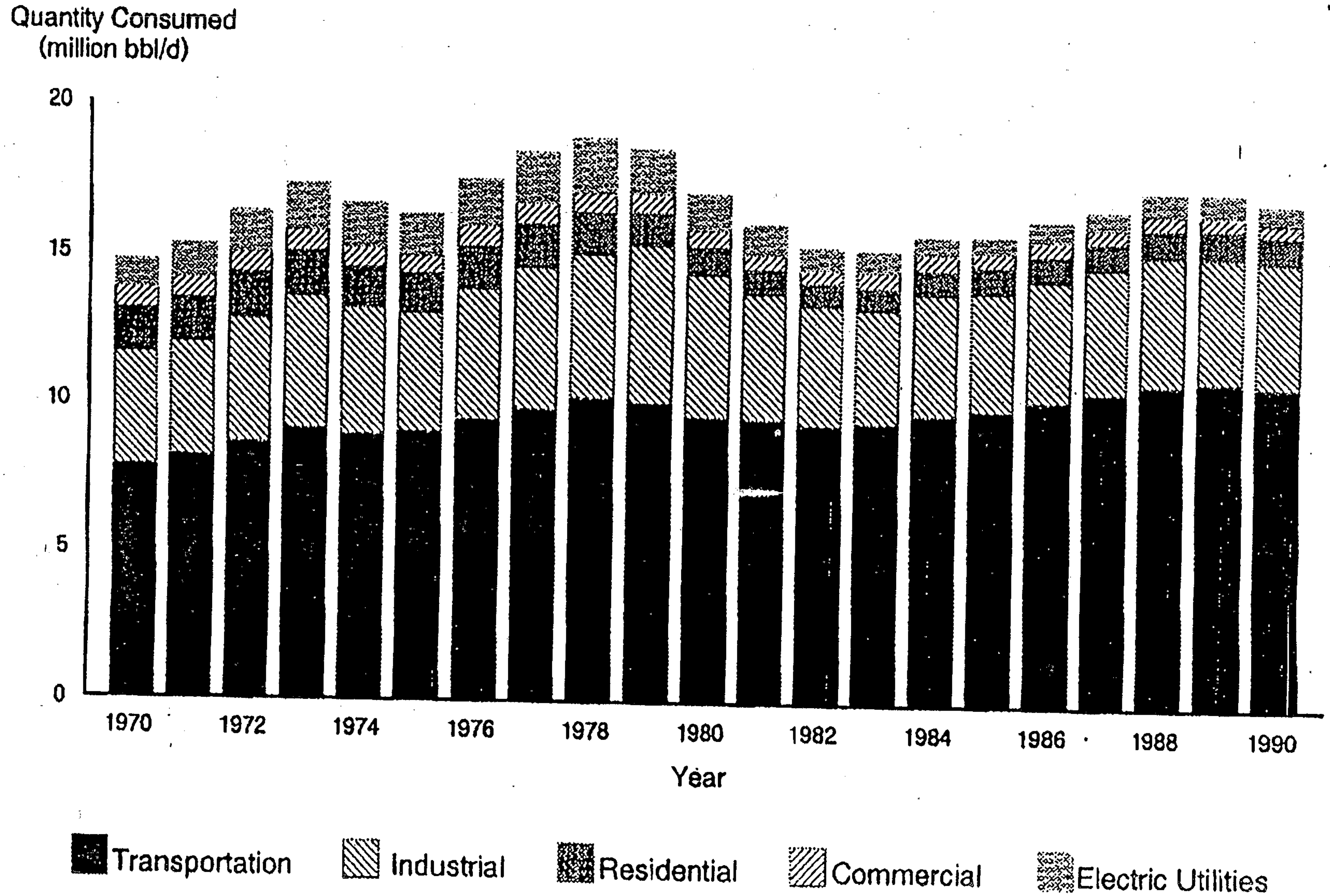
Because LPG's cover a broad range of gases, demand levels are attributable to various end users.

2.5.2 *Demand Determinants*

The demand for refined petroleum products is primarily determined by price level, the price of available substitutes, and economic growth trends. The degree to which price level influences the quantity of petroleum products demanded is referred to as the *price elasticity of demand,* which is explored later in this report. Prices of refined petroleum products affect the willingness of consumers to choose petroleum over other fuels, and may ultimately cause a change in consumer behavior. In the transportation sector, the effect of high gasoline prices on fuel use could reduce discretionary driving in the short term and, in the long term, result in the production of more fuel-efficient vehicles.

In the market for jet fuel, demand is primarily determined by a combination of price concerns and the overall health of the airline industry. In the residential sector, demand for home heating (distillate) is determined in part by price level, and also by temperature levels and climate. Temperature in different areas of the country may determine the degree to which buildings and houses are insulated. Temperature and insulation are exogenous factors which will determine heating needs regardless of the price level of fuel. High prices for home heating oil provide incentive for individuals to conserve by adjusting thermostats, improving insulation, and by using energy-efficient appliances. In some cases, higher oil prices also provide incentive for switching to natural gas or electric heating. (Adjusting thermostats is short-run response, which changing to more energy-efficient appliances or fuels are long-run responses.)

FIGURE 2-2. PETROLEUM CONSUMPTION BY END-USE SECTOR, 1970-1990[1]



In the industrial sector, fuel oil competes with natural gas and coal for the boiler-feed market. High prices relative to other fuels tend to encourage fuel-switching, especially at electric utilities and in industrial plants having dual-fired boilers. Generally speaking, in choosing a boiler for a new plant, management must choose between the higher capital/lower operating costs of a coal unit or the lower capital/higher operating costs of a gas-oil unit. In the utility sector, most new boilers in the early 1980s were coal-fired due to the impact of legislative action, favorable economic conditions, and long-term assured supplies of coal.[22] Today, because the CAA will require utilities to scrub or use a low-sulfur fuel, oil will eventually become more competitive with coal as a boiler fuel, although a significant increase in oil-fired capacity is not expected until 2010.[23]

Demand levels in each of the end-use sectors are also affected, in part, by the economic environment. Periods of economic growth and periods of increased demand for petroleum products typically occur simultaneously. For example, in an expanding economy, more fuel is needed to transport new products, to operate new production capacity, and to heat new homes. Conversely, in periods of low economic growth, demand for petroleum products decreases.

2.5.3 *Past and Present Consumption*

Total consumption of all types of petroleum products has fluctuated over the past 20 years, reflecting the volatility of this market. The consumption level has been sporadic and has shown an overall decline in recent years. Demand for individual petroleum product types has also fluctuated over this period, as shown in Table 2-14. Of all the petroleum products, demand is the greatest for motor gasoline followed by distillate fuel oil. Over the 23-year period from 1970 to 1992, the demand for residual fuel oil has decreased by 50 percent, showing the greatest percentage of change over time of any of the petroleum products; it has also been the only fuel to show a decline in use. This decrease in residual fuel demand reflects a move in the industry from heavier fuels toward lighter, more refined versions. This trend is expected to continue into the future with efforts to further control air emissions.

All other types of fuel show increases in use, with the most growth occurring in the market for jet fuel. Substantial gains in airplane fuel efficiency in the last two decades, which have resulted from improved aerodynamic design and a shift toward higher seating capacities, have been exceeded by even faster growth in passenger miles traveled.[25] The other categories show an average growth rate of approximately 23 percent over this time period. All major petroleum products registered lower demand in 1991 than in 1990, except LPGs. This was the first time since 1980 that demand for all major petroleum products fell simultaneously in the same year. In this case, decreased demand was brought on by warmer winter temperatures, an economic slowdown, and higher prices resulting from the Persian Gulf War.[26]

Motor gasoline demand increased from a 1970 low to a high of 7.4 million barrels per day in 1978. The increase reflected a 31 percent growth in the number of automobiles in use and a 25 percent growth in vehicle miles traveled.[21] From 1985 to 1992, motor gasoline use accounted for about 42 percent of all petroleum products consumed.

Changes in demand for distillate fuel oil were similar to motor gasoline in that consumption reached its lowest and highest levels in 1970 and 1978, respectively. Between 1985 and 1992, consumption was relatively stable and accounted for about 18 percent of total U.S. petroleum consumption. Residual fuel oil demand, in response to lower-priced natural gas and other factors, fell 64 percent, from a high in 1977 of 3.1 million barrels per day to 1.1 million barrels per day in 1992.

TABLE 2-14. PETROLEUM PRODUCTS SUPPLIED* TO THE U.S. MARKET BY TYPE[24]
1970-1992
(MILLION BARRELS PER DAY)

Year	Motor Gasoline	Jet Fuel	Distillate Fuel Oil	Residual Fuel Oil	LPGs	Other Products	Total Demand
1970	5.78	0.97	2.54	2.20	1.22	1.98	14.70
1971	6.01	1.01	2.66	2.30	1.25	1.98	15.21
1972	6.38	1.05	2.91	2.53	1.42	2.08	16.37
1973	6.67	1.06	3.09	2.82	1.45	2.21	17.31
1974	6.54	0.99	2.95	2.64	1.41	2.13	16.65
1975	6.67	1.00	2.85	2.46	1.33	2.00	16.32
1976	6.98	0.99	3.13	2.80	1.40	2.16	17.46
1977	7.18	1.04	3.35	3.07	1.42	2.37	18.43
1978	7.41	1.06	3.43	3.02	1.41	2.51	18.85
1979	7.03	1.08	3.31	2.83	1.59	2.67	18.51
1980	6.58	1.07	2.87	2.51	1.47	2.57	17.06
1981	6.59	1.01	2.83	2.09	1.47	2.08	16.06
1982	6.54	1.01	2.67	1.72	1.50	1.86	15.30
1983	6.62	1.05	2.69	1.42	1.51	1.94	15.23
1984	6.69	1.18	2.84	1.37	1.57	2.07	15.73
1985	6.83	1.22	2.87	1.20	1.60	2.01	15.73
1986	7.03	1.31	2.91	1.42	1.51	2.09	16.28
1987	7.21	1.38	2.98	1.26	1.61	2.22	16.67
1988	7.34	1.45	3.12	1.38	1.66	2.33	17.28
1989	7.33	1.49	3.16	1.37	1.67	2.31	17.33
1990	7.24	1.52	3.02	1.23	1.56	2.42	16.99
1991	7.16	1.45	2.95	1.13	1.60	2.29	16.58
1992	7.16	1.48	3.13	1.10	1.61	2.44	16.92

NOTES: *DOE uses the term "product supply" as an approximation of consumption. It is calculated by adding refinery production, natural gas liquids production, supply of other liquids, imports, and stock withdrawals, and subtracting stock additions, refinery inputs, and exports.

Between the period 1970 to 1990, expanding air travel spurred a 57 percent growth in jet fuel demand. Demand increased from a 1970 low of 1.0 million barrels per day to 1.5 million barrels per day in 1990.

The variation in U.S. petroleum product demand has been linked to changes in the prices of petroleum products relative to one another, and relative to other energy sources. Dramatic petroleum price increases and eventual steep drops were in response to wars, political upheaval in crude oil producing areas, and supply disruptions during the past two decades.

2.5.4 *Imports of Refined Petroleum Products*

Table 2-15 presents import levels and domestic consumption for the past decade. Imports as a percentage of domestic consumption have fluctuated over this time period, although in 1992 levels were 10.6 percent, or roughly the same level as in 1981. Table 2-16 compares exports to imports over the past decade. The import to export ratio has decreased since 1981, due primarily to steady increases in exports.

2.5.5 *Pricing*

As Table 2-17 indicates, prices for petroleum products have shown volatility over the time period from 1978 through 1992. This volatility is mainly attributable to the fluctuations in the global market for crude oil and the inelastic demand for petroleum products. Inelastic demand allows refiners to pass crude oil price increases on to consumers. Because petroleum products are essentially commodity products, produced to standard specifications with little product differentiation and produced by a large number of refiners, little ability for pricing flexibility exists in this industry.

TABLE 2-15. IMPORTS AND DOMESTIC CONSUMPTION OF REFINED PETROLEUM PRODUCTS[25] (MILLION BARRELS PER DAY)

Year	Imports	Domestic Petroleum Product Consumption	Imports As a Percentage of Domestic Consumption
1981	1.60	16.06	10.0%
1982	1.63	15.30	10.6%
1983	1.72	15.23	11.3%
1984	2.01	15.73	12.8%
1985	1.87	15.73	11.9%
1986	2.05	16.28	12.6%
1987	2.00	16.67	12.0%
1988	2.30	17.28	13.3%
1989	2.22	17.33	12.8%
1990	2.12	17.33	12.8%
1991	1.85	16.70	11.1%
1992	1.81	17.00	10.6%

TABLE 2-16. U.S. PETROLEUM PRODUCT IMPORTS AND EXPORTS[25]
(THOUSAND BARRELS PER DAY)

Year	Imports	Exports	Net Imports	Import/ Export Ratio
1981	1,599	367	1,232	4.4
1982	1,625	579	1,046	2.8
1983	1,722	575	1,147	3.0
1984	2,011	541	1,470	3.7
1985	1,866	577	1,289	3.2
1986	2,045	631	1,414	3.2
1987	2,004	613	1,391	3.3
1988	2,295	661	1,634	3.5
1989	2,217	717	1,500	3.1
1990	2,123	748	1,375	2.8
1991	1,845	880	965	2.1
1992	1,805	860	945	2.1

TABLE 2-17. PETROLEUM PRODUCT PRICE LEVELS, 1978-1992[27]

Year	Refiner Prices of Petroleum Products to End Users (Cents Per Gallon Excluding Taxes)				
	Motor Gasoline	Jet Fuel	Distillate Fuel Oil	Residual Fuel Oil	LPGs
1978	48.4	38.7	37.2	29.8	33.5
1979	71.3	54.7	53.4	43.6	35.7
1980	103.5	86.8	77.3	60.7	48.2
1981	114.7	102.4	93.1	75.6	56.5
1982	106.0	96.3	89.9	67.6	59.2
1983	95.4	87.8	85.6	65.1	70.9
1984	90.7	84.2	85.3	68.7	73.7
1985	91.2	79.6	81.7	61.0	71.7
1986	62.4	52.9	53.3	34.3	74.5
1987	66.9	54.3	55.8	42.3	70.1
1988	67.3	51.3	51.1	33.4	71.4
1989	75.6	59.2	58.6	38.5	61.5
1990	88.3	76.7	72.7	44.4	74.5
1991	79.7	65.2	65.7	34.0	73.0
1992	78.4	61.0	62.7	33.8	66.2

2.6 MARKET OUTLOOK

This section presents quantitative production, demand, and price projections available from the literature. Projections are important to the EIA since future market conditions contribute to the potential impacts of the NESHAP which are assessed for the fifth year after regulation.

2.6.1 *Supply Outlook (Production and Capacity)*

The refining industry was operating near maximum capacity in 1991, with an average annual utilization rate of approximately 92 percent.[28] This is an increase from levels of previous years, which were shown earlier in Table 2-4. In the market for motor gasoline, for example, production capacity is nearly at full capacity. As a result, any increases in demand will have to be met by imported products. This will result in an increase in worldwide competition for gasoline. East Coast refiners, accounting for more than 90 percent of all unleaded gas imports to the United States, will be most affected by this increased competition.[29] DOC predicts that, although U.S. refinery output will remain relatively unchanged, net imports of refined petroleum products are expected to increase by 15 percent.[28] DOE predicts net petroleum imports will rise to at least 10 million bbl/d in 2010, and perhaps as high as 15 million bbl/d from the 1990 level of 7 million bbl/d as domestic oil production is expected to decline. Imports are expected to supply between 53 and 69 percent of U.S. petroleum consumption by 2010, compared with 42 percent in 1990. Refined products will account for much of this increase because most of the expansion in the world's refinery system is expected to take place outside the United States.[30]

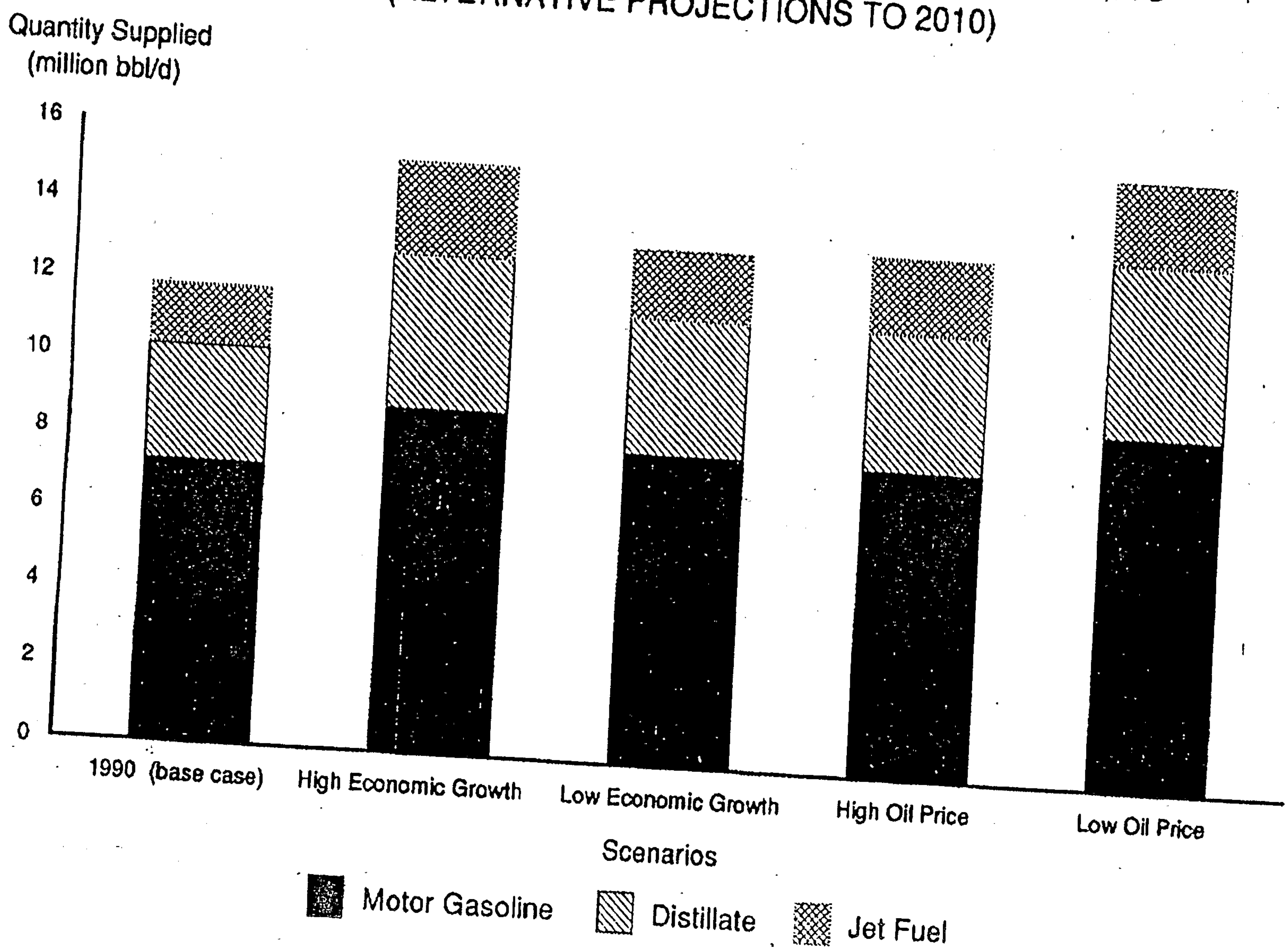
Over the next 5 years, the petroleum industry as a whole plans to increase crude oil distillation capacity by an additional 2 percent, or 272,000 bbl/d, of which 44 percent would be produced by new facilities.[29] (The other 56 percent includes reactivations and expansions.) The level of added demand will determine if this added capacity is sufficient to satisfy the market without driving up prices.

Companies that operate more complex refineries (often the largest refineries) will presumably be in a more favorable position to make the necessary capital investments for the transition to cleaner fuels. Such refineries will most likely be those large enough to benefit from the economies of scale, and with basic downstream configurations to facilitate compliance with the new regulations. A financial analysis of major petroleum refineries in the 1980s conducted by DOE concluded that vertically integrated firms benefitted from integration in a period characterized by increased regulatory activity and price instability.[31] The report found that the larger vertically integrated companies could offset a loss in one subsidiary or business operation with gains from another line of business. (It is important to note, however, that in the long run, both large and small firms would close refineries which operate at a loss over time.)

By contrast, smaller, independent, and less complex refineries will face higher marginal compliance costs, and may not find it economical to spend the required environmental capital. Generally not as flexible as the larger, integrated companies, these firms operate at greater risk from the effects of market instability. As a result, an industry which has seen a high level of consolidation in past years will be likely to see more concentration.[32]

Supply Prediction. Given each of the considerations discussed thus far, DOE has projected the future level of supply in the refining industry. These projections, shown in Figure 2-3, are based on a DOE prediction that the United States will become increasingly more dependent on foreign refined products and crude oil supplies, while domestic refiners will continue to invest in downstream additions to meet environmental specifications.[33] (It should be noted here that DOE makes the assumption that products imported from foreign refineries will meet U.S. specifications.)

FIGURE 2-3. PROJECTED SUPPLY OF PETROLEUM PRODUCTS [1]
(ALTERNATIVE PROJECTIONS TO 2010)



DOE's projections are based on the following four different scenarios and assumptions:

	Assumptions	
Scenario	2010 Oil Price (1990 $)	Annual Economic Growth Rate
High Economic Growth	$33.40	2.7%
Low Economic Growth	$33.40	1.8%
High Oil Price	$40.20	2.2%
Low Oil Price	$23.00	2.2%

As shown in Figure 2-3, projections are the lowest in cases where economic growth is low or when the price of oil is high.

Overall, the effect of the CAA on individual refineries is dependent upon production capacity, economies of scale, degree of self-sufficiency, capital cost, and ability of refiners to "pass through" higher costs to consumers. Predictions of the effect on the aggregate industry are difficult at this time because of the uncertainty of the ability of some refineries to develop plans for compliance pending resolution of key issues affecting their operations. A recent Harvard University study, however, predicted that the promulgation of environmental regulations was likely to result in the early phase out of older, less sophisticated facilities, combined with the upgrade and expansion of more efficient, complex refineries at a faster rate.[34]

2.6.2 *Demand Outlook*

DOC projects the demand for all petroleum products to rise slowly and steadily over the next 5 years, with domestic demand for refined products increasing by 2.1 percent in 1992, assuming an economic recovery and a return to "normal" weather. DOC's longer term demand prediction is for a steady growth rate of 1 percent through 1996.[35, 36] By petroleum product, the 5-year projected growth rates are as follows:

- Motor gasoline: 0-1 percent
- Jet fuel: 2.1 percent
- Distillate fuel: 6.1 percent
- Residual fuel: 0-1 percent
- Other products: 3.6 percent

Given that two-thirds of petroleum product demand is attributable to the transportation sector, projected demand growth for motor gasoline will have the greatest effect on refiners. Industrial demand for distillate fuel reflects the strongest projected growth. According to DOE projections, the consumption of diesel fuel in the transportation sector is expected to grow by over 40 percent between 1990 and 2010.[37] Residential and commercial sectors are expected to show a decrease in demand for petroleum products.

DOE has also projected future levels of demand as outlined in Table 2-18. In comparison with DOE's supply projections in the previous section, these demand projections fall between the high and low economic growth supply projections, and between the high and low oil price projections. Motor gasoline will remain the leading end use of petroleum products throughout DOE's chosen time frame, dropping off during 1990 and 1995, and rising again to higher levels by 2010. DOE predicts the demand for residual oil to rise, level off, and then begin to decline in 2010. Jet fuel and distillate fuel are both projected to rise steadily through 2010.

2.6.3 *Price Outlook*

Given that the demand for motor gasoline is price inelastic as discussed in Section 2.5.5, the added capital investment that refineries will be required to undertake in the production of reformulated gasolines is likely to be passed on to consumers in the form of a price increase. DOC has estimated this price increase to be a 5 to 10 cent-per-gallon rise in the price of motor gasoline.[39] In a recent study undertaken by the National Petroleum Council, the impacts of air quality regulations on petroleum refineries were assessed. One of the conclusions of the study was that the costs of controlling air emissions are likely to be passed along to consumers as increases in the final price of refined products. (The study offered no quantitative projections, however.)[40]

DOE has projected the domestic prices of petroleum products for 2010, as outlined in Table 2-19. DOE projects the average price for all petroleum prices to increase at a rate in the range of 0.4 percent to 2.1 percent annually. These price increases are due to projected increases in both domestic demand and crude oil prices. DOE also accounted for higher refining and distribution expenses in making these projections. The real price of motor gasoline is projected to rise from $1.17 per gallon in 1990 to between $1.30 and $1.74 in 2010, depending on the level of world crude oil prices. On-highway diesel fuel prices are projected to increase to between $1.27 and $1.69 per gallon, primarily because of the added refinery costs of desulfurization. The average retail price of residual fuel oil, the least expensive petroleum product, is projected to be within the range of $25.52 to $40.79 per barrel in 2010.

If refineries are able to accommodate projected increases in demand, the price level will remain fairly stable. However, because the price level in this industry is contingent upon so many factors independent of the industry, any price predictions necessarily have their limitations. In the long run, therefore, price forecasts will need to be modified with the occurrence of any world events which will affect the supply of crude oil to the refineries and therefore to the supply of refined petroleum products. Refineries may also be faced with more environmental legislation, escalating their pollution abatement costs. An increase in regulatory costs would tend to increase the price of refined petroleum products, all other factors held constant.

TABLE 2-18. PROJECTED CONSUMPTION OF PETROLEUM PRODUCTS[38] (MILLION BARRELS PER DAY)*

Product	1989	1990	1995	2000	2005	2010
Motor Gasoline	7.33	7.21	7.22	7.50	7.83	8.08
Distillate Fuel	3.16	3.02	3.25	3.49	3.70	3.87
Residual Fuel	1.37	1.23	1.29	1.53	1.53	1.47
Jet Fuel	1.49	1.49	1.61	1.82	2.01	2.22
Liquefied Petroleum Gases	1.67	1.55	1.70	1.83	1.96	2.08
Total Products Supplied	15.02	14.50	15.07	16.17	17.03	17.72

NOTES: *DOE approximates consumption by adding refinery production, natural gas liquids production, supply of other liquids, imports, and stock withdrawals, and subtracting stock additions, refinery inputs, and exports.

TABLE 2-19. PROJECTED PRICES OF PETROLEUM PRICES[41] (1990 DOLLARS PER GALLON)[a]

Product	1990	Alternative Projections for 2010[b]: High Economic Growth	Low Economic Growth	High Price	Low Price
Motor Gasoline	1.17	1.58	1.57	1.74	1.30
Diesel Fuel	1.18	1.55	1.52	1.69	1.27
No. 2 Heating Oil	0.97	1.23	1.15	1.32	0.96
Residual Fuel	0.46	0.86	0.82	0.97	0.61
Jet Fuel	0.76	0.99	0.95	1.13	0.71

NOTES: [a]Projected prices include estimated State and federal taxes.
[b]Assumptions used for each of the four scenarios are as follows:

	Crude Oil Price/Bbl (1990 $)	Average Annual Economic Growth Rate	Annual Energy Demand Growth Rate	Annual Electricity Demand Growth Rate
High Economic Growth Case:	$33	2.7%	1.4%	2.2%
Low Economic Growth Case:	$33	1.8%	0.9%	1.8%
High Oil Price Case:	$40	2.2%	1.0%	1.9%
Low Oil Price Case:	$23	2.2%	1.3%	2.0%

REFERENCES

1. U.S. Department of Energy. Petroleum Supply Annual, 1992. Volume 1. DOE/EIA-0340(90)/1. Energy Information Administration. Washington, DC. May 1993.

2. Robert Beck and Joan Biggs. OGJ 300. Oil & Gas Journal. Vol. 89. No. 39. Tulsa, OK. September 1991.

3. U.S. Department of Commerce. 1987 Census of Manufactures, Petroleum, and Coal Products. Industry Series. MC87-I-29A. Bureau of the Census. Washington, DC. April 1990. Table 4.

4. Al Foreman. U.S. Department of Commerce. Bureau of the Census. Washington, DC. Personal communication. April 21, 1992.

5. Dun & Bradstreet. Million Dollar Directory.

6. Standard & Poor's. Register of Corporations, Directors, and Executives.

7. Reference 2. Table 36.

8. Reference 2. Table FE3.

9. American Petroleum Institute. Market Shares and Individual Company Data for U.S. Energy Markets, 1950-1989. Discussion Paper #014R. Washington, DC. October 1990.

10. U.S. Department of Energy. Petroleum Marketing Annual, 1990. DOE/EIA-0487(90). Energy Information Administration. Washington, DC. December 1991.

11. U.S. Department of Energy. Petroleum: An Energy Profile. DOE/EIA-0545(91). Energy Information Administration. Washington, DC. August 1991.

12. U.S. Department of Energy. Performance Profiles of Major Energy Producers, 1990. DOE/EIA-0206(90). Energy Information Administration. Washington, DC. December 1991.

13. U.S. Department of Energy. The U.S. Petroleum Refining Industry in the 1980's. DOE/EIA-0536. Energy Information Administration. October 1990.

14. U.S. Department of Energy. Annual Outlook for Oil and Gas. DOE/EIA-0517(91). Energy Information Administration. Washington, DC. June 1991.

15. Reference 12.

16. Reference 13.

17. Cambridge Energy Research Associates. The U.S. Refining Industry: Facing the Challenges of the 1990s. Prepared for U.S. Department of Energy. January 1992.

18. U.S. Department of Energy. Monthly Energy Review. DOE/EIA-0035(93/07). Energy Information Administration. Washington, DC. July 1993. Tables 3.3 to 3.10.

19. Robert S. Pindyck and Daniel L. Rubinfeld. Microeconomics. MacMillan Publishing Co. 1989.

20. U.S. Department of Energy. Petroleum Supply Monthly. Energy Information Administration. Washington, DC. March 1991.

21. U.S. Department of Energy. The U.S. Petroleum Industry: Past as Prologue 1970-1992. DOE/EIA-0572. Energy Information Administration, Office of Oil and Gas. Washington, DC. September 1993.

22. Bonner & Moore Management Science. Overview of Refining and Fuel Oil Production. Houston, TX. April 29, 1982.

23. U.S. Department of Energy. Annual Report to Congress. DOE/EIA-0173(91). Energy Information Administration. Washington, DC. March 1992.

24. Reference 18.

25. Dermot Gately. New York University. Taking Off: The U.S. Demand for Air Travel and Jet Fuel. The Energy Journal. Vol. 9. No. 4. 1988.

26. Reference 10.

27. Reference 10.

28. U.S. Department of Commerce. Petroleum Refining -- U.S. Industrial Outlook 1992. Washington, DC. January 1992.

29. U.S. Department of Commerce. Petroleum Refining -- U.S. Industrial Outlook 1991. Washington, DC. January 1991.

30. U.S. Department of Energy. Annual Energy Outlook, 1992. DOE/EIA-0383(92). Energy Information Administration. Washington, DC. January 1992.

31. Reference 13.

32. Reference 28.

33. Reference 30.

34. Henry Lee and Ranjit Lamech. The Impact of Clean Air Act Amendments on U.S. Energy Security. Harvard University. Energy 93-01. Cambridge, MA. 1993.

35. Reference 28.

36. Reference 29.

37. Reference 30.

38. Reference 11.

39. Reference 29.

40. National Petroleum Council. Estimated Expenditures by Petroleum Refineries to Meet New Regulatory Initiatives for Air Quality. For presentation at the 86th Annual Air & Waste Management Association Meeting. Denver, CO. 93-WA-78A.03. June 13-18, 1993.

41. Reference 28.

3.0 ECONOMIC METHODOLOGY

3.1 INTRODUCTION

The economic methodology used in this study is outlined in this chapter. Baseline values used in the partial equilibrium analysis are presented, and the analytical methods used to conduct each of the following analyses are described separately in this chapter:

- Partial equilibrium analysis
- Impact of control costs on market price and quantity
- Trade impacts and plant closures
- Economic surplus changes
- Labor and energy impacts
- Capital availability analysis.

3.2 MARKET MODEL

3.2.1 *Partial Equilibrium Analysis*

A partial equilibrium analysis is an analytical tool often used by economists to analyze the single market model. This method assumes that some variables are exogenously fixed at predetermined levels. The goal of the partial equilibrium model is to specify market supply and demand, estimate the post-control shift in market supply, estimate the change in market equilibrium (price and quantity), and predict plant closures.

3.2.2 *Market Demand and Supply*

The baseline or pre-control petroleum refining market is defined by a domestic market demand equation, a domestic market supply equation, and a foreign market supply equation. It is further assumed that the markets will clear or achieve an equilibrium. The following equations identify the market demand, supply, and equilibrium conditions:

$$Q^D = \alpha P^\epsilon$$

$$Q^{S_d} = \beta P^\gamma$$

$$Q^{S_f} = \rho P^\gamma$$

$$Q^D = Q^{S_d} + Q^{S_f} = Q$$

where:

Q = annual output or quantity of petroleum products purchased and sold in the United States

Q^D = quantity of the petroleum products domestically demanded annually

$Q^S{}_d$ = quantity of the products produced by domestic suppliers annually

$Q^S{}_f$ = quantity of the products produced by foreign suppliers annually

P = price of the petroleum product

Superscripts ϵ and γ reference price elasticity of demand and price elasticity of supply, respectively.

The constants α, β, and ρ are computed such that the baseline equilibrium price is normalized to one to simplify computations. The market specification assumes that domestic and foreign supply elasticities are the same. This assumption was necessary because data were not readily available to estimate the price elasticity of supply for foreign suppliers.

3.2.3 *Market Supply Shift*

The domestic supply equation shown above may be solved for the price of the petroleum product, *P*, to derive an inverse supply function that will serve as the baseline supply function for the industry. The inverse domestic supply equation for the industry is as follows:

$$P = (Q^{S_d}/\beta)^{\frac{1}{\gamma}}$$

A rational profit maximizing firm will seek to increase the price of the product it sells by an amount that recovers the capital and operating costs of the regulatory control requirements over the useful life of the emission control equipment. This relationship is identified in the following equation:

$$\frac{[(C \cdot Q) - (V + D)]\ (1 - t) + D}{S} = k$$

where:

C = increase in the supply price

Q = output

V = measure of annual operating and maintenance control costs

t = marginal corporate income tax rate

S = capital recovery factor

D = annual depreciation (assumes straight line depreciation)

K = investment cost of emission controls

Thus, the model assumes that individual refineries will seek to increase the product supply price by an amount (*C*) that equates the investment costs in control equipment (*k*) to the present value of the net revenue stream (revenues less expenditures) related to the equipment. Solving the equation for the supply price increase (C) yields the following equation:

$$C = \frac{kS - D}{Q(1 - t)} + \frac{V + D}{Q}$$

Estimates of the annual operation and maintenance control costs and of the investment cost of emission controls (V and k respectively), were obtained from engineering studies conducted by EPA's engineering contractor and are based on first quarter 1992 price levels. The variables depreciation and capital recovery factor (D and S, respectively) are computed as follows:

$$D = \frac{k}{T}$$

$$S = \frac{r(1 + r)^T}{[(1 + r)^T - 1]}$$

where "r" is the discount rate faced by producers and is assumed to be a rate of 10 percent and T is the life of the emission control equipment, which is 10 years for most of the emission control equipment proposed.

Emission control costs will increase the supply price for each refinery by an amount equivalent to the per unit cost of the annual recovery of investment costs and annual operating costs of emission control equipment or C_i (i denotes domestic refinery 1 through 192). The baseline individual refinery cost curves are unknown because production costs for the individual refineries are unknown. Therefore, an assumption is made that the refineries with the highest after-tax per unit control costs are marginal in the post-control market or that those firms with the highest after tax per unit control costs also have the highest per unit production costs. This is a worst case scenario model assumption and may not be the case in reality. Based upon this assumption, the post-control supply function becomes the following:

$$P = (Q^{S_a}/\beta)^{\frac{1}{\gamma}} + C\ (C_i, q_i)$$

where:

$C(C_i, q_i)$ = a function that shifts the post-control supply function

C_i = vertical shift that occurs in the supply curve for the *ith* refinery to reflect post-control costs

q_i = quantity produced by the *ith* refinery

This shift in the supply curve is illustrated in Figure 3-1.

3.2.4 *Impact of Supply Shift on Market Price and Quantity*

The impact of the proposed emission standards on market equilibrium price and output is derived by solving for the post-control market equilibrium and comparing the new equilibrium price and quantity to the pre-control equilibrium. Since post-control domestic supply is assumed to be segmented, or a step function, a special algorithm was developed to solve for the post-control market equilibrium. The algorithm first searches for the segment in the post-control supply function at which equilibrium occurs and then solves for the post-control market price that clears the market.

Since the market clearing price occurs where demand equals post-control domestic supply plus foreign supply, the algorithm simultaneously solves for the following post-control variables:

- Equilibrium market price
- Equilibrium market quantity
- Change in the value of domestic production or revenues to producers
- The quantity supplied by domestic producers
- The net quantity supplied by foreign producers.

The changes in the market equilibrium are assessed by comparing baseline equilibrium values with post-control equilibrium values.

3.2.5 *Trade Impacts*

Trade impacts are reported as the change in both the volume and dollar value of net exports (exports minus imports). It is assumed that exports comprise an equivalent percentage of domestic production in the pre- and post-control markets. The supply elasticities in the domestic and foreign markets have also been assumed to be equal. As the volume of imports rises and the volume of exports falls, the volume of net exports will decline. However, the dollar value of net exports may rise or fall when demand is inelastic, as is the case for the petroleum products of interest. The dollar value of imports will increase since both the price and quantity of imports increase. Alternatively, the quantity of exports will decline, while the price of the product will increase. Price increases for products with inelastic demand result in revenue increases for the producer. Consequently, the dollar value of exports is anticipated to increase. Since the dollar value of imports and exports rise, the resulting change in the value of net exports will depend on the magnitude of the changes for imports relative to exports.

The following algorithms are used to compute the trade impacts:

$$\Delta Q^{S_f} = Q_1^{S_f} - Q_0^{S_f}$$

$$\Delta VIM = (P_1 \bullet Q_1^{S_f}) - (P_0 \bullet Q_0^{S_f})$$

$$\Delta Q_X^{S_d} = \frac{Q_X^{S_d}}{Q_0^{S_d}} (Q_1^{S_d} - Q_0^{S_d})$$

$$\Delta VX = \frac{Q_X^{S_d}}{Q_0^{S_d}} (P_1 Q_1^{S_d} - P_0 Q_0^{S_d})$$

where:

ΔQ^{Sf} = the change in the volume of imports

ΔVIM = the change in the dollar value of imports

ΔQ_X^{Sf} = the change in the volume of exports

ΔVX = the change in the dollar value of exports

Q_X^{Sd} = the quantity of exports by domestic producers in the pre-control market

Subscripts 0 and 1 refer to the pre- and post-control equilibrium values, respectively. All other terms have been previously defined.

The change in the quantity of net exports (ΔNX) is simply the difference between the change in the volume of exports and the change in the volume of imports, expressed as $\Delta Q_X^{Sd} - \Delta Q^{Sf}$. The reported change in the dollar value of net exports (ΔVNX) is the difference between the equations for change in the value of exports and the change in the value of imports, or $\Delta VX - \Delta VIM$.

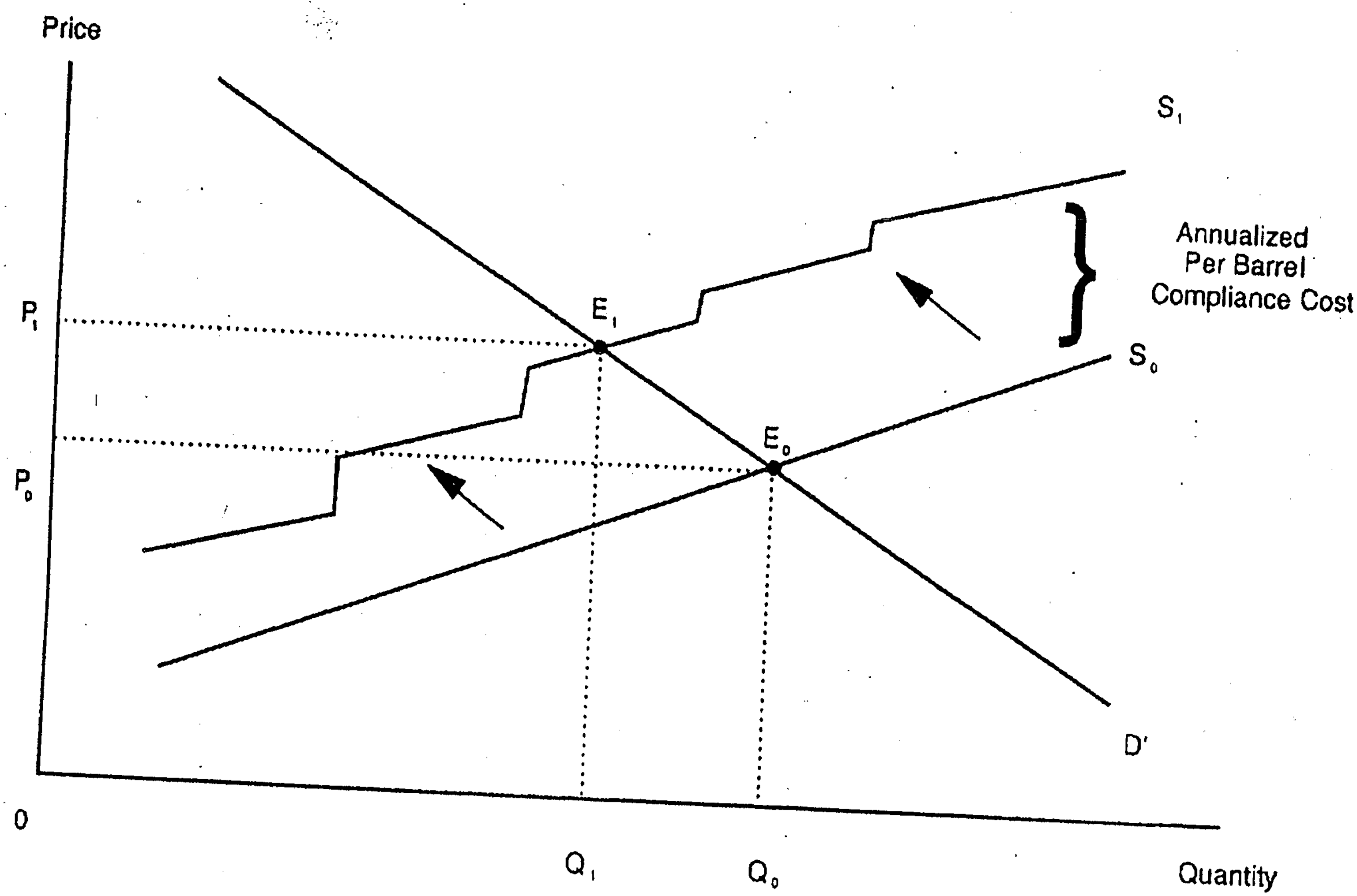
3.2.6 *Plant Closures*

It is assumed that a refinery will close if its post-control supply price exceeds the post-control market equilibrium price. Post-control supply prices for the individual refinery are computed as described in Section 3.2.3, *Market Supply Shift*.

3.2.7 *Changes in Economic Welfare*

Regulatory control requirements will result in changes in the market equilibrium price and quantity of petroleum products produced and sold. These changes in the market equilibrium price and quantity will affect the welfare of consumers of petroleum products, producers of petroleum products, and society as a whole. The methods used to measure these changes in welfare will be described individually in the following sections.

FIGURE 3-1. ILLUSTRATION OF POST-NESHAP MODEL



3.2.7.1 *Changes in Consumer Surplus.* Consumers will bear a loss in consumer surplus, or a dead weight loss, associated with the reduction in the amount of petroleum products produced and sold, and the higher prices paid for the products purchased. This loss in consumer surplus represents the amount consumers would have been willing to pay over the pre-control price for eliminated production. In addition, consumers will be faced with a higher price for post-control output. This consumer surplus change, ΔCS is given by:

$$\Delta CS = \int_{Q_1^D}^{Q_0^D} (Q/\alpha)^{\frac{1}{\epsilon}} \, dQ + P_1 Q_1 - P_0 Q_0$$

The change in consumer surplus includes losses of surplus incurred by both foreign consumers and domestic consumers. Although the change in domestic consumer surplus is the object of interest, no method is available to distinguish the marginal consumer as domestic or foreign. Therefore, an assumption is made that the consumer surplus change is allocable to the foreign and the domestic consumer in the same ratio as sales are divided between foreign and domestic consumers in the pre-control market. The change in domestic production (ΔCS_d) becomes the following:

$$\Delta CS_d = [1 - \left(\frac{Q_x^{S_d}}{Q_0^{S_d} + Q_0^{S_f}} \right)] \; \Delta CS$$

ΔCS_d represents the change in domestic consumer surplus that results from the change in market equilibrium price and quantity resulting from the imposition of regulatory controls. While ΔCS is the change in consumer surplus from the perspective of the world economy, ΔCS_d is the change in consumer surplus relevant to the domestic economy.

3.2.7.2 *Change in Producer Surplus*. The change in producer surplus is composed of two elements. The first element relates to output eliminated as a result of controls. The second element is associated with the change in price and cost of production for the new market equilibrium quantity. The total change in consumer surplus is the sum of these two components. After-tax measures of surplus changes are required to estimate the impacts of control on producers' welfare. The after-tax surplus change is computed by multiplying the pre-tax surplus change by a factor of 1 minus the tax rate, (1-t) where t is the marginal tax rate. Every dollar of after-tax surplus loss represents a complimentary loss in tax revenues of t/(1-t) dollars.

Output eliminated as a result of control costs cause producers to suffer a welfare loss in producer surplus. Refineries remaining in operation after emission controls (M) realize a welfare gain on each unit of production for the incremental increase in the price and realize a decrease in welfare per unit for the capital and operating cost of emission controls. The total change in producer surplus is specified by the following equation:

$$\Delta PS = \left[P_0\, Q_0^{S_d} - P_1 Q_1^{S_d} - \left(\int_{Q_1^{S_d}}^{Q_0^{S_d}} (Q/\beta)^{\frac{1}{\gamma}}\, dQ + \sum_{i=1}^{M} C_i\, q_i\right)\right](1-t)$$

Since domestic surplus changes are the object of interest, the welfare gain experienced by foreign producers due to higher prices is not considered. This procedure treats higher prices paid for imports as a dead-weight loss in consumer surplus. From a world economy perspective, higher prices paid to foreign producers represent simply a transfer of surplus from the United States to other countries. The higher prices paid for imports represent a welfare loss from the perspective of the domestic economy.

3.2.7.3 *Residual Effect on Society*. The changes in economic surplus as measured by the changes in consumer and producer surplus previously discussed must be adjusted to reflect the true change in social welfare as a result of regulation. The adjustments are necessary due to tax effects differences and to the difference between the private and the social discount rates.

Two adjustments to economic surplus are necessary to account for tax effects. The first relates to the per unit control cost (C_i) that reflects after-tax control costs and is used to predict the post-control market equilibrium. True cost of emission controls must be measured on a pre-tax basis.

A second tax-related adjustment is required because changes reflect the after-tax welfare impacts of emission control costs on affected refineries. As noted previously, a one dollar loss in pre-tax surplus imposes an after-tax burden on the affected refinery of (1-t) dollars. Alternatively, a one dollar loss in after-tax producer surplus causes a complimentary loss of t/(1-t) dollars in tax revenue.

Economic surplus must also be adjusted because the private and social discount rates differ. The private discount rate is used to shift the supply curve of firms in the industry since this rate reflects the marginal cost of capital to affected firms. The economic costs of regulation must consider the social cost of capital. This rate reflects the social opportunity cost of resources displaced by investments in emission controls.

The adjustment for the two tax effects and the social cost of capital are referred to as the residual change in economic surplus, $\Delta \acute{R}S$. This adjustment is shown by the following equation:

$$\Delta RS = \sum_{i=1}^{M} (C_i - pc_i) q_i + \Delta PS \bullet [t/(1-t)]$$

where pc_i is the per unit cost of controls for each refinery, with the tax rate assumed to be zero, the discount rate assumed to be the social discount rate of 7 percent, and all other variables have been previously defined.

3.2.7.4 *Total Economic Costs.* The total economic costs of the proposed regulations are the sum of the changes in consumer surplus, producer surplus, and the residual surplus. This relationship is defined in the following equations:

$$EC = \Delta CS_d + \Delta PS + \Delta RS$$

where *EC* is the economic cost of the proposed controls and all other variables have been previously defined.

3.2.8 *Labor Input and Energy Input Impacts*

The estimates of the labor market and energy market impacts associated with the alternative standards are based on input-output ratios and estimated changes in domestic production. The methodologies used to estimate each impact are presented separately in the following sections.

3.2.8.1 *Labor Input Impacts.* The labor market impacts are measured as the number of jobs lost due to domestic output reductions. The estimated number of job losses are a function of the change in level of production that is anticipated to occur as a result of the proposed emission controls. The change in employment is estimated as follows:

$$\Delta L = (Q_0^{S_d} - Q_1^{S_d})\, L_0$$

where:

ΔL = the change in employment

L_0 = the number of production workers per million barrels of annual production

Subscripts 0 and 1 represent pre- and post-control values, respectively.

All other variables have been previously defined.

3.2.8.2 *Energy Input Impacts.* The reduction in energy inputs associated with the proposed standard results from the expected reduction in expenditures for energy inputs as a result of production decreases. The expected change in use of energy inputs is calculated as follows:

$$\Delta E = E_0 P_0 (Q_0^{S_d} - Q_1^{S_d})$$

where:

ΔE = the change in expenditures on energy inputs

E_0 = the baseline expenditure on energy input per dollar of refined petroleum output

All else is as previously defined.

3.2.9 *Baseline Inputs*

The partial equilibrium model requires baseline values for variables and parameters that have been previously described to characterize the petroleum refining market. Table 3-1 lists the variable and parameter inputs to the model that vary for the five petroleum products. Table 3-2 lists variables and parameters that are assumed to be the same for all petroleum products.

The baseline conditions in the petroleum refining industry are characterized by the baseline parameters and variables in the tables. The baseline market prices, quantities, imports, and exports for the five petroleum products were taken from the U.S. Department of Energy, *Petroleum Market Annual*, 1992. Prices are stated in cents per gallon excluding taxes and refinery output is stated in millions of barrels produced per year. Sources for the price elasticity of supply and demand are discussed in Section 3.3, *Industry Supply and Demand Elasticities*. The marginal tax rate of 25 percent, private discount rate of 10 percent, and social discount rate of 7 percent are rates that have been assumed for the analysis as surrogates for the actual rates in the economy. The equipment life of 10 years was obtained from the study of emission control costs conducted for EPA by the engineering contractor. The number of workers per unit of output (L) and the energy expenditure per value of shipments (E) were derived from the U.S. Department of Commerce, *Annual Survey of Manufactures (ASM)*, 1991. Data from the ASM used to derive these estimates include the 1991 annual values for total number of workers employed, total expenditures on energy, and the value of shipments for SIC 2911.

TABLE 3-1. PRODUCT-SPECIFIC BASELINE DATA INPUTS

Variable/ Parameter	Refined Petroleum Product				
	Gasoline	Jet fuel	Residual fuel oil	Distillate fuel oil	LPGs
Price (P_0)[1]	78.40	61.00	33.8	62.7	66.20
Domestic Output, (Q_0^{Sd})[2]	2,576.17	510.635	325.58	1,085.51	719.78
Import ratio[3]	0.04	0.06	0.42	0.07	0.07
Export Ratio[4]	0.01	0.03	0.22	0.07	0.02
Demand Elasticity (γ)	-0.69	-0.15	-0.675	-0.745	-0.8

NOTES: [1]Cents per gallon, excluding taxes (1992).
[2]Millions of barrels per year.
[3]Imports divided by domestic production.
[4]Exports divided by domestic production.

TABLE 3-2. BASELINE INPUTS FOR THE PETROLEUM REFINING INDUSTRY

Variable/Parameter	Value
Supply Elasticity (ϵ)	1.24
Tax rate (t)	0.25
Private Discount rate (r)	0.10
Social Discount rate	0.07
Equipment life (T)	10 years
Labor (L_0)[1]	9.12 workers
Energy (E_0)[2]	$0.03
Number of operating petroleum refineries	192

NOTES: [1]Production workers per million barrels produced per year.
[2]Energy expenditures per dollar value of shipments.

Data inputs also include the number of domestic refineries operating in 1992, annual production per refinery, and control costs per refinery. The number of operating refineries and annual production per refinery were obtained from the *Oil and Gas Journal Refinery Survey*, January 1992. Emission control costs were obtained from engineering studies conducted by an engineering contractor for EPA.

3.3 INDUSTRY SUPPLY AND DEMAND ELASTICITIES

Demand and supply elasticities are crucial components of the partial equilibrium model that is used to quantify the economic impact of regulatory control cost measures on the petroleum refinery industry. This chapter discusses the price elasticities of demand and supply used as inputs to the partial equilibrium analysis. The price elasticities of demand for each product were available from published sources. The price elasticity of supply was estimated for this analysis. The techniques utilized to estimate the price elasticity of supply are discussed in detail in Section 3.3.2, *Price Elasticity of Supply*.

3.3.1 *Price Elasticity of Demand*

The price elasticity of demand, or own-price elasticity of demand, is a measure of the sensitivity of buyers of a product to a change in price of the product. The price elasticity of demand represents the percentage change in the quantity demanded resulting from each 1 percent change in the price of the product.

Petroleum products represent a very important energy source for the United States. Many studies have been conducted which estimate the price elasticity of demand for some or all of the petroleum products of interest. Over one hundred studies of the demand for motor gasoline alone have been conducted (see Dahl and Stern[1] for a survey of these model results). Numerous published sources of the price elasticity of demand for petroleum products exist and are discussed in detail in the *Industry Profile for the Petroleum Refinery NESHAP* (Pechan, 1993). The own-price elasticities of demand used in this analysis are listed in Table 3-3.

TABLE 3-3. ESTIMATES OF PRICE ELASTICITY OF DEMAND

Fuel Type	Long-Run Elasticity
Motor Gasoline	-0.55 to -0.82[2]
Jet fuel	-0.15[3]
Residual Fuel Oil	-0.61 to -0.74[2]
Distillate Fuel Oil	-0.50 to -0.99[2]
Liquified Petroleum Gases	-0.60 to -1.0[2]

The elasticity estimates reflect that each of these products has inelastic demand. Regulatory control costs are more likely to paid by consumers of products with inelastic demand compared with products with elastic demand, all other factors held constant. Price increases for products with inelastic demand lead to revenue increases for the producers. Thus, one can predict that price increases resulting from implementation of regulatory control costs will lead to higher revenues for the petroleum refining industry.

The market changes resulting from the regulations are based upon the midpoint of the range of demand elasticities (with the exception of jet fuel for which a range of elasticities was not provided). A sensitivity analysis of this assumption is made using the upper and lower bounds of the range of elasticities and is reported in Appendix B.

3.3.2 *Price Elasticity of Supply*

The price elasticity of supply, or own-price elasticity of supply, is a measure of the responsiveness of producers to changes in the price of a product. The price elasticity of supply indicates the percentage change in the quantity supplied of a product resulting from each 1 percent change in the price of the product.

3.3.2.1 *Modeling Issues*. Published sources of the price elasticity of supply using current data were not readily available. Two studies estimated the price elasticity of supply for gasoline to be 1.96[4] and 1.47[5], respectively. Since the years of data used in these studies covered time periods during the decade of 1970, it was determined that the price elasticity of supply should be estimated econometrically using time series data inclusive of more current information and of periods with greater market stability.

The petroleum refinery industry has a history of long periods of stable market conditions followed by periods of major market disruptions, which must be considered in estimating the price elasticity of supply using time series data. The Arab oil embargo and the Iranian crisis in 1973 and 1978, respectively, represent major crude oil supply disruptions that had significant repercussions on the U.S. economy, and industrialized economies of countries throughout the world. These market disruptions drastically affected the market equilibrium for petroleum products. The price per barrel of crude oil, the major input into producing petroleum products, increased from an average price of $4.15 per barrel in 1972 to an average price of $35.24 per barrel in 1981[6], an increase of 749 percent in nominal prices and an increase of 249 percent when these prices are deflated by the producer price index for all commodities.[7] These events suggest the possibility of a structural change or break during the periods of the Arab oil embargo and the Iranian crisis as noted by Tsurumi.[4] A Chow test, or F-test, for structural change was conducted for the period 1973 through 1979, or the period relevant to these significant events. The statistical results of this test are presented with the statistical results of the model.

Another concern in estimating the price elasticity of supply for petroleum refinery products is the joint product nature of the five petroleum products. Joint products are products that are produced jointly or in conjunction with other products. Joint products may be categorized as either joint products of fixed proportions, or as joint products of variable proportions. Beef and leather are the classic example of a joint product with fixed proportions. Alternatively, the petroleum products under study represent joint products of variable proportions. Thus, managers at petroleum refineries have some discretion over the level of production between refinery products. The jointness and variability in the jointness of the products further complicates the analysis.

Several model approaches were considered in the *Analysis Plan for the Economic Impact Analysis of Alternative NESHAP for the Petroleum Refinery Industry* (Pechan, 1993). The most theoretically sound methodology involved estimation of a production function with a function of the five petroleum products as the dependent or left-hand-side variable. It was determined that software was not readily available to estimate this type of model. Alternatively, a model estimating the production function for each of the five products treating the price of the alternative four products as dependent or right-hand-side variables was recommended. This approach assumes that the prices of the alternative products are exogenous to the model. In fact the prices of the five products are highly correlated over time and are endogenous to the model. Estimation of this model was not successful.

Two alternative models were considered. The first involved estimation of a supply-demand model, and the second was to estimate a production function for the five products combined. The supply-demand approach estimates the price elasticity of supply using simultaneous supply and demand equations and avoids simultaneous system bias. This method allows for the treatment of the price of alternative joint products as endogenous variables. The results of the model estimated in this manner were less satisfactory than estimation of the production function for the five joint products in terms of significance of the model, significance and signs of the individual parameter estimates, and goodness of fit measures. Consequently, it was determined that the price elasticity of supply would be estimated using a production function for the five products combined.

3.3.2.2 *Model Approach*. The approach used to estimate the price elasticity of supply is consistent with economic theory and makes the best use of available data. The method of deriving a supply elasticity from an estimated production function will be briefly discussed. The industry production function is defined as follows:

$$Q^S = f\ (L, K, M, t)$$

where:

- Q^S = the quantity of motor gasoline, jet fuel, residual fuel oil, distillate fuel oil, and LPGs produced by domestic refineries
- L = the labor input or number of labor hours
- K = real capital stock
- M = the quantity of crude oil processed
- t = a time variable to reflect technology changes

In a competitive market, market forces constrain firms to produce at the cost minimizing output level. Cost minimization allows for the duality mapping of a firm's technology (summarized by the firm's production function) to the firm's economic behavior (summarized by the firm's cost function). The total cost function of the petroleum refinery industry follows:

$$TC = h(C, K, t, Q^S)$$

where TC is the total cost of production, C is the cost of production (including cost of materials and labor), and the other variables have been previously defined. This methodology assumes that capital stock is fixed, or a sunk cost of production. This model assumption is consistent with the goal of modeling post-control market changes likely to occur. Firms facing prospective regulatory emission controls will consider embedded capital stock as a fixed or sunk cost in economic decision making. Firms will make economic decisions that consider those costs of production that are discretionary or avoidable. In the short run, avoidable costs are generally variable costs such as labor and materials. Investments in new capital, such as emission control equipment, are also discretionary . Firms have the discretion to shut down rather than make investments in required emission control equipment. By contrast, costs associated with existing capital are not avoidable or discretionary, but represent sunk costs.

Differentiating the total cost function with respect to Q^S derives the marginal cost function:

$$MC = h'(C, K, t, Q^S)$$

where MC is the marginal cost of production and all other variables have been previously defined.

Profit maximizing competitive firms will choose to produce the quantity of output that equates market price (P) to the marginal cost of production (MC). Setting the price equal to the preceding marginal cost function and solving for Q^S yields the following implied supply function:

$$Q^s = (P, P_L, P_M, K, t)$$

where P is the market price of the petroleum products, P_L is the price of labor, P_M is the price of crude oil, and all other variables have been previously defined.

An explicit functional form of the production function may be assumed to facilitate estimation of the model. For this analysis, the Cobb-Douglas or multiplicative form of the production function is postulated. The Cobb-Douglas production function has the convenient property of yielding constant elasticity measures. The functional form of the production function becomes:

$$Q_t = A\, K_t^{\alpha_K}\, t^{\lambda}\, L_t^{\alpha_L}\, M_t^{\alpha_M}$$

where:

Q_t = sum of the industry output of the five product categories in year t

K_t = real capital stock in year t

L_t = the quantity of labor hours used to produce the petroleum products in year t

M_t = quantity of crude oil processed in year t

A, α_K, α_L, α_M, λ are parameters to be estimated by the model.

This equation can be written in linear form by taking the natural logarithms of both sides of the equation. Linear regression techniques may then be applied. Using the approach described, the implied supply function may be derived as:

$$\ln = \beta_0 + \gamma \ln P + \beta_2 \ln K + \beta_3 \ln P_L + \beta_4 \ln P_M + \beta_5 \ln t$$

where:

P_L = factor price of the labor input
P_M = factor price of the material input
K = real fixed capital.

The coefficients, β_i and γ, are functions of α_i, the coefficients of the production function.

The supply elasticity, γ is equal to the following:

$$\gamma = \frac{\alpha_L + \alpha_M}{1 - \alpha_L - \alpha_M}$$

It is necessary to place some restrictions on the estimated coefficients of the production function in order to have well-defined supply function coefficients. The sum of the coefficients for labor and materials should be less than one. Coefficient values for α_L and α_M that equal to one result in a price elasticity of supply that is undefined, and values greater than one result in negative supply elasticity measures. For these reasons, the production function is estimated with the restriction that the sum of the coefficients for the inputs equal one. This is analogous to assuming that the petroleum refining industry exhibits constant returns to scale or is a long-run constant cost industry. This assumption seems reasonable on an *a priori* basis and is consistent with the data.

3.3.2.3 *Estimated Model*. The estimated model reflects the industry production function for the petroleum products using annual time series data for the time period from 1963 through 1991. The following model was estimated econometrically:

$$\ln Q_t = \ln A + \alpha_K \ln K + \lambda \ln t + \alpha_L \ln L + \alpha_M \ln M$$

where each of the variables and coefficients has been previously defined.

3.3.2.4 *Data.* The data used to estimated the model is enumerated in Table 3-4. This table contains a list of the variables included in the model, the units of measure, and a brief description of the data. The data used in the analysis represents data for the petroleum refining industry, SIC 2911, with two exceptions. The data inputs for quantity produced (Q_t) represents production at the five digit SIC level for gasoline, jet fuel, distillate fuel oil, residual fuel oil, and LPGs. The capital stock variable represents real net capital stock for petroleum and coke products SIC 29. Capital stock data were not readily available for the Petroleum Refining Industry at the four-digit SIC level from published sources for the relevant time periods. However, limited data reviewed for specific years during the study period indicates that the majority of gross capital stock in SIC 29 relates to the petroleum refining industry. Consequently, use of this capital stock data is unlikely to create errors for the analysis.

The capital stock variable represents the most difficult variable to quantify for the econometric model. Ideally this variable should represent the economic value of the capital stock actually used by the refinery industry to produce petroleum products for each year of the study. The most reasonable data for this variable would be the number of machine hours actually used to produce the refinery products each year. This information is unavailable. In lieu of machine hours data, the dollar value of net capital stock in constant 1987 prices, or real net capital stock, is used as a proxy for this variable.

The capital stock data are flawed in two ways. The first flaw occurs because the data represent accounting valuations of capital stock rather than economic valuations. This aberration is not easily remedied, and is generally considered unavoidable in most studies of this kind.

The second flaw involves capital investment that is idle and not actually used for production in a particular year. This error may be corrected by adjusting the capital investment to exclude the portion of capital investment that is idle and does not contribute directly to production in a given year. In an effort to further refine the data, real capital stock was adjusted for capacity utilization. This refinement would then provide a data input that considers the percentage of real capital stock actually utilized in petroleum refining production each year.

TABLE 3-4. PRODUCTION FUNCTION DATA INPUTS

Variable	Unit of Measure	Description
Q_t	Millions of barrels	The output variable includes the sum of annual production for motor gasoline, jet fuel, residual fuel oil, distillate fuel oil, and LPG[7]
t	Years	Technology time trend
K_t	Millions of 1987 dollars	Real capital stock for Petroleum and Coal Products adjusted for capacity utilization[8, 9]
L_t	Thousand of labor man hours	Production worker hours for Petroleum refineries[10]
M_t	Millions of barrels	Gross input of crude oil to petroleum product distillation[7]

3.3.2.5 *Statistical Results.* A restricted least squares estimator was used to estimate the coefficients of the production function model. A log-linear specification was estimated with the sum of the α_i restricted to unity. This procedure is consistent with the assumption of constant returns to scale. The model was further adjusted to correct for first-order serial correlation using the Prais-Winston algorithm. The results of the estimated model are presented in Table 3-5.

TABLE 3-5. ESTIMATED PRODUCTION FUNCTION COEFFICIENTS

Variable		Estimated Coefficients*
Adjusted R^2		0.9680
t	time	0.0481 (2.061)
K_t	Capital Stock	0.4457 (4.916)
L_t	Labor	0.1447 (2.090)
M_t	Materials or crude oil	0.4096 (4.507)

NOTES: *t-ratios are shown in parentheses.

The equation explains about 97 percent of the variation in the output variable. The time variable and labor variable are significant at the 95 percent confidence level, while the capital and crude oil or material variables are significant at the 99 percent confidence level. The F test and the Chi-square test for the estimated model show that the coefficients of the estimated model are jointly significant at the 99 percent confidence level.

Using the estimated coefficients in Table 3-5 and the formula for supply elasticity shown Section 3.3.3.2 *Model Approach*, the price elasticity of supply for the five petroleum products is derived to be 1.24. The calculation of statistical significance for this elasticity measure is not a straightforward calculation since the estimated function in non-linear. No attempt has been made to assess the statistical significance of the estimated elasticity.

A Chow test for structural stability was conducted of the coefficients to determine if a structural change occurred during the period from 1973 through 1979. This period included two significant supply disruptions of crude oil, the major input to the petroleum refining process. The test of structural change for the period using an F-test for linear restrictions leads to a conclusion that a structural break did not occur during the period for the estimated model. It is recognized that this result differs from the conclusion of Tsurmi.[4] However, the model estimated by Tsurmi differed from the model estimated in this analysis in many respects. The data used in the Tsurmi study represented quarterly data rather than annual data used in the present study. It should be noted that the supply elasticity estimates reported in Yang and Hu also do not adjust for structural change.[5] As a further test of the model's results on this issue, the model was re-estimated excluding data for the period from 1973 through 1979. The results were quite similar to those reported in this document in terms of signs of the coefficients and significance tests. The price elasticity of supply estimated with such a model was 1.25. This price elasticity of supply estimate is virtually the same as the estimate used in the model reported.

3.3.2.6 *Limitations of the Supply Elasticity Estimates.* The estimated price elasticity of supply for the five petroleum products reflects that the petroleum refinery industry in the United States will increase production of gasoline, jet fuel, residual fuel oil, distillate fuel oil and LPG jointly by 1.24 percent for every 1.0 percent increase in the price of these products. The preceding methodology does not estimate the supply elasticities for the individual products or directly consider the interrelationships between products. The assumption implicit in use of this supply elasticity estimate is that the elasticities of the individual petroleum products will not differ significantly from the elasticity of the products combined. This does not seem a totally unreasonable assumption since the same factor inputs are used to produce each of the petroleum products. The methodology also does not explicitly consider the cross-price elasticities for the petroleum products. Since these products are joint products, changes in the price of one product will have an effect on the quantity supplied of the other products.

The uncertainty of the supply estimate is acknowledged. It is possible to conduct a sensitivity analysis of the price elasticity supply. Such an analysis would quantify the impact of this assumption on the reported market results.

3.4 CAPITAL AVAILABILITY ANALYSIS

It is necessary to estimate the impact of the proposed emission controls on the affected petroleum refineries' financial performance and their ability to finance the additional capital investment in emission control equipment. Financial data were not available for the majority of the refineries in the industry. Financial data were only available for the largest publicly held petroleum refining companies. For this reason, the capital availability analysis has been conducted on an industrywide basis.

One measure of financial performance frequently used to assess the profitability of a firm is net income before interest expense expressed as a percentage of firm assets, or rate of return on investment. The pre-control rate of return on investment (*roi*) is calculated as follows:

$$roi = \left[\sum_{i=1986}^{1990} \left(\frac{n_i}{a_i} \right) \right] /5 \bullet 100$$

where n_i is income before interest payments and a_i is total assets. A five year average is used to avoid annual fluctuations that may occur in income data. The proposed regulations potentially could have an effect on income before taxes, n_i, for firms in the industry and on the level of assets for firms in the industry, a_i. Since firm-specific data were unavailable for all of the affected firms, sample financial data collected by the API were used.[11] Data from the API study are available in the *Industry Profile for the Petroleum Refinery NESHAP* (Pechan, 1993). The sample studied by API represents 71 percent of net income in the industry and 70 percent of total industry assets. These percentages will be considered to estimate changes in the financial ratio, and are necessary to allocate changes in income and assets resulting from emission controls to the study sample. The average rate of return on investment for firms in the sample was 6 percent. There is a great diversity among the refineries in the industry; therefore, individual firm financial performance may vary greatly from the sample estimate. The post-control return on investment (*proi*) is calculated as follows:

$$proi = \left[\frac{\left(\sum_{i=1986}^{1990} n_i \right) / 5 + \Delta n}{\left(\sum_{i=1986}^{1990} a_i \right) / 5 + \Delta k} \right] \bullet 100$$

where:

$proi$ = post-control return on investment

Δn_i = change in income before interest resulting from implementation of emission controls for firms in the sample

a_i = change in investment or assets for firms in the sample

The ability of affected firms to finance the capital equipment associated with emission control is also relevant to the analysis. Numerous financial ratios can be examined to analyze the ability of a firm to finance capital expenditures. One such measure is historical profitability measures such as rate of return on investment. The analysis approach for this measure has been previously described. The bond rating of a firm is another indication of the credit worthiness of a firm or the ability of a firm to finance capital expenditures with debt capital. Such data are unavailable for many of the firms subject to the regulation, and consequently, bond ratings are not analyzed. Ability to pay interest payments is another criterion sometimes used to assess the capability of a firm to finance capital expenditures. Coverage ratios provide such information. The interest coverage ratio or the number of times income (before taxes and interest) will pay interest expense is a ratio that provides some information about the ability of a firm to cover or pay annual interest obligations. The pre-control measure of coverage ratio is as follows:

$$tc = \left(\sum_{i=1986}^{1990} \frac{ebit_i}{interest_i} \right) / 5$$

where:

tc = number of times earnings will cover annual interest charges

ebit = earnings before interest payments and taxes

interest = annual interest expense.

The baseline five year average of the interest coverage ratio was 7.14 times for the sample of firms in the API study. Post-control coverage ratios may be estimated as follows:

$$ptc = \left[\frac{\left(\sum_{i=1986}^{1990} ebit_i \right) / 5 + \Delta\, ebit}{\left(\sum_{i=1986}^{1990} interest_i \right) / 5 + \Delta\, interest} \right]$$

where $\Delta ebit$ is the estimated change in earnings before interest and taxes of the firm, $\Delta interest_i$ is the anticipated change in interest expense, and all other variables have been previously described. The $\Delta interest$ is calculated by multiplying the capital expenditures for the proposed controls (Δk) by the assumed private cost of capital of 10 percent. Interest costs are generally lower than the overall cost of capital for a firm and this method would tend to overstate the impact of controls on industry interest coverage ratio.. Again the interest coverage ratios of individual petroleum refineries may differ from the average significantly.

Finally, the degree of debt leverage or debt-equity ratio of a firm is considered in assessing the ability of a firm to finance capital expenditures. The pre-control debt-equity ratio is the following:

$$d/e = \frac{d_{1990}}{d_{1990} + e_{1990}}$$

where d/e is the debt equity ratio, d is debt capital and e is equity capital. Since capital information is less volatile than earnings information, it is appropriate to use the latest available information for this calculation. If one assumes that the capital costs of control equipment are financed solely by debt, the debt-equity ratio becomes:

$$pd/e = \frac{d_{1990} + k}{d_{1990} + e_{1990} + k}$$

where pd/e is the post-control debt-equity ratio assuming that the control equipment costs are financed solely with debt. Obviously, firms may choose to issue capital stock to finance the capital expenditure or to finance the investment through internally generated funds. Assuming that the capital costs are financed solely by debt may be viewed as a worse case scenario.

The methods used to analyze the capital availability do have some limitations. The approach matches 1990 debt and equity values with estimated capital expenditures for control equipment. Average 1986 through 1990 income and asset measures are matched with changes in income and capital expenditures associated with the control measures. The control cost changes and income changes reflect 1992 price levels. The financial data used in the analysis represents the most recent data available. It is inappropriate to simply index the income, asset, debt, and equity values to 1992 price levels for the following reasons. Assets, debt, and equity represent embedded values that are not subject to price level changes except for new additions such as capital expenditures. Income is volatile and varies from period to period. For this reason, average income measures are used in the study. The analysis reflects a conservative approach to analyzing the changes likely in financial ratios for the petroleum industry. Some decreases the cost of production expected to result from implementation of emission controls have not been considered. These include labor input and energy input cost decreases. Annualized compliance costs are overstated from a financial income perspective since these costs include a component for earnings or return on investment. In general, the approach followed is a worst case scenario approach that overstates the negative impact of the proposed emission controls on the financial operations of the petroleum refining industry.

REFERENCES

1. Carol Dahl and Thomas Sterner. Analyzing Gasoline Demand Elasticities: A Survey. Energy Economics. July 1991.

2. U.S. Department of Energy. Short-term Energy Outlook, Vol. II. DOE/EIA-0202/42. Energy Information Administration. Washington, DC. August 1980.

3. Robert S. Pindyck and Daniel L. Rubinfeld. Microeconomics. MacMillan Publishing Company. 1989.

4. Hiroki Tsurmi. A Bayesian Estimation of Structural Shifts By Gradual Switching Regressions with an Application to the U.S. Gasoline Market Bayesian Analysis in Econometrics and Statistic Essays in honor of Harold Jeffries. Edited by Arnold Zellner. 1980.

5. Bong-Min Yang and Teh-wei Hu. Gasoline Demand and Supply Under a Disequilibrium Market. Energy Economics. October 1984.

6. U.S. Department of Energy: Petroleum Marketing Annual, 1992. Volume 1 DOE/EIQ-0340(90)/1. Energy Information Administration. Washington, DC. May 1993.

7. U.S. Department of Commerce. Business Statistics 1963-1991. 27th Edition. June 1992.

8. U.S. Department of Commerce. Fixed Reproducible Wealth in the United States 1925-1989.

9. U.S. Department of Commerce. Survey of Current Business. Volume 73. Number 9. September 1993.

10. U. S. Department of Commerce. Annual Survey of Manufacturers. 1963-1991.

11. American Petroleum Institute. Financial Trends for Leading U.S. Oil Companies 1968-1990. Discussion Paper #017R. Washington, DC. October 1991.

4.0 CONTROL COSTS, ENVIRONMENTAL IMPACTS, COST-EFFECTIVENESS

4.1 INTRODUCTION

Inputs to the model outlined in the previous chapter include the quantitative data summarized in Chapter 2.0 and control cost estimates provided by EPA. This chapter summarizes the cost inputs used in this EIA, and the methodology used for allocating costs to each of the five petroleum product markets.

A Regulatory Impact Analysis (RIA) of alternative emission standards includes a Benefit Cost Analysis (BCA). A BCA requires estimates of economic costs associated with regulation, which do not correspond to emission control costs. This chapter presents the progression of steps which were taken to arrive at estimates of economic costs based on the emission control cost estimates. The environmental impacts associated with the chosen regulatory option in this analysis are summarized and the cost-effectiveness of the regulatory option is presented.

4.2 CONTROL COST ESTIMATES

Control cost estimates and emission reductions were provided on a refinery level. The control costs estimated for each refinery can be divided into fixed and variable components. Fixed costs are constant over all levels of output of a process, and usually entail plant and equipment. Variable costs will vary as the rate of output changes. The costs were calculated for new and existing petroleum refinery emission sources. New source costs represent the control of new process units and equipment built (or reconstructed or replaced) in the first 5 years after promulgation. It should be noted for regulatory purposes that some of these units and equipment will be considered new sources and others will be considered part of an existing source. It is not possible to determine how many new units will fall into these two categories; however, the emission points will require control in either case.[3]

Table 4-1 presents the fifth year costs for the regulated sources included in this analysis. Emission control costs are the annualized capital and annual operating and maintenance costs of controls based on the assumption that all affected refineries install controls. The controls associated with each of the five emission points are discussed separately below.

For equipment leaks, the MACT floor level of control is the Petroleum Refinery New Source Performance Standard (NSPS).[1] The chosen control alternative is a level more stringent than the floor, which is the HON negotiated regulation without connector monitoring. The cost for this option was calculated assuming monthly monitoring of gas valves and light liquid valves. The annual costs for the floor are $69 million per year, while the costs for applying the negotiated regulation to petroleum refineries are estimated to be $65.8 million per year.[2]

The MACT floor level control for HAPs from miscellaneous process vents is incineration or equivalent control (i.e., 98 percent reduction or 20 parts per million by volume outlet level). The cost and emission reduction represent the nationwide cost of piping uncontrolled miscellaneous vents to existing flare or fuel gas systems. The annual cost for controlling emissions from miscellaneous vents was estimated to be $11.4 million per year. The miscellaneous process vents include all process vents at a refinery, excluding fluidized catalytic cracking unit catalyst regeneration vents, catalytic reformer catalyst regeneration vents, and sulfur plant vents.

A MACT floor analysis performed on wastewater collection and treatment systems indicated that the MACT floor level of control for this emission point is compliance with the benzene waste operations NESHAP (BWON). No costs are therefore anticipated for the industry to reach the MACT floor level of control.

TABLE 4-1. SUMMARY OF COSTS IN THE FIFTH YEAR BY EMISSION POINT[4]

Emission Point	Option	Annual Fifth Year Costs ($1,000/yr) (1992 Dollars)			Annual Emission Reduction (Thousand Mg/yr)		Cost-Effectiveness ($/Mg)	
		Existing Sources	New Construction	Total	VOC	HAP	VOC	HAP
Equipment Leaks	Floor	$69,000	$0	$69,000	130	35	$531	$1,971
	Option 1[1]	$66,000	$(210)	$65,790	160	44.6	$411	$1,475
Miscellaneous Process Vents	Floor[1]	$11,000	$370	$11,370	180	8.4	$63	$1,353
Wastewater Systems	Floor[1]	$0	$0	$0	0	0	0	0
Storage Vessels	Floor[1]	$3,700	$98	$3,798	11	0.7	$345	$5,425
TOTAL FOR OPTIONS CHOSEN		$80,700	$258	$80,958	351	53.7	$231	$1,508

NOTES:
[1] Designates chosen alternative.
[2] Brackets indicate negative values.
[3] 1992 dollars.
[4] Costs shownreflect complicance costs excluding monitoring, reporting, and recordkeeping costs.

The MACT floor level of control for floating roof storage vessels requires control equivalent to the VOL Storage NSPS requirements (which are listed in subpart Kb of CFR Part 60), seals and conversion to floating roof or 95 percent control for fixed roof vessels. This level of control applies to vessels larger than 1,115 barrels storing liquids with true vapor pressures greater than or equal to 3.4 psia.[5] The annual cost for MACT floor control is estimated to be $3.8 million.

Control cost estimates were provided on an emission point and on a refinery basis. A methodology was developed to allocate these costs to the specific products in this analysis. The allocation was based on each refinery's estimated production of the five products of interest. The *Oil & Gas Journal*'s U.S. Refinery Survey publishes total daily output by refinery. Each refinery's total production was multiplied by 0.90 since the five products of interest accounted for 93 percent of total refinery output. Production of each specific product was estimated based on the assumption that each refinery produces the national average mix of the five products.

Emission control costs for the selected control alternative include those associated with storage vessels, process vents, and equipment leaks (net of recovery credits). Costs are allocated to the five products as follows:

- Motor gasoline - all costs associated with storage vessel controls plus gasoline's "share" of process vent and equipment leak costs.
- Jet fuel, residual fuel oil, distillate fuel oil, and LPG - each products' "share" of process vent and equipment leak costs.

Product "shares" are computed, for each refinery, as the ratio of the production of that product to total production of the five products of interest.

4.3 MONITORING, RECORDKEEPING, AND REPORTING COSTS

In addition to provisions for the installation of control equipment, the proposed regulation includes provisions for monitoring, recordkeeping, and reporting (MRR). EPA estimates that the total annual cost for refineries to comply with the MRR requirements is approximately $30 million. After incorporating MRR costs, the total cost of compliance of the Chosen Alternative is $111 million.

In order to calculate the costs of MRR associated with the petroleum refinery NESHAP, estimates of hours per item (i.e., a required MRR action), frequency of required action per year, and number of respondents were estimated based on the requirements in the proposed rule for all of the emission points. To compute the costs associated with the burden estimates, a wage rate of $32 per hour (in 1992 dollars) was assumed. This assumption was based on estimate that 85 percent of the labor will be accomplished by technical personnel (typically by an engineer with a wage rate of $33 per hour), 10 percent will be completed by a manager (at $49 per hour), and 5 percent by clerical personnel (at $15 per hour). All of the wage rates include an additional 110 percent for overhead. Costs were annualized assuming an expected remaining life for affected facilities of 15 years from the date of promulgation of the subject NESHAP, and using an interest rate of 7 percent.

Compliance requirements vary in terms of frequency. This variance is taken into account in the annualization of costs. Performance tests to demonstrate compliance with the control device requirements are required once. Compliance requirements also include monitoring of operating paramenters of control devices and records of work practice and other inspections. These activities must be reported semiannually. The compliance requirements that must be met only once are annualized over the time from the year in which they are to take place to the expected end of facility life.

The MRR requirements are outlined separately for each emission point. The proposed compliance determination provisions for storage vessels include inspections of vessels and roof seals. If a closed vent system and control device is used for venting emissions from storage vessels, the owner must establish appropriate monitoring procedures. For wastewater stream and treatment operations, the MRR requirements are outlined in the rule for the BWON.

For miscellaneous process vents, the proposed standard specifies the performance tests, monitoring requirements, and test methods necessary to determine whether a miscellaneous process vent stream is required to apply control devices and to demonstrate that the allowed emission levels are achieved when controls are applied. The format of these requirements, as with the format of the miscellaneous process vent provisions, depends on the control device selected. The MRR requirements for miscellaneous process vents are summarized by control device in Table 4-2.

For equipment leaks, because the provisions of the proposed rule are work practice and equipment standards, monitoring, repairing leaks, and maintaining the required records constitutes compliance with the rule. The HON equipment leak provisions are appropriate to determine continuous compliance with the petroleum refinery equipment leak standards. In summary, these provisions require periodic monitoring with a portable hydrocarbon detector to determine if equipment is leaking.

4.4 ESTIMATES OF ECONOMIC COSTS

Air quality regulations affect society's economic well-being by causing a reallocation of productive resources within the economy. Resources are allocated away from the production of goods and services (refined petroleum products) to the production of cleaner air. Estimates of the economic costs of cleaner air require an assessment of costs to be incurred by society as a result of emission control measures. By definition, the economic costs of pollution control are the opportunity costs incurred by society for productive resources reallocated in the economy to pollution abatement. The economic costs of the regulation can be measured as the value that society places on goods and services not produced as a result of resources being diverted to the production of improved air quality. The conceptually correct valuation of these costs requires the identification of society's willingness to be compensated for the foregone consumption opportunities resulting from the regulation. In contrast to the economic cost of regulation, emission compliance costs consider only the direct cost of emission controls to the industry affected by the regulation. Economic costs are a more accurate measure of the costs of the regulation to society than an engineering estimate of compliance costs. However, compliance cost estimates provide an essential element in the economic analysis.

Economic costs are incurred by consumers, producers, and society at large as a result of pollution control regulations. These costs are measured as changes in consumer surplus, producer surplus, and residual surplus to society. Consumer surplus is a measure of well-being or of the welfare of consumers of a good and is defined as the difference between the total benefits of consuming a good and the market price paid for the good. Pollution control measures will result in a loss in consumer surplus due to higher prices paid for refined petroleum products and to the deadweight loss in surplus caused by reduced output of petroleum products in the post-control market.

Producer surplus is a measure of producers welfare that reflects the difference between the market price charged for a product and the marginal cost of production. Pollution controls will result in a change in producer surplus that consists of three components. These changes include surplus gains relating to increased revenues experienced by firms in the petroleum industry experiencing higher post-control prices, surplus losses associated with increased costs of production for annualized emission control costs, and surplus losses due to reductions in post-control output. The net change in producer surplus is the sum of these surplus gains and losses.

TABLE 4-2. MISCELLANEOUS PROCESS VENTS — MONITORING, RECORDKEEPING, AND REPORTING REQUIREMENTS FOR COMPLYING WITH 98 WEIGHT-PERCENT REDUCTION OF TOTAL ORGANIC HAP EMISSIONS OR A LIMIT OF 20 PARTS PER MILLION BY VOLUME

Control Device	Parameters to be Monitored[a]	Recordkeeping and Reporting Requirements for Monitored Parameters
Thermal Incinerator	Firebox temperature[b] [63.644(a)(1)(i)]	1. Continuous records[c]
		2. Record and report the firebox temperature averaged over the full period of the performance test - NCS[d]
		3. Record the daily average firebox temperature for each operating day[e]
		4. Report all daily average temperatures that are outside the range established in the NCS or operating permit and all operating days when insufficient monitoring data are collected[f] - PR[g]
Catalytic Incinerator	Temperature upstream and downstream of the catalyst bed [63.644(a)(1)(ii)]	1. Continuous records
		2. Record and report the upstream and downstream temperatures and the temperature difference across the catalyst bed averaged over the full period of the performance test - NCS
		3. Record the daily average upstream temperature and temperature difference across catalyst bed for each operating day[e]
		4. Report all daily average upstream temperatures that are outside the range established in the NCS or operating permit - PR

TABLE 4-2 (continued).

Control Device	Parameters to be Monitored[a]	Recordkeeping and Reporting Requirements for Monitored Parameters
		5. Report all daily average temperature differences across the catalyst bed that are outside the range established in the NCS or operating permit - PR 6. Report all operating days when insufficient monitoring data are collected[f]
Boiler or Process Heater with a design heat input capacity less than 44 megawatts and Vent Stream is <u>not</u> introduced with or as the primary fuel[h,i]	Firebox temperature[b] [63.644(a)(4)]	1. Continuous records 2. Record and report the firebox temperature averaged over the full period of the performance test - NCS 3. Record the daily average firebox temperature for each operating day[e] 4. Report all daily average firebox temperatures that are outside the range established in the NCS or operating permit and all operating days when insufficient monitoring data are collected[f] - PR

TABLE 4-2 (continued).

Control Device	Parameters to be Monitored[a]	Recordkeeping and Reporting Requirements for Monitored Parameters
Flare	Presence of a flame at the pilot light [63.644(a)(2)]	1. Hourly records of whether the monitor was continuously operating and whether the pilot flame was continuously present during each hour
		2. Record and report the presence of a flame at the pilot light over the full period of the compliance determination - NCS
		3. Record the times and durations of all periods when a pilot flame is absent or the monitor is not operating
		4. Report the times and durations of all periods when all pilot flames of a flare are absent - PR

TABLE 4-2 (continued).

Control Device	Parameters to be Monitored[a]	Recordkeeping and Reporting Requirements for Monitored Parameters
All Control Devices	Presence of flow diverted to the atmosphere from the control device [63.644(c)(1)] <u>or</u>	1. Hourly records of whether the flow indicator was operating and whether flow was detected at any time during each hour. 2. Record and report the times and durations of all periods when the vent stream is diverted through a bypass line or the monitor is not operating - PR
	Monthly inspections of sealed valves [63.644(c)(2)]	1. Records that monthly inspections were performed 2. Record and report all monthly inspections that show the valves are not closed or the seal has been changed - PR

NOTES: [a]Regulatory citations are listed in brackets.

[b]Monitor may be installed in the firebox or in the ductwork immediately downstream of the firebox before any substantial heat exchange is encountered.

[c]"Continuous records" is defined in §63.641 of this subpart.

[d]NCS = Notification of Compliance Status described in §63.652(e) of this subpart.

[e]The daily average is the average of all recorded parameter values for the operating day. If all recorded values during an operating day are within the range established in the NCS or operating permit, a statement to this effect can be recorded instead of the daily average.

[f]When a period of excess emission is caused by insufficient monitoring data, as described in §63.552(f)(3)(i)(C) of this subpart, the duration of the period when monitoring data were not collected shall be included in the Periodic Report.

[g]PR = Periodic Reports described in §63.652(f) of this subpart.

[h]No monitoring is required for boilers and process heaters with heat input capacities $\geq$44 megawatts or for boilers and process heaters where the vent stream is introduced with or as the primary fuel. No recordkeeping or reporting associated with monitoring is required for such boilers and process heaters.

[i]Process vents that are routed to refinery fuel gas systems are not regulated under this subpart. No monitoring, recordkeeping, or reporting is required for boilers and process heaters that combust refinery fuel gas.

Additional adjustments or changes in the residual surplus to society are necessary to reflect the economic costs to society of pollution controls, and these adjustments are referred to as the change in residual surplus to society. Specifically, adjustments are necessary to consider tax gains or losses associated with the regulation and to adjust for differences between the social discount rate and the private discount rate. Since control measures involve the purchase of long-lived assets, it is necessary to annualize the cost of emission controls. Annualization of costs require the use of a discount rate or the cost of capital. The private cost of capital (assumed to be 10 percent) is the relevant discount rate to use in estimating annualized compliance costs and market changes resulting from the regulation. Firms in the petroleum refinery industry will make supply decisions in the post-control market based upon increases in the costs of production. The private cost of capital more accurately reflects the capital cost to firms associated with the pollution controls. Alternatively, the social costs of capital (assumed to be 7 percent)[6] is the relevant discount rate to consider in estimating the economic costs of the regulation. The economic cost of the regulation represents the cost of the regulation to society or the opportunity costs of resources displaced by emission controls. A risk-free discount rate or the social discount rate better reflects the capital cost of the regulation to society.

The sum of the change in consumer surplus, producer surplus and residual surplus to society constitutes the economic costs of the regulation. Table 4-3 summarizes the economic costs associated with the Chosen Regulatory Alternative. The economic cost for the Chosen Alternative for all petroleum products is $132.35 million annually. The economic costs for individual products range from $11.84 million annually to $66.71 million annually for residual fuel oil and motor gasoline, respectively. More details concerning the methodology used to estimate these welfare changes or the economic cost of the regulation are discussed in Section 3.2.7 *Changes in Economic Welfare*.

TABLE 4-3. ESTIMATES OF THE ANNUALIZED ECONOMIC COSTS ASSOCIATED WITH ALTERNATIVE NESHAPS BY PETROLEUM PRODUCT MARKET[1] (MILLIONS OF $1992)

Petroleum Product Market	Change in Consumer Surplus	Change in Producer Surplus	Change in Residual Surplus	Loss in Surplus Total
Motor Gasoline	$250.26	$(129.27)	$(54.28)	$66.71
Jet Fuel	$72.31	$(43.02)	$(16.26)	$13.03
Residual Fuel Oil	$16.30	$(2.45)	$(2.01)	$11.84
Distillate Fuel Oil	$81.75	$(41.10)	$(17.74)	$22.91
LPGs	$55.57	$(26.27)	$(11.44)	$17.86
TOTAL	$476.19	$(242.11)	$(101.73)	$132.35

NOTES: [1]Brackets indicate negative costs or benefits.

4.5 ESTIMATED ENVIRONMENTAL IMPACTS

Table 4-4 reports estimates of annual emission reductions associated with the chosen alternative. The estimate of total HAP emission reductions is 54,000 Mg per year, and the total VOC emission reduction associated with the regulatory alternative is 351,000 Mg per year.

4.6 COST EFFECTIVENESS

Cost effectiveness is computed as annualized costs divided by the emission reductions, and is presented in Table 4-4 for each pollutant. Economic cost effectiveness is computed by dividing the annualized economic costs by the estimated emission reductions.

Generally, a dominant alternative results in the same or higher emission reduction at a lower cost than all other alternatives. Because this analysis evaluated only one alternative, however, there is no basis for comparison.

TABLE 4-4. ESTIMATED ANNUAL REDUCTIONS IN EMISSIONS AND COST-EFFECTIVENESS ASSOCIATED WITH THE CHOSEN REGULATORY ALTERNATIVE

	HAP Emission Reduction (Mg/yr x 10^3)	VOC Emission Reduction (Mg/yr x 10^3)
Chosen Alternative	53.7	351
	HAP Cost-Effectiveness* ($/Mg)	VOC Cost-Effectiveness* ($/Mg)
Chosen Alternative	$2,465	$377

NOTES: *Cost-effectiveness is computed as estimated annualized economic costs divided by estimated emissions reduced. Comparisons are made between the chosen alternative and the baseline conditions.

REFERENCES

1. Oommen, Roy. Letter from Roy Oommen to James Durham, U.S. Environmental Protection Agency. November 23, 1993.

2. Oommen, Roy. Letter from Roy Oommen, Radian, to Larry Sorrels, U.S. Environmental Protection Agency. January 26, 1994.

3. Oommen, Roy. Letter from Roy Oommen, Radian, to James Durham, U.S. Environmental Protection Agency. Chemical and Petroleum Branch. November 10, 1993.

4. Zarate, Marco. Letter from Marco A. Zarate to James Durham. U.S. Environmental Protection Agency. Chemical and Petroleum Branch. November 30, 1993.

5. Murphy, Pat. Letter from Patrick Murphy, Radian, to James Durham, U.S. Environmental Protection Agency. December 3, 1993.

6. U.S. Office of Management and Budget. Transmittal Memorandum No. 64. Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs. Circular Number A-94. Washington, DC. October 29, 1992.

5.0 PRIMARY ECONOMIC IMPACTS AND CAPITAL AVAILABILITY ANALYSIS

5.1 INTRODUCTION

Estimates of the primary economic impacts resulting from implementation of the NESHAP and the results of the capital availability analysis are presented in this chapter. Primary impacts include changes in the market equilibrium price and output levels, changes in the value of shipments or revenues to domestic producers, and plant closures. The capital availability analysis assesses the ability of affected firms to raise capital and the impacts of control costs on plant profitability.

5.2 ESTIMATES OF PRIMARY IMPACTS

The partial equilibrium model is used to analyze the market outcome of the proposed regulation. The purchase of emission control equipment will result in an upward vertical shift in the domestic supply curve for refined petroleum products. The height of the shift is determined by the after-tax cash flow required to offset the per unit increase in production costs. Since the control costs vary for each of the domestic refineries, the post-control supply curve is segmented, or a step function. Underlying production costs for each refinery are unknown; therefore, a worst case scenario has been assumed. The plants with the highest control costs per unit of production are assumed to also have the highest pre-control per unit cost of production. Thus, firms with the highest per unit cost of emission control are assumed to be marginal in the post-control market.

Foreign supply is assumed to have the same price elasticity of supply as domestic supply. The U.S. had a negative trade balance for each of the refined products in 1992 with the exception of distillate fuel oil that had a slightly positive trade balance of $1.1 million. Therefore net exports are negative for all products except distillate fuel oil in the baseline model. Foreign and domestic post-control supply are added together to form the total post-control market supply. The intersection of this post-control supply with market demand will determine the new market equilibrium price and quantity. Post-control domestic output is derived by deducting post-control imports from the post-control output.

Table 5-1 reveals the primary impacts predicted by the partial equilibrium model. The range of anticipated price increases for the five products vary from $0.03 to $0.14 per barrel produced for residual fuel oil and jet fuel, respectively. The percentage increases for each product are less than 1 percent and range from 0.24 percent to 0.53 percent.

Production is expected to decrease by 12.52 million barrels per year for all products, an overall decrease in domestic production of 0.24 percent. The estimated annual reductions in production of the individual products range from 0.65 million barrels to 5.67 million barrels for jet fuel and motor gas, respectively. The production percentage decreases range from 0.13 percent to 0.50 percent for jet fuel and residual fuel oil, respectively.

Value of domestic shipments or revenues for domestic producers are expected to increase for the five products approximately $107.41 million annually. The predicted changes in revenues for individual products range from an increase of $55.63 million in motor gasoline revenues to a decrease in residual fuel revenues of $11.92 million annually. The percent changes range from an increase of 0.41 percent in jet fuel to a decrease of 0.26 percent in residual fuel oil revenues. Economic theory predicts that revenue increases are expected to occur when prices are increased for inelastic goods, all other factor held constant. This revenue increase results given that the percentage increase in price exceeds the percentage decrease in quantity for goods with inelastic demand. All of the refined petroleum products follow the expected trend except residual fuel oil. Residual fuel oil has the highest trade deficit of the five products with over 40 percent of domestic demand being satisfied by imports. The magnitude of residual fuel oil imports causes domestic residual fuel oil revenues to decrease in the post-control market.

TABLE 5-1. SUMMARY OF PRIMARY IMPACTS

	Estimated Impacts[1]		
Refined Product	Price Increases[2]	Production Decreases[3]	Value of Domestic Shipments[4]
Motor gasoline			
Amount	$0.09	(5.67)	$55.63
Percentage	0.29%	(0.22%)	0.07%
Jet fuel			
Amount	$0.14	(0.65)	$53.22
Percentage	0.53%	(0.13%)	0.41%
Residual fuel			
Amount	$0.03	(1.62)	($11.92)
Percentage	0.24%	(0.50%)	(0.26%)
Distillate fuel			
Amount	$0.08	(2.78)	$8.06
Percentage	0.29%	(0.26%)	0.03%
LPG			
Amount	$0.07	(1.80)	$2.42
Percentage	0.26%	(0.25%)	0.01%

NOTES: [1]Brackets indicate decreases or negative values.
[2]Prices are shown in price per barrel ($1992).
[3]Annual production quantities are shown in millions of barrels.
[4]Values of domestic shipments are shown in millions of 1992 dollars.

It is anticipated that approximately 7 refineries may close as a result of the decrease in production predicted by the model. Those refineries with the highest per unit control costs are assumed to be marginal in the post-control market. Refineries that have post-control supply prices that exceed the market equilibrium price are assumed to close. This assumption is consistent with the perfect competition theory that presumes all firms in the industry are price takers. Firms with the highest per unit control costs may not have the highest underlying cost of production. This is a worst case assumption that is likely to bias the results and as a result, overstate the number of plant closures and other adverse effects of the proposed emission controls.

The estimated primary impacts reported depend on the set of parameters used in the partial equilibrium model. One of the parameters, the price elasticity of demand, consists of a range for four of the five refined products. The midpoint of the range of elasticities was used to estimate the reported primary and secondary impacts. A sensitivity analysis of this assumption is contained in Appendix B. Sensitivity analyses were performed for the low and high end of the ranges of elasticities. In general, the sensitivity analysis shows that the estimated primary impacts are relatively insensitive to reasonable changes of price elasticity of demand estimates.

5.3 CAPITAL AVAILABILITY ANALYSIS

The capital availability analysis involves examining pre- and post-control values of selected financial ratios. These ratios include rate of return on investment, times interest earned coverage ratio, and the debt-equity ratio. (Each of these ratios are explained in detail in Section 3.4.) Data were not available to estimate the ratios for many refineries in the industry. Consequently, these ratios have been analyzed on an industrywide basis. The industrywide ratios represent an average for the industry. Individual firms within the industry may have financial ratios that differ significantly from the average. Net income was averaged for a five-year period (1986 thorough 1990) to avoid annual fluctuations that may occur in income due to changes in the business cycle. Debt and equity capital are not subject to annual fluctuations; therefore, the most recent data available (1990) was used in the analysis.

The financial statistics provide insight regarding firms' abilities to raise capital to finance the investment in emission control equipment. Table 5-2 shows the estimated impact on financial ratios for the industry.

TABLE 5-2. ANALYSIS OF FINANCIAL RATIOS

Financial Ratios	Pre-Control Ratios	Post-Control Ratios
Rate of return on investment	5.91%	5.91%
Coverage Ratio (or Times Interest Earned)	7.08	7.07
Debt-Equity Ratio	62.75%	62.76%

As the table shows, the financial ratios remain virtually unchanged as a result of the proposed emission controls.

5.4 LIMITATIONS

Several qualifications of the primary impact results are required. A single national market for a homogenous product is assumed in the partial equilibrium analysis. However, there are some regional trade barriers that would protect individual refineries. The analysis also assumes that the refineries with the highest control costs are marginal in the post-control market. Refineries that are marginal in the post-control market have per unit control costs that significantly exceed the average. This may be the result of the engineering method used to assign costs to individual refineries. Additionally, the cost allocation methodology assigns all of the control costs to the five petroleum products of interest. The result of the foregoing list of qualifications is overstatement of the impacts of the chosen alternative on the market equilibrium price and quantity, revenues, and plant closures. Finally, some refineries may find it profitable to expand production in the post-control market. This would occur when a firm found its post-control incremental unit costs to be smaller than the post-control market price. Expansion by these firms would result in a smaller decrease in output and increase in price than would otherwise occur.

The results of the sensitivity analysis are reported in Appendix B. These results show slightly more adverse impacts when demand is more elastic. The analysis is relatively insensitive to reasonable variations in the price elasticity of demand.

The capital availability analysis also has limitations. First, future baseline performance may not resemble past levels. The tools used in the analysis are limited in scope and do not fully describe the financial position of individual firms within the industry but are more reflective of industry averages.

5.5 SUMMARY

The estimated impacts of the proposed emission controls are relatively small. Predicted price increases and reductions in domestic output are less than 1 percent for each of the refined products. The value of domestic shipments or revenues to domestic producers for the 5 petroleum products combined are anticipated to increase. Emission control costs are small relative to the financial resources of affected producers, and on average, refineries should not find it difficult to raise the capital necessary to finance the purchase and installation of emission controls.

6.0 SECONDARY ECONOMIC IMPACTS

6.1 INTRODUCTION

Implementation of emission controls may have an impact on secondary markets including the labor market, the energy market, foreign trade, and regional effects. The potential changes in employment, use of energy inputs, balance of trade, and regional refinery distribution are presented.

6.2 LABOR MARKET IMPACTS

The estimated labor impacts associated with the NESHAP are based on the results of the partial equilibrium analyses of the five refined petroleum products and are reported in Table 6-1. The number of workers employed by firms in SIC 2911 is estimated to decrease by approximately 114 workers as a result of the proposed emission controls. The loss in number of workers depends primarily on the reduction in production reported in Chapter 5. Gains in employment anticipated to result from operation and maintenance of control equipment have not been included in the analysis due to lack of reliable data. Estimates of employment losses do not consider potential employment gains in industries that produce substitute products. Similarly, losses in employment in industries that use petroleum products as an input or in industries that provide complement goods are not considered. The changes in employment reflected in this analysis are only direct employment losses due to reductions in domestic production of refined petroleum products.

The loss in employment is relatively small. The magnitude of predicted job losses directly results from the relatively small decrease in production anticipated and the relatively low labor intensity in the industry.

TABLE 6-1. SUMMARY OF SECONDARY REGULATORY IMPACTS

Refined Product	Estimated Impacts[1] Labor Input[2]	Energy Input[3]
Motor gasoline		
Amount	(52)	($5.79)
Percentage	(0.22%)	(0.22%)
Jet fuel		
Amount	(6)	($ .52)
Percentage	(0.13%)	(0.13%)
Residual fuel		
Amount	(15)	($ .71)
Percentage	(0.50%)	(0.50%)
Distillate fuel		
Amount	(25)	($2.27)
Percentage	(0.26%)	(0.26%)
LPGs		
Amount	(16)	($1.56)
Percentage	(0.25%)	(0.25%)
Total five products		
Amount	(114)	($10.85)

NOTES: [1] Brackets indicate reduction or negative value.
[2]Indicates estimated reduction in number of jobs.
[3]Reduction in energy use in millions of 1992 dollars.

6.3 ENERGY INPUT MARKET

The method used to estimate reductions in energy input use relates the energy expenditures to the level of production. An estimated decrease in energy use of $10.85 million annually is expected for the industry. The individual product energy use changes are reported in Table 6-1. As production decreases, the amount of energy input utilized by the refining industry also declines. The changes in energy use do not consider the increased energy use associated with operating and maintaining emission control equipment. Insufficient data were available to consider such changes in energy costs.

6.4 FOREIGN TRADE

The implementation of the NESHAP will increase the cost of production for domestic refineries relative to foreign refineries, all other factors being equal. This change in the relative price of imports will cause domestic imports of refined petroleum products to increase and domestic exports to decrease. The balance of trade overall for refined petroleum products is currently negative (imports exceed exports). The NESHAP will likely cause the balance of trade to become more negative. Net exports are likely to decline by 2.26 million barrels per year. The range of net export decreases varies from 0.21 million barrels to 0.91 million barrels for LPGs and residual fuel oil, respectively. The related percent range from 0.54 percent to 40.92 percent for LPGs and distillate fuel oil, respectively. The large percentage decrease in exports of distillate is the result of the product having a very small positive trade balance in the pre-control market. The dollar value of the total decline in net exports is expected to amount to $68.22 million annually. The predicted changes in the trade balance are reported in Table 6-2.

6.5 REGIONAL IMPACTS

No significant regional impacts are expected from implementation of the NESHAP. The plant closures estimated are approximately 7 nationwide. Due to the manner used to estimate control costs for the individual refinery and the method of allocating the costs to products, the facilities predicted to close do not necessarily represent the facilities most likely to close. However, the facilities postulated in the model are dispersed through the United States and not specific to a geographical region. Employment impacts are directly related to plant closure and production decreases. Employment impacts are also dispersed throughout the country.

TABLE 6-2. FOREIGN TRADE (NET EXPORTS) IMPACTS

	Estimated Impacts[1]		
Refined Product	Amount[2]	Percentage	Dollar Value of Net Export Change[3]
Motor Gasoline	(0.43)	(0.54%)	($21.92)
Jet fuel	(0.23)	(1.41%)	($ 8.14)
Residual fuel	(0.91)	(0.81%)	($16.81)
Distillate fuel	(0.48)	(40.92%)	($12.67)
LPG	(0.21)	(0.54%)	($ 8.68)
Total	(2.26)		($68.22)

NOTES: [1]Brackets indicate reductions or negative values.
[2]Millions of barrels.
[3]Millions of dollars ($1992).

6.6 LIMITATIONS

The estimates of the secondary impacts associated with the emission controls are based on changes predicted by the partial equilibrium model. The limitations described in the Primary Economic Impacts chapter is equally applicable to Secondary Economic Impacts. As previously noted, the employment losses do not consider potential employment gains for operating the emission control equipment. Likewise, the gains or losses in markets indirectly affected by the regulations, such as substitute product markets, complement products markets, or in markets that use petroleum products as an input, have not been considered. It is important to note that the potential job losses predicted by the model are only those directly linked to predicted production losses in the petroleum refining industry.

6.7 SUMMARY

The estimated secondary economic impacts are relatively small. Approximately 114 job losses may occur nationwide. Energy input reductions are estimated to be $10.85 million annually. A decrease is net exports of 2.26 million barrels annually in refined products is anticipated to occur. No significant regional impacts are expected.

7.0 POTENTIAL SMALL BUSINESS IMPACTS

7.1 INTRODUCTION

The Regulatory Flexibility Act requires that special consideration be given to the effects of all proposed regulations on small business entities. The Act requires that a determination be made as to whether the subject regulation will have a significant impact on a substantial number of small entities. A substantial number is considered to be greater than 20 percent of the small entities identified. The following criteria are provided for assessing whether the impacts are significant. Whenever any of the following criteria are met, the impact on small business entities is determined to be significant:

1. Annual compliance costs (annualized capital, operating, reporting, etc.) increase as a percentage of cost of production for small entities for the relevant process or product by more than 5 percent;
2. Compliance costs as a percent of sales for small entities are at least 10 percent higher than compliance costs as a percent of sales for large entities;
3. Capital costs of compliance represent a significant portion of capital available to small entities, considering internal cash flow plus external financing capabilities; and
4. The requirements of the regulation are likely to result in closure of small entities.

7.2 METHODOLOGY

Data are not readily available to estimate the small business impacts for two of the criteria (Numbers One and Three) established in the introduction. The information necessary to make such comparisons are generally considered proprietary by small business firms. Consequently, the analysis will focus on the remaining two criteria of the potential closure of small businesses and a comparison of the compliance costs as a percentage of sales for small and large business entities.

The closure method of analysis will focus on the number of petroleum refineries expected to close as a result of the proposed emission controls and the relative size of the firms at risk. Alternatively, a measure of annual compliance costs including MRR costs relating to motor gasoline as a percentage of motor gasoline sales will also be considered. The ratio of costs to sales will be compared for small refineries to the same ratio for all other refineries. The applicable ratios for the other refined petroleum products may differ in magnitude from those reported, but the differential between the ratios for small businesses and larger business should remain relatively the same.

7.3 SMALL BUSINESS CATEGORIZATION

Consistent with Title IV, Section 410H of the CAA, a petroleum refinery is classified as a small business if it has less than 1,500 employees or if its production is less than or equal to 50,000 barrels of oil per day. A refinery must also be unaffiliated with a larger business entity to be considered a small business entity. Information necessary to distinguish refinery size by number of employees was not readily available. However, daily production data were available from the *Oil and Gas Journal Refinery Survey* (1-1-92). Based upon this size criterion, there were 63 refineries that were small business entities in January 1992.

7.4 SMALL BUSINESS IMPACTS

The results of the partial equilibrium analysis lead to the conclusion that approximately seven refineries are at risk of closure. This estimate represents approximately three percent of the domestic refineries in operation and eleven percent of those designated to be small businesses. The estimated number of closures is therefore less than 20 percent of the small refineries. However, it is important to note that the firms designated in the model as at greatest risk for closure were small refineries.

Compliance costs as a percentage of sales were computed both for 63 small refineries and for those refineries that are not considered small. The cost to sales ratio for the small businesses were 0.191 percent of sales while the cost to sales ratio for all other refineries was 0.082 percent. The differential between these two rates exceeds ten percent, and consequently, a conclusion is drawn that a significant number of small businesses are adversely affected by the proposed regulations.

APPENDIX A
PRODUCTION CAPACITY OF OPERABLE PETROLEUM REFINERIES BY FIRM AND REFINERY
(AS OF JANUARY 1, 1991)

APPENDIX B
SENSITIVITY ANALYSES

APPENDIX B

SENSITIVITY ANALYSES

INTRODUCTION

The sensitivity analysis contained in this Appendix explores the degree to which the results presented earlier in this report are sensitive to the estimates of the price elasticity of demand.

The results presented in this report are based upon the price elasticities of demand shown in Table B-1 for the individual petroleum products. The range of demand elasticity measures is also shown. Jet fuel is the only product that has a single measure of demand elasticity and a sensitivity analysis will not be conducted for this product. This elasticity measure for jet fuel is sufficiently small that reasonable deviations in the measure are unlikely to have an impact on the model results.

TABLE B-1. PRICE ELASTICITY OF DEMAND

Refined Product	Elasticity Midpoint	Range of Elasticity
Motor gas	-0.69	-0.55 to -0.82
Jet fuel	-0.15	-0.15
Refined fuel oil	-0.675	-0.61 to -0.74
Distilled fuel oil	-0.745	-0.50 to -0.99
LPG	-0.8	-0.60 to -1.0

The sensitivity analysis results are presented in Tables B-2 and B-3. Table B-2 reports estimates for the low measure of elasticity and Table B-3 for the high measure.

The results using the low measure of elasticity differ very little from the reported results. The signs of the changes in price, quantity, and value of shipments are

TABLE B-2. SENSITIVITY ANALYSIS FOR ESTIMATED PRIMARY IMPACTS WITH THE LOW MEASURE OF THE PRICE ELASTICITY OF DEMAND[1]

Refined Product	Market Price Change (%)	Market Output Change (%)	Change in the Value of Shipments (%)
Motor Gasoline	0.31%	(0.19%)	0.12%
Residual Fuel	0.25%	(0.49%)	(0.24%)
Distillate Fuel	0.35%	(0.22%)	0.13%
LPGs	0.30%	(0.22%)	0.08%

NOTES: [1] Brackets indicate decreases or negative values.

TABLE B-3. SENSITIVITY ANALYSIS FOR ESTIMATED PRIMARY IMPACTS WITH THE HIGH MEASURE OF THE PRICE ELASTICITY OF DEMAND[1]

Refined Product	Market Price Change (%)	Market Quantity Change (%)	Change in the Value of Shipments (%)
Motor Gasoline	0.25%	(0.22%)	0.02%
Residual Fuel	0.23%	(0.51%)	(0.28%)
Distillate Fuel	0.23%	(0.26%)	(0.04%)
LPGs	0.22%	(0.26%)	(0.04%)

NOTES: [1] Brackets indicate decreases or negative values.

unchanged and the relative size of the changes are not significantly altered. The results of this analysis tend to present relatively more favorable results for the industry.

The analysis conducted with the high end of the elasticity range also does not differ significantly from previously reported results for price increases and quantity decreases. The change in value of shipments becomes virtually zero for Distillate and LPG as a result of the proximity of the elasticity measures to unitary elastic.

In summary, the sensitivity analysis does not indicate that the model results are sensitive to reasonable changes in the price elasticity of demand. This conclusion provides support for greater confidence in the reported model results.

TECHNICAL REPORT DATA

(Please read Instructions on reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-453/D-94-052		

4. TITLE AND SUBTITLE Economic Impact Analysis for the Petroleum Refineries NESHAP	5. REPORT DATE July 1994 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Emission Standards Division Research Triangle Park, NC 27711	10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. 68-D1-0144
12. SPONSORING AGENCY NAME AND ADDRESS Director Office of Air Quality Planning and Standards Office of Air and Radiation U.S. Environmental Protection Agency Research Triangle Park, NC 27711	13. TYPE OF REPORT AND PERIOD COVERED 14. SPONSORING AGENCY CODE EPA/200/04

15. SUPPLEMENTARY NOTES

16. ABSTRACT

An economic analysis of the industries affected by the Petroleum Refineries National Emissions Standard for Hazardous Air Pollutants (NESHAP) was completed in support of this proposed standard. The industry for which economic impacts was computed was the petroleum refinery industry.

Affected refineries must control HAP emissions by the level of control required in the standard. Several types of economic impacts, among them product price changes, output changes, job impacts, and effects on foreign trade, were computed for the selected regulatory alternatives.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Control Costs Industry Profile Economic Impacts	Air Pollution control	

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (Report)	21. NO. OF PAGES
Release Unlimited	Unclassified	147
	20. SECURITY CLASS (Page) Unclassified	22. PRICE

PA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE