CHAPTER 1: Industry Characterization

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In understanding the impact of emissions standards on regulated industries, it is important to assess the nature of the regulated and otherwise affected industries. The industries affected are the nonroad diesel engine and equipment manufacturing, oil-refining, and fuel-distribution industries. This chapter provides market share information for the above industries. This information is provided for background purposes. In the remainder of this draft RIA, to the extent data regarding engine/equipment populations, sales or other industry specific data has been used, that data is explained and referenced in the relevant section of the draft RIA. The information presented in this chapter will be most helpful for the reader who is unfamiliar with the engine/equipment industry and/or the oil refining and fuel-distribution industries.

Nonroad engines are generally distinguished from highway engines in one of four ways: (1) the engine is used in a piece of motive equipment that propels itself in addition to performing an auxiliary function (such as a bulldozer grading a construction site); (2) the engine is used in a piece of equipment that is intended to be propelled as it performs its function (such as a lawnmower); (3) the engine is used in a piece of equipment that is stationary when in operation but portable (such as a generator or compressor) or (4) the engine is used in a piece of motive equipment that propels itself, but is primarily used for off-road functions (such as off-highway truck).

The nonroad category is also different from other mobile source categories because: (1) it applies to a wider range of engine sizes and power ratings; (2) the pieces of equipment in which the engines are used are extremely diverse; and (3) the same engine can be used in widely varying equipment applications (e.g., the same engine used in a backhoe can also be used in a drill rig or in an air compressor).

A major consideration in regulating nonroad engines is the lack of vertical integration in this field. Although some nonroad engine manufacturers also produce equipment that rely on their own engines, most engines are sold to various equipment manufacturers over which the original engine manufacturer has minimal control. A characterization of the industry affected by this rulemaking must therefore include equipment manufacturers as well as engine manufacturers.

Sections 1 and 2 characterize the nonroad engine and equipment industries based on different manufacturers and their products and the diversity of the manufacturer pool for the various types of equipment. They describe the nonroad diesel engine market and related equipment markets by horsepower category. Additional information related to engine/equipment profiles, including employment figures, production costs, information on engine component materials and firm characteristics, are available in the docket.[1]

1.1 Characterization of Engine Manufacturers

For purposes of discussion, the characterization of nonroad engine manufacturers is arranged by the power categories used to define the new emission standards. The information detailed in this section was derived from the Power Systems Research database and trade journals.[2] We recognize that the PSR database is not comprehensive, but have not identified a better source to provide consistent data for identifying additional companies.

1.1.1 Engines Rated between 0-19 kW (0 and 25 hp)

In year 2000, sales of engines in this category comprised 18% (approximately 135,828 units) of the nonroad market. The largest manufacturers of engines in this category are Kubota (36,601 units) and Yanmar (32,126 units). Seventy three percent of Yanmar's engines are four-cycle, water-cooled, indirect injection models. A majority of Kubota's engines are also four-cycle, water-cooled indirect injection models. Another major manufacturer in this category is Kukje with 21,216 units.

1.1.2 Engines Rated between 19 and 56 kW (25 and 75 hp)

This is the largest category, comprised of 38% of engines with approximately 281,157 units sold in year 2000. Direct Injection (DI) engines account for 59% of this category with 165,427 units. Yanmar has approximately 19% of the DI market share, followed by Deutz (16%), Kubota (13%), Hatz (12%), Isuzu(10%) ,Caterpillar/Perkins(10%) and Deere (8%). Kubota dominates the Indirect Injection (IDI) market with 51 percent of sales , followed by Daewoo Heavy Industries (12%), Ihi-Shibaura (12%), Isuzu(8%) and Caterpillar/Perkins (5%). Ag tractors, generator sets, skid-steer loaders and refrigeration and air conditioning units are the largest selling engines in this power range.

1.1.3 Engines Rated between 56 and 130 kW (75 and 175 hp)

In year 2000, manufacturers sold approximately 206,028 engines in this power range. This represents the second-largest category of nonroad engines with 28% of the total market. Almost all of these engines are DI. The top three manufacturers are John Deere (28%), Caterpillar/Perkins (20%) and Cummins (17%). Other manufacturers include Case/ New Holland, Deutz, Hyundai Motor, Isuzu, Toyota and Komatsu. The engines in this power range are used mostly in agricultural equipment such as ag tractors. The second-largest use for these engines is in construction equipment such as tractor/loader/backhoes and skid-steer loaders.

1.1.4 Engines Rated between 130 and 560 kW (175 and 750 hp)

Engines in this power range rank fourth(15% of the total market) in nonroad diesel engines sales with approximately 108,172 units sold in year 2000. Almost all of these are DI engines. Deere has approximately 32% of the DI market, followed by Caterpillar/Perkins (22%), Cummins (21%), Case/New Holland (8%),Volvo (4%), and then by Komatsu and Detroit Diesel (each 3%). The largest selling engines in this category are used in agricultural equipment (ag tractors), followed by construction equipment (wheel loaders, bulldozers, and excavators).

1.1.5 Engines Rated over 560 kW (750 hp)

This is the smallest nonroad category with approximately 5,633 engines comprising 1% of the total nonroad market and consist of all DI engines. Caterpillar is the largest manufacturer (44%), followed by Cummins (19%), Komatsu (18%), and Detroit Diesel (11%). Power generation is the principal application in this range, followed by large off-highway trucks and other types of construction equipment such as crawlers , wheel loaders and bulldozers.

1.2 Characterization of Equipment Manufacturers

Nonroad equipment can be grouped into several categories. This section considers the following seven segments: agriculture, construction, general industrial, lawn and garden, material handling, pumps and compressors, and welders and generator sets. Engines used in locomotives, marine applications, aircraft, recreational vehicles, underground mining equipment, and all spark-ignition engines within the above categories are not included in this proposed rulemaking. Table 1.2-1 below contains examples of the types of nonroad equipment which would be impacted by this proposal, arranged by category.

Table 1.2-1
Sampling of Nonroad Equipment Applications

Segment	Applications		
Agriculture	Ag Tractor Baler Combine	Sprayer Windrower Other Ag Equipment	
Construction	Bore/drill Rig Crawler Excavator Grader Off-highway Tractor	Off-highway Truck Paver Plate Compactor Roller Wheel Loader/Dozer	Tamper/Rammer Scraper Skid-Steer Loader Trencher
General Industrial	Concrete/Ind. Saw Crushing Equipment	Oil Field Equipment Refrigeration/AC	Scrubber/sweeper Rail Maintenance
Lawn and Garden	Lawn and Garden Tractor	Commercial Mower	Trimmer/edger/cutter
Pumps and Compressors	Air Compressor Hydro Power Unit Pressure Washer	Pump Gas Compressor	Irrigation Set
Material Handling	Aerial Lift Crane	Forklift Terminal Tractor	Rough-Terrain Forklift
Welders and Generators	Generator Set, Welder	Lt Plant/Signal Board	

Based on horsepower rating of the engine it uses, a fraction of applications such as air compressors, generator sets, hydropower units, irrigation sets, pumps and welders is considered to be stationary and hence not subject to EPA's proposed.standards. However, the tables in sections 1.2.1 to 1.2.5 account for all equipment manufactured, whether stationary or mobile within an engine horsepower category.

For purposes of discussion, nonroad equipment is grouped into five power ranges similar to those used for characterizing nonroad engines. This section explores the characteristics of nonroad equipment applications and the companies involved in manufacturing these equipment. This analysis includes several numerical summaries of different categories.

1.2.1 Equipment Using Engines Rated under 19 kW (0 and 25 hp)

The applications with the most sales are ag tractors followed by generator sets. There are about 29 total applications with engines rated under 19 kW. The six leading manufacturers produce 46% of the equipment in this category. Their collective sales volume over five years (1996 to 2000) was approximately 251,000 pieces of equipment in a market which has a five year total sales volume of 551,000. These manufacturers and the major equipment types manufactured by them are shown in Table 1.2-2.

Table 1.2-2
Characterization of the Top 6 Equipment Manufacturers for Engines Rated below 19 kW

Original Equipment Manufacturer	Major Equipment Manufactured	Average Annual Sales	Percentage of Market	Engine Characterization*
Ingersoll-Rand	Refrigeration/AC, Skid-steer loaders, and Excavators	13,394	12%	W,NA, I
Deere & Company	Agricultural tractors, Commercial mowers, Lawn & garden tractors	11,042	10%	W,NA, I
Korean Gen-sets	Generator Sets	9,970	9%	W,NA, I
China Gen-sets	Generator Sets	5,559	5%	W,NA,D/ I
SDMO	Generator Sets	5,191	5%	W/A,NA, D/I
Kubota Corp.	Ag tractors,Lawn & garden tractors Commercial mowers	5,117	5%	W,NA,I

*W=water-cooled, A=air-cooled,O=oil cooled;NA=naturally aspirated,T=turbocharged;I=indirect injection,D=direct injection.

For these top six OEMs, their sales are typified by generator sets, skid-steer loaders, ag tractors, commercial mowers, and refrigeration/air conditioning units. The sales of the equipment are listed in Table 1.2-3. The top six manufacturers have equipment that are typical of the market. Fifty-six OEMs produce 92% of the equipment in this horsepower range.

Table 1.2-3
Equipment Sales Distribution for Engines Rated below 19 kW

Application Description	Five-year sales Volume (1996-2000)	Average Annual Sales	Percentage of Total Sales
Generator sets	171,435	34,287	31.1
Agricultural tractors	59,863	11,973	9.5
Commercial mowers	59,713	11,943	9.5
Refrigeration/AC	57,668	11,534	9.2
Welders	32,284	6,457	5.1
Light plants/Signal boards	28,239	5,648	4.5
Skid-steer loaders	23,685	4,737	3.8
Lawn & garden tractors	17,879	3,576	2.8
Pumps	16,262	3,252	2.6
Rollers	12,063	2,413	1.9
Pressure washers	11,959	2,392	1.9
Plate compactors	11,535	2,307	1.8
Utility vehicles	8,502	1,700	1.4
Aerial lifts	7,058	1,412	1.1
Excavators	6,118	1,224	1.0
Mixers	4,639	928	0.7
Scrubbers/sweepers	2,829	566	0.4
Commercial turf equipment	2,627	525	0.4
Finishing equipment	2,351	470	0.4
Other general industrial equipment	2,334	467	0.4
Tampers/rammers	2,156	431	0.3
Tractor/loader/backhoes	1,794	359	0.3
Dumpers/tenders	1,689	338	0.3
Air compressors	1,516	303	0.2
Hydraulic power units	797	159	0.1
Trenchers	776	155	0.1
Concrete/industrial saws	733	147	0.1
Irrigation sets	614	123	0.1
Wheel loaders/bulldozers	502	100	0.1
Other agricultural equipment	426	85	0.1
Surfacing equipment	362	72	0.1
Bore/drill rigs	275	55	0.0
Listed Total		110,137	91.4
Grand Total		**110,289**	**100.0**

1.2.2 Equipment Using Engines Rated between 19 and 56 kW (25 and 75 hp)

All market segments are represented within the 19 to 56 kW range. They are made up of 55 applications and about 17 % of total sales are by Ingersoll- Rand. For the 19 to 56 kW range, the equipments use either direct or indirect injection engines that are water or oil-cooled and are either naturally aspirated or turbo-charged. The six leading manufacturers produce 53% of the equipment in this category. These manufacturers are listed in Table 1.2-4. They manufacture equipment typical of the market e.g. agricultural tractors, generator sets, skid-steer loaders and refrigeration/AC. These top selling applications represent about 70% of the market as seen in Table 1.2-5. The top 90% of the market is supplied by 60 different companies.

Table 1.2-4
Characterization of the Top 6 Equipment
Manufacturers for Engines Rated between 19 and 56 kW

Original Equipment Manufacturer	Major Equipment Manufactured	Average Annual Sales	Percentage of Market	Engine Characterization*
Ingersoll-Rand	Refrigeration A/C, Skid-steer loaders, Air compressors	40,199	17%	W/O,NA/T,D/I
Case New Holland	Agricultural tractors, Skid-steer loaders	23,194	10%	W/O,NA/T,D/I
Thermadyne Holdings	Generator sets	19,090	8%	A,NA,D
Deere & Company	Agricultural tractors, Skid-steer loaders, Commercial mowers	17,752	7%	W,NA/T,D
Kubota Corp.	Agricultural tractors, Excavators, Wheel Loaders, Bulldozers	14,391	6%	W,NA/T,D/I
United Technologies Co.	Refrigeration/AC	12,484	5%	W,NA,D/I

*W=water-cooled, A=air-cooled,O=oil cooled;NA=naturally aspirated, T=turbocharged, I=indirect injection, D=direct injection.

Table 1.2-5
Equipment Sales Distribution across Applications between 19 and 56 kW

Application Description	Five-year sales Volume (1996-2000)	Average Annual Sales	Percentage of Total Sales
Agricultural tractors	286,295	57,259	24%
Generator sets	223,960	44,792	19%
Skid-steer loaders	177,925	35,585	15%
Refrigeration/AC	142,865	28,573	12%
Welders	60,035	12,007	5.0%
Commercial mowers	47,735	9,547	3.9%
Air compressors	33,840	6,768	2.8%
Trenchers	26,465	5,293	2.2%
Aerial lifts	25,810	5,162	2.1%
Forklifts	23,480	4,696	1.9%
Rollers	18,010	3,602	1.5%
Excavators	16,485	3,297	1.4%
Rough terrain forklifts	13,530	2,706	1.1%
Scrubbers/sweepers	11,770	2,354	1.0%
Light plants/signal boards	11,720	2,344	1.00%
Pumps	9,290	1,858	0.77%
Bore/drill rigs	9,000	1,800	0.74%
Utility vehicles	8,460	1,692	0.70%
Wheel Loaders/bulldozers	6,985	1,397	0.58%
Pressure washers	6,700	1,340	0.55%
Pavers	6,395	1,279	0.53%
Commercial turf	5,760	1,152	0.48%
Tractor/loader/backhoes	5,115	1,023	0.42%
Irrigation sets	4,300	860	0.36%
Concrete/industrial saws	3,400	680	0.28%
Other general industrial	3,400	680	0.28%
Chippers/grinders	2,625	525	0.22%
Crushing/processing equipment	2,305	461	0.19%
Hydraulic power units	1,950	390	0.16%
Terminal tractors	1,765	353	0.15%
Surfacing equipment	1,490	298	0.12%
Dumpers/tenders	1,055	211	0.09%
Listed Total		239,984	99.3%
Grand Total		241,710	100.0%

1.2.3 Equipment Using Engines Rated between 56kW and 130 kW (75 and 175 hp)

Engines rated between 56 and 130 kW are all direct injection engines that are either water-cooled (94%), oil-cooled (4%) or air-cooled (2%). The six leading manufacturers produce 49% of the equipment in this category. Their collective sales volume over five years (1996 to 2000) was approximately 440,000 pieces of equipment in a market which has a five year total sales volume of 905,000. These manufacturers are shown in Table 1.2-6.

Table 1.2-6
Characterization of the Top 6 Equipment
Manufacturers for Engines Rated between 56kW and 130 kW (75 and 175 hp)

Original Equipment Manufacturer	Major Equipment Manufactured	Average Annual Sales	Percentage of Market	Engine Characterization*
Case New Holland	Ag Tractors, Combines, Crawlers, Skid-steer loaders, Tractors/loaders/backhoes	26,717	15%	W,T,D
Deere & Company	Ag Tractors, Combines, Wheel Loaders/Dozers	25,648	14%	W,T,D
Caterpillar	Generator Sets, Scrapers, Crawlers, Excavators, Wheel loaders, bulldozers, Graders, Rough terrain fork-lifts	13,670	8%	W,T/N,D
Ingersoll-Rand	Air compressors, Rollers, Bore/drill rigs	10,169	6%	W,T,D
Agco	Agricultural tractors, Combines, Sprayers	6,182	3%	W/A,T,D
Landini Holding	Agricultural tractors	5,467	3%	W,T/N,D

*W=water-cooled, A=air-cooled,O=oil cooled;NA=naturally aspirated, T=turbocharged, I=indirect injection, D=direct injection.

Of these top six OEMs, their sales are typified by agricultural tractors, tractors/loaders/backhoes, generator sets, skid-steer loaders, rough terrain fork-lifts,excavators, air compressors and crawlers. The sales of these equipment are listed in Table 1.2-7. The top six manufacturers have engines that are typical of the market. Seventy-two OEMs produce 90% of the equipment in this horsepower range.

Table 1.2-7
Equipment Sales Distribution across Applications between 56 and 130 kW

Application Description	Five-yr sales Volume (1996-2000)	Average Annual Sales	Percentage of Total Sales
Agricultural tractors	185,315	37,063	20%
Tractor/loader/backhoes	106,780	21,356	12%
Generator sets	103,490	20,698	11%
Skid-steer loaders	74,040	14,808	8.2%
Rough terrain forklfts	56,770	11,354	6.3%
Excavators	50,140	10,028	5.5%
Air compressors	32,080	6,416	3.5%
Crawlers	30,260	6,052	3.3%
Forklifts	29,705	5,941	3.3%
Wheel Loaders/bulldozers	27,520	5,504	3.0%
Rollers	23,195	4,639	2.6%
Commercial turf equipment	17,425	3,485	1.9%
Other general industrial	16,580	3,316	1.8%
Scrubbers/sweepers	16,005	3,201	1.8%
Irrigation sets	15,745	3,149	1.7%
Windrowers	11,385	2,277	1.3%
Pumps	10,265	2,053	1.1%
Sprayers	8,830	1,766	1.0%
Listed Total		163,108	90.1%
Grand Total		181,094	100.0%

1.2.4 Equipment Using Engines Rated between 130 and 560 kW (175 and 750 hp)

For the 130 to 560 kW range (where 560 kW is included in the range), most of the equipment uses direct injection engines that are water-cooled and turbo charged . A few are naturally aspirated. The six leading manufacturers produce 56% of the equipment in this category. These manufacturers are listed in Table 1.2-8. Their products have the following applications : ag tractors, combines, generator sets, wheel loaders/bull dozers , which is typical of the market.

The 130 to 560 kW range is characterized by applications as shown in Table 1.2-9. They represent about 94% of the market. The top 90% of this market is supplied by 60 OEMs.

Table 1.2-8
Characterization of the Top 6 Equipment Manufacturers
for Engines Rated between 130 and 560 kW

Original Equipment Manufacturer	Major Equipment Manufactured	Average Annual Sales	Percentage of Market	Engine Characterization*
Deere & Company	Ag Tractors, Combines, Wheel Loaders/bulldozers	27,990	27%	W,T,D
Case New Holland	Ag Tractors, Combines, Crawlers, Generator Sets, Scrapers, Crawlers,	14,778	14%	W,T,D
Caterpillar	Excavators,wheel loaders/dozers, graders	13,151	13%	W,T/N,D
Komatsu	Crawlers, Excavators,Graders, Wheel Loaders/Dozers	4,941	5%	W,T,D
Ingersoll-Rand	Air Compressors, Rollers, Bore/Drill Rigs	3,683	4%	W,T,D
Agco	Ag Tractors, Combines, Sprayers	3,194	3%	W/A,T,D

*W=water-cooled, A=air-cooled,O=oil cooled;NA=naturally aspirated, T=turbocharged, I=indirect injection, D=direct injection.

Table 1.2-9
Equipment Sales Distribution across Applications between 130 and 560 kW

Application Description	Five-yr sales Volume (1996-2000)	Average Annual Sales	Percentage of Total Sales
Agricultural tractors	149,589	29,918	29.0%
Generator sets	57,400	11,480	11.0%
Wheel loaders/bulldozers	43,475	8,695	8.3%
Combines	35,743	7,149	6.8%
Excavators	35,166	7,033	6.7%
Crawlers	28,478	5,696	5.4%
Air compressors	20,884	4,177	4.0%
Graders	14,814	2,963	2.8%
Sprayers	12,193	2,439	2.3%
Terminal ractors	12,141	2,428	2.3%
Forest equipment	12,101	2,420	2.3%
Pumps	9,901	1,980	1.9%
Off-highway trucks	9,377	1,875	1.8%
Cranes	9,356	1,871	1.8%
Scrapers	7,097	1,419	1.4%
Bore/drill rigs	7,047	1,409	1.3%
Irrigation sets	6,835	1,367	1.3%
Rollers	6,055	1,211	1.2%
Other agricultural equipment	5,935	1,187	1.1%
Chippers/grinders	4,669	934	0.9%
Other construction equipment	4,142	828	0.8%
Listed Total		98,480	94.0%
Grand Total		492,398	100.0%

1.2.5 Equipment Using Engines Rated over 560 kW (750 hp)

The largest engines, those rated over 560 kW, are only produced for the nonroad market segments of construction equipment and welders and generators. As much as 35% of the equipment in this power range is manufactured by Caterpillar. Most equipment manufacturers must buy engines from another company. For most power categories, the Power Systems Research database estimates that between 5 and 25 percent of equipment sales are from equipment manufacturers that also produce engines. Since vertically integrated manufacturers are typically very large companies, such as John Deere and Caterpillar, the companies that make up this fraction of the market are in a distinct minority.

As in the previous category, the equipment rated over 560 kW uses mostly turbocharged, direct injection engines that are water-cooled. The leading six manufacturers produce 81% of the equipment in this power range. These manufacturers are shown in Table 1.2-10. Although generator sets make up the majority of equipment sold in this range, a fraction of them are considered stationary, and hence not impacted by the proposed rule. Off-highway trucks , wheel loaders/dozers and crawlers also have significant sales (see Table 1.2-11).

Table 1.2-10
Characterization of the Top 6 Equipment Manufacturers for Engines Rated over 560 kW

Original Equipment Manufacturer	Major Equipment Manufactured	Average Annual Sales	Percentage of Market	Engine Characterization*
Caterpillar	Generator Sets, Off-highway trucks, crawler tractors	1,857	35%	W,T,D
Komatsu	Crawlers, Wheel Loaders/Dozers, Off-Highway Trucks	1,376	26%	W,T,D
Multiquip	Generator Sets	336	6%	W,T,D
Kohler	Generator Sets	335	6%	W,T,D
Cummins	Generator Sets	325	6%	W,T,D
Onis Visa	Generator Sets	107	2%	W,T,D

*W=water-cooled, A=air-cooled,O=oil cooled;NA=naturally aspirated, T=turbocharged, I=indirect injection, D=direct injection.

Table 1.2-11
Equipment Sales Distribution across Applications over 560 kW

Application Description	Five-yr sales Volume (1996-2000)	Average Annual Sales	Percentage of Total Sales
Generator sets	14,237	2,847	54%
Off-highway trucks	4,048	810	15%
Crawlers	3,857	771	15%
Wheel loaders/bulldozers	2,567	513	9.8%
Off-highway tractors	542	108	2.1%
Excavators	371	74	1.4%
Oil field equipment	225	45	0.9%
Chippers/grinders	132	26	0.5%
Listed Total		5,196	99.1%
Grand Total		5,241	100.0%

Section 1.3 characterizes the U.S. petroleum refinery industry, market structure and trends as it pertains to distillate fuels, including nonroad diesel fuel. In addition, it covers refinery operations that are directly impacted by EPA's proposed regulations. Section 1.4 discusses distribution of refined petroleum products through pipelines from refineries, as well as storage operations for these products. Both Sections 1.3 and 1.4 are based on a report prepared by RTI under EPA contract, which is available in the docket.[3]

1.3 Refinery Operations

1.3.1 The Supply-Side

This section describes the supply side of the petroleum refining industry, including the current refinery production processes and raw materials used. It also discusses the need for potential changes in refinery production created by the new EPA rule. Finally, it describes the three primary categories of petroleum products affected by the rule and the ultimate costs of production currently faced by the refineries.

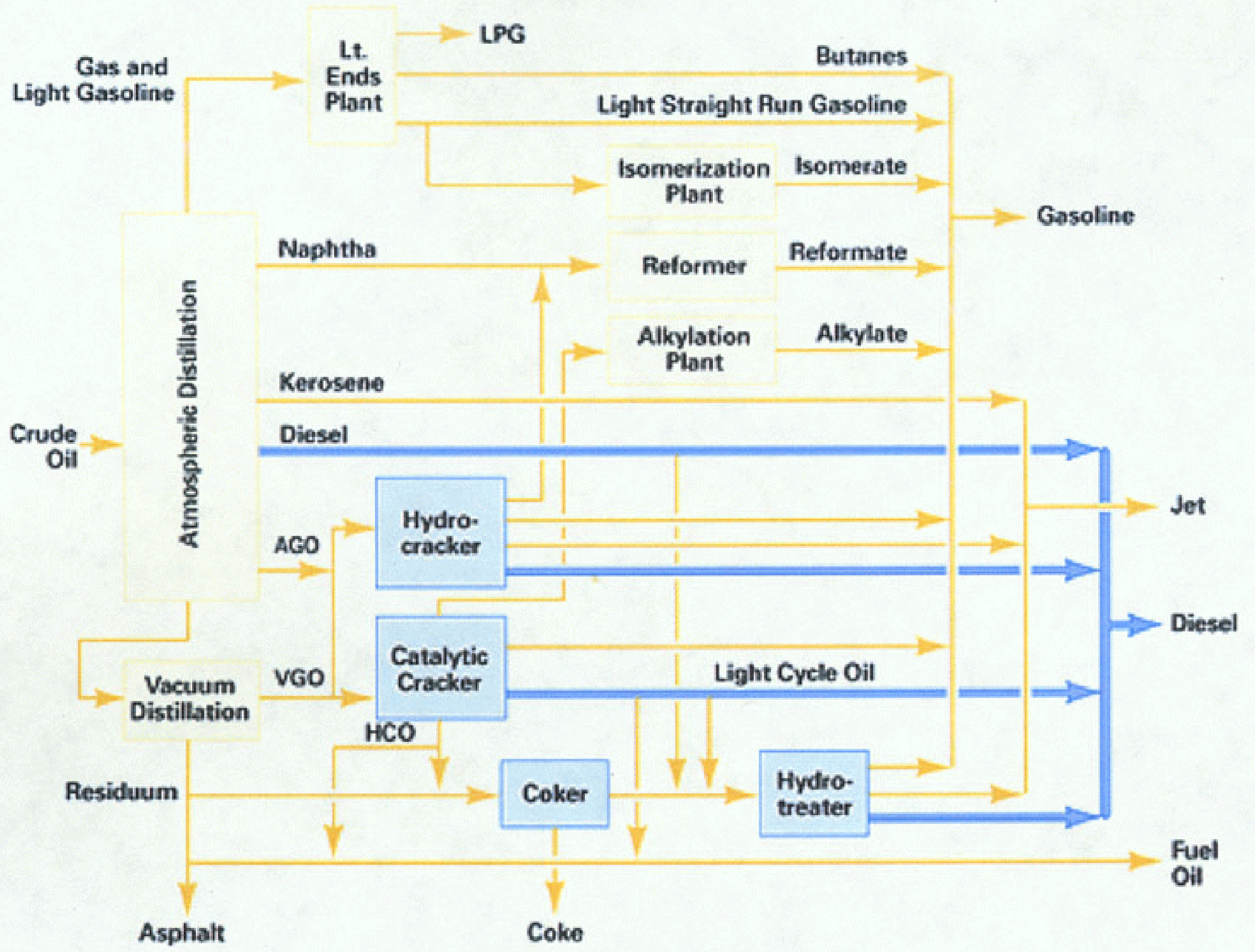
Refinery Production Processes/Technology. Petroleum refining is the thermal and physical separation of crude oil into its major distillation fractions, followed by further processing (through a series of separation and chemical conversion steps) into highly valued finished petroleum products. Although refineries are extraordinarily complex and each site has a unique configuration, we will describe a generic set of unit operations that are found in most medium and large facilities. A detailed discussion of these processes can be found in EPA's sector notebook of the petroleum refining industry (EPA, 1995); simplified descriptions are available on the web sites of several major petroleum producers (Flint Hills Resources, 2002; Chevron, 2002).

Figure 1.3-1 shows the unit operations and major product flows in a typical refinery. After going through an initial desalting process to remove corrosive salts, crude oil is fed to an atmospheric distillation column that separates the feed into several fractions. The lightest boiling range fractions are processed through reforming and isomerization units into gasoline or diverted to lower-value uses such as LPG and petrochemical feedstocks. The middle-boiling fractions make up the bulk of the aviation and distillate fuels produced from the crude. In most refineries, the undistilled liquid (called bottoms) is sent to a vacuum still to further fractionate this heavier material. Bottoms from the vacuum distillation can be further processed into low-value products such as residual fuel oil, asphalt, and petroleum coke.

A portion of the bottoms from the atmospheric distillation, along with distillate from the vacuum still, are processed further in a catalytic cracking unit or in a hydrocracker. These operations break large hydrocarbon molecules into smaller ones that can be converted to high-value gasoline and middle distillate products. Bottoms from the vacuum still are increasingly processed in a coker to produce saleable coke and gasoline and diesel fuel blendstocks. The cracked molecules are processed further in combining operations (alkylation, for example), which combine small molecules into larger, more useful entities, or in reforming, in which petroleum molecules are reshaped into higher quality species. It is in the reforming operation that the octane rating of gasoline is increased to the desired level for final sale. A purification process called hydrotreating helps remove chemically bound sulfur from petroleum products and is critically important for refineries to process their refinery streams into valuable products and to achieve the low sulfur levels that the proposed regulations will mandate.

For each of the major products, several product streams from the refinery will be blended into a finished mixture. For example, diesel fuel will typically contain a straight-run fraction from crude distillation, distillate from the hydrocracker, light-cycle oil from the catalytic cracker, and hydrotreated gas oil from the coker. Several auxiliary unit operations are also needed in the refinery complex, including hydrogen generation, catalyst handing and regeneration, sulfur recovery, wastewater treatment, and blending and storage tanks. Table 1.3-1 shows average yields of major products from U.S. refineries.

Figure 1.3-1
The Modern Refinery



Source: Chevron. 2002. Diesel Fuel Refining and Chemistry. As accessed on August 19, 2002. <www.chevron.com/prodserv/fuels/bulletin/diesel/L2_4_2rf.htm>.

Table 1.3-1
Yields of Major Petroleum Products from Refinery Operations

Product	Gallons per Barrel of Crude	Percentage of Total Feed*
Crude Feed	42.0	100.0%
Gasoline	19.4	46.0%
Highway diesel fuel	6.3	15.0%
Jet Fuel	4.3	10.0%
Petroleum Coke	2.0	5.0%
Residual Fuel Oil	1.9	4.5%
LP Gas	1.9	4.5%
Home heating oil	1.6	4.0%
Asphalt	1.4	3.0%
Nonroad diesel fuel	0.8	2.0%
Other Products	4.0	9.5%
Total	43.6	104.0%

*Note: Total exceeds 100 percent due to volume gain during refining.
Source: Calculated from EIA data in Petroleum Supply Annual 2001. U.S. Department of Energy, Energy Information Administration (EIA). 2002a. Petroleum Supply Annual 2001, Tables 16, 17, and 20. Washington, DC.

Potential Changes in Refining Technology Due to EPA Regulation. Over the next few years, EPA regulations will come into effect that require much lower levels of residual sulfur for both gasoline and highway diesel fuel. To meet these challenges, refineries are planning to add hydrotreater units to their facilities, route more intermediate product fractions through existing hydrotreaters, and operate these units under more severe conditions to reduce levels of chemically bound sulfur in finished products. As has been documented in economic impact analyses for the gasoline and highway diesel rules, these changes will require capital investments for equipment, new piping, and in-process storage; increased use of catalyst and hydrogen; and modifications to current operating strategies.

The addition of lower sulfur limits for nonroad diesel fuel will result in additional refinery changes similar in nature to those required for highway diesel fuel. Product streams formerly sent directly to blending tanks will need to be routed through the hydrotreating operation to reduce their sulfur level. In addition, because an increasing fraction of the total volumetric output of the facility must meet ultra-low sulfur requirements, flexibility will be somewhat reduced. For example, it will become more difficult to sell off spec products if errors or equipment failures occur during operation.

Types of Products. The major products made at petroleum refineries are unbranded commodities, which must meet established specifications for fuel value, density, vapor pressure, sulfur content, and several other important characteristics. As Section 1.3.2 describes, they are transported through a distribution network to wholesalers and retailers, who may attempt to differentiate their fuel from competitors based on the inclusion of special additives or purely through adroit marketing. Gasoline and highway diesel are taxed prior to final sale, whereas nonroad fuel is not. To prevent accidental or deliberate misuse, nonroad diesel fuel must be dyed prior to final sale.

A total of $158 billion of petroleum products were sold in the 1997 census year, accounting for a nontrivial 0.4 percent of GDP. Table 1.3-2 lists the primary finished products produced; as one might expect, the percentages are quite close to the generic refinery output shown in Table 1.3-1. Motor gasoline is the dominant product, both in terms of volume and value, with almost three billion barrels produced in 1997. Distillate fuels accounted for less than half as much as gasoline, with 1.3 billion barrels produced in the U.S. in the same year. Data from the Energy Information Administration (EIA) suggest that 60 percent of that total is low-sulfur highway diesel, with the remainder split between nonroad diesel and heating oil. Jet fuel, a fraction slightly heavier than gasoline, is the third most important product, with a production volume of almost 600 million barrels.

Table 1.3-2
Types of Petroleum Products Produced by U.S. Refineries

Products	Total Produced (thousand barrels)	Percentage of Total
Liquified Refinery Gases	243,322	3.9%
Finished Motor Gasoline	2,928,050	46.4%
Finished Aviation	6,522	0.1%
Jet Fuel	558,319	8.8%
Kerosene	26,679	0.4%
Distillate Fuel Oil	1,348,525	21.4%
Residual Fuel Oil	263,017	4.2%
Naphtha for Feedstock	60,729	1.0%
Other Oils for Feedstock	61,677	1.0%
Special Naphthas	18,334	0.3%
Lubricants	63,961	1.0%
Waxes	6,523	0.1%
Petroleum Coke	280,077	4.4%
Asphalt and Road Oil	177,189	2.8%
Still Gas	244,432	3.9%
Miscellaneous	21,644	0.3%
Total	6,309,000	100.0%

Primary Inputs. Crude oil is the dominant input in the manufacture of refined petroleum products, accounting for 74 percent of material cost, or about $95 billion in 1997, according to the latest Economic Census (U.S. Census Bureau, 1999). The census reported almost equal proportions of imported and domestic crude in that year, with 2.5 billion barrels imported and 2.8 billion barrels originating from within the U.S. More recent data published by the EIA show a higher import dependence in the most recent year, with 3.4 billion barrels, or 61.7 percent, imported out of a total of 5.5 billion barrels used by refineries during 2001 (EIA, 2002a).

Crude oil extracted in different regions of the world have quite different characteristics, including the mixture of chemical species present, density and vapor pressure, and sulfur content. The cost of production and the refined product output mix vary considerably depending on the type of crude processed. A light, sweet crude oil, such as that found in Nigeria, will process very differently from a heavy, sulfur-laden Alaska or Arabian crude. The ease of processing any particular material is reflected in its purchase price, with sweet crudes selling at a premium. The result of these variations is that refineries are frequently optimized to run only certain types of crude; they may be unable or unwilling to switch to significantly different feed materials.

In addition to crude oil, refineries may also feed to their refineries hydrocarbon by-products purchased from chemical companies and other refineries and/or semiprocessed fuel oils imported from overseas. In 1997, the Census reported that these facilities purchased $11 billion of hydrocarbons and imported $2.4 billion of unfinished oils. Other significant raw materials purchased include $600 million for precious metal catalysts and more than $800 million in additives.

Costs of Production. According to the latest Economic Census, there were 244 petroleum refining establishments in the United States in 1997, owned by 123 companies and employing 64,789 workers. Data from EIA using a more stringent definition shows 164 operable refineries in 1997, a number that fell to 153 by January 1, 2002. As seen in Table 1.3-3, value of shipments in 2000 was $216 billion, up from $158 billion in the 1997 census year. The costs of refining are divided into the main input categories of labor, materials, and capital expenditures. Of these categories, the cost of materials represents about 80 percent of the total value of shipments, as defined by the Census, varying from year to year as crude petroleum prices change (see Table 1.3-4). Labor and capital expenditures tend to be more stable, each accounting for 2 to 4 percent of the value of shipments.

Table 1.3-3
Description of Petroleum Refineries—Census Bureau Data

NAICS 324110—Petroleum Refineries	Establishments	Companies	Employment	Value of Shipments ($$10^6$)
2000	(NA)	(NA)	62229	$215,592
1999	(NA)	(NA)	63619	$144,292
1998	(NA)	(NA)	64920	$118,156
1997	244	123	64789	$157,935
1992 (reported as SIC 2911)	232	132	74800	$136,239

Sources:
1992 data from U.S. Census Bureau. 1992 Census of Manufactures, Industry Series MC920I-29A. Table 1A.
1997 data from US Census Bureau, 1997 Economic Census - Manufacturing, Industry Series EC97M-3241A, Table 1.
1998-2000 data from US Census Bureau, Annual Survey of Manufactures-2000, 2000, Statistics for Industry Groups and Industries M00(AS)-1, Table 2.

Table 1.3-4
Petroleum Refinery Costs of Production, 1997–2000

Petroleum Refinery Costs of Production	1997	1998	1999	2000
Cost of Materials (10^6)	$127,555	$92,212	$114,131	$178,631
as % of shipment value	80.4%	78.0%	79.1%	82.9%
Cost of Labor (10^6)	$3,885	$3,965	$3,983	$3,995
as % of shipment value	2.4%	3.4%	2.8%	1.9%
Capital Expenditures (10^6)	$4,244	$4,169	$3,943	$4,453
as % of shipment value	2.7%	3.5%	2.7%	2.1%

Source: U.S. Census Bureau, Annual Survey of Manufactures. 2000. 2000 Statistics for Industry Groups and Industries M00(AS)-1, Tables 2 and 5.

Refinery Production Practices. Refining, like most continuous chemical processes, has high fixed costs from the complex and expensive capital equipment installed. In addition, shutdowns are very expensive, because they create large amounts of off-specification product that must be recycled and reprocessed prior to sale. As a result, refineries attempt to operate 24 hours per day, 7 days per week, with only 2 to 3 weeks of downtime per year. Intense focus on cost-cutting has led to large increases in capacity utilization over the past several years. A Federal Trade Commission (FTC) investigation into the gasoline price spikes in the Midwest during the summer of 2000 disclosed an average utilization rate of 94 percent during that year, and EIA data from 2001 show that a 92.6 percent utilization rate was maintained in 2001 (FTC, 2001; EIA, 2002a).

Because of long lead times in procuring and transporting crude petroleum and the need to schedule pipeline shipments and downstream storage, refinery operating strategies are normally set several weeks or months in advance. Once a strategy is established for the next continuous run, it is difficult or impossible to change it. Exact proportions of final products can be altered slightly, but at a cost of moving away from the optimal cost profile established initially. The economic and logistical drivers combine to generate an extremely low supply elasticity. One recent study estimated the supply elasticity for refinery products at 0.24 (Considine, 2002). The FTC study discussed above concluded that refiners had little or no ability to respond to the shortage of oxygenated gasoline in the Midwest in the summer of 2000, even with some advance warning that this would occur.

1.3.2 The Demand Side

This section describes the demand side of the market for refined petroleum products, with a focus on the distillate fuel oil industry. It discusses the primary consumer markets identified and their distribution by end use and PADD. This section also considers substitution possibilities available in each of these markets and the feasibility and costs of these substitutions. Figure 1.3-2 is a map of the five PADD regions.

Uses and Consumers. Gasoline, jet fuel, and distillate fuel oils account for almost 80 percent of the value of refinery product shipments, with gasoline making up about 51 percent (U.S. Census Bureau, 1999). Actual and relative net production volumes of these three major products, along with residual fuel oils, are shown in Table 1.3-5, broken out by PADD and for the country as a whole. PADD III, comprising the states of Texas, Louisiana, Arkansas, Alabama, Mississippi, and New Mexico, is a net exporter of refined products, shipping them through pipelines to consumers on the East Coast and also to the Midwest. Compared to gasoline production patterns, distillate production is slightly lower in PADD V (the West Coast) and higher in PADD II (the Midwest).

The primary end-use markets for distillate and residual fuel oils are divided by EIA as follows:

- residential—primarily fuel oil for home (space) heating;
- commercial—high-sulfur diesel (HSD), low-sulfur diesel (LSD), and fuel oil for space heating;
- industrial—LSD for highway use, HSD for nonroad fuels, and residual fuel oil for operating steam boilers and turbines (power generation);
- oil companies—mostly fuel oil and some residual fuel for internal use;
- farm—almost exclusively HSD;
- electric utility—residual fuel and distillate fuel oil for power generation;
- railroad—HSD and LSD used for locomotives;
- vessel bunking—combination of fuel oil and residual fuel for marine engines;
- on-highway diesel—LSD for highway trucks and automobiles;
- military—HSD sales to the Armed Forces; and
- off-highway diesel—HSD and LSD used in construction and other industries.

Figure 1.3-2
PADD Districts of the United States

As Table 1.3-6 indicates, the highway diesel fuel usage of 33.1 billion gallons represents the bulk of distillate fuel usage (58 percent) in 2000. Residential distillate fuel usage, which in the majority is fuel oil, accounts for 11 percent of total usage in 2000. Nonroad diesel fuel is primarily centered on industrial, farm, and off-highway diesel (construction) usage. In 2000, these markets consumed about 13 percent of total U.S. distillate fuels.

To determine the regional consumption of distillate fuel usage, 2000 sales are categorized by PADDs. As shown in Table 1.3-7, PADD I (the East Coast) consumes the greatest amount of distillate fuel at 20.9 billion gallons. However, residential, locomotive, and vessel bunking consumers account for 6.4 billion gallons of the distillate fuel consumed, which means that at least one-third of the total consumed in PADD I is due to fuel oil and not to diesel fuel consumption.

Table 1.3-5
Refinery Net Production of Gasoline and Fuel Oil Products by PADD

	Motor Gasoline		Distillate Fuel Oil		Jet Fuel		Residual Fuel Oil	
PADD	Quantity (1,000 bbl)	Percent (%)	Quantity (1,000 bbl)	Percent (%)	Quantity (1,000 bbl)	Percent (%)	Quantity (1,000 bbl)	Percent (%)
I	369,750	12.6%	170,109	12.6%	30,831	5.5%	38,473	14.6%
II	641,720	21.9%	316,023	23.4%	80,182	14.4%	24,242	9.2%
III	1,306,448	44.6%	629,328	46.7%	288,749	51.7%	132,028	50.2%
IV	97,869	3.3%	54,698	4.1%	9,787	1.8%	4,151	1.6%
V	512,263	17.5%	178,367	13.2%	148,770	26.6%	64,123	24.4%
Total	2,928,050	100.0%	1,348,525	100.0%	558,319	100.0%	263,017	100.0%

Source: U.S. Department of Energy, Energy Information Administration (EIA). 2002a. Petroleum Supply Annual 2001, Tables 16, 17, and 20. Washington, DC. Table 17.

Table 1.3-6
Distillate Fuel Oil by End Use (2000)

End Use	2000 Usage (thousand gallons)	Percentage Share (%)
Residential	6,204,449	10.8%
Commercial	3,372,596	5.9%
Industrial	2,149,386	3.8%
Oil Company	684,620	1.2%
Farm	3,168,409	5.5%
Electric Utility	793,162	1.4%
Railroad	3,070,766	5.4%
Vessel Bunking	2,080,599	3.6%
On-Highway Diesel	33,129,664	57.9%
Military	233,210	0.4%
Off-Highway Diesel	2,330,370	4.1%
Total	57,217,231	100.0%

Source: U.S. Department of Energy, Energy Information Administration (EIA). 2001b. Fuel Oil and Kerosene Sales, 2000, Tables 7-12. Washington, DC.

Table 1.3-7
Distillate Fuel Oil by End Use and PADD

End Use	PADD (Thousand Gallons)				
	I	II	III	IV	V
Residential	5,399,194	628,414	1,117	38,761	136,962
Commercial	2,141,784	568,089	346,578	102,905	213,240
Industrial	649,726	600,800	420,400	241,146	237,313
Oil Company	19,101	41,727	560,905	29,245	33,643
Farm	432,535	1,611,956	552,104	220,437	351,377
Electric Utility	304,717	133,971	194,786	8,492	151,196
Railroad	499,787	1,232,993	686,342	344,586	307,059
Vessel Bunking	490,150	301,356	1,033,333	173	255,586
On-highway Diesel	10,228,244	11,140,616	5,643,703	1,474,611	4,642,490
Military	70,801	36,100	9,250	4,163	112,895
Off-highway Diesel	669,923	608,307	516,989	180,094	355,056
Total	20,905,962	16,904,329	9,965,507	2,644,613	6,796,817

Table 1.3-8 presents a closer look at on-highway consumption of distillate fuel, which is entirely LSD fuel. PADD I (the East Coast) and PADD II (the Midwest) consume almost 65 percent of all U.S. distillate fuel sold for on-highway use.

Table 1.3-9 shows that residential consumption of distillate fuel (primarily fuel oil) is centered in PADD I (the East Coast). Fuel-oil-fired furnaces and water heaters in New York and New England consume most of this heating oil; in most of the rest of the country, residential central heating is almost universally provided by natural gas furnaces or electric heat pumps. A comparison of Tables 1.3-5 and 1.3-9 reveals that PADD I produces far less distillate fuel oil than it consumes. The balance is made up by shipments from PADD III and imports from abroad.

Tables 1.3-10, 1.3-11, and 1.3-12 focus on diesel sales for industrial, agricultural, and construction use. Industrial use of diesel fuel is fairly evenly spread across PADDs. PADD II (the Midwest) has the highest percentage of diesel usage at 28 percent, while PADD V (the West Coast) has the lowest percentage at 11 percent. In contrast, agricultural purchases of diesel are in the great majority (51 percent) centered in PADD II (the Midwest). For construction only, distillate fuel sales are available, but these sales are assumed to be principally diesel fuel. Construction usage of diesel fuel, as with industrial usage, is fairly evenly spread across PADDs, with the exception of PADD IV. PADD IV represents only 8 percent of total construction usage.

Table 1.3-8
Sales for On-Highway Use of Distillate Fuel by PADD (2000)

PADD	Distillate Usage (Thousand Gallons)	Share of Distillate Fuel Used
I	10,228,244	30.9%
II	11,140,616	33.6%
III	5,643,703	17.0%
IV	1,474,611	4.5%
V	4,642,490	14.0%
Total	33,129,664	100.0%

Table 1.3-9
Sales for Residential Use of Distillate Fuel by PADD (2000)

PADD	Distillate Usage (Thousand Gallons)	Share of Distillate Fuel Used
I	5,399,194	87.0%
II	628,414	10.1%
III	1,117	0.0%
IV	38,761	0.6%
V	136,962	2.2%
Total	6,204,448	100.0%

Table 1.3-10
Industrial Use of Distillate Fuel by PADD (2000)

PADD	Distillate Usage (Thousand Gallons)	Share of Distillate Fuel Used
I	649,726	30.2%
II	600,800	28.0%
III	420,400	19.6%
IV	241,146	11.2%
V	237,313	11.0%
Total	2,149,385	100.0%

Table 1.3-11
Adjusted Sales for Farm Use of Distillate Fuel by PADD (2000)

PADD	Distillate Usage (Thousand Gallons)	Share of Distillate Fuel Used
I	432,535	13.6%
II	1,611,956	50.9%
III	552,104	17.4%
IV	220,437	7.0%
V	351,377	11.1%
Total	3,168,409	100.0%

Table 1.3-12
Sales for Construction Use of Off-Highway Distillate Fuel by PADD (2000)

PADD	Distillate Usage (Thousand Gallons)	Share of Distillate Fuel Used
I	510,876	26.9%
II	549,299	28.9%
III	394,367	20.8%
IV	150,060	7.9%
V	295,235	15.5%
Total	1,899,837	100.0%

Substitution Possibilities in Consumption. For engines and other combustion devices designed to operate on gasoline, there are no practical substitutes, except among different grades of the same fuel. Because EPA regulations apply equally to all gasoline octane grades, price increases will not lead to substitution or misfueling. In the case of distillate fuels, it is currently possible to substitute between LSD, HSD, and distillate fuel oil, although higher sulfur levels are associated with increased maintenance and poorer performance.

With the consideration of more stringent nonroad fuel and emission regulations, substitution will become less likely. Switching from nonroad ultralow-sulfur diesel (ULSD) to highway ULSD is not financially attractive, because of the taxes levied on the highway product. Misfueling with high-sulfur fuel oil will rapidly degrade the performance of the exhaust system of the affected engine, with negative consequences for maintenance and repair costs.

1.3.3 Industry Organization

To determine the ultimate effects of the EPA regulation, it is important to have a good understanding of the overall refinery industry structure. The degree of industry concentration, regional patterns of production and shipment, and the nature of the corporations involved are all important aspects of this discussion. In this section, we look at market measures for the United States as a whole and by PADD region.

Market Structure—Concentration. There is a great deal of concern among the public about the nature and effectiveness of competition in the refining industry. Large price spikes following supply disruptions and the tendency for prices to slowly fall back to more reasonable levels have created suspicion of coordinated action or other market imperfections in certain regions. The importance of distance in total delivered cost to various end-use markets also means that refiners incur a wide range of costs in serving some markets; because the price is set by the highest cost producer serving the market as long as supply and demand are in balance, profits are made by the low-cost producers in those markets.

There is no convincing evidence in the literature that markets should be modeled as imperfectly competitive, however. Although the FTC study cited earlier concluded that the extremely low supply and demand elasticities made large price movements likely and inevitable given inadequate supply or unexpected increases in demand, their economic analysis found no evidence of collusion or other anticompetitive behavior in the summer of 2000. Furthermore, the industry is not highly concentrated on a nationwide level or within regions. The 1997 Economic Census presented the following national concentration information: four-firm concentration ratio (CR) of 28.5 percent, eight-firm CR of 48.6 percent, and an HHI of 422. Merger guidelines followed by the FTC and Department of Justice consider that there is little potential for pricing power in an industry with an HHI below 1,000.

Two additional considerations were important in making a determination as to whether we can safely assume that refineries act as price-takers in their markets. First, with greater concentration in regional or local markets than at the national level, as well as with significant transport costs, competition from across the country will not be effective in restraining prices. Secondly, several large mergers have occurred since the 1997 Economic Census was conducted, all of which have prompted action by the FTC to ensure that effective competition was retained.

To investigate these issues, RTI estimated concentration measures that are not based on refinery-specific production figures (which are not available), but rather on crude distillation capacity, which is the industry's standard measure of refinery size. We aggregated the total capacity controlled by each corporate parent, both at the PADD level and nationwide, and then calculated CR-4, CR-8, and HHI figures. The results are presented in Table 1.3-13.

Table 1.3-13
2001 Concentration Measures for Refineries Based on Crude Capacity

PADD	Quantity	CR-4	CR-8	HHI
I	1,879,400	71.6%	91.3%	1,715
II	3,767,449	54.6%	78.2%	1,003
III	8,238,044	48.8%	68.0%	822
IV (current)	606,650	59.6%	90.1%	1,310
IV (future)	606,650	45.4%	80.5%	918
V	3,323,853	61.3%	90.9%	1,199
National	17,815,396	41.89%	65.50%	644

Note: Quantity is crude distillation capacity in thousands of barrels per stream day.
Source:U.S. Department of Energy, Energy Information Administration (EIA). 2002b. Refinery Capacity Data Annual. As accessed on September 23, 2002. http://www.eia.doe.gov/oil_gas/petroleum/data_publications/ refinery_capacity_data/refcap02.dbf. Washington, DC. See text discussion.

The data in this table provide several interesting conclusions:

- The current and future state of PADD IV shows the impact of FTC oversight to maintain competition. As part of approving the Phillips-Conoco merger, the FTC ordered the merged company to divest two refineries in PADD IV—Commerce City, Colorado, and Woods Cross, Utah. Once those divestitures take place, the concentration levels will drop below 1,000, a level that is not generally of concern.
- The only region that is highly concentrated is PADD I, which is generally dominated by two large refineries. In this case, however, imports of finished petroleum products, along with shipments from PADD III, should prevent price-setting behavior from emerging in this market. Table 1.3-14 shows imports of refined products for PADD I and the entire country. About 90 percent of total U.S. imports of gasoline and distillate fuels come into PADD I, aided by inexpensive ocean transport. It is reasonable to assume that any attempts to set prices by the dominant refineries would be defeated with increased imports.

Table 1.3-14
PADD I and Total U.S. Imports of
Gasoline and Fuel Oil Products by Top Five Countries of Origin

Top Five Countries of Origin	Finished Motor Gasoline		Distillate Fuel Oil		Residual Fuel	
	PADD I Import	Total U.S. Import	PADD I Import	Total U.S. Import	PADD I Import	Total U.S. Import
Venezuela	21,017	21,257	16,530	16,530	17,667	18,341
Brazil	8,286	8,286	1,472	1,832	8,361	9,105
Canada	41,711	43,778	30,350	35,165	9,483	11,723
Russia	869	968	10,345	10,345	174	1,051
Virgin Islands, USA	38,135	38,882	30,810	31,540	13,412	13,502
Sum of Top Five	110,018	113,171	89,507	95,412	49,097	53,722
Total	153,633	165,878	112,318	125,586	91,520	107,688
Percentage of Total U.S. Imports	92.6%		89.4%		85.0%	

Source: U.S. Department of Energy, Energy Information Administration (EIA). 2002a. Petroleum Supply Annual 2001. Tables 16, 17, and 20. Washington, DC. Table 20.

- Markets in PADDs II and III, which are not overly concentrated or geographically isolated, should be expected to behave competitively, with little potential for price-setting among its refineries.
- The four large mergers (Exxon-Mobil, BP-Amoco, Chevron-Texaco, and Phillips-Conoco) have not increased nationwide concentration to a level that would be a concern for competitive reasons.

Market Structure—Firms and Facilities. PADD III has the greatest number of refineries affected by the EPA nonroad regulation and will account for the largest volume of new ULSD nonroad fuel. Tables 1.3-15 and 1.3-16 present the number of operating refineries and the number of crude distillation units in each PADD; output volumes were presented in Table 1.3-5. PADD III also accounts for 45 to 50 percent of U.S. refinery net production of finished motor gasoline, distillate fuel oil, and residual fuel oil. Similarly, PADD IV contains the fewest number of affected facilities and accounts for the smallest share of distillate production. Still, because compliance costs per unit of output are likely to depend on refinery scale, the small size and geographic isolation of the PADD IV refineries suggest that the financial impact may be greatest on these operations.

Table 1.3-15
Number of Petroleum Refineries by PADD

PADD	Number of Facilities	Percentage of Total
I	16	11.1%
II	28	19.4%
III	54	37.5%
IV	14	9.7%
V	32	22.2%
Total	144	100.0%

Table 1.3-16
Number of Crude Distillation Facilities by PADD

PADD	Number of Facilities	Percentage of Total
I	12	8.6%
II	26	18.7%
III	50	36.0%
IV	16	11.5%
V	35	25.2%
Total	139	100.0%

According to the EIA Petroleum Supply Annual 2001, the top three owners of crude distillation facilities are ExxonMobil Corp. (11 percent of U.S. total), Phillips Petroleum Corp. (10 percent), and BP PLC (9 percent). Table1.3-17 gives an overview of the top refineries in each PADD, in descending order of total crude distillation capacity. As operating refineries attempt to run at full utilization rates, this measure should correlate directly to total output. Information is not available on actual production of highway diesel, nonroad diesel, and other distillate fuels for each refinery. It should be noted that PADD III has more than 50 percent of the total crude distillation capacity as well as the three largest single facilities.

Firm Characteristics. Many of the large integrated refineries are owned by major petroleum producers, which are among the largest corporations in the United States. According to Fortune Magazine's Fortune 500 list, ExxonMobil is the second largest corporation in the world, as well as in the U.S. Chevron Texaco ranks as the eighth largest U.S. corporation, placing it fourteenth in the world. The newly merged Phillips and Conoco entity will rank in the top 20 in the United States, and six more U.S. petroleum firms make the top 500. BP Amoco (fourth worldwide) and Royal Dutch Shell (eighth worldwide) are foreign-owned, as is Citgo (owned by Petroleos de Venezuela).

Many of the smallest refineries are certified as small businesses by EPA. A total of 21 facilities owned by 13 different parent companies qualify or have applied for small business status (EPA, 2002). These small refineries are concentrated in the Rocky Mountain and Great Plains region of PADD IV, and their conversion to ULSD is likely to require significant flexibility on the part of EPA.

1.3.4 Markets and Trends

There is considerable diversity in how different markets for distillate fuels have been growing over the past several years. Table 1.3-18 shows that residential and commercial use of fuel oil has been dropping steadily since 1984, while highway diesel use has nearly doubled over the same period. Farm use of distillate has been flat over the 15-year period, while off-highway use, mainly for construction, has increased by 40 percent.

Table 1.3-17
Top Refineries in Each PADD by Total Crude Distillation Capacity

	Name of Company	Location of Facilities		Crude Distillation Capacity (barrels/day)	Percentage of Total PADD Crude Distillate Capacity	Percentage of Total U.S. Crude Distillate Capacity
PADD I	Sunoco Inc. (R&M)	Philadelphia	PA	330,000	20.9%	2.0%
	Phillips 66 Co.	Linden	NJ	250,000	15.9%	1.5%
	Phillips 66 Co.	Trainer	PA	180,000	11.4%	1.1%
	Motiva Enterprises LLC	Delaware City	DE	175,000	11.1%	1.1%
	Sunoco Inc.	Marcus Hook	PA	175,000	11.1%	1.1%
	TOTAL			1,576,600	100.0%	9.7%
PADD II	BP Products North America, Inc.	Whiting	IN	410,000	12.0%	2.5%
	Phillips 66 Co.	Wood River	IL	288,300	8.4%	1.8%
	Flint Hills Resources LP	Saint Paul	MN	265,000	7.7%	1.6%
	ExxonMobil Refg & Supply Co.	Joliet	IL	235,500	6.9%	1.4%
	Marathon Ashland Petro LLC	Catlettsburg	KY	222,000	6.5%	1.4%
	Conoco Inc.	Ponca City	OK	194,000	5.7%	1.2%
	Marathon Ashland Petro LLC	Robinson	IL	192,000	5.6%	1.2%
	Williams Refining LLC	Memphis	TN	180,000	5.3%	1.1%
	TOTAL			3,428,053	100.0%	21.1%

(continued)

Figure 1.3-17 (continued)
Top Refineries in Each PADD by Total Crude Distillation Capacity

	Name of Company	Location of Facilities		Crude Distillation Capacity (barrels/day)	Percentage of Total PADD Crude Distillate Capacity	Percentage of Total U.S. Crude Distillate Capacity
PADD III	ExxonMobil Refg & Supply Co.	Baytown	TX	516,500	6.8%	3.2%
	ExxonMobil Refg & Supply Co.	Baton Rouge	LA	488,500	6.4%	3.0%
	BP Products North America, Inc.	Texas City	TX	437,000	5.8%	2.7%
	ExxonMobil Refg & Supply Co.	Beaumont	TX	348,500	4.6%	2.1%
	Deer Park Refg Ltd Ptnrshp	Deer Park	TX	333,700	4.4%	2.1%
	Citgo Petroleum Corp.	Lake Charles	LA	326,000	4.3%	2.0%
	Chevron U.S.A. Inc.	Pascagoula	MS	295,000	3.9%	1.8%
	Flint Hills Resources LP	Corpus Christi	TX	279,300	3.7%	1.7%
	Lyondell Citgo Refining Co. Ltd.	Houston	TX	274,500	3.6%	1.7%
	Premcor Refg Group Inc	Port Arthur	TX	255,000	3.4%	1.6%
	Conoco Inc.	Westlake	LA	252,000	3.3%	1.6%
	Phillips 66 Co.	Belle Chasse	LA	250,000	3.3%	1.5%
	Motiva Enterprises LLC	Port Arthur	TX	245,000	3.2%	1.5%
	Marathon Ashland Petro LLC	Garyville	LA	232,000	3.1%	1.4%
	Motiva Enterprises LLC	Norco	LA	228,000	3.0%	1.4%
	Motiva Enterprises LLC	Convent	LA	225,000	3.0%	1.4%
	Phillips 66 Co.	Sweeny	TX	213,000	2.8%	1.3%
	Valero Refining Co. Texas	Texas City	TX	204,000	2.7%	1.3%
	Chalmette Refining LLC	Chalmette	LA	182,500	2.4%	1.1%
	Atofina Petrochemicals Inc.	Port Arthur	TX	178,500	2.4%	1.1%
	Total			7583080	100.0%	46.7%

(continued)

Figure 1.3-17 (continued)
Top Refineries in Each PADD by Total Crude Distillation Capacity

	Name of Company	Location of Facilities		Crude Distillation Capacity (barrels/day)	Percentage of Total PADD Crude Distillate Capacity	Percentage of Total U.S. Crude Distillate Capacity
PADD IV	Conoco Inc.	Commerce City	CO	62,000	2.0%	0.4%
	Sinclair Oil Corp.	Sinclair	WY	62,000	2.0%	0.4%
	Conoco Inc.	Billings	MO	60,000	1.9%	0.4%
	TOTAL			567,370	18.4%	3.5%
PADD V	BP West Coast Products LLC	Los Angeles	CA	260,000	8.4%	1.6%
	Chevron U.S.A. Inc.	El Segundo	CA	260,000	8.4%	1.6%
	BP West Coast Products LLC	Cherry Point	WA	225,000	7.3%	1.4%
	Chevron U.S.A. Inc.	Richmond	CA	225,000	7.3%	1.4%
	Williams Alaska Petro Inc.	North Pole	AK	197,928	6.4%	1.2%
	TOTAL			3,091,198	100.0%	19.0%
Total U.S.	(excluding Virgin Islands)			16,246,301		100.0%

Source:U.S. Department of Energy, Energy Information Administration (EIA). 2002b. Refinery Capacity Data Annual. As accessed on September 23, 2002. <http://www.eia.doe.gov/oil_gas/petroleum/data_publications/refinery_capacity_data/refcap02.dbf>. Washington, DC.

Table 1.3-18
Sales of Distillate Fuel Oils to End Users 1984-1999 (thousands of barrels per day)

Year	Resi-dential	Com-mercial	Indust-rial	Oil Co.	Farm	Electric Utility	Rail-road	Vessel Bunkering	Highway Diesel	Military	Off-Highway Diesel	All Other	Total
1984	450	319	153	59	193	45	225	110	1,093	45	109	44	2,845
1985	471	294	169	57	216	34	209	124	1,127	50	105	12	2,868
1986	476	280	175	49	220	40	202	133	1,169	50	111	9	2,914
1987	484	279	190	58	211	42	205	145	1,185	58	113	5	2,976
1988	498	269	170	57	223	52	212	150	1,304	64	119	4	3,122
1989	489	252	167	55	209	70	213	154	1,378	61	107	2	3,157
1990	393	228	160	63	215	48	209	143	1,393	51	116	(s)	3,021
1991	391	226	152	59	214	39	197	141	1,336	54	110	(s)	2,921
1992	406	218	144	51	228	30	209	146	1,391	42	113	(s)	2,979
1993	429	218	128	50	211	38	190	133	1,485	31	127	(s)	3,041
1994	413	218	136	46	209	49	200	132	1,594	34	130	(s)	3,162
1995	416	216	132	36	211	39	208	129	1,668	24	126	—	3,207
1996	436	223	137	41	217	45	213	142	1,754	24	134	—	3,365
1997	423	210	141	41	216	42	200	137	1,867	22	136	—	3,435
1998	367	199	147	37	198	63	185	139	1,967	18	142	—	3,461
1999	381	196	142	38	189	60	182	135	2,091	19	140	—	3,572

Source: U.S. Department of Energy, Energy Information Administration (EIA). 2001a. Annual Energy Review, 2000, Table 5-13. Washington, DC.

1.4 Distribution and Storage Operations

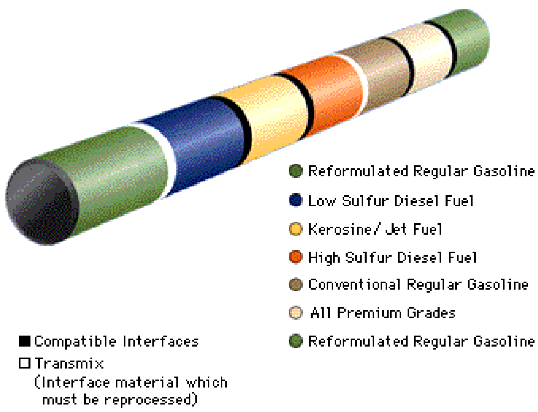
Refined petroleum products, including gasoline, distillates, and jet fuel, are transported by barge and truck and through pipelines from refineries to the wholesale and retail networks in the major markets of the United States. The most important of these routes is the 86,500-mile pipeline network, operated by nearly 200 separate companies (AOPL, 2000; FERC, 2002). Terminals and other storage facilities are located near refineries, along pipelines at breakout stations, and at bulk plants near major consumer markets. There are currently more than 1,300 terminals for refined products in the U.S. (API, 2002).

1.4.1 The Supply-Side

Pipelines are constructed of large-diameter welded steel pipe and typically buried underground. Pumps at the source provide motive force for the 3 to 8 miles per hour flow in the piping network (API, 1998; AOPL, 2000). Periodically, the line pressure is boosted at strategically placed pumping stations, which are often located at breakout points for intermediate distribution of various components. The product is moved rapidly enough to ensure turbulent flow, which prevents back-mixing of components. Figure 1.4-1 shows a typical configuration of several refined components on the Colonial Pipeline, a major artery connecting East Texas producing sites to Atlanta, Charlotte, Richmond, and New Jersey.

The pipelines do not change the physical form of the petroleum products that they carry and only add value by moving the products closer to markets. Operating costs of transporting products in a pipeline are quite small, so most of the cost charged to customers represents amortization of capital costs for construction. According to the 1997 Economic Census, revenues for pipeline transportation, NIACS code 48691, were $2.5 billion, of which only $288 million represented wags and salaries (U.S. Census Bureau, 2000). Almost all pipeline companies act as a common carrier (they do not take ownership of the products they transport), so their revenues and economic value added are equivalent. Census data for storage operations are not broken down in enough detail to permit estimation of revenues or value added.

Figure1.4-1
Typical Sequence in which Products are Batched While in Transit on Colonial System



The most important impact of additional EPA regulation on the distribution network has been to increase the number of different products handled by each pipeline. Although some concern has been expressed by these firms in relation to the gasoline and highway diesel regulations, the incremental effect of reducing sulfur content for nonroad diesel should be minor. The Colonial Pipeline mentioned previously currently handles 38 grades of motor gasoline, 16 grades of distillate products, 7 grades of kerosene-type fuels (including jet fuel), and an intermediate refinery product, light cycle oil (Colonial, 2002).

As Figure1.4-1 shows, these pipelines are shipping low-sulfur gasoline, LSD fuel, and high-sulfur nonroad fuel in the same pipeline. In most cases, the interface (mixing zone) between products is degraded to the poorer quality material. When they begin handling ULSD and gasoline, they may be forced to downgrade more interface material to nonroad or fuel oil and will need to carefully prevent contamination in storage tanks and pumping stations.

Importantly, changeover to ULSD for nonroad applications will not add additional complexity to their operations. EPA expects that there will be no physical difference between 15 ppm diesel fuel destined for the highway market and 15 ppm diesel fuel destined for the off-highway market prior to the terminal level when dye must be added to off-highway diesel fuel to denote its untaxed status. This will allow pipeline operators to ship such fuels in fungible batches. Consequently, the introduction of 15 ppm off-highway diesel should not result in increased difficulty in limiting sulfur contamination during the transportation of ultra-low sulfur products. Pipeline operators will continue to have a market for the downgraded mixing zone material generated during the shipment of 15 ppm diesel fuel by pipeline. After the implementation of EPA's 15 ppm highway diesel requirement and the envisioned off-highway diesel fuel controls, the pipelines that transport the majority of the nation's diesel fuel are projected to continue to carry HSD fuel and/or 500 ppm diesel fuel. These pipelines would blend their downgraded 15 ppm diesel into the 500 ppm and/or HSD fuel that they ship. A fraction of the pipelines are projected to carry only a single grade of diesel fuel (15 ppm fuel) after the EPA's highway program is implemented. These pipelines currently carry only 500 ppm highway diesel fuel. In EPA's highway diesel final rule, EPA projected that these pipelines would install an additional storage tank to contain the relatively low volumes of downgraded 15 ppm diesel fuel generated during pipeline transportation of the product. EPA projected that this downgraded material would be sold into the off-highway diesel market. The implementation of the envisioned nonroad diesel fuel controls would not change this practice. We expect that these pipeline operators would continue to find a market for the downgraded 15 ppm fuel, either as 500 ppm off-highway diesel fuel or for use in stationary diesel engines.

1.4.2 The Demand-Side

Demand for distribution through pipelines (versus barge or truck movement) is driven by cost differentials with these alternate means of transportation. The National Petroleum Council estimated in a comprehensive 1989 report that water transport of a gallon of petroleum products was about three times as expensive per mile as transport via pipeline, and truck transportation was up to 25 times as expensive per mile (National Petroleum Council, 1989). A recent pipeline industry publication shows that pipelines handle around 60 percent of refined petroleum product movements, with 31 percent transported by water, 5.5 percent by truck, and 3.5 percent by rail (AOPL, 2001).

Pipeline transport charges make up only a small portion of the delivered cost of fuels. Industry publications cite costs of about 1$ per barrel, equal to 2.5 cents per gallon, for a 1600 mile transfer from Houston to New Jersey, and about 2 cents per gallon for a shipment of 1100 miles from Houston to Chicago (AOPL, 2002; Allegro, 2001). Although average hauls are shorter and somewhat more expensive per mile, average transport rates are on the order of 0.06 to 0.18 cents per barrel per mile.

1.4.3 Industry Organization

Just as it has with other transportation modes defined by site-specific assets and high fixed costs, the federal government has traditionally regulated pipelines as common carriers. Unlike railroad and long-haul trucking, however, pipeline transport was not deregulated during the 1980s, and the Federal Energy Regulatory Commission (FERC) still sets allowable tariffs for pipeline movements. A majority of carriers, therefore, compete as regulated monopolies.

Most pipelines are permitted small annual increases in rates without regulatory approval, typically limited to 1 percent less than the increase in the producer price index (PPI). If regulatory changes caused significant cost increases, for instance from the addition of tankage to handle two grades of nonroad diesel fuel, pipeline operators would have to engage in a rate case with FERC to pass their increased costs along to consumers. If they chose not to request rate relief, the pipelines would absorb any costs above the allowable annual increases.

1.4.4 Markets and Trends

Pipeline firms have seen slowly rising demand for their services over the past several years. The latest available data, from the 1996 to 1999 period, are displayed in Table 1.4-1. Pipelines have not only captured almost all of the overall increase in total product movements, but they have taken some share away from water transport during the period. Railroad shipments have grown as well, but from a very small base.

Table 1.4-1
Trends in Transportation of Refined Petroleum Products

					Percentage Change
	1996	**1997**	**1998**	**1999**	**1996-1999**
Pipelines	280.9	279.1	285.7	296.6	5.6%
Water Carriers	154.1	148.3	147.1	147.5	–4.3%
Motor Carriers	28.0	26.0	26.7	27.6	–1.4%
Railroads	16.0	16.2	16.2	18.2	13.8%
Totals	479.0	469.6	475.7	489.9	2.2%

Note: All figures, except percentages, in billions of ton miles.
Source: Association of Oil Pipe Lines (AOPL). 2001. Shifts in Petroleum Transportation. As accessed on November 20, 2002. <www.aopl.org/pubs/facts.html>.

References to Chapter 1

1. RTI. 2003. Industry Profile for Nonroad Diesel Tier 4 Rule. Prepared for the U.S. Environmental Protection Agency. EPA Contract Number 68-D-99-024, April 2003. (Docket A-2001-28).

2. Power Systems Research(PSR). 2002. OELink Sales Database.

3. See endnote 1.

Allegro Energy Group. 2001. How Pipelines Make the Oil Market Work—Their Networks, Operations, and Regulations. New York: Allegro.

American Petroleum Institute (API). 1998. "All About Petroleum." As accessed on November 20, 2002. <api-ec.api.org/filelibrary/AllAboutPetroleum.pdf>.

American Petroleum Institute (API). 2001. "Pipelines Need Operational Flexibility to Meet America's Energy Needs." As accessed on November 20, 2002. <api-ep.api.org/industry/index.cfm>.

American Petroleum Institute (API). 2002. "Marketing Basic Facts." As accessed on September 25, 2002. <www.api.org/industry/marketing/markbasic.htm>.

Association of Oil Pipe Lines (AOPL). 2000. "Fact Sheet: U.S. Oil Pipe Line Industry." As accessed on November 20, 2002. <www.aopl.org/pubs/pdf/fs2000.pdf>.

Association of Oil Pipe Lines (AOPL). 2001. "Shifts in Petroleum Transportation." As accessed on November 20, 2002. <www.aopl.org/pubs/facts.html>.

Association of Oil Pipe Lines (AOPL). 2002. "Why Pipelines?" As accessed on November 20, 2002. <www.aopl.org/about/pipelines.html>.

Business & Company Resource Center. <http://www.gale.com/servlet/Item DetailServlet?region=9&imprint=000&titleCode=GAL49&type=1&id=115085>.

Chevron. 2002. "Diesel Fuel Refining and Chemistry." As accessed on August 19, 2002. <www.chevron.com/prodserv/fuels/bulletin/diesel/L2_4_2rf.htm>.

Colonial. 2002. "Frequently Asked Questions." As accessed on September 24, 2002. <www.colpipe.com/ab_faq.asp>.

Considine, Timothy J. 2002. "Inventories and Market Power in the World Crude Oil Market." As accessed on November 1, 2002. <http://www.personal.psu.edu/faculty/ c/p/ cpw/resume/finvmarketpower.html>.

Dun & Bradstreet. Million Dollar Directory. <http://www.dnb.com/dbproducts/description/ 0,2867,2-223-1012-0-223-142-177-1,00.html>.

Federal Energy Regulatory Commission (FERC). 2002. FERC Form No. 6, Annual Report of Oil Pipelines. <www.ferc.fed.us/oil/oil_list.htm>.

Flint Hills Resources. 2002. "Refining Overview." As accessed on September 10, 2002. <www.fhr.com/Refining101/default.asp>.

Federal Trade Commission (FTC). Midwest Gasoline Price Investigation, March 29, 2001, p.7. As accessed September 25, 2002. <www.ftc.gov/os/2001/03/mwgasrpt.htm>.

Freedonia Group. 2001. "Diesel Engines and Parts in the United States to 2005—Industry Structure." <http://www.freedoniagroup.com/scripts/cgiip.exe/WService=freedonia /abstract.html?ARTNUM=1153>.

Hoover's Online. <http://www.hoovers.com/>.

National Petroleum Council. 1989. "Petroleum Storage and Transportation." System Dynamics. Volume II. Washington, DC: National Petroleum Council.

U.S. Department of Agriculture, National Agricultural Statistics Service (USDA-NASS). 2002. Agricultural Statistics 2002. Washington, DC: U.S. Department of Agriculture.

U.S. Department of Energy, Energy Information Administration (EIA). 2001a. Annual Energy Review, 2000. Washington, DC: Department of Energy.

U.S. Department of Energy, Energy Information Administration (EIA). 2001b. Fuel Oil and Kerosene Sales, 2000, Tables 7-12. Washington, DC: Department of Energy.

U.S. Department of Energy, Energy Information Administration (EIA). 2002a. Petroleum Supply Annual 2001. Washington, DC: Department of Energy.

U.S. Department of Energy, Energy Information Administration (EIA). 2002b. Refinery Capacity Data Annual. As accessed on September 23, 2002. <http://www.eia.doe.gov/oil_gas/petroleum/data_publications/refinery_capacity_data/refcap02.dbf>. Washington, DC: Department of Energy.

U.S. Environmental Protection Agency. 1995a. EPA Office of Compliance Sector Notebook Project: Profile of the Motor Vehicle Assembly Industry. EPA310-R-95-009. Washington, DC: U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency (EPA). 1995b. Profile of the Petroleum Refining Industry. EPA Industry Sector Notebook Series. U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency (EPA). 2000. Heavy-Duty Standards/Diesel Fuel RIA. EPA420-R-00-026. Washington, DC: U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency (EPA). 2002. Highway Diesel Progress Review. EPA420-R-02-016. Washington, DC: EPA Office of Air and Radiation.

1992 data from U.S. Census Bureau. 1992 Census of Manufactures, Industry Series MC920I-29A. Table 1A.

1997 data from US Census Bureau, 1997 Economic Census - Manufacturing, Industry Series EC97M-3241A, Table 1.

1998-2000 data from US Census Bureau, Annual Survey of Manufactures-2000, 2000, Statistics for Industry Groups and Industries M00(AS)-1, Table 2.