6. Mid-Term Analysis of ULSD Regulations

Assumptions

The National Energy Modeling System (NEMS) was used to perform petroleum market analysis of the impact of new requirements for ultra-low-sulfur diesel fuel (ULSD) from 2007 through 2015. The Petroleum Market Module (PMM) of NEMS were modified to produce a ULSD Regulation case. Analysis of the Regulation case focuses on changes relative to a reference case using the oil price and macroeconomic assumptions of the *Annual Energy Outlook 2001* (*AEO2001*) reference case but including some adjustments to provide a more accurate reflection of the diesel fuel market. The differences between the reference case for this study and the *AEO2001* reference case are discussed in Appendix B.

The projected investment costs and average marginal prices resulting from the NEMS analysis represent the investment and price levels necessary to meet all demand requirements under the new ULSD Rule. As discussed in Chapter 5, some refiners may choose to drop out of the highway diesel market or even close down instead of investing for compliance with the Rule. ULSD supply could be inadequate in the short term if enough refineries chose to forgo investment. The NEMS analysis does not capture this uncertainty of supply, because NEMS is a long-run equilibrium model. By definition, the NEMS analysis projects the level of domestic production and imports necessary to meet all demand requirements. As a result, the NEMS analysis reflects more aggressive investment behavior than that portrayed for individual refiners in the short-term analysis.

The NEMS analysis reflects the "80/20" rule, which requires the production of 80 percent ULSD and 20 percent 500 ppm highway diesel between June 2006 and June 2010, and a 100 percent requirement for ULSD after June 2010. Because each model region acts as a single unit, the provision of the ULSD Rule allowing small refiners, which account for about 5 percent of current highway diesel production, to delay investment until June 2010 is not modeled explicitly. However, the production requirements are adjusted downward by 4 percent to reflect an assumption that most small refiners will choose to delay investment.[113]

The requirement for 80 percent ULSD is not phased in and begins on June 1, 2006. Therefore, the full market impact of the requirement can be expected to occur at that time. Because NEMS is an annual average model, the full economic impact of the 80/20 rule cannot be seen until 2007. In the same manner, projections for 2011 represent the first full year of 100 percent ULSD compliance. The results for 2010 reflect a partial year at the 80 percent requirement and a partial year at the 100 percent requirement. For the purpose of assessing the market impacts of the new ULSD requirements, 2007 will be discussed as the first full year of the 80/20 requirement, and 2011 will be discussed as the 100 percent requirement.

The House Committee on Science requested that, if practical, the EIA analysis use the same assumptions as those used by the U.S. Environmental Protection Agency (EPA) in its Regulatory Impact Analysis (RIA). The assumptions are compared in Table 13. The Regulation case for this study is based on the following assumptions:

- Highway diesel at the refinery gate will contain a maximum of 7 parts per million (ppm) sulfur. Although sulfur content is limited to 15 ppm at the pump, there is a general consensus that refineries will need to produce diesel somewhat below 10 ppm in order to allow for contamination during the distribution process. The EPA assumed in its RIA that refineries would produce highway diesel at 7 ppm.

- The capital costs for the distillate hydrotreaters reflected in NEMS are $1,331 per barrel per day for a notional 25,000 barrel per day unit that processes low-sulfur feed streams with incidental dearomatization, and $1,849 per barrel per day for a second, 10,000 barrel per day unit that processes higher sulfur feed streams with greater aromatics improvement. A range of capital costs from a number of other studies is provided in Chapter 7. Because of differences in methodology, the sets of capital costs are not directly comparable. For instance, the EPA estimated the capital cost for a new distillate hydrotreater to range from $1,240 per barrel per day to $1,680 per barrel per day, but those estimates

[113] In its Regulatory Impact Analysis, the U.S. EnvironmentalProtection Agency included investment by small refineries in cost estimates for full compliance but not for the transition period. See 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).

Table 13. Comparison of EIA and EPA Assumptions

Parameter	EPA	EIA	Sensitivity Analyzed
Sulfur Content at Refinery	7 ppm	7 ppm	None
Capital Costs for New Diesel Hydrotreaters	$1,240-$1,680 per barrel per day[a]	$1,331-$1,849 per barrel per day[b]	$1,655-$2,493 per barrel per day[b]
Percent of Production from Revamped Equipment	80 percent	80 percent	66.7 percent
Total Percentage of Downgraded ULSD	4.4 percent total	4.4 percent total	10 percent total
Revenue Loss Associated with Downgrade	0.2 to 0.3 cents per gallon for all highway diesel	0.2 to 0.3 cents per gallon ULSD based on model results	0.7 cents per gallon ULSD based on model results for 10 percent downgrade
Capital Cost for Distributing Two Highway Diesels (Excluding Above Revenue Loss)	0.7 cents per gallon through 2010	0.7 cents per gallon through 2010	None
Lubricity Additives	0.2 cents per gallon	0.2 cents per gallon	None
Loss of Energy Content	0 percent	0.5 percent	1.8 percent
Yield Loss	1.3 percent yield loss (weight) at a cost of 0.1 to 0.2 cents per gallon	Variable model result (about 1.5 percent by volume)	Variable model result (about 1.5 percent by volume)
Loss of Fuel Efficiency	None	None	4 percent loss starting in 2010, phased out by 2015
Change in Non-Road Diesel Standards	None	None	None
Change in Other Highway Diesel Properties	None	None	None
Import Availability	Not studied	Same as reference	No imports
Return on Investment	7% before tax (estimated 5.2% after tax)	5.2% after tax	10% after tax

[a]The low end of the range is for straight-run distillate; the high end is for light cycle oil.
[b]The low end of the range is for units processing low-sulfur feed with incidental dearomatization; the high end is for higher sulfur feeds with greater aromatics improvement.

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

are associated with units processing 100 percent straight-run distillate and 100 percent light cycle oil, respectively.[114]

- Revamping (retrofitting) existing units to produce ULSD will be undertaken by refineries representing 80 percent of highway diesel production; the remaining refineries will build new units. Other analyses have assumed 60 percent revamps and 40 percent new builds, but the assumption of 80 percent revamps and 20 percent new units was used in the EPA's RIA. The capital cost of a revamp is assumed to be 50 percent of the cost of new equipment, which is consistent with the EPA analysis.

- The total amount of ULSD downgraded to a lower value product because of sulfur contamination in the distribution system is assumed to be 4.4 percent, an increase of 2.2 percent from the reference case. This assumption is based on the EPA's assessment that 2.2 percent of diesel fuel is currently downgraded and its assumption that the amount of downgrade will double with the new Rule. This downgrade assumption is associated with considerable uncertainty, because EPA's estimate of current downgrade was not based on a scientific survey. The EPA's estimation methodology was based on a survey by the Association of Oil Pipelines, in which six respondents provided estimates of the current diesel fuel downgrade, ranging from 0.2 percent to 10.2 percent.

- The costs associated with ULSD distribution are based in part on EPA assumptions and in part on NEMS results. This analysis uses the EPA's capital cost estimate of 0.7 cents per gallon for additional storage tanks to handle ULSD during the transition period. The capital expenditures are assumed to be fully amortized during the transition period. The ULSD Rule is assumed to increase the operating costs for distribution by 0.2 cents per gallon over the entire period. In addition, the EPA estimated a revenue loss of 0.2 to 0.3 cents per gallon for all highway diesel as a result of product downgrades. For this

[114]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), Table V.C-9.

analysis, the revenue loss estimate is based on NEMS model results, at 0.3 cents per gallon of ULSD during the transition period and 0.2 cents per gallon after 2010.

- A cost of 0.2 cents per gallon is assumed for the addition of lubricity additives, consistent with estimates by the EPA and with industry analyses. Lubricity additives are needed to compensate for the reduction of aromatics and high-molecular-weight hydrocarbons stripped away by the severe hydrotreating used in the desulfurization process.
- The energy content of ULSD is assumed to decline by 0.5 percent, because undercutting and severe desulfurization will result in a lighter stream composition than that for 500 ppm diesel. The EPA's analysis made no explicit adjustment to the energy content of diesel fuel but estimated a cost associated with a 1.3-percent (by weight) loss of yield. In the NEMS analysis, the yield loss is a variable model result (generally around 1.5 percent by volume). The National Petrochemical and Refining Association (NPRA) quoted a range of 1 to 4 percent energy loss in comments to the rulemaking docket. NPRA also estimated a yield loss of 1 to 5 percent.
- In accordance with the EPA's RIA, changes to engine after-treatment devices are assumed to result in no loss of fuel efficiency. Discussions with some engine and emission control technology manufacturers indicated considerable uncertainty about this assumption.
- No change in the sulfur level of non-road diesel is assumed. The EPA analysis of ULSD reflects no change in non-road standards, although the EPA is in the process of promulgating "Tier 3" non-road engine emission limits around 2005 or 2006, which are expected to be linked to sulfur reduction for non-road diesel fuel.[115] The level of sulfur reduction required for Tier 3 vehicles is highly uncertain because of the diversity of the non-road market.
- No changes to other highway diesel specifications, such as aromatics or cetane, are assumed. Some refiners anticipate changes to these parameters in the future because of their relationship to emissions of particulate matter (PM). The State of California already limits aromatics to 10 percent by volume, which is reflected in this analysis. Proposals for similar requirements in other States are not included.
- Imports of diesel meeting the new ULSD standard are assumed to be available to U.S. markets, but the level of imports relative to the level of product supplied by refineries in the United States is a model result. Refineries in Canada, Northern Europe, and the Caribbean Basin (including Venezuela) are assumed to make upgrades to produce diesel fuel meeting the 15 ppm sulfur cap for 2006. Canada is moving forward with plans to harmonize with diesel regulations in the United States. European refiners will reduce diesel sulfur to 50 ppm for a new European standard in 2005. Some isolated European production of diesel meeting the ULSD standard is assumed, due to tax incentives for 10 ppm diesel in some markets.[116] In order to divert ULSD from European markets, prices in the United States would have to exceed the tax incentives plus shipping costs. In 2000 less than 5 percent of U.S. imports of highway diesel came from Europe.
- In accordance with the EPA's RIA, the before-tax rate of return on investment is assumed to be 7 percent. Between 1977 and 1999 the combined before-tax return on investment for refiners and marketers averaged 7 percent, which is equivalent to a 5.2-percent after-tax rate.[117] Because NEMS operates on an after-tax basis, the 5.2-percent rate is used in the model. Most of the studies compared in Chapter 7 assumed a 10-percent after-tax return on investment.

The Committee indicated that this analysis was to be as consistent as possible with the assumptions underlying the EPA's RIA, and that sensitivity analysis should be provided for assumptions that diverge significantly from those in other studies or from expectations of industry experts.[118] In addition to the Regulation case, this report provides sensitivity analyses for five assumptions associated with a greater uncertainty, for a Severe case that combines the assumptions of the five individual sensitivities, for a No Imports case, and for a 10% Return on Investment case:

- In the Higher Capital Cost case, the capital cost of the first notional hydrotreater is 24 percent higher than in the Regulation case, and the capital cost of the second notional unit is 33 percent higher.[119]
- In the 2/3 Revamp case, two-thirds of upgrades at refineries are assumed to be accomplished by retrofitting existing equipment and one-third by construction of new units. With the exception of the

[115] U.S. Environmental Protection Agency, *Reducing Air Pollution from Non-road Engines*, EPA420-F-00-048 (Washington, DC, November 2000), p. 3.

[116] Germany and the United Kingdom have proposed tax incentives for sales of 10 ppm diesel.

[117] Based on financial information from Form EIA-28 (Financial Reporting System).

[118] EIA did not assess the validity of these asumptions.

[119] The capital costs used in this case are based on recent work by EnSys, with revisions based on correspondence with Mr. Martin Tallett, April 23, 2001.

EPA, all other cost analyses for ULSD have used an assumption of 60 percent revamps and 40 percent new units. The two-thirds revamp assumption was developed from EIA's individual refinery analysis (see Chapter 5 and Appendix D).

- In the 10% Downgrade case, a total of 10 percent of the 15 ppm diesel is assumed to be downgraded to a lower value product because of contamination with higher sulfur products in the distribution system. Before 2010 the contaminated product is assumed to be downgraded to 500 ppm highway diesel and does not result in additional production of 15 ppm highway diesel. After 2010, when all highway diesel must meet the 15 ppm sulfur standard, refineries must produce an extra 7.8 percent of highway diesel above the reference case level, which will be sold as non-road diesel or heating oil. The EPA assumption of 4.4 percent total downgrade after the ULSD Rule takes effect in June 2006 (2.2 percent higher than in the reference case) is on the low end of downgrade estimates, which range up to 17.5 percent by Turner Mason.
- In the 4% Efficiency Loss case, manufacturers are assumed to meet the emissions requirements by installing after-treatment technology on new vehicles beginning in 2010, resulting in a 4-percent loss of fuel efficiency. The loss in new vehicle efficiency is assumed to be fully phased out by 2015 as a result of technological improvements.[120]
- In the 1.8% Energy Loss case, a greater loss of energy content is assumed than in the Regulation case, which assumed a 0.5-percent loss. The loss of energy content is associated with more severe undercutting and desulfurization due to heavier crude oil inputs.[121]
- The Severe case combines the assumptions of the four sensitivity cases above. This scenario is more in line with the assumptions used by alternative studies related to ULSD than with the EPA's RIA.
- The No Imports case assumes that no foreign imports of ULSD will be available. This assumption is not included in the Severe case because it is considered to be relatively unlikely. The greatest uncertainty for import availability is likely to occur in the early years of the program because foreign refiners may delay investment until the market outlook for ULSD is more certain. Thus far, only Canada has announced its intent to align with the final U.S. level and timing for reducing sulfur in highway diesel fuel.[122] Environment Canada expects to launch a public consultation process in the next few months to facilitate the rulemaking, which is similar to the U.S. ULSD Rule while taking into account issues unique to the Canadian market.[123]
- The 10% Return on Investment case uses the after-tax rate of return assumed by most other studies (10 percent), which is higher than the 5.2-percent after-tax rate used in the Regulation and other sensitivities, consistent with the EPA's assumption.

Although the assumption of non-road diesel sulfur content is also highly uncertain, a sensitivity analysis would have required significant changes to the model structure and was not within the scope of this study. Sensitivity analysis of other diesel properties was also beyond the scope of the study.

Results

Discussions of all results are framed in terms of changes from the reference case. In the Regulation case and in all the sensitivity cases, projections for 2007 reflect the first full year of the program at 80 percent ULSD and 20 percent 500 ppm highway diesel, and 2011 reflects the first full year of 100 percent ULSD. During the years requiring 80 percent ULSD, the reference case and sensitivity cases project that the greatest price increase will occur in 2007, because all investment for compliance with the "80/20" provision of the ULSD Rule must be met by that time. Similarly, a second peak in marginal prices is projected in 2011, because all investment for full compliance with the Rule must be in place by that time. Year-to-year variations in marginal prices can reflect differences in levels of demand for diesel and other products, oil price projections, the economics of domestic production versus imports, and other factors.

In the reference case, demand for transportation distillate (highway diesel) is projected to increase by 2.5 percent per year from 1999 to 2015. In the Regulation case, highway diesel demand is projected to grow at a slightly higher rate of 2.6 percent per year for the same period, largely due to the 2.2 percent additional (4.4 percent total) downgrades of highway diesel in the distribution

[120] This assumption is based on interviews with engine and technology manufacturers. Although this case reflects a scenario in which losses in efficiency from emission contol are not overcome by new technology, the considerable time available for research and development may provide government and industry ample time to resolve the fuel efficiency loss issues associated with advanced emission control technologies.

[121] The National Petrochemical and Refining Association provided data indicating that energy loss may be greater than assumed by the EPA. Letter from Terrence S. Higgins to James M. Kendell, February 8, 2001.

[122] Public Works and Government Services Canada, *Canada Gazette*, Vol. 135, No. 7 (February 17, 2001), p. 454.

[123] Maureen Monaghan, Natural Resources Canada, "Canadian Sulfur Standards for Gasoline and Diesel Sulfur," presentation to the U.S. Department of Energy (March 12, 2001).

system. In other words, the additional downgrades must be offset by more ULSD production after 2010. The effect of downgrades is more pronounced in the 10% Downgrade case and the Severe case, where highway diesel demand is projected to increase by 2.9 percent and 3.1 percent per year, respectively, from 1999 to 2015.

Regulation Case

In the Regulation case, cumulative investment in distillate hydrotreating and hydrogen units is projected to be $4.2 billion higher than projected in the reference case in 2007 and $6.3 billion higher in 2011, when upgrades for meeting full compliance with the ULSD Rule will be complete (Table 14). In the early part of the transition period, upgrades for making ULSD may be constrained by specialized workforce and manufacturing limitations and access to capital, all of which will be in competition with projects for meeting the requirements for low-sulfur gasoline (see Chapter 3). The projected $2.1 billion in investment between 2007 and 2011 reflects expenditures for meeting expectations of growing demand for highway diesel, in addition to full compliance with the Rule. After 2011, incremental upgrades to meet future distillate demand are projected to continue, resulting in another $0.5 billion of investment in desulfurization equipment by 2015.

The Regulation case results in an increase in the marginal annual pump price for ULSD of 6.5 to 7.2 cents per gallon between 2007 and 2011 (Table 15). The peak differential is projected to occur in 2011, when all refiners must produce 100 percent ULSD. The projected differential declines after 2011, reaching 5.1 cents per gallon in 2015. About 0.7 cents of this decline is the result of no longer needing to include EPA's estimate of additional capital investments for distribution and storage of a second highway diesel fuel during the transition period. A drop in capital expenses for distribution systems occurs after 2010 as a reflection of the EPA's assumption that these investments will be fully amortized during the transition period. The remainder of the drop in the post-2011 differential occurs because refineries are expected to have completed the upgrades necessary for full compliance, and to be making incremental improvements that will make ULSD production less challenging. A similar decline in the price differential also occurs in all the sensitivity cases.

Through 2010, the Regulation case projections for highway diesel consumption exceed the reference case levels by up to 10,000 barrels per day, which can be attributed to the assumption of 0.5 percent loss in energy content. In 2011, the differential in consumption increases to 83,000 barrels per day, due mostly to the downgrade of 2.2 percent of ULSD to lower value non-road markets.

In a refinery, the impact of a change in the makeup or production level of a product can filter through to other products, because it changes the mix of total refinery production. The ULSD Rule is projected to result in slightly lower yields of higher sulfur distillate used for non-road and heating purposes, because its production is replaced by ULSD that is produced by refineries but is downgraded to higher sulfur products in the distribution system. The availability of the downgraded ULSD reduces the projected prices for high-sulfur distillate by about 1 cent per gallon relative to the reference case. The analysis revealed no clear trends for other distillate products as a result of the ULSD Rule.

Table 14. Variation from Reference Case Projections of Cumulative Capital Expenditures for Hydrogen and Distillate Hydrotreating Units in EIA Sensitivity Cases, 2007, 2010, and 2015
(Billion 1999 Dollars)

Analysis Case	2007	2010	2015
Regulation	4.2	6.3	6.8
Higher Capital Cost	5.4	7.8	8.8
2/3 Revamp	4.6	6.9	7.6
10% Downgrade	4.2	6.7	7.3
4% Efficiency Loss	4.2	6.3	6.9
1.8% Energy Loss	4.2	6.3	6.9
Severe	5.9	9.3	10.5
No Imports	4.4	6.5	7.0

Source: National Energy Modeling System, runs DSUREF. D043001B, DSU7PPM.D043001A, DSU7HC.D043001A, DSU7INV.D043001A, DSU7DG10.D043001A, DSU7TRN.D043001A, DSU7BTU.D043001A, DSU7ALL.D050101A, and DSU7IMP0.D043001A.

Higher Capital Cost Case

Because of limited experience in producing diesel containing less than 10 ppm sulfur, the capital costs for hydrotreaters able to mass produce ULSD are uncertain. The Higher Capital Cost case results in refinery investment for hydrogen and distillate hydrotreating units totaling $5.4 billion in 2007, which is $1.2 billion above the Regulation case level. By 2011 the Higher Capital Cost case is projected to require $7.8 billion of investment, $1.5 billion more than in the Regulation case. The higher investment costs translate to a higher projected price path for ULSD. Relative to the reference case, price differentials are projected to range from 7.5 to 7.8 cents per gallon between 2007 to 2010, peaking at 8.1 cents per gallon in 2011, the first full year of full compliance. These prices are 0.8 cents per gallon higher on average than those in the Regulation case.

2/3 Revamp Case

The 2/3 Revamp case results in a higher projected price path for ULSD, with price differentials ranging from 6.9 to 7.6 cents per gallon higher than in the reference case from 2007 to 2011. Prices are generally higher than in the Regulation case, with the differential between the two cases at its widest in 2011 at 0.4 cents per gallon. The 2/3

Revamp case reflects greater reliance on new equipment than in the Regulation case, resulting in an additional $600 million of investment for full compliance in 2011.

10% Downgrade Case

The 10% Downgrade case reflects a net downgrade increase of 7.8 percent over the reference case and 5.6 percent over the Regulation case. Total highway diesel consumption increases by up to 10,000 barrels per day in the transition period in both the 10% Downgrade case and the Regulation case. After 2010, the 10% Downgrade case results in an additional 289,000 barrels per day of highway diesel consumption, compared with an additional 83,000 barrels per day in the Regulation case. The greatest impact from downgrade in either the 10% Downgrade or Regulation case on refiners and consumers occurs after 2011, because until that time the contaminated product can be downgraded to 500 ppm highway diesel with no net increase in highway diesel production. Because all highway diesel supplied must meet the 15 ppm sulfur cap in June 2010, ULSD exceeding 15 ppm sulfur at some point in the distribution system must be downgraded to non-road markets and must be offset by additional ULSD production after 2010. This means that refiners must produce 212,000 barrels per day more ULSD after 2010 than in the Regulation case, which translates to an additional $500 million of investment by 2015.

Aside from the impacts on ULSD on demand and refinery investment, the 10% Downgrade case has implications for the economics of pipelines and marketers, because they incur a revenue loss when a portion of the ULSD going into the system comes out of the system as a lower value product. Table 16 shows the costs associated with ULSD distribution in the Regulation and 10% Downgrade cases. The capital costs, which are assumed to be the same in both cases, reflect additional infrastructure required for carrying a second highway diesel product during the transition period. The estimate for capital expenditures was taken from the EPA's RIA and is fully amortized over the transition period. The additional annual diesel fuel distribution costs in the Regulation case differ slightly from the EPA estimates (see Table 26 in Chapter 7), because different revenue losses associated with product downgrade are assumed.

Table 15. Variations from Reference Case Projections in the Regulation and Sensitivity Analysis Cases, 2007-2015

Analysis Case	2007	2008	2009	2010	2011	2015	2007-2010 Average	2011-2015 Average
Difference Between End-Use Prices of ULSD and 500 ppm Diesel (1999 Cents per Gallon)[a]								
Regulation	7.0	6.7	6.5	6.8	7.2	5.1	6.8	5.4
Higher Capital Cost	7.8	7.6	7.5	7.6	8.1	5.8	7.6	6.2
2/3 Revamp	7.3	6.9	6.9	7.1	7.6	5.4	7.1	5.7
10% Downgrade	7.4	7.1	6.8	7.2	9.1	5.7	7.2	6.4
4% Efficiency Loss	7.0	6.7	6.5	6.9	7.3	5.3	6.8	5.7
1.8% Energy Loss	7.3	7.0	6.6	6.9	7.4	5.2	7.0	5.5
Severe	8.8	8.4	8.4	8.6	10.7	6.8	8.6	7.4
No Imports	8.6	8.1	7.8	8.0	8.8	6.2	8.1	6.8
Total Highway Diesel Fuel Consumption (Thousand Barrels per Day)								
Regulation	10	10	8	8	83	85	9	83
Higher Capital Cost	10	9	8	7	82	83	9	82
2/3 Revamp	10	10	8	8	82	84	9	82
10% Downgrade	10	10	8	8	289	303	9	295
4% Efficiency Loss	10	10	8	19	103	108	12	107
1.8% Energy Loss	41	41	39	47	127	131	42	128
Severe	41	40	39	57	355	374	44	366
No Imports	10	9	7	7	81	83	8	81
Total Imports of Highway Diesel Fuel (Thousand Barrels per Day)								
Regulation	-36	-1	-1	0	0	0	-10	0
Higher Capital Cost	-36	-1	-1	0	0	0	-10	0
2/3 Revamp	-36	-1	-1	0	0	0	-10	0
10% Downgrade	-36	-1	-1	0	0	0	-10	0
4% Efficiency Loss	-36	-1	-1	0	0	0	-10	0
1.8% Energy Loss	-36	-1	-1	0	0	0	-10	0
Severe	-36	-1	-1	0	0	0	-10	0
No Imports	-120	-125	-125	-125	-125	-125	-124	-125

[a]End-use prices include marginal refinery gate prices, distribution costs, and Federal and State taxes but exclude county and local taxes.

Source: National Energy Modeling System, runs DSUREF.D043001B, DSU7PPM.D043001A, DSU7HC.D043001A, DSU7INV.D043001A, DSU7DG10.D043001A, DSU7TRN.D043001A, DSU7BTU.D043001A, DSU7ALL.D050101A, and DSU7IMP0.D043001A.

4% Efficiency Loss Case

The 4% Efficiency Loss case reflects an expectation, by some engine and emission technology manufacturers, that emission requirements for new heavy-duty vehicles in 2010 will be met by installing after-treatment technology, which could result in a 4-percent loss of fuel efficiency. Technological improvements are assumed to fully offset the loss in fuel efficiency of new vehicles by 2015.[124] The combined impact of the ULSD requirement and less efficient new vehicles results in 19,000 barrels per day of additional highway diesel consumption in 2010 and 107,000 barrels per day in 2011 through 2015. The introduction of less fuel-efficient vehicles accounts for 11,000 barrels per day of the additional demand in 2010 and 24,000 barrels per day of demand after 2010. Refiners are projected to invest an additional $100 million dollars through 2015 relative to the Regulation case to provide for the slightly higher diesel demand.

The additional demand for highway diesel results in prices that are 5.7 cents per gallon above reference case prices on average between 2011 and 2015. This differential is 0.3 cents higher than when no fuel efficiency loss is assumed. Owners of vehicles purchased between 2010 and 2015 would see the greatest impact under this case, because diesel vehicles of that vintage would consume relatively more diesel fuel.

1.8% Energy Loss Case

Due to changes in refinery processing, ULSD is expected to have slightly less energy content than 500 ppm diesel. The 1.8% Energy Loss case reflects a greater loss of energy content than the Regulation case, which assumes a 0.5-percent loss per barrel. This case results in an average increase in ULSD consumption of 42,000 barrels per day between 2007 and 2010. Due to the 100 percent ULSD requirement, the impact of the lower energy content is greatest after 2010 when it widens to 128,000 barrels per day. Relative to the Regulation case, the 1.8% Energy Loss case results in an average of 33,000 barrels per day of additional demand through 2010 and 45,000 barrels per day after full compliance. This additional demand does not change refinery investment patterns relative to the Regulation case, because it can be provided through higher utilization rates.

The price differentials from the reference case average 7.0 cents per gallon between 2007 and 2010 and 5.5 cents per gallon between 2011 and 2015. In anticipation of higher demand, refineries are expected to build slightly more capacity in the transition period than they would in the Regulation case. Because of the slightly different investment pattern, prices in the 1.8% Energy Loss case are 0.2 cents per gallon higher than in the Regulation case on average through 2010 and comparable to Regulation case prices after 2010.

Severe Case

In the Severe case, the ULSD requirement in combination with the five sensitivity assumptions results in an average of 44,000 barrels per day of additional highway diesel consumption between 2007 and 2010 and an average of 366,000 barrels per day of additional demand between 2011 and 2015. The ULSD regulation by itself accounts for about 9,000 barrels per day of the additional consumption through 2010 and about 83,000 barrels per day after 2010. The combined effect of the five

Table 16. Variations from Reference Case Projections of Fuel Distribution Costs in the Regulation and 10% Downgrade Cases
(1999 Cents per Gallon)

Analysis Case and Cost Component	Average Annual Cost, June 2006 - June 2010	Average Annual Cost After June 1, 2010
Regulation		
Total	**1.2**[a]	**0.4**[a]
Capital Costs	0.7	0.0
Operating Costs	0.2	0.2
Downgrade Revenue Loss	0.3	0.2
10% Downgrade		
Total	**1.6**	**0.9**
Capital Costs	0.7	0.0
Operating Costs	0.2	0.2
Downgrade Revenue Loss	0.7	0.7

[a]The additional annual diesel fuel distribution costs in the Regulation case differ slightly from the EPA estimates (see Table 26 in Chapter 7), because different revenue losses associated with product downgrade are assumed.

Sources: **Capital Costs and Operating Costs:** 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, web site www.epa.gov/otaq/regs/hd2007/frm/ria-v.pdf. Operating Costs include operating, existing mix, transmix, and testing cost estimates. **Downgrade Revenue Loss:** Energy Information Administration, Office of Integrated Analysis and Forecasting, based on projected price differentials for ULSD versus 500 ppm diesel.

[124]This assumption is based on interviews with engine and technology manufacturers.

assumptions raises demand beyond that in the Regulation case by about 35,000 barrels per day through 2010 and by about 283,000 barrels per day after 2010. The higher downgrade assumption accounts for about 212,000 barrels of the additional demand after 2010. The Severe case results in a projected increase in refinery investments for hydrogen and distillate hydrotreating totaling $9.3 billion in 2011, $3.0 billion more than in the Regulation case. Higher demand in the Severe case results in marginal prices 1.7 to 3.5 cents per gallon above those in the Regulation case.

No Imports Case

In 1999, 87 percent of all imports of highway diesel went to PADD I (the East Coast), which is less self-sufficient than other regions in terms of refinery production. The East Coast is expected to continue to be the major market for imported highway diesel; however, a slight reduction in imports is projected under the ULSD Rule, because it is more economical for domestic refiners to provide the last barrel supplied. The No Imports case assumes that imports of highway diesel fuel are zero and, therefore, 120,000 to 125,000 barrels per day lower than projected in the reference case. The lack of imports means that domestic refineries must produce that much more ULSD. During the transition years, prices in the No Imports case are only slightly lower than in the Severe case, indicating the sensitivity of the market to imports. The requirement for more production results in marginal prices 1.1 to 1.6 cents per gallon higher than in the Regulation case. The higher prices in the No Imports case result in a slight dampening of demand, by up to 2,000 barrels on average when compared to the Regulation case. When imports of ULSD are not available, refineries are projected to meet the additional ULSD requirement by investing an additional $200 million in desulfurization equipment through 2015, and by reducing jet fuel production and importing more jet fuel. More ULSD is also shipped from PADDs II-IV to PADD I to compensate for the lack of imports.

10% Return On Investment Case

This case assumes that refiners will realize a higher rate of return than is assumed in the Regulation case and in all the other sensitivity cases for this analysis, which assume a 5.2-percent after-tax return on investment. Because the 10% Return on Investment case must be compared with an alternative reference case that uses a consistent rate of return, the projected price differentials are presented separately from those for the cases that are compared with the reference case (with a 5.2-percent after-tax rate (Table 17). The resulting price differentials range from 7.5 to 8.0 cents per gallon between 2007 and 2011 and are 0.9 cents per gallon higher on average than when the 5.2-percent after-tax rate is assumed. The different return on investment affects the payback of investment but does not affect the level of investment.

Regional Variations in Refining Costs

Differences between regional refinery gate prices in the analysis cases relative to those in the reference case reflect variations in the marginal costs of producing ULSD between regions (Table 18). The cost curve analysis described in Chapter 5 indicates that PADD IV, which contains relatively small refineries, can be expected to be the highest cost region; however, these costs are obscured by the aggregate model representation in NEMS. The Petroleum Market Module provides refining costs for three separate regions: PADD I (the East Coast), PADDs II-IV aggregated (mid-U.S.), and PADD V (the West Coast). In the transition years of the Regulation case, regional refining costs (excluding distribution costs) range from an average of 4.8 cents per gallon in PADD V to 5.3 cents per gallon in the other regions, with an average U.S. cost of 5.2 cents per gallon.

The relative patterns of regional costs during the transition period are similar in all the sensitivity cases, with PADD I as the highest cost region of the three NEMS regions, PADD V as the lowest cost region, and PADDs II-IV (and the U.S. average) falling in between. The relatively high ULSD production cost in PADD IV is masked in the mid-term analysis, because PADD IV is aggregated both with PADD II and with the largest and lowest cost refining region, PADD III. Average marginal refining costs generally are expected to fall by about 0.5 to 0.8 cents per gallon after 2011, as refineries make incremental improvements to meet incremental increases in demand more efficiently.

Conclusion

The ULSD Rule is projected to require total refinery investments ranging from $6.3 billion in the Regulation case to $9.3 billion in the Severe case, resulting in highway diesel fuel price increases that range from 6.5 to 10.7

Table 17. Variations from Alternative Reference Case Projections in the 10% Return on Investment Case, 2007-2015

Year	Difference Between End-Use Prices of ULSD and 500 ppm Diesel (1999 Cents per Gallon)[a]
2007	7.9
2008	7.5
2009	7.6
2010	7.7
2011	8.0
2015	5.7
2007-2010 Average	7.7
2011-2015 Average	6.0

[a]End-use prices include marginal refinery gate prices, distribution costs, and Federal and State taxes but exclude county and local taxes.

Source: NEMS runs DSUREF10.D043001A and DSU7PPM10.D043001A.

cents per gallon between 2007 and 2011. Because this analysis is based on results from a long-run equilibrium model, it does not capture the uncertainty of supply discussed in Chapter 5. The NEMS analysis reflects more aggressive investment than is portrayed for individual refiners in the short-term analysis. In the Regulation case, which uses many of the EPA's assumptions, prices are projected to increase by 6.5 to 7.2 cents per gallon between 2007 and 2011. The widest price differential—10.7 cents per gallon in 2011—is projected in the Severe case, which is based on assumptions more consistent with industry views. This peak price differential is associated with a requirement for additional ULSD supplies of 272,000 barrels per day above demand levels in the Regulation case, of which 206,000 barrels per day results from the 10-percent downgrade assumption.

Because NEMS is a long-run equilibrium model, it cannot address short-term supply issues; however, the No Imports case does provide some implications for short-term supply. When no availability of ULSD grade imports is assumed, the marginal price of ULSD is projected to exceed prices reflecting access to imports by about 1.2 to 1.6 cents per gallon between 2007 and 2011.

Table 18. Variations from Reference Case Projections of ULSD Marginal Refinery Gate Prices by Region in the Regulation and Sensitivity Analysis Cases, 2007-2015
(1999 Cents per Gallon)

Analysis Case and Producing Region	2007-2010 Average	2011-2015 Average	Analysis Case and Producing Region	2007-2010 Average	2011-2015 Average
Regulation			**4% Efficiency Loss . . .**		
U.S. Average	5.2	4.7	U.S. Average	5.2	5.1
PADD I.	5.3	4.8	PADD I.	5.3	5.3
PADDs II-IV	5.3	4.8	PADDs II-IV	5.3	5.2
PADD V	4.8	4.3	PADD V	4.8	4.5
Higher Capital Cost			**1.8% Energy Loss . . . .**		
U.S. Average	6.4	5.2	U.S. Average	5.5	4.8
PADD I.	6.6	5.5	PADD I.	5.6	5.3
PADDs II-IV	6.6	5.3	PADDs II-IV	5.6	4.9
PADD V	5.4	4.9	PADD V	5.2	4.4
2/3 Revamp			**Severe . . . . . .**		
U.S. Average	5.7	4.9	U.S. Average	7.0	6.4
PADD I.	6.0	5.0	PADD I.	7.4	6.8
PADDs II-IV	6.0	5.0	PADDs II-IV	7.4	6.3
PADD V	5.0	4.5	PADD V	5.9	5.2
10% Downgrade			**No Imports . . . . . .**		
U.S. Average	5.2	5.2	U.S. Average	6.6	6.1
PADD I.	5.3	5.4	PADD I.	6.9	6.8
PADDs II-IV	5.3	5.3	PADDs II-IV	6.9	6.3
PADD V	4.8	4.7	PADD V	4.8	4.3

Source: NEMS runs DSUREF.D043001B, DSU7PPM.D043001A, DSU7HC.D043001A, DSU7INV.D043001A, DSU7DG10.D043001A, DSU7TRN.D043001A, DSU7BTU.D043001A, DSU7ALL.D050101A, and DSU7IMP0.D043001A.