5. Short-Term Impacts on ULSD Supply

Background

This chapter addresses the transition to ultra-low sulfur diesel fuel (ULSD) when the ULSD Rule takes effect in 2006. Whether there will be adequate supply was one of the key questions raised by the House Committee on Science in its request for analysis. The Charles Rivers Associates/Baker and O'Brien (CRA/BOB) study done for the American Petroleum Institute (API) estimated a shortfall of 320,000 barrels per day when the regulation is introduced in 2006. The issue of future supply of highway diesel fuel "received considerable attention during the comment period" on the Notice of Proposed Rulemaking (NPRM) published by the U.S. Environmental Protection Agency (EPA).[96] The EPA noted that "numerous commenters to the proposed rule indicated that they believed that the 15 ppm sulfur cap would cause shortages in highway diesel fuel supply" but that "a number of commenters also thought otherwise (i.e., that future supplies would be adequate)."[97]

While it is possible that some refiners may decide to shut down altogether because of this regulation, others might just abandon the highway diesel market. Few refineries can operate without producing gasoline because gasoline is a high-margin, high-volume product that provides significant revenue to refiners. On the other hand, it may be possible for some refineries to operate without producing ULSD. Some refineries could sell higher sulfur distillate products into the non-road, rail, ship, or heating oil markets. Some refiners could also decide to export distillate products if they are in the right location.

Because there are other markets for distillate products, some refiners may opt to delay upgrading their facilities to produce ULSD. Refiners' recent experiences with investing to meet new fuel standards have not been encouraging. As the EPA pointed out in the Regulatory Impact Analysis for this regulation, both the 500 ppm diesel fuel and reformulated gasoline standards resulted in overinvestment and oversupply of the fuels, and "of late, relatively poor refining margins have not allowed refiners to recoup the full cost of environmental standards."[98] Overly aggressive expansion to produce ULSD could result in similar oversupply of product and reduced margins, and some refiners may therefore wait to see whether adequate margins develop.

Another uncertainty is possible regulation of non-road diesel fuel. In addition, some States are proposing their own regulations for highway diesel fuel, which may add to the EPA requirements. Some refiners may wait to see whether additional requirements are established for highway or non-road diesel before investing to upgrade their refineries to produce ULSD.

The EPA has taken steps to monitor the ULSD supply situation. Its Final Rulemaking requires refiners and importers to submit a variety of information to ensure a smooth transition, and to evaluate compliance once the program begins. Refiners and importers expecting to produce highway diesel in 2006 are required to register with the EPA by December 31, 2001. Annual precompliance reports are required from 2003 through 2005, containing estimates of ULSD and 500 ppm sulfur fuel that will be produced at each refinery and projections of the numbers of credits that will be generated or needed by each refinery. A time line for compliance is also required, as well as other information.

The EPA will produce an annual report summarizing information from the precompliance reports without disclosing individual company plans. This information will give refiners a better indication of the potential market for credits and the availability of credits in each region. The EPA will also require annual reports after the program takes effect, in order to monitor production of ULSD and 500 ppm sulfur diesel fuel.[99] In addition, an independent advisory panel will be set up to look at issues of diesel supplies and related technologies, and to report to the EPA annually on the progress being made by industry to comply with the ULSD Rule.[100]

[96] U.S. Environmental Protection Agency, *Regulatory Impact Analysis: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Requirements*, EPA420-R-00-026 (Washington, DC, December 2000), Chapter IV, p. IV-33.

[97] U.S. Environmental Protection Agency, *Regulatory Impact Analysis: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Requirements*, EPA420-R-00-026 (Washington, DC, December 2000), Chapter IV, p. IV-33.

[98] U.S. Environmental Protection Agency, *Regulatory Impact Analysis: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Requirements*, EPA420-R-00-026 (Washington, DC, December 2000), Chapter IV, p. IV-34.

[99] U.S. Environmental Protection Agency, "Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements: Final Rule," Pre-publication Final Rulemaking (December 21, 2000), pp. 158-160.

[100] *Diesel Fuel News* (March 5, 2001), p. 3.

Cost Analysis

To assess the supply situation during the transition to ULSD in 2006, estimates of ULSD costs and supply were developed based on refinery-specific analysis of investment requirements. The relative costs can provide insights into whether refiners will make the investments to produce ULSD and give an indication of possible supply. Four scenarios describing investment behavior under different assumptions were developed to provide a range of possible responses to the ULSD Rule.

Using refinery-specific data collected by the Energy Information Administration (EIA), the ULSD product costs are estimated for each refinery based on its size, the sulfur content of the feeds, the fraction of cracked stocks in the feed, the boiling range of the feed, and the fraction of highway diesel produced. Cost curves were then developed in a three-step process. In the first step the cost of producing ULSD for each refinery was estimated for several strategies of ULSD production, based on refinery operation data for 1999. The strategies start by maintaining ULSD production at current highway diesel production levels. Then they consider both reductions and increases from current production to find the most economical level of production for individual refineries. In the second step the cost and volume information for individual refineries is used to construct cost curves for the U.S. refining industry using a variety of scenario assumptions about how refiners may respond with refinery investment in preparation for summer 2006, when ULSD requirements for highway diesel begin. The third step consists of adjusting the cost curves to reflect changes in refinery capacity from 1999 to 2006.

Appendix D describes in detail the refinery-by-refinery analysis and development of the cost model used as the basis for developing the cost curves. Table 6 provides samples of the ULSD cost model results for cases representing various refinery configurations and situations. The case descriptions in the table indicate whether the refinery in that particular case falls within the higher or lower part of the range in terms of hydrotreater unit capacity, sulfur content of the hydrotreater feed, and the fraction of cracked stock in the feed. The costs in this analysis assume a 5.2-percent after-tax return on

Table 6. Sample Results from the ULSD Cost Model

Refinery Characteristics and Costs	Case A	Case B	Case C	Case D	Case E	Case G	Case H	Case I	Case J	Case K	Case L
Hydrotreater Capacity Range[a]	H	H	H	H	H	L	L	H	H	H	HR
Feed Sulfur Content Range[a]	H	H	L	L	H	H	H	M	M	M	M
Percent Cracked Stock Range[a]	H	H	H	H	L	H	H	H	M	M	M
Revamp or New Unit[b]	N	R	N	R	R	N	R	N	N	R	R
Current Highway Diesel Production (Thousand Barrels per Day)	50.0	50.0	50.0	50.0	50.0	10.0	10.0	0.0	32.4	32.4	32.4
Hydrotreater Feeds (Thousand Barrels per Day)											
Straight-Run Distillate	34.0	34.0	34.0	34.0	50.0	6.8	6.8	33.0	25.3	25.3	18.4
Light Cycle Oil	8.0	8.0	8.0	8.0	0.0	1.6	1.6	4.0	2.1	2.1	0.0
Coker Distillate	8.0	8.0	8.0	8.0	0.0	1.6	1.6	23.0	5.1	5.1	2.3
Total	50.0	50.0	50.0	50.0	50.0	10.0	10.0	60.0	32.4	32.4	20.7
Hydrogen Consumption (Standard Cubic Feet per Barrel)	550	550	402	402	248	550	550	590	395	395	305
Feed Sulfur Content (Parts per Million)											
Straight-Run Distillate	9,000	9,000	1,100	1,100	9,000	9,000	9,000	6,000	6,000	6,000	6,000
Light Cycle Oil	25,000	25,000	3,800	3,800	0	25,000	25,000	15,000	13,000	13,000	13,000
Coker Distillate	22,000	22,000	5,700	5,700	0	22,000	22,000	14,000	14,000	14,000	14,000
ULSD Cost Components (1999 Dollars per Barrel)											
Hydrotreater											
Capacity Changes	0.73	0.55	0.70	0.55	0.36	1.21	0.74	0.72	0.81	0.55	0.49
Other	0.83	0.74	0.75	0.68	0.54	0.96	0.79	0.87	0.78	0.67	0.62
Hydrogen Production											
Capacity Changes	0.20	0.20	0.22	0.22	0.05	0.35	0.35	0.30	0.19	0.19	0.00
Other	0.52	0.53	0.55	0.54	0.12	0.56	0.57	0.88	0.40	0.41	0.13
Sulfur and Other	0.27	0.06	0.07	0.06	0.06	0.41	0.10	0.19	0.19	0.07	0.08
Total Cost (1999 Dollars per Barrel)	**2.54**	**2.08**	**2.27**	**2.05**	**1.12**	**3.49**	**2.56**	**2.97**	**2.37**	**1.88**	**1.31**
Total Cost (1999 Cents per Gallon)	**6.0**	**5.0**	**5.4**	**4.9**	**2.7**	**8.3**	**6.1**	**7.1**	**5.6**	**4.5**	**3.1**

[a]H = refinery in the higher range; M = refinery in the middle range; L = refinery in the lower range.
[b]N = new unit; R = revamped unit.
Note: Only refineries in Petroleum Administration for Defense Districts (PADDs) I-IV are included in the short-term analysis.
Source: Energy Information Administration, Officeof Integrated Analysis and Forecasting.

investment, which is estimated to be equivalent to the 7-percent before-tax return on investment assumed in the EPA's analysis.

The cases in Table 6 were designed to represent the types of individual refinery situations that lie behind the cost curve results. Cases A and B represent refiners producing highway diesel fuel as a high fraction of their distillate pool. These refineries run a higher sulfur crude oil, do not have hydrocracking facilities, and have relatively large-scale highway diesel production. Thirty-two percent of the highway diesel they produce comes from cracked stock, which is about the average for Petroleum Administration for Defense District II (PADD II) (see Appendix D, Table D1). The cost of producing highway diesel at current production levels in the refineries of Cases A and B is 6.0 cents per gallon if a new hydrotreater is required and 5.0 cents per gallon if the current hydrotreater can be revamped. The cost of the incremental hydrogen to produce ULSD represents 28 percent of the added cost for Case A and 35 percent for Case B.

Cases C and D have the same volumes as A and B but use a lower sulfur crude oil. The cost of the added hydrogen is similar to the result for Cases A and B, because this analysis is estimating the cost to produce ULSD with 7 ppm sulfur rather than the current 500 ppm. Total costs, however, are just 0.1 cents per gallon lower for a revamped unit (Case D compared to Case B) and 0.6 cents per gallon lower for a new unit (Case C compared to Case A).

Case E shows a refinery producing ULSD only from straight-run distillate derived from a high-sulfur crude. The cost of production from a hydrotreater that has been revamped is only 2.7 cents per gallon. This is slightly more than half the cost of Case B, which has to handle 32 percent cracked stocks.

Cases G and H represent the same mix of hydrotreater feed as in Cases A and B, but the total feedstock volume is only 10,000 barrels per day, compared to 50,000 barrels per day in Cases A and B. This is the type of situation represented by comparing ULSD production in PADD IV with that in PADD II and PADD III. For a new hydrotreater unit, the ULSD cost would be 8.3 cents per gallon (2.3 cents per gallon higher than in Case A). If the unit can be revamped, the cost is 6.1 cents per gallon (1.1 cents per gallon higher than in Case B).

Some refineries currently produce high volumes of distillate product but no highway diesel. These refineries might consider entering the highway diesel market when the ULSD Rule takes effect if they anticipate that the price differential between ULSD and their other distillate products can more than offset the added investment and operating costs they would incur. Case I illustrates a non-road diesel producer converting to the production of highway diesel. The refinery runs a moderately high-sulfur crude oil and has substantial volumes of cracked distillates from the fluid catalytic cracker (FCC) and coker units. Because of quality requirements for non-road diesel products, cracked stocks still make up 45 percent of the feed to the hydrotreater for highway diesel production. The large percent of cracked stocks means a moderately high per-barrel investment and operating cost for the hydrotreater. Additionally, the per-barrel cost for hydrogen is quite high. Most of the refineries with high-volume distillate production and no highway diesel production had costs of highway diesel production in the higher portion of the cost range.

Cases J, K, and L provide an illustration of refineries achieving improved economics by reducing the volume of ULSD diesel below current highway production levels. As shown in Table 6, the cost of added hydrogen is generally a large component of the cost of producing ULSD. The cost for hydrogen grows as the fraction of cracked stocks increases, eventually requiring the construction of new hydrogen production capacity. However, if there is only a modest percent of cracked stock in the hydrotreater feed and the refiner reduces the input to the hydrotreater, then the incremental hydrogen requirement for ULSD production can be provided by existing refinery production sources.

Cases J and K show the costs for a new and revamped hydrotreater for a refinery running a medium-sulfur crude and with 22 percent cracked stock in the highway diesel production pool. Case L shows that if the input level is reduced from 32,400 barrels per day to 20,700 barrels per day when the unit is revamped, then the cost of ULSD production is reduced from 4.5 cents per gallon to 3.1 cents per gallon. Given the costs for Cases K and L, the preferred option for the refiner would be Case K if the price differential between highway and non-road diesel exceeds 6.9 cents per gallon and Case L if the differential is less than 6.9 cents per gallon.[101]

These sample cases highlight several situations that can cause refineries to have potentially high ULSD production costs and discourage them from investing to produce ULSD. Small refineries with less than 10,000 barrels per day of highway diesel production will have very high relative costs unless they can revamp an existing unit. The fraction of cracked stocks in the ULSD hydrotreater feed is extremely important. The need for hydrogen increases with the fraction of cracked stocks and may require new hydrogen production capability. If a refinery's other distillate products are primarily

[101] Calculated by taking the difference in total cost ($1.88 \times 32.4 - 1.31 \times 20.7$) divided by the change in volume ($32.4 - 20.7$), expressed in cents per gallon.

non-road diesel fuels with cetane requirements that limit the volume of cracked stocks, then it is often impossible for the refinery to reduce the cracked stocks going into highway diesel. Thus, refineries with moderate cracked stocks and a smaller scale will have high ULSD cost, and refineries with high cracked stocks and a moderate to large scale may also have ULSD costs that they view as uncompetitive.

Analysis of ULSD Production Decisions

Economic Considerations

Scenarios are analyzed to estimate the volumes of ULSD that refiners might produce at the beginning of the ULSD requirement in the summer of 2006. Each scenario defines a set of strategic principles that might characterize the economic rationale behind investment decisions that may be commonly made by refiners in this situation. Refiners have a choice as to how much ULSD they produce. Some refiners may decide to produce no highway diesel when the ULSD Rule comes into effect. While most refiners who are currently producers of highway diesel will likely continue to produce it, they could increase or decrease production from current levels. Because there is uncertainty associated with refiners' behavior, four supply scenarios were constructed, any one of which may turn out to be closest to the actual behavior of the refining industry in this situation.

In making the ULSD decision a refiner will look at the available options, analyze the costs to produce various levels of ULSD, and determine the impact on other distillate products. Then the refiner will try to estimate his relative competitive position for producing ULSD. The competitive assessment considers the cost of ULSD production for other refiners and looks at the mid-term competition for market share, including an analysis of current market share, regional market competition, the impact of new entrants that may have a significant cost advantage, synergies with other refineries within the same company, and potential changes in the price differential between ULSD and non-road fuels on a mid-term basis.

In a number of past instances when refiners have been required to meet new product specifications, they have not only made facility changes that would enable them to meet the demand for the product with new specifications, but have done so in such numbers and volumes that their ability to supply the market has exceeded market demand. In the case of ULSD, refiners have more choice in deciding to participate in the highway market or alternatively to produce products only for non-road distillate markets. This choice becomes a particular issue for refiners facing an expensive investment decision and the likelihood that they would be at a significant competitive cost disadvantage relative to other market competitors.

While most U.S. refiners look upon gasoline as an essential product, they could operate in the refinery business without producing any highway diesel. Thus, it is possible that some refiners will cease or significantly decrease highway diesel production when ULSD specifications take effect in 2006. This would create a transition market in which some refiners with higher costs would decrease production and be replaced by more cost-competitive refiners.

The set of more cost-competitive refiners falls into two categories—those increasing production of highway diesel from current levels and those currently producing little or no highway diesel. Will refiners in the second group jump into the market because they recognize that they would have a competitive position, or will they wait to see how the supply and margin picture unfolds before making a large-dollar commitment? Later entrants into the market could also be the beneficiaries of improved technologies that reduce the cost of compliance.

Refiners who estimate that their costs to produce ULSD are on the high end of the range will be far less likely to invest to produce ULSD. No one wants to be the marginal supplier after making a large investment, especially when the product is a secondary fuel product. The question is what differential cost will be perceived to be too high—is it 1 or 2 cents per gallon above what the refiner perceives is the average cost in the market? How does the refiner assess the possible competitive threats of a large-volume refiner who has previously not been a highway diesel producer but may now enter the market with better economics to produce highway diesel and reduce market prices? Refiners will likely try to retain highway market share, even if their relative competitive cost is modestly above the average cost in the region, rather than shifting into new markets. Refining companies with multiple refineries will view strategies in the context of their total system and could rebalance production on a system basis.

One of the key decisions in preparing to produce ULSD is whether to build a new hydrotreater or revamp an existing unit. This analysis assumes that revamps are more likely if a refinery installed new distillate hydrotreating units in the 1990s, or if the proportion of cracked stocks in the refinery's hydrotreater feed is small. New units are assumed at refineries where current hydrotreating capacity is less than highway diesel production. As shown in Table 7, the estimates indicate that 46 percent of the refineries in PADDs I-IV, accounting for 63 percent of highway diesel production capacity, would revamp existing units. PADD IV has the

Table 7. Estimate of Revamps and New Hydrotreaters for ULSD Production

Region	Number of Refineries			Percent Revamp	ULSD Production Volume (Thousand Barrels per Day)			Percent Revamp
	Revamp	New	Total		Revamp	New	Total	
PADD I	4	7	**11**	36	139	77	**216**	64
PADD II	14	13	**27**	52	442	158	**599**	74
PADD III	22	23	**45**	49	603	423	**1,026**	59
PADD IV	5	10	**15**	33	46	72	**117**	39
Total	**45**	**53**	**98**	**46**	**1,229**	**729**	**1,957**	**63**

PADD = Petroleum Administration for Defense District.

Note: Although 98 refineries are considered in this analysis, 87 are current producers of low-sulfur diesel. Not all of these refineries are expected to produce ULSD economically.

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

lowest proportion of revamps because of the larger amount of cracked stocks that refineries in that region must process. PADD II has the highest percentage of revamps because of the extensive upgrading that took place in the early 1990s and the moderate levels of cracked stocks in the feed. The EPA assumed that 80 percent of ULSD production capacity would be revamped units.

Supply Scenarios

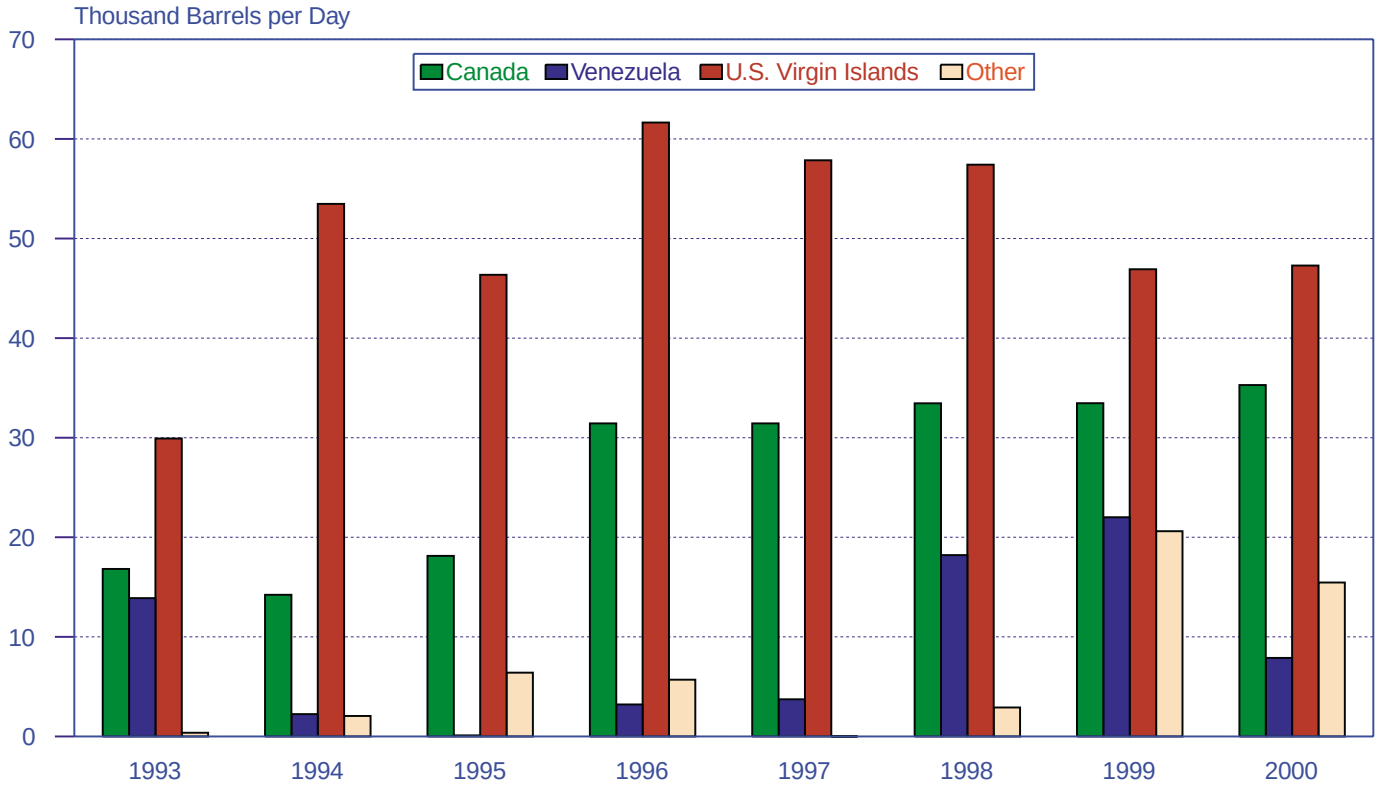
The first of the four supply scenarios was developed based on the rationale that there is a high probability that refiners will produce at least a moderate level of ULSD. In the other three scenarios there is decreasing probability that the additional volumes would be produced. The description of the specific scenarios follows:

- **Scenario 1—Competitive Investment.** The first scenario includes only those refiners who are likely to prepare to produce ULSD in 2006. They currently hold market share and are estimated to be able to produce ULSD at a competitive cost. Refiners with highway diesel as a relatively low fraction of their distillate production are assumed to abandon the market unless their cost per unit of production is competitive at current highway diesel production levels. Some refiners are assumed to reduce highway diesel production below current levels when they have a more competitive ULSD production at a reduced production rate.
- **Scenario 2—Cautious Expansion by Competitive Producers.** In this scenario, refiners base ULSD production decisions on the assumption that the price differential between ULSD and non-road distillate products will remain wide. Current producers with competitive cost structures for ULSD production and high fractions of highway diesel production (greater than 70 percent of total distillate production) are assumed to maintain current production levels and may even push production of ULSD toward 100 percent of distillate production if only minor increases in per unit production costs occur at increased volume. Other refiners are also assumed to increase their fraction of highway production if the economics are only slightly poorer at higher volumes. Those whose current production is focused primarily on non-road markets are assumed to stay with those markets.
- **Scenario 3—Moderate New Market Entry.** While refineries that are currently producing little or no highway diesel may be hesitant to jump into the ULSD market, this scenario assumes that a select few will decide to take the risk. This is based on the belief that a limited number of refineries think they can gain market share without depressing the price differential between ULSD and non-road diesel to the extent of ruining margins and return on investment. These refiners are assumed to have favorable cost structures for ULSD production (probably in the lower third).
- **Scenario 4—Assertive Investment.** The fourth scenario assumes that a larger number of refiners will compete to increase their shares of the ULSD market. In this scenario, refiners believe that most of their competitors are overly cautious, and that they can succeed by taking a contrary strategy (which in reality is adopted by far more refiners than anticipated).

Imports

Historically, imports have been a small part of low-sulfur diesel supply. The only significant volumes of low-sulfur diesel fuel have been imported into PADD I, which totaled 123,000 barrels per day in 1999 then declined slightly in 2000 to 106,000 barrels per day (Figure 4). Imports made up 5 percent of low-sulfur diesel product supplied for the United States as a whole in 2000 and 14 percent of product supplied in PADD I. The PADD I imports come from three main sources—Canada, the Virgin Islands, and Venezuela. Low-sulfur diesel imports from the Virgin Islands reached 62,000 barrels per day in 1996 and have fallen to 47,000 barrels per day in 2000. Imports from Canada, which have been fairly constant for the past few years, totaled 35,000 barrels per day in 2000. Imports from Venezuela grew sharply in 1998 and 1999, to 22,000 barrels per day in 1999, before falling to 8,000 barrels per day in 2000.

Figure 4. Imports of Low-Sulfur Diesel Fuel into PADD I, 1993-2000



Source: Energy Information Administration, Form EIA-814, "Monthly Imports Report."

Other countries are also planning to lower the sulfur content of diesel fuel. Canada has announced plans to require a 15 ppm sulfur diesel fuel in mid-2006, mirroring the U.S. regulation.[102] A 50 ppm ULSD becomes mandatory across Europe in 2005. The European Commission is also discussing a gradual phase-in to 10 ppm sulfur, starting with a 10-percent supply requirement in January 2007.[103]

Given these changes, Canadian refiners currently exporting to the United States may make the investment to produce ULSD for the U.S. market. The East Coast has been the main market for a large refinery in the Virgin Islands that is jointly owned by Amerada Hess and PdVSA, Venezuela's national oil company. Both of the plant's owners see the United States as a strategic market. Venezuela is planning to upgrade its domestic refineries, but because it is also interested in expanding its presence in Latin American markets,[104] it is not clear whether it would supply ULSD to the U.S. market.

Refineries worldwide will be investing to produce lower sulfur diesel fuel. Even a refinery designed to produce diesel with 50 ppm sulfur could produce some amounts at less than 15 ppm. Thus, it is conceivable that limited amounts of ULSD could be imported from other sources. In the early part of the transition to ULSD, imports beyond historical levels probably are less likely and quantities less than historical levels probably are more likely.[105]

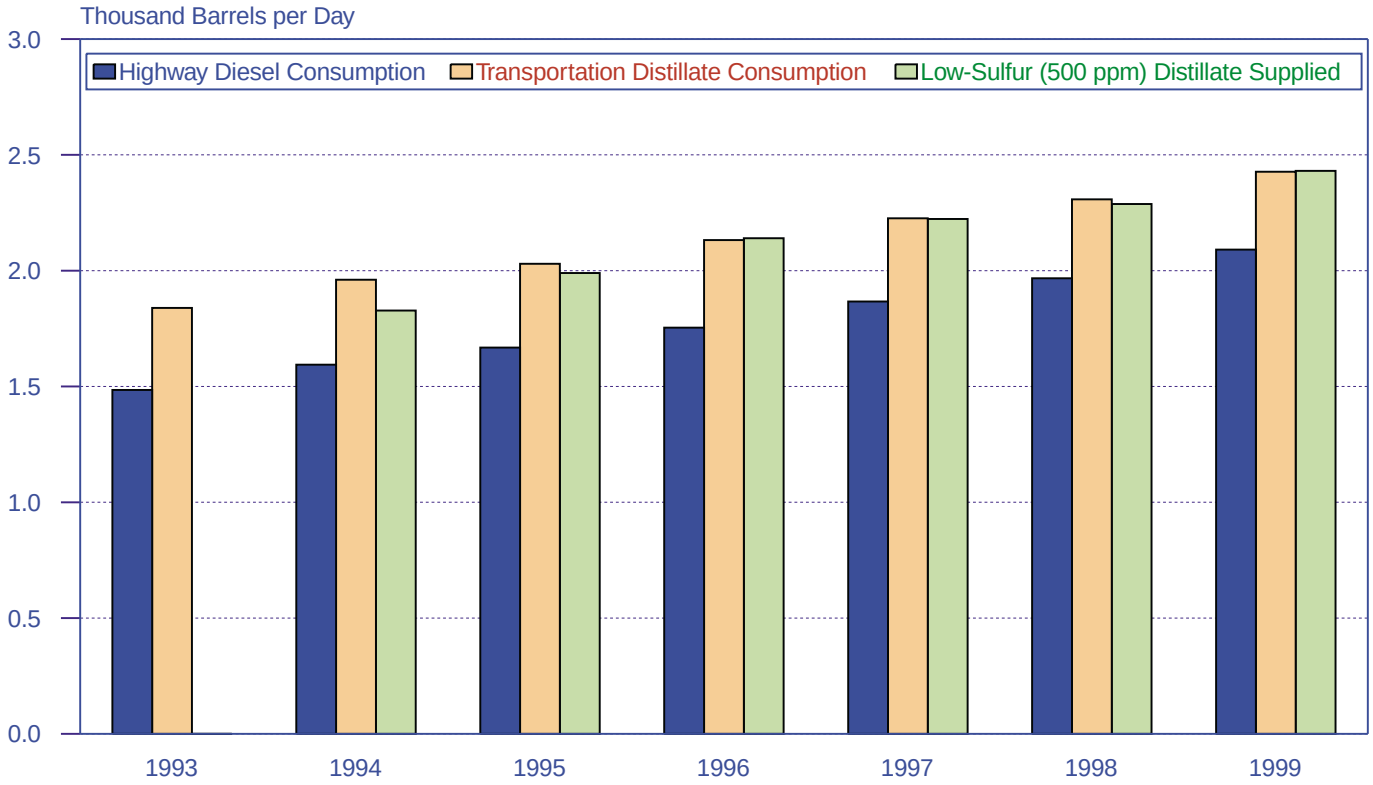
Demand Issues

The number of vehicles that actually need ULSD when the regulation takes effect in 2006 will be small. The EPA has mandated that 80 percent of the refinery output of less than 500 ppm diesel fuel be ULSD in order to provide retail availability for the trucks that need ULSD. As a result, the supply of ULSD will be much larger than the demand provided by vehicles that need ULSD. The concern is whether enough fuel will be available to supply all highway diesel vehicles.

Current production of low-sulfur diesel fuel is greater than what is required by the market. Highway diesel fuel consumption accounted for 86 percent of transportation distillate demand in 1999. Yet low-sulfur diesel product supplied (a surrogate for demand) has nearly equaled transportation distillate demand in recent years (Figure 5). Consequently, the amount of low-sulfur

[102] Public Works and Government Services Canada, *Canada Gazette*, Vol. 135, No. 7 (February 17, 2001), p. 454.
[103] *Diesel Fuel News* (March 5, 2001), p. 11.
[104] *Oil Daily* (February 27, 2001), p. 2.
[105] EIA's Office of Oil and Gas is planning to issue a report in 2001 on the availability of product imports.

Figure 5. Low-Sulfur Diesel Consumption and Product Supplied, 1993-1999



Sources: Energy Information Administration, *Petroleum Supply Annual*, DOE/EIA-0340, and *Fuel Oil and Kerosene Sales*, DOE/EIA-0525 (Washington, DC, 1993-1999).

diesel fuel currently being consumed in the market is more than 15 percent higher than that required for highway vehicles. There are several reasons for this. The logistics of the distribution system dictate in some areas that only one type of fuel can be distributed. Because the price differential between low-sulfur diesel and other distillate products has been only 2 to 3 cents per gallon or less in recent years, the incentive to maintain separate product infrastructure has not been great. An important question is the extent to which the demand for ULSD will remain above that required for highway vehicles after the ULSD regulation takes effect in 2006. A larger price differential between ULSD and higher sulfur distillate products may provide some incentive to avoid consuming ULSD in markets where it is not required, but in some areas it may continue to be impractical to distribute more than one product.

It is also unclear how much 500 ppm sulfur diesel fuel will be in the market after the regulation takes effect. Refiners will be investing for the long term and not just to produce 80 percent ULSD in the transition period, and many refiners (if they invest to produce ULSD at all) may be producing 100 percent ULSD in the transition period. Some refiners could continue to supply 500 ppm diesel fuel by purchasing credits, and some small refiners could continue to produce 500 ppm sulfur fuel until 2010 (see box on page 45).

For the above reasons, the amount of ULSD actually needed to balance demand in 2006 is highly uncertain. A range of demand estimates has been developed to account for some of the uncertainty. In the mid-term analysis for this study, transportation distillate demand in PADDs I-IV[106] in the 2 / 3 Revamp case (see Chapter 6) amounts to about 2.7 million barrels per day. At the U.S. level, transportation distillate demand is projected to be 3.0 million barrels per day in 2006, increasing by 3.2 percent per year from the 1999 level of 2.4 million barrels per day. This compares to an average rate of increase of 3.5 percent per year from 1982 to 1999. Transportation distillate demand rose sharply from 1982 to 1989 and again from 1991 to 1999, at annual average growth rates of 4.7 and 4.0 percent, respectively, but fell in 1990 and 1991, at the time of the Iraqi invasion of Kuwait.

The probable downgrading of some ULSD to 500 ppm sulfur diesel in the distribution system was not taken into account in this part of the analysis. The requirement to produce 80 percent ULSD is at the refinery gate, and

[106] PADD V was not included in this analysis because supply concerns are less of an issue in the transition period and the requirement for CARB diesel makes the PADD V market different from PADDs I-IV.

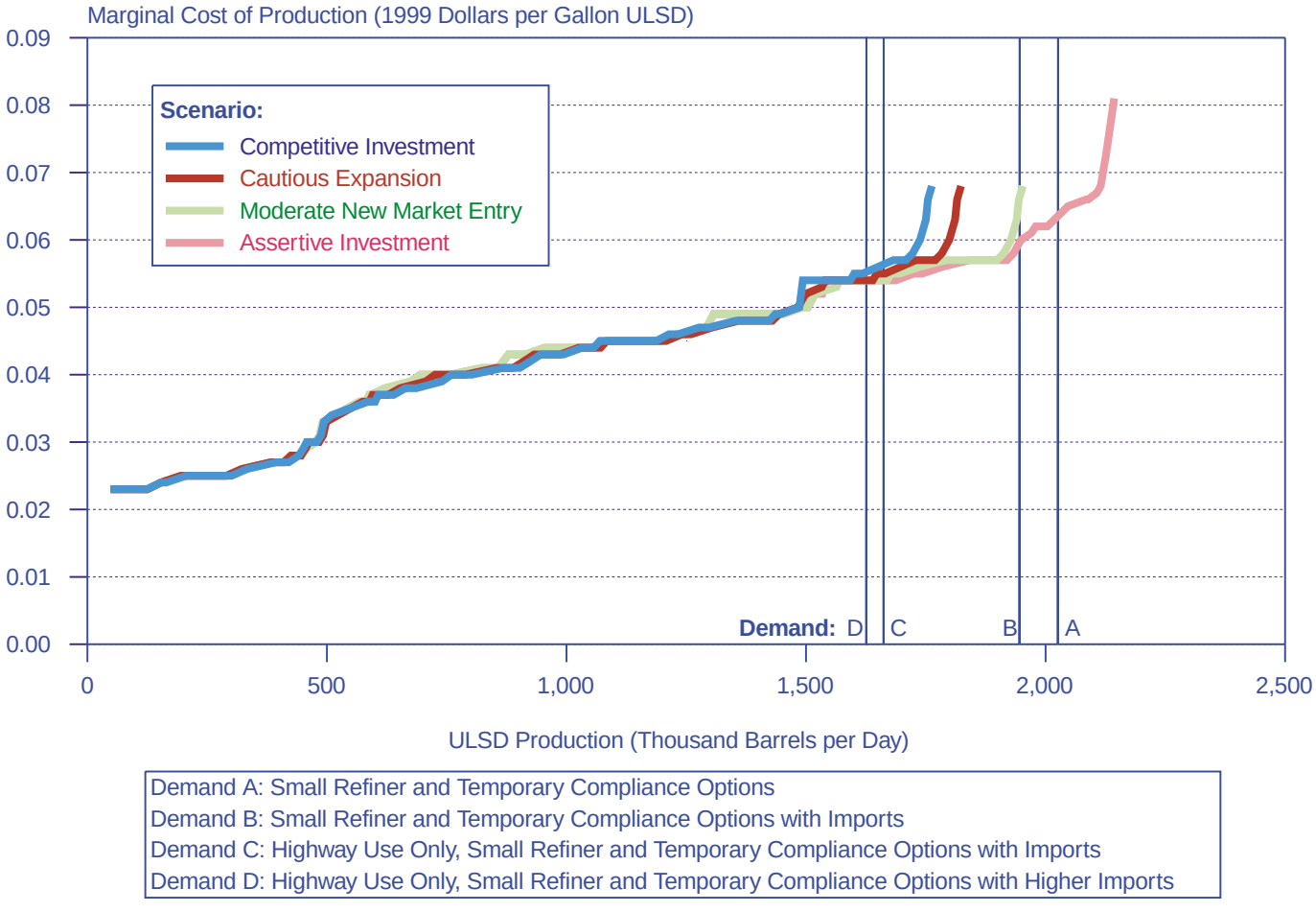
supplies that are downgraded to a higher sulfur level in the distribution system can still be sold as highway diesel during the transition period.

Cost Curves and Demand Estimates for 2006

Figure 6 shows the combined cost curves for PADDs I-IV for each of the scenarios, together with four estimates of demand.[107] The EPA estimates that, under the small refiner option, up to 5 percent of the market could delay making the transition to ULSD until 2010.[108] In addition, the temporary compliance option mandates that ULSD production must constitute 80 percent of low-sulfur diesel production. Assuming the full extent of the small refiner, temporary compliance, and credit trading provisions of the Rule, ULSD demand is estimated at just over 2.0 million barrels per day (Demand A). As indicated above, imports from the Virgin Islands and Canada are likely to continue. At their recent historical level of 80,000 barrels per day, imports would reduce domestic demand for ULSD to 1.95 million barrels per day (Demand B, which matches the demand projection in the mid-term analysis described in Chapter 6). Demand C in Figure 6 is based on the same assumptions as Demand B and, in addition, assumes that ULSD will be used only for highway consumption (86 percent of transportation distillate demand), resulting in a demand estimate of 1.7 million barrels per day. Demand D assumes a higher estimate for imports—116,000 barrels per day—which was the level for PADDs I-IV in 2000.

The cost curves in Figure 6 show the estimated volumes of ULSD that could be produced at increasing cost levels. The curves show the wide range of costs to produce ULSD across the population of U.S. refiners that might choose to become ULSD producers. There are some refiners at the upper range of the cost curves that would

Figure 6. ULSD Cost Curve Scenarios with 2006 Demand Estimates



Sources: Cost curve scenarios: Appendix D. Demand estimates: National Energy Modeling Sytem, run DSU7INV.D043001A.

[107] A range of demand estimates are shown in Figure 6, but no feedback effects are represented. Feedback effects are included in the mid-term analysis (Chapter 6).

[108] U.S. Environmental Protection Agency, *Regulatory Impact Analysis: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Requirements*, EPA420-R-00-026 (Washington, DC, December 2000), Chapter V, p. V-134.

have much higher costs and could have concerns that margins in the marketplace would not be high enough to provide a satisfactory rate of return.

The cost curves in Figure 6 were developed using capital cost and return on investment assumptions consistent with those used in the EPA's analysis. Those assumptions were used in order to provide a comparison with the EPA's analysis results and should not be viewed as the assumptions that EIA considers the most likely. However, concerns about the adequacy of ULSD supply are based on the possible reluctance of higher cost producers to invest to produce ULSD in 2006. Because of the uncertainty of these assumptions, two additional sets of supply scenarios are provided, using higher capital cost assumptions and a higher required return on investment, as discussed later in this chapter.

Total ULSD production on the Scenario 1 (Competitive Investment) and Scenario 2 (Cautious Expansion) cost curves extends beyond the lower demand estimates (C and D) and would meet the highway demand estimates even if no ULSD imports were available. In Scenario 3 (Moderate New Market Entry), production just reaches the mid-term analysis demand estimate that includes imports (Demand B). In Scenario 4 (Assertive Investment), ULSD production surpasses the mid-term analysis demand estimate that does not include imports. None of the supply curves, however, provides enough supply to reach the demand estimate that does not include the temporary compliance option (see Table 8 below). Some refiners may be able to produce ULSD with a cost of about 2.5 cents per gallon; however, at the volumes needed to meet demand, costs are estimated at 5.4 to 6.8 cents per gallon.[109] ULSD prices could show an even higher differential if supply falls short of demand.

The four factors that have the strongest influence on the cost of producing ULSD are the production volume of 500 ppm diesel, the fraction of cracked stocks in the feedstock, the scale of the hydrotreater unit, and whether a new or revamped unit is required.

500 ppm Diesel Supply Issues in 2006

In 2006, 500 ppm highway diesel could come from two sources: either from refiners who produce both 500 ppm and 15 ppm highway diesel or from refiners who are now producing highway diesel but who choose not to make investments to produce ULSD and purchase credits to sell 500 ppm diesel. Few refineries are assumed to fall into the first group. Possible candidates would be refiners with large current production of highway diesel who have multiple distillate hydrotreating units and decide to revamp or replace a large unit to produce ULSD and maintain a second unit to produce 500 ppm highway diesel. This would also mean that the refiner would anticipate selling the 500 ppm diesel as non-road diesel in 2011, because building one large hydrotreater in 2006 would be more economical than building a second hydrotreater for ULSD in 2010. If the decision is made to invest to produce ULSD, a refiner is likely to invest to produce the full volume of highway diesel as ULSD. Some product that fails to meet the ULSD specifications could be downgraded to 500 ppm diesel fuel and sold as highway diesel during the transition period, but few refiners are assumed to produce both 15 ppm and 500 ppm diesel.

Production of 500 ppm highway diesel can clearly come from refiners who are now producing low-sulfur highway diesel and decide not to convert their refinery facilities in 2006. In Scenario 2, the number of non-producers of ULSD in PADDs I-IV totals 21. The characteristics of the 21 refineries that are the potential sources of 500 ppm highway diesel production in 2006 in Scenario 2 differ across the various PADDs. PADD I has 5 refineries and PADD II has 5 refineries that are assumed not to invest to produce ULSD. Nine of these ten refineries currently produce less than 10,000 barrels per day of highway diesel, and the other is under 20,000 barrels per day.

The profile of the PADD III refiners is quite different from those in the other PADDs. While PADD III has some small refineries in this group, several moderately large refineries are also included, which accounts for the fact that PADD III represents 56 percent of the total volume of PADD I-IV production that is estimated not to convert from low-sulfur diesel to ULSD in 2006. Most of these refineries are on the high end of the cost range and would have to build new units and/or deal with relatively high fractions of cracked stocks to produce ULSD.

Six refineries in PADD IV are estimated to have relatively high costs of ULSD production and are assumed not to invest to produce ULSD. The PADD IV refiners are relatively small. Most have some cracked stocks in the highway diesel feed stream and would need to build new units. The refiners not producing ULSD would need to obtain waivers or purchase credits to continue to sell 500 ppm diesel fuel into the highway market.

[109] These are marginal costs on the industry supply curve, based on average refinery costs for producing ULSD. These cost estimates do not include additional costs for distribution, estimated at 1.1 cents per gallon in the mid-term analysis. Costs were not adjusted to take sulfur credit trading into account, because of the uncertainty about whether trading would occur and the value of the credits. If credit trading occurred, costs could be reduced.

Twenty-nine refineries in Scenario 1 are in the cost range below 4 cents per gallon, and all are refineries for which it is assumed that the existing unit could be revamped. Most of these refineries have little or no cracked stocks in the hydrotreater feed to produce ULSD. For the few that do have cracked stocks, a revamped unit at a reduced throughput was found to obtain better economics of ULSD production and put them in the cost range under 4 cents per gallon. Twenty-five refineries are in the cost range from 4 to 5 cents per gallon. Thirteen are assumed to construct new units, and most of these refineries have a low percentage of cracked stocks in the hydrotreater feed. A couple of units in this cost range are assumed to reduce throughput from current highway diesel production levels. Above 5 cents per gallon, a couple of refineries with a high percentage of cracked stocks are assumed to revamp existing units. The rest, which have moderate levels of cracked stocks, are assumed to build new units. The refineries above 5 cents per gallon also include a number of smaller refineries with ULSD production under 10,000 barrels per day.

Regionally, PADD IV has the highest estimated costs for ULSD production. The refineries in PADD IV are smaller on average, have more cracked stocks to process, and have the lowest proportion of revamps. In PADD I, a large heating oil market provides an outlet for some of the more difficult streams to hydrotreat so it tends to show lower costs for producing ULSD. PADD II refineries are also toward the lower end of the cost curve. They tend to be more moderate in size (which gives better economies of scale), have moderate levels of cracked stocks, and had extensive revamps in the early 1990s to put them in a better position to upgrade to produce ULSD. PADD III has a mixture of small and large refineries with a variety of configurations and as a result shows a wide range of lower and higher cost ULSD producers. Some of the refineries in PADD III are among the highest as far as the proportion of cracked stocks in the feedstock going to the hydrotreater. Sixty-four percent of the refineries in PADD IV that are assumed to produce ULSD in Scenario 4 have estimated costs greater than 5 cents per gallon compared to 31 percent in PADD III, 22 percent in PADD II, and 17 percent in PADD I.

Scenario 1 has the lowest production volume of the four scenarios but the highest probability that production volumes of ULSD will at least reach these estimates in 2006. Of the 87 refineries in PADDs I-IV that currently produce highway diesel, only 66 are estimated to produce ULSD in Scenario 1. Of the 21 refineries that are estimated to terminate ULSD production in Scenario 1, the cost of ULSD production ranges from 6 to 13 cents per gallon.[110] Two-thirds of these refineries currently produce less than 10,000 barrels per day of highway diesel. PADD IV refineries are disproportionately in the higher cost range.

Scenario 2 assumes that the number of refineries that will produce ULSD is the same as in Scenario 1, but that these refineries will increase production if their competitive position is not greatly affected. Comparing Scenario 3 to Scenario 2, ULSD production is estimated to increase at nine refineries, and one refinery that currently produces only non-road distillate product is assumed to enter the ULSD market. All of these factors raise the estimated production level in Scenario 3 by 129,000 barrels per day over that in Scenario 2.

The probability of reaching the total volume production of Scenario 4 is the lowest. In this scenario, refineries with higher costs of production are assumed to enter the ULSD market in 2006. The added production volumes in Scenario 4 come from three types of situations. First, some refineries are assumed to expand production beyond the Scenario 3 level if unit costs are only slightly

Table 8. Supply and Demand Estimates in the Reference Case, 2006
(Thousand Barrels per Day)

	Demand	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Total Supply		1,763	1,823	1,952	2,143
Number of Refineries Producing ULSD		66	66	67	74
Differences Between Supply and Demand					
Small Refiner Option	2,533	-770	-709	-580	-389
Small Refiner and Temporary Compliance Options (Demand A)	2,026	-264	-203	-74	117
Small Refiner and Temporary Compliance Options with Imports (Demand B)	1,946	-184	-123	6	197
Highway Use Only, Small Refiner and Temporary Compliance Options with Imports (Demand C)	1,662	100	161	290	481
Highway Use Only, Small Refiner and Temporary Compliance Options with Higher Imports (Demand D)	1,626	136	197	326	517

Sources: Cost curve scenarios: Appendix D. Demand estimates: National Energy Modeling Sytem, run DSU7INV.D043001A.

[110] The highest estimated costs by region are 9 cents per gallon for PADD I, 13 cents per gallon for PADD II, 7 cents per gallon for PADD III, and 12 cents per gallon for PADD IV.

higher. Second, five of the refineries entering the market were viewed in Scenario 3 as having too high a cost. The third and largest portion of additional volume comes from two refineries that currently are not producers of highway diesel. All of the additional volume in Scenario 4 comes from refiners with costs of ULSD production higher than 5 cents per gallon.

Table 8 shows the differences between the demand and supply estimates. The largest shortfall, which occurs between Scenario 1 (assuming the most cautious investment strategy) and the highest demand estimate, is estimated at 770,000 barrels per day. The widest surplus, 517,000 barrels per day, is under Scenario 4 (the most aggressive investment strategy) and the lowest demand estimate that also accounts for import availability. Assuming the mid-term analysis demand estimate, which is similar to the *AEO2001* projection, Scenarios 3 and 4 project sufficient supply.

Some analysts contend that demand could exceed the estimates in this analysis that assume the temporary compliance option of 80 percent ULSD production. Most refiners that invest to produce ULSD will plan to produce 100 percent ULSD unless they have a market for the higher sulfur product after 2010. Those producing 100 percent ULSD will generate credits which can then be sold to those who decide to delay investing to produce ULSD. Credit trading programs have been successful in the utility industry, but how well credit trading will work in a less-regulated industry remains unclear. Refiners may be less than enthusiastic about selling credits to their competitors that would allow them to sell product produced at a lower cost in the same market as ULSD, possibly at a price similar to the price of ULSD.[111] Refiners who wait to invest can also take advantage of improvements in technology that could help them compete more effectively with those who invested early. Credits could increase sharply in value if markets were tight, but they would have less value if supplies were ample.

To provide a further range of demand estimates, Tables 9 and 10 show the projections for high and low macroeconomic growth cases along with the supply estimates from the cost curves. Transportation distillate demand is projected to increase by 4.0 percent per year from 1999 to 2006 in the high macroeconomic growth case and by 2.7 percent per year in the low macroeconomic growth case.

Table 9. Supply and Demand Estimates in the High Economic Growth Case, 2006
(Thousand Barrels per Day)

	Demand	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Total Supply		1,763	1,823	1,952	2,143
Number of Refineries Producing ULSD		66	66	67	74
Differences Between Supply and Demand					
Small Refiner Option	2,669	-906	-845	-716	-525
Small Refiner and Temporary Compliance Options	2,135	-372	-311	-183	8
Small Refiner and Temporary Compliance Options with Imports	2,055	-292	-231	-103	88
Highway Use Only, Small Refiner and Temporary Compliance Options with Imports	1,756	7	68	196	387
Highway Use Only, Small Refiner and Temporary Compliance Options with Higher Imports	1,720	43	104	232	423

Sources: Cost curve scenarios: Appendix D. Demand estimates: National Energy Modeling Sytem, run HM2001.D101600A.

Table 10. Supply and Demand Estimates in the Low Economic Growth Case, 2006
(Thousand Barrels per Day)

	Demand	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Total Supply		1,763	1,823	1,952	2,143
Number of Refineries Producing ULSD		66	66	67	74
Differences Between Supply and Demand					
Small Refiner Option	2,447	-685	-624	-495	-304
Small Refiner and Temporary Compliance Options	1,958	-195	-134	-6	186
Small Refiner and Temporary Compliance Options with Imports	1,878	-115	-54	74	266
Highway Use Only, Small Refiner and Temporary Compliance Options with Imports	1,604	159	220	349	540
Highway Use Only, Small Refiner and Temporary Compliance Options with Higher Imports	1,568	195	256	385	576

Sources: Cost curve scenarios: Appendix D. Demand estimates: National Energy Modeling Sytem, run LM2001.D101600A.

[111] Many analysts contend that the prices of ULSD and 500 ppm diesel will converge in the phase-in period, because most trucks can use 500 ppm fuel but only 20 to 25 percent of production will be 500 ppm fuel. The higher demand than supply will tend to push the price to the same level as ULSD. The need to purchase credits to sell 500 ppm product will also tend to push up its price.

Two additional sets of the four supply scenarios are provided that vary the hydrotreater capital cost assumptions and the return on investment assumption. The capital costs assumed in the initial set of four scenarios in this chapter are similar to those used in the EPA analysis (see Chapter 7 for a comparison of capital cost assumptions). Because of the uncertainty associated with the cost of installing distillate hydrotreating capable of producing diesel fuel containing less than 10 ppm sulfur, a second set of scenarios was developed assuming capital costs for the hydrotreater units that are about 40 percent higher than the initial set (Figure 7). The higher capital costs in this scenario reduce the projected production of ULSD by 25,000 to 55,000 barrels per day and increase the cost estimates from 0.4 cents per gallon to 1.0 cents per gallon.

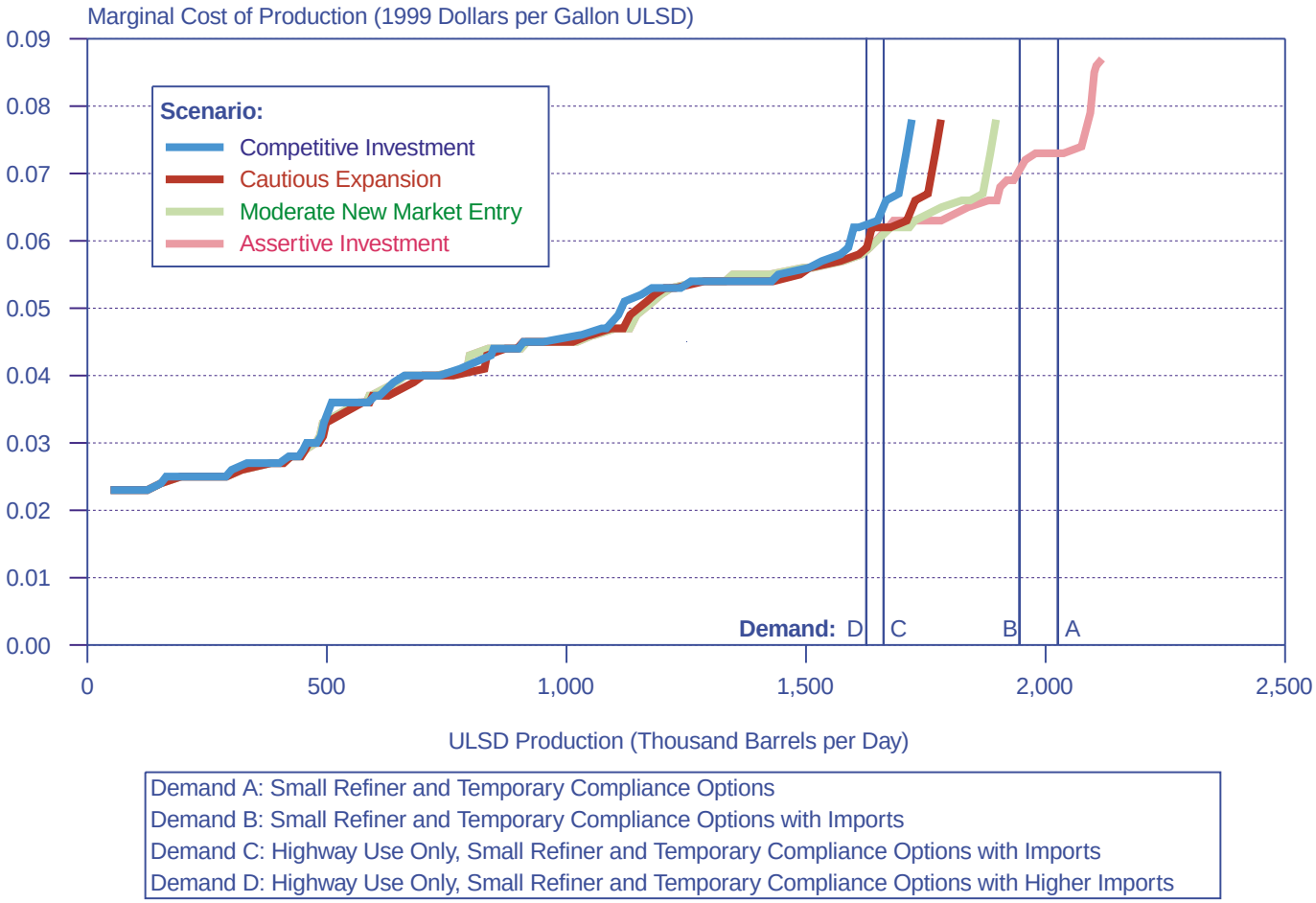
A third set of supply scenarios was developed assuming a 10-percent required return on investment (Figure 8), rather than 5.2 percent assumed in the initial set of scenarios. The higher assumed rate results in a reduction in production of 40,000 to 66,000 barrels per day across the four scenarios. The cost estimates increase by 0.8 to 1.2 cents per gallon from the first set of scenarios. Because of the reduced volumes, estimated production levels in Scenario 3 fall short of the demand level projected in the mid-term analysis (Demand B) in both the higher capital cost and higher required return on investment sensitivities (Tables 11 and 12).

Balancing Demand and Supply in 2006

These supply curves, along with the demand estimates for 2006, indicate the possibility of a tight diesel market when the ULSD Rule is implemented. Supply scenarios that assume more cautious investment indicate inadequate supply compared with the demand levels projected in the *Annual Energy Outlook 2001*. Only more aggressive investment scenarios or lower demand cenarios show adequate supply to meet estimated demand. This analysis compares supply and demand at an aggregate level. Maintaining a balance of supply and demand across regions and throughout the distribution system would be more difficult.

Improvements in supply could result if more refiners undertook investments to produce ULSD, if capacity expansions by refiners were greater than anticipated in

Figure 7. ULSD Higher Capital Cost Sensitivity Case Cost Curve Scenarios with 2006 Demand Estimates



Sources: Cost curve scenarios: Appendix D. Demand estimates: National Energy Modeling Sytem, run DSU7INV.D043001A.

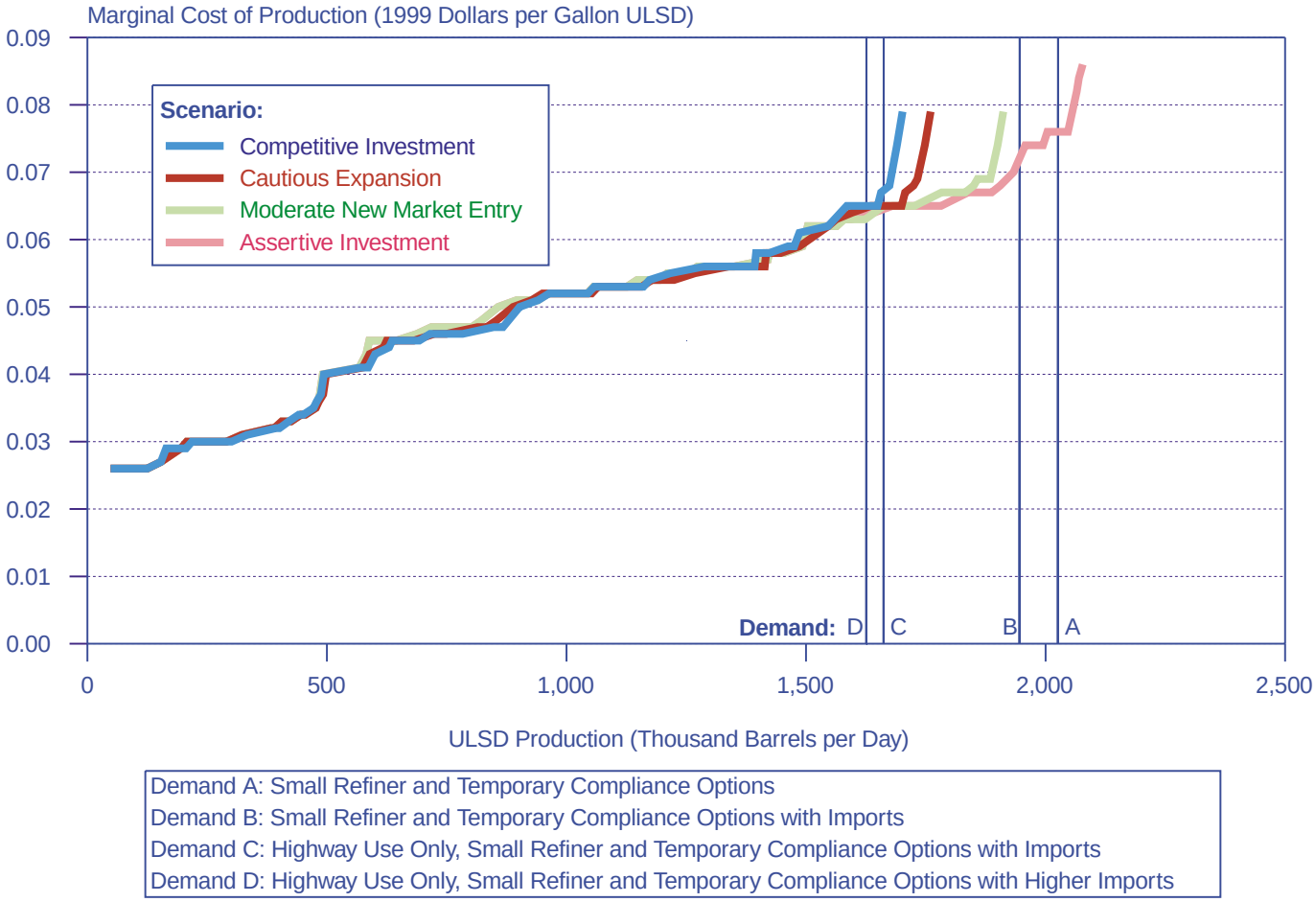
this analysis, and/or if more imports were available. On the demand side, slower growth in the highway diesel market than these demand estimates and/or curtailing of ULSD consumption for non-road uses would also improve the situation.

If supplies fall short of demand, sharp price increases could occur to balance supply and demand. That type of situation could result in a number of responses, some of which could begin to occur as soon as the price differential between ULSD and other products started to widen—possibly even before it became clear that a market supply problem existed. Refiners would attempt to maximize ULSD production. Some additional production may be possible by, for example, shifting some non-road distillate or jet fuel streams into ULSD. This would be limited, however, because only the lower sulfur streams could be used and additional hydrotreating may be necessary. Imports of jet fuel or other products could then replace the lost production of those fuels. Additional imports of ULSD could be forthcoming if there were large price differentials between markets. Such responses would require higher costs, however, because lower cost options would be exercised first.

Sharply higher prices would also curtail demand for diesel fuel. Truckers would reduce consumption to the extent possible and try to pass higher fuel costs to customers, who would then look for alternative means to transport goods.

In 2006, the quantity of fuel actually needed for vehicles requiring ULSD will be much less than the required 80 percent of diesel production. If it becomes apparent that the supply is inadequate, or that markets are becoming tight, additional low-sulfur diesel supplies could become available if the required proportion of ULSD production were reduced. Allowing more 500 ppm diesel into the highway market could alleviate some of the stress on the market. If the requirement were 70 percent instead of 80 percent, for example, the demand estimates shown in Table 8 would be reduced by 217,000 to 253,000 barrels per day, enough to eliminate the shortfalls indicated except for Demand A in Scenario 1 and the highest

Figure 8. ULSD 10% Return on Investment Sensitivity Case Cost Curve Scenarios with 2006 Demand Estimates



Sources: Cost curve scenarios: Appendix D. Demand estimates: National Energy Modeling Sytem, run DSU7INV.D043001A.

Table 11. Supply and Demand Estimates in the Higher Capital Cost Sensitivity Case, 2006
(Thousand Barrels per Day)

	Demand	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Total Supply		1,721	1,782	1,897	2,118
Number of Refineries Producing ULSD		61	61	61	72
Differences Between Supply and Demand					
Small Refiner Option	2,533	-812	-751	-636	-415
Small Refiner and Temporary Compliance Options	2,026	-305	-244	-130	92
Small Refiner and Temporary Compliance Options with Imports	1,946	-225	-164	-50	172
Highway Use Only, Small Refiner and Temporary Compliance Options with Imports	1,662	58	119	234	455
Highway Use Only, Small Refiner and Temporary Compliance Options with Higher Imports	1,626	94	155	270	491

Sources: Cost curve scenarios: Appendix D. Demand estimates: National Energy Modeling Sytem, run DSU7INV.D043001A.

Table 12. Supply and Demand Estimates in the 10% Return on Investment Sensitivity Case, 2006
(Thousand Barrels per Day)

	Demand	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Total Supply		1,702	1,760	1,912	2,078
Number of Refineries Producing ULSD		61	61	63	71
Differences Between Supply and Demand					
Small Refiner Option	2,533	-831	-773	-621	-455
Small Refiner and Temporary Compliance Options	2,026	-325	-266	-114	51
Small Refiner and Temporary Compliance Options with Imports	1,946	-245	-186	-34	131
Highway Use Only, Small Refiner and Temporary Compliance Options with Imports	1,662	39	97	249	415
Highway Use Only, Small Refiner and Temporary Compliance Options with Higher Imports	1,626	75	133	285	451

Sources: Cost curve scenarios: Appendix D. Demand estimates: National Energy Modeling Sytem, run DSU7INV.D043001A.

demand estimate across all scenarios. However, a lower requirement for ULSD production would reduce retail availability for the vehicles that require ULSD. Other responses providing greater flexibility, increasing participation, and encouraging technological improvements would also help to alleviate supply concerns.[112]

Given the variety of responses, it is difficult to know the magnitude or duration of a possible tight market situation. Supply shifts and demand responses would require time before the effect would be felt. It would take time for additional imports to enter the market, and importers would have to believe that prices would remain high enough for long enough to make it worthwhile to divert supplies from other markets.

Summary

Whether there will be adequate supply is one of the key questions raised by the House Committee on Science in its request for analysis. To assess the supply situation during the transition to ULSD in 2006, cost curves and estimates of ULSD supply are developed based on refinery-specific analysis of investment requirements. Supply is estimated for four scenarios of investment behavior, and a range of demand is projected for comparison with the supply curves. In addition, two other sets of supply sensitivities are provided, assuming higher capital costs and higher required return on investment.

Supply scenarios that assume more cautious investment indicate inadequate supply compared with the demand levels projected in the *Annual Energy Outlook 2001*. Only more aggressive investment scenarios or lower demand cenarios show adequate supply to meet estimated demand. The two sets of supply sensitivities show even lower production estimates than the initial set. This indicates the possibility of a tight market supply situation when the ULSD Rule takes effect in 2006. While considerable uncertainty exists in both the supply and demand estimates, this analysis indicates that even though the market could see supply meet demand at a cost increase for production between 5.4 and 7.6 cents per gallon, there are a number of scenarios in which inadequate supply of ULSD could result.

[112] Short-term responses are possible, such as the regulatory response that took place when the 500 ppm diesel fuel requirements came into effect on October 1, 1993. As a result of localized outages and price spikes, the EPA sent a letter to marketers and major consumers of diesel fuel granting "enforcement discretion" in cases of extreme difficulty in obtaining supplies, extending through October 22, 1993.