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INDUSTRY PROFILE
FOR THE
PETROLEUM REFINERY NESHAP

DRAFT

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SECTION 1

INTRODUCTION

Section 112 of the Clean Air Act (CAA) lists source categories of major and area sources of hazardous air pollutants (HAPs) for which regulations must be developed. The U.S. Environmental Protection Agency (EPA) is currently preparing a National Emission Standard for Hazardous Air Pollutants (NESHAP) for emission sources in petroleum refineries. Before promulgating a NESHAP, it is necessary to perform an economic impact analysis on the affected industry.

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. Section 112 of the CAA contains a list of HAPs for which EPA has published a list of HAP source categories that must be regulated. Refinery HAP sources include fluid catalytic cracking units, catalytic reforming units, and sulfur plant units. None of these sources is currently controlled by existing NESHAPs. The subject NESHAP will therefore regulate emissions from these refinery sources.

PURPOSE OF THE INDUSTRY PROFILE

The primary purpose of this report is to present industry data requisite to performing an economic impact analysis of the petroleum refining industry. This industry profile will have several uses. First, it will define the current structure of the refining industry. Second, it will summarize information on production, supply, demand, pricing, foreign trade, and other industry characteristics. Third, it will highlight industry trends and factors that will be considered when the economic impact analysis is performed.

ORGANIZATION OF REPORT

The remaining sections in this report discuss different aspects of the refining industry. Section 2 presents an overview of the basic structure of the industry. Refineries are characterized by two measures: (1) crude oil distillation capacity, which measures the magnitude of the refinery production capability, and (2) plant complexity, which measures the potential product slate of each refinery. Section 2 also summarizes basic employment levels in the industry, levels of horizontal and vertical integration, diversification, and market concentration among refineries.

Section 3 provides some background on selected market characteristics, including product differentiation and the availability of substitutes. The market for foreign trade is also discussed in this section. Section 3 also summarizes the factors which affect petroleum product supply and demand. The effects of existing regulations on the current product slate and refinery capacity utilization characteristics are all discussed. Quantitative estimates of the price elasticities of supply and demand are also presented.

Section 4 presents historical industry data including trends in product supply and consumption, and price levels by petroleum product type. Section 4 also presents financial data for publically held firms operating refineries.

Section 5 discusses projections for supply, demand, and price level in the petroleum refining industry. A discussion is included on Clean Air Act programs and their potential effects on petroleum refiners.

Finally, the appendix to this report presents detailed, plant-level capacity and operating statistics for refineries operating in the United States.

SECTION 2

INDUSTRY STRUCTURE

The petroleum industry can be divided into five distinct sectors: exploration, production, refining, transportation, and marketing. This section reviews the products and processes of the refining sector of the industry and presents a basic refining industry profile that includes employment and geographical distribution.

PRODUCTS AND PROCESSES

Crude oil – unprocessed oil obtained directly from the ground – has limited uses. It is the refining process that transforms crude oil into numerous different petroleum products which have a variety of applications. 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. Table 2-1 gives an overview by Petroleum Administration for Defense Districts (PADDs), of the various refined petroleum products produced in the United States.[1]

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.

[1] The U.S. petroleum market is segmented into five regions called PADDs. These were established in the 1940s for the purpose of dividing the country into economically and geographically distinct regions. Much of the U.S. petroleum data is maintained by PADD.

Table 2-1

1995 PETROLEUM PRODUCT NET PRODUCTION
(1,000 barrels)

PADD							
Product	I	II	III	IV	V	Total U.S.	Percent of Total
Motor Gasoline	310,554	647,944	1,214,003	88,511	461,391	2,722,403	46.63
Distillate Fuel Oil	151,155	280,817	510,061	47,212	162,490	1,151,735	19.73
Jet Fuels	31,487	71,143	257,697	10,548	145,884	516,759	8.85
Residual Fuel Oil	56,121	22,394	123,782	3,714	81,590	287,601	4.93
Liquefied Refinery Gases	17,330	47,412	141,608	2,586	29,846	238,782	4.09
Still Gas	22,404	47,408	108,894	7,540	49,996	236,242	4.05
Petroleum Coke	17,849	47,498	105,698	5,078	53,832	229,955	3.94
Asphalt and Road Oil	31,375	66,818	41,666	12,683	17,852	170,394	2.92
Other Oils for Petrochemical Feedstock Use	90	8,419	76,445	244	3,462	88,660	1.52
Lubricants	6,279	8,238	39,654	0	9,519	63,690	1.09
Naphtha for Petrochem Feedstock Use	2,250	8,448	50,216	0	1,856	62,770	1.08
Kerosene	1,960	8,121	7,354	786	961	19,182	0.33
Special Naphthas	848	4,352	12,416	0	597	18,213	0.31
Miscellaneous Products	609	3,774	8,615	1,165	1,847	16,010	0.27
Aviation Gasoline	80	1,116	4,527	184	1,929	7,836	0.13
Waxes	1,679	886	4,249	70	829	7,713	0.13

Source: Petroleum Supply Annual 1995, Volume 1, Table 17.

U.S. REFINERY CHARACTERISTICS

It is important to note the distinction between refineries and firms. A *refinery* is an individual establishment or facility that processes crude oil, while a *firm* is a corporate entity that owns or operates several refineries. There are currently 175 operable petroleum refineries in the United States, controlled by 108 firms. (DOE, Energy Information Administration, 1994). 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. The Standard Industrial Classification (SIC) code for all petroleum refineries is 2911.

REFINERY CAPACITY AND COMPLEXITY

An economic impact analysis requires that plants in the industry be identified and classified by some production factor or other descriptive, quantifiable characteristic. This can be difficult in the case of petroleum refineries, because refineries have many different specialties, targeted product slates, and capabilities. Some refineries produce output only by processing crude oil through basic atmospheric distillation and have very little ability to alter their mix of product yields. These refineries are said to have low complexity. In contrast, refineries which have assorted downstream processing units can substantially vary their mix of product yields and have a higher level of complexity. Because of their different sizes and complexities, 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 a characteristic often used to categorize petroleum refineries in market analyses. (A detailed discussion of market characteristics, based on distillation capacity, will be presented in Section 4). Capacity may refer either to the number of barrels produced per *calendar* day, or to the number of barrels produced per *stream* day. Barrels per stream day denotes the amount that a unit can process while running at full capacity, under optimal crude oil and product slate conditions. Barrels per calendar day represents the maximum amount that is processed in a 24-hour period, after making allowances for downtime and other limitations. Barrels per calendar day is always less than or equal to barrels per stream day. Throughout this report, barrels per calendar day and barrels per stream day will be referred to as "barrels per day" (bbl/d). Any bbl/d data that is presented in a table will reflect consistent measurement within that table; barrel per calendar day data will not be compared to barrel per stream day data.

National refining production capacity as of January 1, 1995 is summarized by PADD and by state in Table 2-2.[2] Figure 2-1 shows the geographic breakdown for each PADD. 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 relatively little capacity. The availability of petroleum products in each PADD plays a role in the import/export characteristics of each region.

The geographical distribution of refining capacity is important for several reasons. Regional markets may differ due to the quality of crude supplied and regional product demand. 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.

[2] The appendix at the end of this report lists the production capacity for all firms and refineries in the petroleum refining industry. Consult this appendix for specific data on individual refineries.

Table 2-2

PRODUCTION CAPACITY OF OPERABLE PETROLEUM REFINERIES (JANUARY 1, 1995)

	Number of Operable Refineries			Atmospheric Crude Distillation Capacity					
				Barrels per Calander Day			Barrels per Stream Day		
	Total	Operable	Idle	Total	Operable	Idle	Total	Operable	Idle
PAD District I Totals	18	16	2	1,571,740	1,386,740	185,000	1,666,500	1,473,500	193,000
Delaware	1	1	0	140,000	140,000	0	152,000	152,000	0
Georgia	2	1	1	33,540	5,540	28,000	42,000	10,000	32,000
New Jersey	6	5	1	586,000	506,000	80,000	616,000	533,000	83,000
Pennsylvania	7	7	0	747,700	670,700	77,000	788,000	710,000	78,000
Virginia	1	1	0	53,000	53,000	0	56,000	56,000	0
West Virginia	1	1	0	11,500	11,500	0	12,500	12,500	0
PAD District II Totals	34	33	1	3,447,465	3,431,265	16,200	3,594,220	3,576,920	17,300
Illinois	7	7	0	1,001,765	1,001,765	0	1,054,000	1,054,000	0
Indiana	3	3	0	443,100	434,400	8,700	461,000	451,500	9,500
Kansas	4	4	0	294,800	294,800	0	305,700	305,700	0
Kentucky	2	2	0	218,900	218,900	0	226,300	226,300	0
Michigan	2	2	0	115,600	115,600	0	123,000	123,000	0
Minnesota	2	2	0	297,100	297,100	0	309,220	309,220	0
North Dakota	1	1	0	58,000	58,000	0	60,000	60,000	0
Ohio	4	4	0	488,000	488,000	0	501,000	501,000	0
Oklahoma	7	6	1	408,000	400,500	7,500	428,000	420,200	7,800
Tennessee	1	1	0	89,000	89,000	0	91,000	91,000	0
Wisconsin	1	1	0	33,200	33,200	0	35,000	35,000	0
PAD District III Totals	65	61	4	7,010,500	6,882,900	127,600	7,445,207	7,307,307	137,900
Alabama	3	3	0	121,000	121,000	0	127,000	127,000	0
Arkansas	3	3	0	63,900	63,900	0	66,000	66,000	0
Louisiana	20	19	1	2,384,150	2,356,550	27,600	2,487,500	2,457,500	30,000
Mississippi	5	4	1	342,800	334,800	8,000	392,900	384,000	8,900
New Mexico	3	3	0	94,600	94,600	0	99,107	99,107	0
Texas	31	29	2	4,004,050	3,912,050	92,000	4,272,700	4,173,700	99,000
PAD District IV Totals	15	15	0	507,675	507,675	0	535,700	535,700	0
Colorado	2	2	0	85,500	85,500	0	95,000	95,000	0
Montana	4	4	0	141,950	141,950	0	147,700	147,700	0
Utah	5	5	0	150,500	150,500	0	158,000	158,000	0
Wyoming	4	4	0	129,725	129,725	0	135,000	135,000	0
PAD District V Totals	43	40	3	2,896,900	2,873,100	23,800	3,084,604	3,059,350	25,254
Alaska	6	6	0	263,500	263,500	0	281,300	281,300	0
Arizona	1	0	1	3,800	0	3,800	4,000	0	4,000
California	25	24	1	1,910,300	1,902,200	8,100	2,044,050	2,035,550	8,500
Hawaii	2	2	0	147,500	147,500	0	152,000	152,000	0
Nevada	1	1	0	7,000	7,000	0	7,000	7,000	0
Oregon	1	1	0	0	0	0	0	0	0
Washington	7	6	1	564,800	552,900	11,900	596,254	583,500	12,754
U.S. Total	175	165	10	15,434,280	15,081,680	352,600	16,326,231	15,952,777	373,454

Table 2-2 (continued)

PRODUCTION CAPACITY OF OPERABLE PETROLEUM REFINERIES (JANUARY 1, 1995)

	Downstream Charge Capacity (barrels per stream day)							
	Vacuum Distillation	Thermal Cracking	Catalytic Cracking Fresh	Recycled	Catalytic Hydro-cracking	Catalytic Reforming	Catalytic Hydro-treating	Fuels Solvent Deasphalting
PAD District I Totals	724,450	44	645,500	18,200	90,440	331,920	926,100	0
Delaware	95000	45000	70000	5,000	18,000	54,000	123,000	0
Georgia	0	0	0	0	0	0	0	0
New Jersey	274200	24000	285000	11,000	17,000	77,500	300,500	0
Pennsylvania	320250	0	263000	200	51,000	185,220	470,800	0
Virginia	29000	14000	27500	2,000	0	11,500	27,800	0
West Virginia	6000	0	0	0	4,440	3,700	4,000	0
PAD District II Totals	1,423,300	396,500	1,267,800	36,800	152,190	919,100	2,444,300	30,200
Illinois	400450	116600	387000	3,000	66,500	299,700	668,700	0
Indiana	247200	30000	165000	4,200	0	96,500	313,300	0
Kansas	107150	52400	98800	3,000	3,190	79,700	248,500	0
Kentucky	92000	59500	100000	0	0	44,500	217,800	10,000
Michigan	38000	0	47000	1,000	0	30,000	98,300	0
Minnesota	192000	68000	99000	0	0	74,500	325,800	0
North Dakota	0	0	26000	3,600	0	12,100	19,100	0
Ohio	167000	40500	176000	17,000	77,500	162,600	196,500	10,000
Oklahoma	147000	29500	116000	5,000	5,000	96,500	289,500	10,200
Tennessee	12000	0	42000	0	0	15,000	52,000	0
Wisconsin	20500	0	11000	0	0	8,000	14,800	0
PAD District III Totals	3,337,695	1,006,000	2,643,400	84,700	631,800	1,861,600	5,269,750	143,500
Alabama	39000	12000	0	0	0	27,200	71,300	0
Arkansas	25420	0	19100	0	0	12,000	52,000	5,500
Louisiana	1233300	464000	903300	4,000	175,000	508,400	1,400,400	35,000
Mississippi	311875	75000	68000	0	71,000	96,000	258,700	0
New Mexico	19000	0	34500	4,500	0	30,800	63,300	0
Texas	1709100	455000	1618500	76,200	385,800	1,187,200	3,424,050	103,000
PAD District IV Totals	213,900	39,200	177,800	20,600	8,900	111,880	353,100	9,000
Colorado	35000	0	27500	1,000	0	19,500	45,000	0
Montana	62100	20700	55900	6,000	4,900	33,030	155,400	4,000
Utah	50300	8500	45400	7,600	4,000	29,600	62,500	5,000
Wyoming	66500	10000	49000	6,000	0	29,750	90,200	0
PAD District V Totals	1,549,050	598,500	848,500	9,000	502,950	642,850	1,923,000	68,000
Alaska	26000	0	0	0	9,050	12,000	12,000	0
Arizona	2000	0	0	0	0	0	0	0
California	1134050	507100	647800	2,000	419,900	478,850	1,574,400	50,000
Hawaii	74300	12400	22000	0	18,000	13,000	14,000	0
Nevada	6000	0	0	0	0	0	0	0
Oregon	15000	0	0	0	0	0	0	0
Washington	291700	79000	178700	7,000	56,000	139,000	322,600	18,000
U.S. Total	7,248,395	2,123,200	5,583,000	169,300	1,386,280	3,867,350	10,916,250	250,700

Source: Petroleum Supply Annual 1994, Table 36.

Figure 2-1

PETROLEUM ADMINISTRATION FOR DEFENSE (PAD) DISTRICTS

Table 2-3 shows the distribution of atmospheric distillation operating capacity among the 108 firms in the industry. This table divides firms into four groups of 27 firms each according to atmospheric distillation capacity. The top quarter, which contains the 27 firms with highest operation capacity, constitutes 79.6 percent of the total national capacity, with an average capacity of 454,907 bbl/d. As a group, the remaining 72 firms (the lower three-quarters of the industry) produce 20.4 percent of the total national operating capacity. Additional analysis of market concentration will be presented in the next section of this report.

Table 2-3

NATIONAL DISTRIBUTION BY ATMOSPHERIC DISTILLATION CAPACITY

	Number of Firms	Average Atmospheric Distillation Operating Capacity (bbl/d)	Total Operating Capacity (bbl/d)	Percentage of National Total
	27	454,907	12,282,500	79.6
	27	83,643	2,258,365	14.6
	27	26,623	718,825	4.7
	27	6,466	174,590	1.1
Total	108	142,910	15,434,280	100.0

Source: Petroleum Supply Annual 1994, Table 38.

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. Table 2-4 lists the processes and corresponding capacity factors used in this analysis. The complexity factors are arranged by four types of refining processes. 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 diversify product output, to improve yields of preferred products, or to process lower quality crude. 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 potentially less affected by regulation.

Tables 2-5 and 2-6 summarize the refinery complexity distribution for U.S. refineries as of January 1, 1995. To arrive at a value for complexity, a listing is made of all processing units, along with the capacity and complexity factor for each process. The contribution of each process to the total processing capacity is calculated by multiplying the complexity factor by the ratio of its process capacity to total atmospheric distillation capacity.

Table 2-4

COMPLEXITY FACTORS

Refinery Processes by Process Type	Complexity Factor
Separation Processes	
Atmospheric distillation	1.0
Vacuum distillation	2.0
Breakdown Processes	
Thermal cracking	3.0
Coking	5.5
Catalytic cracking	6.0
Hydrocracking	10.0
Change Processes	
Isomerization	3.0
Catalytic reforming	5.0
Buildup Processes	
Alkalization	11.0
Supporting Operations (Other)	
Catalytic hydrotreating	2.0
Hydrodesulfurization	7.0
Aeromatics	33.0
Lube oil manufacturing	44.0

Source: The Pace Company. Oil Industry Forecast (1982).

Table 2-5

1995 REFINERY COMPLEXITY DISTRIBUTION:
NUMBER OF REFINERIES

	Size Range (1,000 barrels per day)						
Complexity Range	0-10	10-30	30-50	50-100	100-175	175+	Total
Under 3	25	15	2	1	1	0	44
3-5	4	2	5	5	0	0	16
5-7	2	8	6	12	2	2	32
7-9	0	4	6	17	14	15	56
9-11	0	0	1	3	5	8	17
Over 11	0	1	0	3	5	3	12
Total refineries	31	30	20	41	27	28	177

Source: Calculated from Petroleum Supply Annual 1994 and The Pace Company (1982).

The following example illustrates how refinery complexity helps to differentiate between plants and explains the method used to derive complexity. Assume there are two refineries that must be compared. Both have a 100,000 bbl/d atmospheric distillation capacity. One has no downstream charge capacity, while the other has a downstream capacity of 15,000 bbl/d for thermal cracking and 30,000 bbl/d for catalytic reforming. An economic analysis that solely examines atmospheric distillation capacity would not distinguish between the two. However, an analysis that accounts for complexity would note the fundamental difference between the product slate of each.

The formula for complexity is:

$$\sum_{i=1}^{n} cf_i \left(\frac{Process_i\ Capacity}{Atmospheric\ Distillation\ Capacity} \right)$$

where: cf_i = the complexity factor from Table 2-3

$Process_i$ = the appropriate downstream process capacity

Table 2-6

1995 REFINERY COMPLEXITY DISTRIBUTION: OPERABLE CAPACITY

	Size Range (thousand barrels per day)							
Complexity Range	0-10	10-30	30-50	50-100	100-175	175+	Total Capacity	Percentage of Total
Under 3	116,240	250,900	80,000	80,000	128,200	0	655,340	4.2
3-5	27,250	50,000	209,850	352,000	0	0	639,100	4.1
5-7	7,000	168,400	247,870	891,750	350,000	486,500	2,151,520	13.8
7-9	0	73,555	271,050	1,172,915	1,905,600	3,854,400	7,277,520	46.8
9-11	0	0	44,000	198,000	671,900	2,132,000	3,045,900	19.6
Over 11	0	29,900	0	208,100	663,600	878,900	1,780,500	11.5
Total capacity	150,490	572,755	852,770	2,902,765	3,719,300	7,351,800	15,549,880	100.0
Percentage of total	1.0	3.7	5.5	18.7	23.9	47.2	100.0	

Source: Calculated from Petroleum Supply Annual 1994 and The Pace Company (1982).

Since the refinery with no downstream charge capacity is only capable of atmospheric distillation, its complexity by definition is 1.0. The second refinery's complexity is calculated using the formula from above as follows:

$$\textit{Complexity} = 1 + 3\left(\frac{15{,}000}{100{,}000}\right) + 5\left(\frac{30{,}000}{100{,}000}\right) = 2.95$$

Although neither refinery can be considered extremely complex, the second refinery, by virtue of its downstream cracking and reforming capabilities, has greater ability to alter its yield.

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 2-6 indicates, over 75 percent of the operable capacity (50,000 to 100,000 bbl/d) can be found at refineries with above-average complexity (above 7.0).

MARKET CONCENTRATION

Market concentration can be measured as 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. For example, at one extreme, a concentration of 100 percent would indicate monopoly control of the industry by one firm. Alternatively, a 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 (API, 1990). Concentration is measured based on refining capacity which is based on information developed from "Petroleum Supply Annual" data on operable refining capacity per calendar day (DOE, 1995a). Table 2-7 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. As Table 2-7 indicates, the market concentration for the top four firms in 1995 has decreased to under 27 percent.

In addition to standard units of measure, API uses the Herfindahl-Hirschman index to gauge market concentration. The Herfindahl-Hirschman index is defined as the sum of the squared market shares (expressed as a percentage) for all firms in the industry. If a monopoly existed (one firm with a market share of 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. The last row of Table 2-7 reports the Herfindal-Hirschman index for the petroleum refining industry. Since 1988, this index has been less than 500, indicating a relatively unconcentrated industry.

Table 2-7

CONCENTRATION IN REFINING CAPACITY

	Percentage of Market Concentration							
Refinery Industry Concentration	1980	1985	1986	1987	1988	1989	1990*	1995*
4-firm	29.0	34.4	33.2	32.2	32.3	31.6	31.4	26.7
8-firm	49.0	54.4	53.0	52.0	53.3	50.0	50.1	43.8
15-firm	67.0	73.0	71.6	70.5	72.8	68.9	67.7	61.6
20-firm	74.5	80.3	79.0	77.2	80.4	77.9	76.7	70.5
30-firm	82.3	88.8	87.9	86.3	89.0	88.2	87.0	82.3
Herfindahl-Hirschman Index	381.5	494.6	471.2	448.2	465.4	431.9	N/A	N/A

NOTES: * Calculated by Mathtech.
N/A Not available.
Source: Petroleum Supply Annual 1994, Volume I.

INDUSTRY INTEGRATION AND DIVERSIFICATION

Vertical and horizontal integration are measures of the control a firm has over the product and factor markets for its good or service. *Diversification* indicates the extent to which a firm has developed other revenue producing operations, in addition to petroleum refining.

Vertical Integration

Vertical integration exists when the same firm engages in several stages of the production and marketing process. Some firms that operate petroleum refineries are vertically integrated because they explore and produce crude oil (which supplies the input for refineries), and market finished petroleum products after refining. Firms that are vertically integrated could be indirectly affected by the NESHAP at several stages of production if the regulation results in reduced refinery throughput.

Major refineries are more likely to be *vertically integrated* than independents. A definition of major energy producers, *majors*, was originally developed by DOE's Energy Information Administration (EIA) in 1976. (DOE, 1991b). EIA requires all majors to provide financial information on Form EIA-28, which is incorporated into EIA's Financial Reporting System (FRS). Selection criteria for the original list of 27 publicly-owned majors included those firms which had either at least one percent of the production or the reserves of oil, gas, coal, or uranium, one percent of the refining capacity, or one percent of petroleum product sales. EIA's current list reflects mergers, acquisitions, and spinoffs from the original list. Table 2-8 lists 17 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 over 53 percent of nationwide production. Major firms in the petroleum industry are likely to be vertically integrated.

Table 2-8

MAJOR ENERGY FIRMS WITH REFINING CAPACITY
(January 1, 1995)

Company	Barrels per Calendar Day (Operating)	Percentage of National Total
Amerada Hess Corp.	0	0.0
Amoco Oil Co.	998,000	6.5
Ashland Oil Inc.	346,500	2.2
Chevron U.S.A. Inc.	1,206,000	7.8
Coastal	236,500	1.5
Conoco Inc.	438,000	2.8
Exxon Co. U.S.A.	992,000	6.4
Fina Oil & Chemical Co.	230,000	1.5
Kerr-McGee Refining Corp.	50,800	0.3
Marathon Oil Co.	570,000	3.7
Mobil Oil Corp.	929,000	6.0
Phillips 66 Co.	320,000	2.1
Shell Oil Co.	761,000	4.9
Sun Co. Inc.	385,000	2.5
Texaco Refining & Marketing Inc.	350,600	2.3
Total Petroleum Inc.	169,600	1.1
Unocal Corp.	220,700	1.4
Total	8,203,700	53.15

Source: Petroleum Supply Annual 1994.

We caution that, by definition, major refineries need not be vertically integrated. However, majors tend to be larger than independents, and accordingly, are more likely to engage in greater degree of vertical integration. In short, we use the distinction between majors and independents as an indicator of *tendency* to vertically integrate.

Horizontal Integration

Horizontal integration exists when a firm owns or operates several establishments within the same stage of the production process. Some oil companies are horizontally integrated because they operate several refineries, often distributed across different regions of the country. Horizontally integrated firms may be affected by emission regulations differently depending on the existing regulations in different regions. For example, some of a firm's facilities may be located in nonattainment areas and may therefore already have substantial emission controls in place, while facilities in attainment areas may be less stringently controlled.

Figure 2-2 shows the horizontal integration of the industry, portrayed by the number of refineries operated by each firm. Note that 75 of the 108 firms in the industry operate only one refinery. Typically these are the smaller independent firms. Major firms generally operate several refineries, and the largest, Chevron, operates 10. Nine firms operate four or more refineries.

Diversification

Diversification, or *conglomeration*, exists when firms produce a variety of unrelated products. Large diversified firms might find it easier to raise capital to purchase and install emission control equipment than smaller undiversified firms. However, firms will not subsidize petroleum product production with profit from other operations, but will close unprofitable operations instead.

REFINERY INDUSTRY EMPLOYMENT

Refinery industry employment data for 1995 are not currently available. The 1992 Census of Manufactures for petroleum and coal products lists the 1992 data for employment

Figure 2-2

HORIZONTAL INTEGRATION IN THE PETROLEUM REFINING INDUSTRY and number of establishments for SIC code 2911. (U.S. Department of Commerce, 1992 Census of Manufactures). The Census of Manufactures data are summarized in Table 2-9.

There is a discrepancy between the number of establishments reported in the Census of Manufactures for the petroleum refining industry and what DOE data reports. For 1992, the Census lists 232 establishments, while DOE includes 199. In Table 2-9, the number of establishments is adjusted by scaling the total number of refineries reported by DOE in 1992 by the percentage of establishments in each employment class reported in the Census of Manufactures.

According to the adjusted refinery data, approximately 4 percent of refinery employees work in plants of fewer than 100 people. The remaining 96 percent of the labor force in the industry work in establishments of 100 or more employees.

Table 2-9

EMPLOYMENT IN THE PETROLEUM REFINING INDUSTRY (1992)

Establishments with an average of:	All Establishments	Number of Refineries	Total Employees (1,000)	Percent of Total
1 to 4 employees	17	15	z	7.33
5 to 9 employees	7	6	z	3.02
10 to 19 employees	11	9	0.2	4.74
20 to 49 employees	35	30	1.2	15.09
50 to 99 employees	22	19	1.7	9.48
100 to 249 employees	45	39	8.0	19.40
250 to 499 employees	49	42	16.9	21.12
500 to 999 employees	26	22	18.1	11.21
1,000 to 2,499 employees	20	17	28.9	8.62
All establishments	232	199	75.0	100.00

Notes: z less than 100.
Source: U.S. Census of Manufacturers, 1992.

SECTION 3

MARKET CHARACTERISTICS

An economic impact analysis should consider the characteristics of markets in which petroleum products are traded. This section describes several market characteristics including product differentiation, availability of substitutes, and foreign trade. Also, this section describes the determinants of market supply and demand and discusses price elasticities.

PRODUCT DIFFERENTIATION

Product differentiation is a form of non-price competition used by firms to target or protect a specific market. Firms can distinguish their product from those of competing firms by adjusting the quality of the product, by advertising to develop a brand name, or by providing additional goods or services along with a product.

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. Petroleum products are by nature quite homogenous – there is little difference between premium gasoline produced at different refineries. This tends to limit the role that product differentiation plays in the market for refined petroleum products. How-ever, we do note that many major refineries spend considerable resources on product promotion through advertising focused on brand identification.

FOREIGN TRADE

Foreign producers may gain a competitive advantage if they are able to produce without any regulation while domestic production becomes and more costly because of emission controls. Foreign trade in petroleum products is substantial, as the data in Table 3-1 show. For example, U.S. imports average 1,605 thousand barrels per day in 1995. Exports averaged 942 thousand barrels per day during this year.

Table 3-1

U.S. PETROLEUM PRODUCT IMPORTS AND EXPORTS
(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	861	944	2.1
1993	1,833	1,006	827	1.8
1994	1,933	942	991	2.1
1995	1,605	942	949	1.7

Source: Petroleum Supply Annual 1995, Volume 1.

Table 3-2 shows the different levels of foreign trade in each PADD in 1995. PADD I is by far the region with the largest net imports – its imports, 328,947 thousand barrels, exceeded its exports of 13,481 thousand barrels. Conversely, PADD V was a net exporter of products during 1995.

Table 3-2

1995 IMPORTS AND EXPORTS OF PETROLEUM PRODUCTS BY PADD
(Thousand barrels)

PADD	Imports	Exports	Net Imports
I	328,947	13,481	315,466
II	30,055	10,104	19,951
III	194,700	185,738	8,962
IV	6,881	157	6,724
V	4,621	102,487	(97,866)
U.S. Total	565,204	296,908	253,237

Source: Petroleum Supply Annual, 1995, Volume 1.

Some measure of the extent of foreign competition can be obtained by comparing imports or exports against domestic consumption or production. Table 3-3 shows the percentage of imports that constitutes domestic consumption and the percentage of exports that constitutes domestic production. For example, in 1995, imports represented about 9.1 percent of domestic consumption. During the same year, U.S. producers exported about 5.3 percent of their output.

SUPPLY DETERMINANTS

In the short run, refineries face fixed capacity levels. They must then decide how much crude oil to allocate for the production of each of the refinery's products ranging from gasoline to jet and tanker fuel, kerosene, and asphalt. If the refinery is a profit maximizer, it will allocate crude across its product slate such that total refinery profit is maximized. If the refinery has perfect flexibility in adjusting its product slate, it will allocate a given amount of crude oil among its products such that the incremental profit each on the last barrel of each product is the same. Otherwise, the refinery could increase total profits by allocating less

Table 3-3

DEPENDENCY ON FOREIGN TRADE
(Million barrels per day)

Year	Imports	Domestic Petroleum Product Consumption	Exports	Domestic Refinery Output
1981	1.60	16.06	0.37	13.99
1982	1.63	15.30	0.58	13.39
1983	1.72	15.23	0.58	13.14
1984	2.01	15.73	0.54	13.68
1985	1.87	15.73	0.58	13.75
1986	2.05	16.28	0.63	14.52
1987	2.00	16.67	0.61	14.63
1988	2.30	17.28	0.66	15.02
1989	2.22	17.33	0.72	15.17
1990	2.12	17.33	0.75	15.26
1991	1.85	16.70	0.88	15.20
1992	1.81	17.03	0.86	15.30
1993	1.83	17.24	0.90	15.25
1994	1.93	17.72	0.84	15.26
1995	1.61	17.73	0.86	15.99

Source: Petroleum Supply Annual 1995, Volume 1.

crude to less incrementally profitable products and more crude to more incrementally profitable products. Furthermore, the optimal level of total crude used by the refinery will drive incremental profits to zero for each product. If this were not the case, the refinery could either increase or decrease its total use of crude and increase profits.

In practice, technological constraints limit the flexibility refineries have in adjusting their product slates. Nonetheless, the hypothetical case described above identifies the determinants of short-run supply. Specifically, the quantity of a given product (e.g., gasoline) that a refinery will supply at a given price (i.e., the price of gasoline) depends on the marginal cost of that product (i.e., the marginal cost of producing a barrel of gasoline) as well as the prices and marginal costs of all other products included in the refinery's slate.

In the long run, refineries have time to change capacity. They will increase capacity if expected future prices are sufficient to cover the cost of additional capacity as well as variable operating and maintenance costs. Accordingly, the long-run supply of refined products also depends on the incremental costs of expanding capacity. To the extent that the NESHAP increases the production costs of refined products, the decision to expand production capacity will depend on whether refineries can expect future prices to rise sufficiently to cover these additional costs associated with emission controls.

Refinery yields across product slates differ by region. As Table 3-4 shows, a percentage difference of 10 percent between PADDs is not uncommon. For example, the average yield of jet fuel in PADD V is over 16 percent, or 6 percent greater than any other PADD. PADD V seems to have the most unique product slate, with relatively little distillate fuel oil yield, and relatively high yields of residual fuel, jet fuels, petroleum coke and still gas. These regional differences in refinery yield are attributable to several factors, including local crude oil characteristics and regional petroleum product demand.

Capacity utilization rates of petroleum refineries have been rising in recent years, to a high of 92.6 percent in 1994 (DOE, 1994). This indicates that existing refineries are operating closer to full capacity, and will have less freedom to increase production by using existing capacity more intensively. If capacity utilization rates were low, domestic refineries could presumably increase utilization to increase the available supply. However, if utilization rates are high, then this option is not available, and further petroleum product supply will either need to be imported or new domestic refineries will have to be built. Table 3-5 shows operable capacity and capacity utilization by PADD since 1985. Note that operable capacity has remained relatively constant, while capacity utilization has risen steadily.

Table 3-4

REFINERY YIELDS BY PADD, 1995

Products	PADDs (percentage of total yield)				
	I	II	III	IV	V
Liquefied Refinery Gases	3.0	4.1	5.8	1.5	3.3
Finished Motor Gasoline	45.6	51.5	44.9	48.4	44.0
Finished Aviation Gasoline	0.2	0.1	0.2	0.1	0.2
Naphtha-Type Jet Fuel	0.0	0.0	0.0	1.5	0.0
Kerosene-Type Jet Fuel	5.4	6.1	10.5	4.8	16.1
Kerosene	0.3	0.7	0.3	0.5	0.1
Distillate Fuel Oil	25.9	24.0	20.7	28.2	17.9
Residual Fuel Oil	9.6	1.9	5.0	2.2	9.0
Naphtha for Petrochemical Feedstock Use	0.4	0.7	2.0	0.0	0.2
Other Oils for Petrochemical Feedstock Use	0.0	0.7	3.1	0.1	0.4
Special Naphthas	0.1	0.4	0.5	0.0	0.1
Lubricants	1.1	0.7	1.6	0.0	1.0
Waxes	0.3	0.1	0.2	0.0	0.1
Petroleum Coke	3.1	4.1	4.3	3.0	5.9
Asphalt and Road Oil	5.4	5.7	1.7	7.6	2.0
Still Gas	3.8	4.1	4.4	4.5	5.5
Miscellaneous Products	0.1	0.3	0.4	0.7	0.2
Processing Gain (-) or Loss (+)	−4.3	−5.1	−5.6	−3.4	−6.1

Source: Petroleum Supply Annual 1995, Volume 1.

Existing Federal, State and local regulations can affect the supply of petroleum products. Some refineries that are already regulated may have previously altered their production rates. The promulgation of a NESHAP may have additional effects upon supply however, so the burden placed on individual refineries as a result of regulations will vary. Those establishments already in ozone, carbon monoxide (CO), or particulate matter (PM_{10}) nonattainment areas may be only marginally effected by the NESHAP, due to the efficiency of existing controls. Conversely, existing controls cause these establishments to be operating at marginal profit levels, additional costs caused by the NESHAP could be especially burdensome.

Table 3-5

AVERAGE ANNUAL OPERABLE AND CAPACITY UTILIZATION RATES

Year/Element	PADD District I	II	III	IV	V	Total U.S.
1985						
Op. Capacity	1,538	3,367	7,199	558	3,010	15,671
% Utilization	75.4	81.5	77.2	77.6	75.6	77.6
1986						
Op. Capacity	1,456	3,296	7,106	534	3,065	15,459
% Utilization	84.3	85.9	83.5	81.0	78.2	82.9
1987						
Op. Capacity	1,450	3,282	7,174	535	3,202	15,642
% Utilization	86.6	86.9	82.5	81.7	79.1	83.1
1988						
Op. Capacity	1,464	3,302	7,449	537	3,176	15,927
% Utilization	88.5	88.7	81.8	84.7	84.2	84.4
1989						
Op. Capacity	1,452	3,267	7,377	552	3,054	15,701
% Utilization	87.2	89.2	84.2	83.4	88.4	86.3
1990						
Op. Capacity	1,505	3,307	7,165	555	3,091	15,624
% Utilization	83.5	92.0	85.6	83.4	87.9	87.1
1991						
Op. Capacity	1,492	3,338	7,235	551	3,092	15,707
% Utilization	81.3	92.3	83.7	83.9	87.1	86.0
1992						
Op. Capacity	1,520	3,379	7,136	510	2,914	15,460
% Utilization	81.5	92.7	86.0	86.4	90.6	87.9
1993						
Op. Capacity	1,541	3,381	6,789	518	2,914	15,143
% Utilization	88.0	95.0	92.1	87.4	88.5	91.5
1994						
Op. Capacity	1,526	3,324	6,905	508	2,886	15,150
% Utilization	89.3	97.8	92.5	91.1	89.0	92.6

Source: Petroleum Supply Annual 1995, 1994, 1993, 1992.

Although it is beyond the scope of this profile to review all State and local regulations, the following Federal regulations are important to note. There are four Control Technique Guidelines (CTG) documents which regulate VOC emissions from petroleum refinery sources.[1] The CTGs call for reasonably available control technology (RACT) on all existing VOC sources within an ozone nonattainment area. Also, NO_x RACT rules will be instituted soon in ozone nonattainment areas and in the ozone transport region. Currently 90 refineries, or 44 percent of the domestic total, are located in ozone nonattainment areas.

Other Federal regulations exist which affect refineries. New Source Performance Standards (NSPSs) exist for several refinery source categories, including fuel gas combustion devices, claus sulfur recovery plants, and fluid catalytic cracking unit catalyst regenerators. There are also NSPSs for industrial boilers used in petroleum refineries. Thirty-seven refineries are located in CO nonattainment areas and others (not quantified) are in PM_{10} nonattainment areas. Other NESHAPs, such as the currently existing NESHAP for benzene, may already affect refineries.

It is possible that existing State or local regulations are more stringent than the proposed NESHAP. California's South Coast Air Quality Management District (SCAQMD) mandates control of reactive organic gases (ROG) from petroleum refinery flares and bulk terminals.[2] Based on California's past record of strict regulation (31 of the 32 refineries in California are in ozone nonattainment areas), it is possible that a NESHAP would impose very little additional cost on existing refineries in that State.

In a recent survey performed for DOE, refiners indicated that compliance with new regulations of air emissions is expected to be feasible, although the lack of coordination among different regulatory agencies may hinder companies in some regions (Cambridge Energy Research, 1992). Additionally, other requirements of the CAA may affect the refining industry. Title II requirements for the development of

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[1] USEPA - 450/2-77-036; USEPA - 450/2-77-025; USEPA - 450/2-78-047; USEPA - 450/2-78-036.

[2] California South Coast Air Quality Management District. Final Air Quality Management Plan, 1991 Revision, Appendix IV-A, July 1991.

reformulated motor gasoline blends and oxygenated fuels are a specific concern. These issues will be addressed in detail in later in this report.

MARKET DEMAND DETERMINANTS

Generally, the demand for refined petroleum products is determined by price levels, economic growth trends, and weather conditions. Prices of refined petroleum products affect the willingness of consumers to choose petroleum over other fuels. Other things being the same, an increase in the price of a product reduces the quantity demanded on that product. For example, 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. Also, prices of substitutes affect the demand for petroleum; all else the same, higher prices of substitute goods increase the demand for refined products. Also, demand tends to grow with economic expansion and weather extremes.

Figure 3-1 shows a 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. Together, these 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 is the output from petroleum refineries which will be most affected by the CAA. The industrial sector constitutes the second highest percentage of demand for petroleum products, followed by residential and electric utility demands.

Figure 3-1

PETROLEUM CONSUMPTION BY END-USE SECTOR

Source: U.S. Department of Energy, 1991a.

In the residential sector, demand for home heating is affected by weather and climate. Of course, regional temperature differences determine the degree to which buildings and houses are insulated. 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 a short-run response, while changing to more energy-efficient appliances or fuels are long-run responses.

In the industrial sector, fuel oil competes with natural gas and coal for the boiler-feed market. High petroleum prices relative to other fuels tend to encourage fuel-switching, especially at electric utilities and in industrial plants having dual-fired boilers. Generally, 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 (Bonner and Moore, 1982). 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 (DOE, 1992).

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. A decline in total petroleum product demand for the years 1989 to 1991, for example, is attributable in part to a slowdown in domestic economic activity and in part to moderate fuel efficiency gains (Hinton, 1992).

The demand for most types of petroleum products, particularly in the residential sector, is affected by weather. As noted earlier, consumer demand for home heating oil is partly a function of the temperature and humidity levels. Weather extremes increase petroleum demand for heating and air-conditioning. In past years, petroleum refineries have realized reduced profits because mild winters have reduced residential fuel demand. Demand for transportation fuels is also determined by the weather, peaking in the summer months as vehicle miles traveled typically increase. However, the effects of weather conditions on the demand for petroleum products are typically cyclical and short-term.

The demand for petroleum products is also affected by international developments. For example, after the Iraqi invasion of Kuwait in August 1991, the demand for jet fuel increased as troops and supplies were transported from the United States to the Middle East. This increase in military demand was offset partially by reduced international air travel.

ELASTICITIES OF SUPPLY AND DEMAND

Supply Elasticity

As stated earlier in this section, prices of petroleum products affect the quantities supplied by the industry. There is a direct relationship between price and quantity supplied; as the price of a product falls, quantity supplied will decrease. To determine the extent to which suppliers will respond to increased compliance costs, one issue to be examined is the extent to which producers can "pass through" increased costs to consumers. The effect of emission control costs on product prices depends on the price elasticities of both supply and demand.

The degree to which quantity supplied is responsive to a change in price is measured by the price elasticity of supply. By definition, the price elasticity of supply is the percentage change in quantity supplied that results from a one percent increase in price. Supply becomes more elastic (i.e., more responsive to price changes) as the percentage change in quantity supplied increases. For a given demand curve, more elastic supply will result in a larger share of emission control costs being shifted to buyers through higher product prices. In the short run, supply elasticity is largely determined by the incremental costs of additional production. Short-run supply will be relatively elastic if incremental production costs rise slowly. This will more likely be the case when excess capacity exists in the industry.

In the long run, supply elasticity is determined by the costs of additional capacity. Long-run supply will be relatively elastic if additional units of capacity result in just small increases in per barrel production costs.

A literature search of private firms, DOE/EIA, universities, and research laboratories was conducted to identify any existing quantitative estimates of supply elasticities. Unfortunately, no estimates of supply elasticities were obtained.

DEMAND ELASTICITIES

The degree to which emission control costs will lead to higher price levels for refined petroleum products depends upon the responsiveness of consumers to changes in price. Demand price elasticity is a measure of buyers' sensitivity to price changes. It is defined as the percentage change in the quantity of a good demanded per one percent change in price. Demand is more elastic (inelastic) the larger (smaller) the absolute percentage change in quantity demanded in response to a given percentage change in price.

Other things being the same, more inelastic demand results in a larger share of compliance costs being passed on to buyers in the form of higher prices. Also, other things being the same, a good that has few good substitutes will have more inelastic demand than a good for which many good substitutes are available.

Demand elasticities can be measured both in the short-run and the long-run. Demand tends to be more inelastic in the short run because buyers options for adjusting to higher prices are limited. Over time, however, demand tends to become more elastic as buyers have more time to adjust to price changes (e.g., by finding or developing substitutes). In short, the total response to a price change increases as the time allowed for behavioral adjustments increases.

We conducted a literature search of private firms, DOE/EIA, universities, and research laboratories to identify existing estimates of the price elasticities of demand for different refined petroleum products. We found numerous estimates of demand elasticities for motor gasoline, but relatively few for jet fuel and distillate oil. Lack of available data was the most common reason cited for this scarcity. Nonetheless, estimates of demand elasticities for gasoline, jet fuel, and residual and distillate fuel are available.

The main source of data is a 1981 study conducted by DOE which surveyed existing price elasticity analyses for gasoline and other petroleum products (DOE, 1981). The most comprehensive source of demand elasticities for distillate and residual fuel is a study by Bohi and Zimmerman which compiled the results of various demand studies (Bohi and Zimmerman, 1984). A study of demand elasticities for jet fuel was conducted by Dermot Gately, of New York University's Department of Economics (Gately, 1968). An energy model developed by DRI/McGraw-Hill, Inc. reports price elasticities of demand for motor gasoline (Gibbons, 1989).

The studies that we reviewed all used historical data to estimate demand elasticities, and most controlled for variations in non-price determinants of demand. As might be expected, there are disparities among the estimates reported in the literature. From the evidence that Bohi and Zimmerman examined, the level of aggregation of the data appears to be the single most important factor that accounts for variations in results among the studies. The specification of the demand functions (including the demand determinants included in the functions), the level of aggregation, and the time periods all vary by model and account for the disparity among estimates. Because price sensitivity depends on the particular petroleum product and the specific application for which the petroleum is used, the range of estimates compiled here are organized by petroleum product. The estimates are reported in a table at the end of this section.

Motor Gasoline

Bohi and Zimmerman report estimates of price elasticity of demand for gasoline centering around -0.43.

DRI developed its Energy Model to forecast vehicle demand for oil (Gibbons, 1989). In doing so, DRI developed a structure to analyze the primary determinants of fuel use within specific vehicle categories. Their model is based on the notion that the demand for motor fuels is derived primarily from the demand for travel and consumers' preferences for particular vehicles. The model takes into account that the decision to buy a vehicle is based on the current macroeconomic environment, as well as the price of fuels. In general, the higher the price level of gasoline, the greater the incentive on the part of consumers to opt for more fuel-efficient vehicles. DRI reports different demand elasticities for motor gasoline, depending on the type of vehicle using the fuel. For light trucks, they report an estimate of −0.026; for automobiles, −0.064; for medium trucks, −0.0288; and for heavy trucks, −0.0227.

DOE reports elasticity estimates for motor gasoline ranging from -0.1 to -0.3. These estimates are consistent with the estimates described above in that they suggest that the demand for gasoline is relatively inelastic.

Jet Fuel

Relatively few studies report estimates of demand elasticities for jet fuel. The effect of an increase in fuel costs on the airline industry depends on the ability of airlines either to cut fuel usage (by decreasing weight (carrying less fuel) and reducing speed) or to pass higher costs on to customers. Therefore, the price elasticity of demand for jet fuel depends both on the ability to conserve fuel and on the demand for travel.

Jet fuel demand has grown 46.5 percent since 1982 as air travel has increased and fuel efficiency has improved (DOE, 1991c). Historical data indicate that the demand for jet fuel is affected by changes in price. For example, as shown in Table 3-6, jet fuel consumption fell when real jet fuel prices rose substantially between 1979 and 1982.

Table 3-6

GROWTH RATES FOR JET FUEL DEMAND

Time Periods	Average Annual Growth Rates (%) Fuel Consumption
1965-1969	13.34
1969-1976	0.00
1976-1979	2.94
1979-1982	-2.21
1982-1986	6.51

Source: Dermot Gately (1988). *Taking Off: The U.S. Demand for Air Travel and Jet Fuel.* The Energy Journal. Vol. 9, No. 4.

Gately (1988) examines the extent to which changes in jet fuel prices affected demand and reports an estimated short-run demand elasticity for jet fuel of -0.10. (This is similar to the findings of some other authors who used earlier data, although there have also been higher estimates.) Also, Gately finds that price elasticity increases in absolute value with distance. We note, however, that however, Gately uses data that are highly aggregated across destinations, distances, and trip purposes.

Pindyck and Rubinfeld (1989) report estimates of short-run elasticities for jet fuel ranging from 0.0 to -0.15. These estimates suggests that demand for jet fuel as an input to the production of airline flight-miles is relatively inelastic. This conclusion is consistent with the estimates reported by Gately.

Distillate and Residual Fuel

There are few studies of commercial and industrial energy demand, and those available are hampered by the lack of detailed information on the way in which energy is used in these sectors. For example, data on residential consumption of fuel oil do not distinguish among consuming sectors, making it difficult to obtain reliable estimates of residential demand behavior. The only residential fuel oil study reviewed by Bohi and Zimmerman (1984) estimated demand from State-level data and reported a short-run price elasticity of demand of -0.18 to -0.19.

As noted above, the paucity of data on commercial and industrial energy consumption limited the studies of these sectors. Models use aggregate-level data, which are drawn from diverse sample populations. DOE reports estimated long-run price elasticities of -0.5 and -0.7 for wholesale purchases of both residual and distillate oil by commercial and industrial users.

Demand for fuel by electric utilities generally varies by location. For example, demand is more elastic for those areas having with the greatest proportion of dual-fired capacity, while the lower elasticity estimates are found in regions where a single fuel represents a high proportion of total fuel costs. Bohi and Zimmerman report price elasticity of demand estimates for industrial fuel oil ranging from -0.23 to -1.57.

DOE's estimates are taken from DOE/EIA's demand models whose results are published in *Short-Term Energy Outlook* (DOE, 1980). For distillate fuel consumption, there are limits in the short run as to the amounts of possible efficiency increases, decreased fuel utilization rates, and fuel switching that are required to achieve lower consumption as real prices increase. For long-term price elasticities, DOE/EIA uses several different models with different parameters. The ranges of price elasticities generated by these models for each fuel type are listed in Table 3-7. In all sectors and for all fuel types, the demand for petroleum products appears quite inelastic, particularly in the short run.

Summary of Demand Elasticities

Table 3-7 lists short-run and long-run demand elasticity estimates byr petroleum product and by sector (residential, commercial, industrial, and transportation). Bohi and Zimmerman presented their interpretation of the consensus estimates of price elasticities by fuel type and consuming sector, based on the studies they examined. Cases are labeled uncertain if there are not enough independent estimates on which to base a conclusion, or the range of estimates is so wide that the elasticity must be considered uncertain. Generally, long-run estimates show more variation than short-run estimates. Short-run elasticities for all petroleum products ranged from -0.1 to -0.4 in DOE's summary report.

These results indicate that the demand for gasoline is less elastic than the demand for other petroleum products. For non-transportation uses, the demand for distillate and other petroleum products is fairly price-inelastic in the short run, and perhaps slightly elastic in the long run. Generally, most available evidence indicates that the demand for petroleum products is relatively inelastic in the short run.

Table 3-7

PRICE ELASTICITIES OF DEMAND FOR PETROLEUM PRODUCTS

Data Source	Fuel Sector/Type	Short-Run Elasticity Range	Long-Run Elasticity Range
DOE's literature review	Sector:		
	Residential	-0.10 to -0.40	-0.50 to -1.10
	Commercial	-0.10 to -0.40	-0.50 to -1.10
	Industrial	-0.10 to -0.40	-0.60 to -2.80
	Transportation	-0.10 to -0.30	-0.30 to -0.90
DOE's *Short-Term Energy Outlook (STEO)**	Fuel Type:		
	Distillate	-0.43	-0.50 to -0.99
	Motor Gasoline	-0.16	-0.55 to -0.82
	Residual -		
	Nonutility	-0.19	-0.61 to -0.74
	Utility	-0.53	-0.61 to -0.74
Bohi and Zimmerman	Sector:		
	Residential	-0.18 to -0.19	uncertain
	Commercial	-0.20 to -1.5	uncertain
	Industrial	-0.23 to -1.57	uncertain
	Transportation	-0.43	0.7
Gately, NYU	Jet Fuel	-0.10	–**
Pindyck and Rubinfeld	Jet Fuel	0 to -0.15	–
DRI/McGraw-Hill, Inc.	Gasoline:		
	Automobiles	-0.064	–
	Light Trucks	-0.026	–
	Medium Trucks	-0.029	–
	Heavy Trucks	-0.023	–

Notes: *Long-run elasticity estimates are presented as a range over all STEO models.

**Source did not estimate long-run elasticity.

SECTION 4

HISTORICAL DATA

This section presents historical supply and consumption trends by petroleum product and financial data for firms in the industry.

PAST AND PRESENT SUPPLY AND CONSUMPTION

Domestic supply is comprised of domestic production, imports, and stock draw-off, less exports and stock additions. By definition, this measure is also equal to domestic consumption. Table 4-1 shows petroleum product supply and its components since 1980. Historically, motor gasoline has been the product that comprises the largest share of total supply. Table 4-2 lists the percentage of refinery yield of different petroleum products from 1991 through 1995. The data show that the yields for most products has been relatively stable, but significant regulatory costs could cause some reshuffling of the product slate.

The supply of residual fuel oil has decreased steadily since 1980. This decrease in residual fuel supply reflects a move in the industry from heavier fuels toward lighter, more refined versions. This trend is expected to continue into the future as efforts to control air emissions go into effect. All other types of fuel show increases in use, including 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 (Gately, 1988). All major petroleum products registered lower demand in 1991 than in 1990, except liquified petroleum gas. This was the first time since 1980 that demand for all major petroleum products fell simultaneously in the same year. In 1991, decreased demand was brought on by warmer winter temperatures, an economic slowdown, and higher prices resulting from the Persian Gulf situation (DOE, 1991c).

Table 4-1

U.S. PETROLEUM PRODUCTS SUPPLIED, 1980-1995

(Million barrels per day)

Year	Motor Gasoline	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
1993	7.48	1.47	3.04	1.08	1.73	2.43	17.23
1994	7.60	1.53	3.16	1.02	1.88	2.52	17.71
1995	7.79	1.51	3.21	0.85	1.90	2.46	17.72

Source: Petroleum Supply Annual, 1995, 1994, 1993, 1992.

Table 4-2

REFINERY YIELDS, 1991-1995

Products	1991	1992	1993	1994	1995
	(percentage of total yield)				
Liquefied Refinery Gases	3.8	4.3	4.1	4.2	4.5
Finished Motor Gasoline	45.7	46.0	46.1	45.5	46.4
Finished Aviation Gasoline	0.2	0.2	0.2	0.2	0.2
Naphtha-Type Jet Fuel	1.2	1.0	0.8	0.3	0.1
Kerosene-Type Jet Fuel	9.1	8.9	9.2	9.8	9.7
Kerosene	0.3	0.3	0.3	0.4	0.4
Distillate Fuel Oil	21.3	21.2	21.9	22.3	21.8
Residual Fuel Oil	7.0	6.4	5.8	5.7	5.4
Naphtha for Petrochemical Feedstock Use	0.9	1.2	1.0	1.1	1.2
Other Oils for Petrochemical Feedstock Use	2.0	2.1	2.0	1.8	1.7
Special Naphthas	0.4	0.4	0.4	0.4	0.3
Lubricants	1.1	1.1	1.1	1.2	1.2
Waxes	0.1	0.1	0.1	0.1	0.1
Petroleum Coke	4.1	4.2	4.3	4.3	4.3
Asphalt and Road Oil	3.0	3.0	3.2	3.1	3.2
Still Gas	4.7	4.7	4.6	4.6	4.5
Miscellaneous Products	0.5	0.3	0.3	0.3	0.3
Processing Gain (-) or Loss (+)	−5.1	−5.5	−5.4	−5.3	−5.3

Source: Petroleum Supply Annual, 1995, 1994, 1993, 1992, 1991.

FINANCIAL DATA

Firms affected by air quality regulations often must invest in emission control equipment and incur other capital costs in order to comply with the standards. The ability of affected firms to raise capital for these investments depends on their financial positions. Below, we present recent historical data on two key financial ratios, the ratio of net income to assets and the ratio of long-term debt to long-term debt plus equity. The former ratio is a measure of return on investment. The latter ratio is a measure of potential risk faced by creditors or equity holders supplying capital to affected firms.

Firm specific financial data are needed to analyze the impact of the proposed regulations on firm profitability and to provide insight about the ability of firms to raise capital to finance the investment in emission control equipment. Below, we present financial data for publically held firms operating petroleum refineries. The 18 firms included in the sample operated 65 refineries representing 54.4 percent of the industry's total refining capacity in 1995. Note that all financial data are reported at the firm level and therefore do not isolate the contribution of petroleum refining to a company's financial status.[1]

Table 4-3 reports financial statistics for the publically held firms. Three year (1993-1995) historical net income and asset figures are reported as well as recent (1995) stockholder equity and long term debt. Because changes in the long-term debt ratio represent actual structural changes, the most recent available data are presented.

Table 4-4 reports the ratio of net income to assets and long-term debt to long-term debt plus equity for the 18 publically held firms operating petroleum refineries. To reduce the effect of business cycles and short-term perturbations, the profitability ratios found in Table 4-4 are three-year averages

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[1] We note that firm-level financial data do not pose an issue for conducting a financial analysis of the impacts of proposed NESHAPs. The purpose of this analysis is to assess the ability of affected firms to raise the capital required to finance investments required to achieve compliance. The financial resources available to the firm (not the refinery) will determine ability to raise capital.

computed over the 1993-1995 period. We caution that the firm-specific data reported in Tables 4-3 and 4-4 might not be representative of all firms in the petroleum refining industry. Specifically, financial data are more likely to be available for publically-held firms which may have greater financial resources than firms that are not publically held.

Table 4-3

FINANCIAL STATISTICS FOR PUBLICALLY HELD FIRMS
OPERATING REFINERIES
($ million)

Company	NET INCOME			ASSETS			Long-term Debt	EQUITY
Year	1995	1994	1993	1995	1994	1993	1995	1995
Amerada Hess Corp	394.4	73.7	268.2	7,756.4	8,337.9	8,641.5	2,523.2	2,660.4
Amoco Oil Co.	1,862.0	1,789.0	1,820.0	29,845.0	29,316.0	28,486.0	3,962.0	14,848.0
Ashland Oil Inc.	24.0	197.0	142.2	6,992.0	5,815.0	5,551.8	1,828.0	1,655.0
Chevron U.S.A. Inc.	930.0	1,693.0	1,265.0	34,330.0	34,407.0	34,736.0	4,664.0	14,355.0
Coastal	270.4	232.6	115.8	10,658.8	10,534.6	10,227.1	3,790.2	2,678.8
Conoco Inc. (DuPont)	3,293.0	2,727.0	555.0	37,312.0	36,892.0	37,053.0	5,678.0	8,436.0
Diamond Shamrock	47.3	75.8	18.4	2,245.4	1,620.8	1,349.2	957.5	624.7
Exxon Co. U.S.A.	6,470.0	5,100.0	5,280.0	17,318.0	16,460.0	14,859.0	7,778.0	40,436.0
Fina Oil & Chemical Co.	104.4	102.0	70.4	2,487.7	2,493.9	2,511.4	530.6	1,178.1
Kerr-McGee Refining Corp.	31.0	90.0	77.0	3,232.0	3,698.0	3,547.0	632.0	1,416.0
Marathon Oil Co. (USX Corp.)	88.0	321.0	29.0	10,109.0	10,951.0	10,822.0	3,367.0	2,872.0
Mobil Oil Corp.	2,376.0	1,079.0	2,084.0	42,138.0	41,542.0	40,733.0	4,629.0	17,951.0
Murphy Oil	118.6	106.6	102.1	2,119.1	2,312.0	2,168.9	204.6	1,101.1
Phillips 66 Co.	469.0	484.0	243.0	11,978.0	11,453.0	11,035.0	3,097.0	3,188.0
Shell Oil Co.	1,520.0	508.0	781.0	27,021.0	26,379.0	26,851.0	1,301.0	13,853.0
Sun Co Inc.	140.0	90.0	288.0	5,184.0	6,465.0	5,900.0	888.0	1,699.0
Texaco Refining & Marketing Inc.	607.0	910.0	1,068.0	24,937.0	25,505.0	26,626.0	5,503.0	9,519.0
Unocal Corp.	260.0	153.0	213.0	9,891.0	9,337.0	9,706.0	3,698.0	2,930.0

Source: Moody's Industrial Manual, 1995.

Table 4-4

FINANCIAL RATIOS FOR PUBLICALLY HELD FIRMS OPERATING REFINERIES

COMPANY	NI/A[a] (Percent)	LTD/(LTD+E)[b] (Percent)
Amerada Hess Corp	2.98	48.68
Amoco Oil Co.	4.78	21.06
Ashland Oil Inc.	2.91	52.48
Chevron U.S.A. Inc.	3.76	24.52
Coastal	1.97	58.59
Conoco Inc. (DuPont)	7.00	40.23
Diamond Shamrock	2.71	60.52
Exxon Co. U.S.A.	34.64	16.13
Fina Oil & Chemical Co.	3.69	31.05
Kerr-McGee Refining Corp.	1.89	30.86
Marathon Oil Co. (USX Corp.)	1.37	53.97
Mobil Oil Corp.	3.88	20.50
Murphy Oil	4.96	15.67
Phillips 66 Co.	3.00	49.28
Shell Oil Co.	2.80	8.59
Sun Co Inc.	-0.17	34.33
Texaco Refining & Marketing Inc.	3.35	36.63
Unocal Corp.	2.18	55.79

Notes: [a] Average ratio of net income to assets, 1993 through 1995.

[b] Ratio of long-term debt to long-term debt plus equity, 1995.

Source: Computed from data in Moody's Industrial Manual, 1995.

SECTION 5

MARKET OUTLOOK

This section describes the market outlook for the petroleum refining industry. First, we discuss factors affecting future market supply. We then examine the outlook for demand or consumption of refined products. Finally, we describe expected future trends in refined product prices. Much of the discussion in this section relies on DOE's Annual Energy Outlook for 1996 (AEO96) Forecast.

SUPPLY OUTLOOK

Exogenous factors that increase the cost of refining products will affect the future market supply in the petroleum market. Below, we discuss the outlook of two of the most important of these, clean air regulations and the price of crude oil. Also, we describe future expected additions to refining capacity which will affect both the amount and mix of products that can be refined. We note that additions to capacity are endogenous in that they are determined by expected future prices of refined products.

Clean Air Act Requirements

While several air quality regulations are likely to affect the refining industry in the future, the reformulated gasoline program is expected to receive the most attention. Reformulated gasoline has been mandated in several areas of the country since 1995. Beginning in 1998, reformulated gasoline must comply with EPA's "complex model" which requires reductions in several emissions. Additional emission reductions will be required by 2000. Also, traditional gasoline must meet an "anti-dumping" requirement in that it must burn as cleanly as 1990 gasoline. DOE expects the complex model and anti-dumping requirements to add 3 to 5 cents to the per-gallon price of gasoline by 2000 (DOE, 1996b).

Producing larger amounts of reformulated gasoline will require substantial changes to refinery operations, such as modifying operations of existing units and adding new refining capacity. The extent to which this program will affect the future supply of refined petroleum products will depend in part on the opportunities that EPA grants other ozone nonattainment areas to opt-in to the program.

Reformulated gasoline requirements initially apply only to the nine ozone nonattainment areas with the highest ozone design values during the period from 1987 to 1989. Any other ozone nonattainment area can opt-in to the program at the request of the governor of the State in which it is located. EPA may delay the opt-in of some States by up to 3 years if, after consultation with DOE, it determines that there is insufficient domestic capacity to produce the reformulated gasoline needed to supply opt-in areas. EPA data show 87 ozone nonattainment areas that are eligible to opt-in to this program (Federal Register, 1991).

Costs associated with this program include costs for the addition of oxygenates, the control of benzene, aromatics, sulfur, (RVP) levels, and other parameters that refiners may adjust to meet program requirements. Cambridge Energy Research Associates (CERA) concluded that the 1995 reformulated gasoline requirements do not appear to pose significant technical problems to the industry, although the percentage of production that refiners plan to reformulate varied widely based on their market position and perception of future opt-ins (CERA, 1992). The annual nationwide costs for reformulated gasoline in ozone nonattainment areas are a direct function of the amount of fuel consumed in the areas requiring its use. Nationwide costs will also depend upon the extent to which nonattainment areas opt-in to the program.

The Federal alternative fuel programs include provisions for fleet clean fuels in 21 ozone/CO nonattainment areas and the California general vehicle clean fuels program. The general vehicle clean fuels program, if successful in California, may be broadened to include other States. This program could have long-range effects on motor gasoline demand and, subsequently, on petroleum refining. The State of California's motor vehicle control program is more likely to affect refineries than the Federal alternative fuels programs. Low emission vehicle standards have been adopted in California that could be met with any combination of technologies and fuels; vehicle manufacturers will ultimately determine the technologies and fuels that will be used to meet these standards.

It is difficult to predict the impact of the clean fuels program on the U.S. supply of refined petroleum products, given the uncertainty as to whether California's program will be adopted in areas other than where it is mandated. For example, if only selected areas of the country will be required to use alternative fuels, refiners will be forced to alter their production and distribution based on regional markets. Projections of the ability of petroleum refiners to provide a supply of clean fuels are not available.

Overall, refineries are projecting large capital investments over the next decade to comply with the CAA programs. Recognizing the possibility that other markets may be permitted to opt-in to the reformulated gasoline program, several firms are projecting capital investment to prepare their refineries to produce as much reformulated gasoline as possible, even if they do not directly supply gasoline to any of the nine worst ozone nonattainment areas. Other firms, particularly smaller refineries, have postponed any firm capital investment plans pending final decisions on the number of States which will opt-in to the program.

To meet the new regulations, domestic refiners will be likely to either modify existing facilities or expand downstream operations. For example, more ether, isomerization, and alkylation units will be necessary to produce gasoline components. Additional hydroprocessing and hydrocracking units will need to be added to convert unfinished oils into lighter, cleaner hydrocarbons (DOE, 1996b).

One obstacle common to each of these new regulations is the need for the refining industry to develop expanded storage and distribution systems for the new fuels. For example, reformulated gasoline will need to be stored in separate storage tanks, as will low- and high-sulfur diesel fuels. One possibility is that refineries could use existing storage tanks to hold higher RVP fuels. Oxygenates, which are difficult to transport through existing U.S. pipeline systems, will also need to be stored in tanks.

World Crude Oil Prices

Changes in crude oil prices significantly affect the costs of refined products. For example, DOE estimates that crude oil costs of gasoline were less than 40 cents per gallon in 1994. However, because of higher crude prices, DOE predicts that, by 2015, the crude oil content of gasoline will increase to about 60 cents (DOE, 1996b).

DOE's AEO96 forecasts world crude prices out to 2015 for a reference (baseline), for high and low economic growth scenarios. The average annual percentage increases in crude oil prices for the three forecast scenarios are:

- Reference case – 2.4 percent.
- High economic growth – 2.7 percent.
- Low economic growth – 2.1 percent (DOE, 1996b).

DOE expects domestic crude oil production to decline through 2005, but to increase after than as accumulating technological advances and rising prices stimulate faster crude recovery. They predict that onshore production will decrease at an average annual rate of 1.7 percent over the 1994-2005 period, then increase at a rate of 1.3 percent annually through 2015. Offshore production is expected to decline at an average rate of approximately 0.7 percent throughout the forecast period. Crude output from Alaska is expected to decline at an average annual rate of 3.5 percent between 1994 and 2015. However, increased domestic production from enhanced oil recovery is expected to slow the overall downward trend (DOE, 1996b).

Refining Capacity

DOE projects refinery capacity will grow by 2015, ranging from 0.9 million barrels per day in the low economic growth case to 2.0 million barrels per day in the high growth case. The economic growth scenarios reflect different assumptions about petroleum consumption and refined product imports, which in turn, drive the capacity projections. DOE expects that refineries will continue to be used intensively, at 90 to 94 percent of capacity. These rates are comparable to recent utilization rates, but higher than those observed in the 1980s and early 1990s. DOE expects current and future investments in equipment for desulfurization, alkylation, isomerization, coking, and other processes will allow U.S. refineries to process lower quality crude oils in the future. The ability to do so will become increasingly important as higher quality crude reserves are depleted over time (DOE, 1996b).

However, DOE does not expect the growth in domestic refining capacity to keep pace with consumption. As a result, they expect increases in net imports of refined products. Depending on the economic growth scenario, they predict growth in refined product imports ranging between 0.6 and 3.0 million barrels per day by 2015 (DOE, 1996b).

DEMAND OUTLOOK

Short-run fluctuations in the demand for refined petroleum products depend largely on variations in weather, but long-run changes in future demand are primarily determined by economic growth and technological changes that affect energy use efficiency. DOE's AEO96 has projected consumption of various refined products over the period 1994 through 2015. Table 5-1 shows the annual average percentage increase in consumption over this period for the three economic growth rate scenarios – low growth, the reference case, and high growth. For example, DOE forecasts average annual rates of increase in the consumption of gasoline ranging from 0.3 to 0.8 percent, depending on the economic growth scenario.

Table 5-1

DOE PROJECTIONS OF REFINED PETROLEUM PRODUCT CONSUMPTION
(Average Percent Annual Growth Rate, 1994-2015)

Product	Low Economic Growth	Reference Case	High Economic Growth
Motor Gasoline[a]	0.3%	0.6%	0.8%
Jet Fuel[b]	1.4	1.9	2.4

Distillate Fuel	0.8	1.2	1.6
Residual Fuel	0.9	1.2	1.4
Liquified Petroleum Gas	0.4	0.9	1.3
Other[c]	0.2	0.5	0.8

Notes: [a] Includes ethanol (blends of 10 percent or less) and ethers blended into gasoline.
[b] Includes naphtha and kerosene type.
[c] Includes unfinished oils, natural gasoline, motor gasoline blending compounds, aviation gasoline, lubricants, still gas, asphalt, road oil, petroleum code, and miscellaneous petroleum products.

Source: *Annual Energy Outlook*, 1996, U.S. Department of Energy, Table B2.

Among the various refined products, DOE projects the strongest growth in the consumption of jet fuel. In 1994, gasoline accounted for about 61 percent of total motor vehicle consumption of refined products. However, DOE expects gasolines share of vehicle consumption to fall to about 53 percent by 2015, largely because of increases in the consumption of jet and diesel fuel (DOE, 1996b).

PRICE OUTLOOK

Future prices of refined products depend, of course, on market demand and supply. Table 5-2 shows DOE's AEO96 forecasts of refined product prices over the period 1994 through 2015. For example, DOE expects that the price of motor gasoline to increase by an average annual rate of 0.6 to 1.2 percent, depending on the economic growth scenario. As Table 5-2 indicates, the largest percentage increases in prices are expected for jet fuel and residual fuel.

Table 5-2

DOE PROJECTIONS OF REFINED PETROLEUM PRODUCT PRICES
(Average Percent Annual Growth Rate, 1994-2015)

Product	Low Economic Growth	Reference Case	High Economic Growth
Motor Gasoline[a]	0.6%	0.9%	1.2%
Jet Fuel[b]	1.9	2.3	2.7
Distillate Fuel	0.6	0.9	1.2

Residual Fuel	2.0	2.3	2.6
Liquified Petroleum Gas	0.8	1.1	1.3

Notes: [a] Includes ethanol (blends of 10 percent or less) and ethers blended into gasoline.
[b] Includes naphtha and kerosene type.

Source: *Annual Energy Outlook*, 1996, U.S. Department of Energy, Table B12.

We caution that future prices of refined products depend on future events affecting demand and supply. Some of these events are difficult to predict. For example, crude oil prices, which affect the supply of refined products, can be affected significantly by highly uncertain international events. We do note, however, that DOE's price predictions account for estimates of the effects of the reformulated gasoline program.

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APPENDIX

PETROLEUM REFINERY OPERATING CHARACTERISTICS

Table A1 presents detailed operating characteristics (as of January 1, 1995) of all petroleum refineries operating in the United States.