CHAPTER 10: Economic Impact Analysis

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An Economic Impact Analysis (EIA) was prepared to estimate the economic impacts of this proposal on producers and consumers of nonroad engines and equipment and related industries. The Nonroad Diesel Economic Impact Model (NDEIM), developed for this analysis, was used to estimate market-level changes in prices and outputs for affected engine, equipment, fuel, and application markets as well as the social costs and their distribution across economic sectors affected by the program. The basis for this analysis is provided in the Economic Impact Analysis technical support document (RTI, 2003).

10.1 Overview of Results

This section provides a summary of the EPA economic analysis approach and presents an overview of its results. As described below, the overall economic impact of the proposed emission control program on society should be minimal. According to this analysis, the average price of goods and services produced using equipment and fuel affected by the proposal is expected to increase by about 0.02 percent. A more detailed description of this analysis is presented in the following sections of Chapter 10 and the corresponding appendices.

10.1.1 What is an Economic Impact Analysis?

Regulatory agencies conduct economic impact analyses of potential regulatory actions to inform decision makers about the effects of a proposed regulation on society's current and future well-being. In addition to informing decision makers within the Agency, economic impact analyses are conducted to meet the statutory and administrative requirements imposed by Congress and the Executive office. The Clean Air Act requires an economic impact analysis under section 317, while Executive Order 12866–Regulatory Planning and Review requires Executive Branch agencies to perform benefit-costs analysis of all rules it deems to be "significant" (typically over $100 million annual social costs) and submit these analysis to the Office of Management and Budget (OMB) for review. This economic impact analysis estimates the potential market impacts of the proposed rule's compliance costs and provides the associated social costs and their distribution across stakeholders for comparison with social benefits (as presented in Chapter 9).

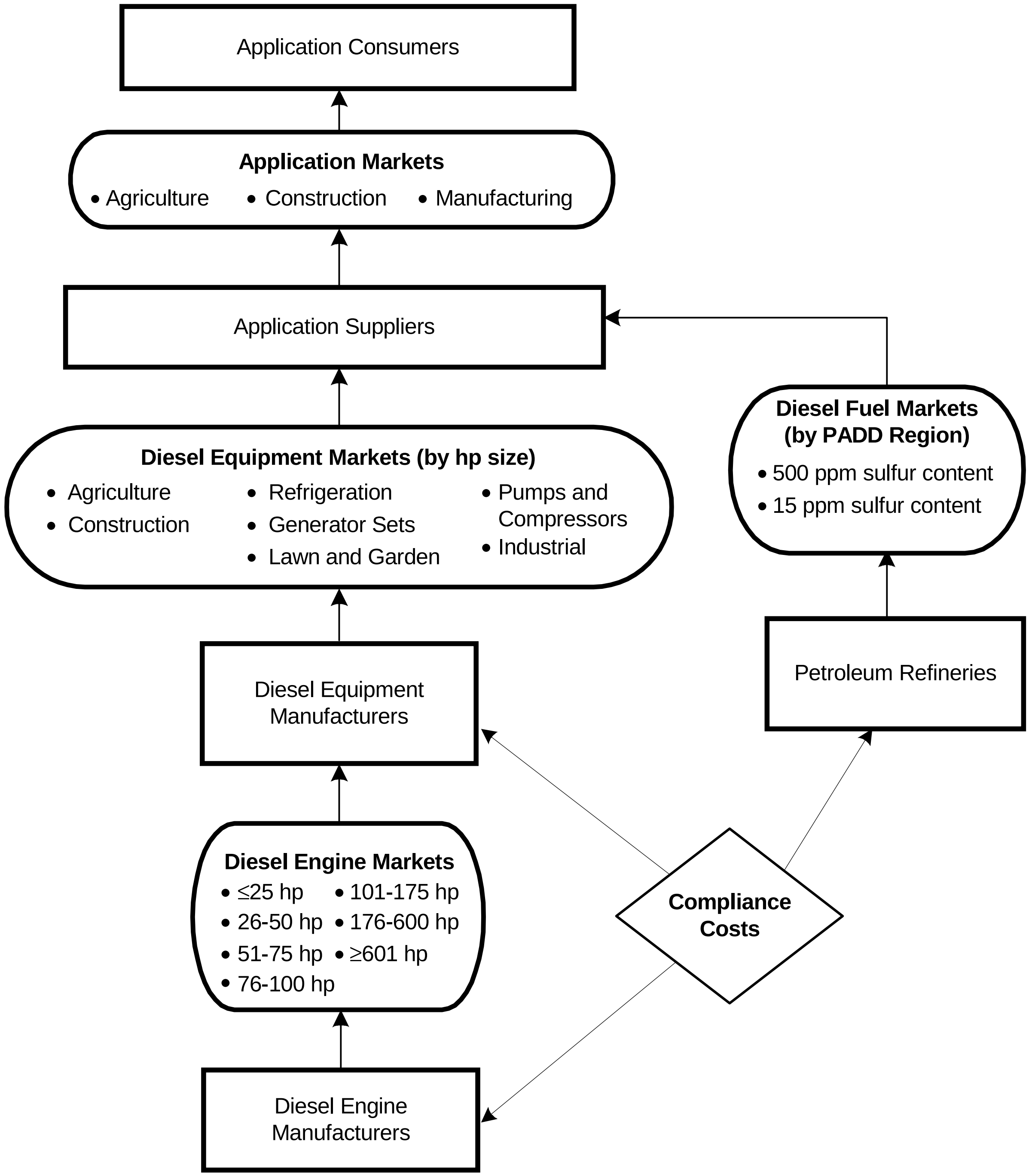
10.1.2 What is EPA's Economic Analysis Approach for this Proposal?

The underlying objective of an EIA is to evaluate the effect of a proposed regulation on the welfare of affected stakeholders and society in general. Using information on the expected compliance costs of the proposed program as presented in Chapters 6 and 7, this EIA explores how the companies that produce nonroad diesel engines, equipment, or fuel may change their production behavior in response to the costs of complying with the standards. It also explores how the consumers who use the affected products may change their purchasing decisions. For example, the construction industry may reduce purchases if the prices of nonroad diesel equipment increase, thereby reducing the volume of equipment sold (or market demand) for such equipment. Alternatively, the construction industry may pass along these additional costs to the consumers of their final goods and services by increasing prices, which would mitigate the potential impacts on the purchases of nonroad diesel equipment.

The Nonroad Diesel Economic Impact Model (NDEIM) developed for this analysis evaluates how producers and consumers are expected to respond to the regulatory costs associated with the proposed emission control program. The conceptual approach is to link significantly affected markets to mimic how compliance costs will potentially ripple through the economy. The NDEIM employs a multi-market partial equilibrium framework to track changes in price and quantity for over 50 integrated product markets. Figure 10.1-1 illustrates the industry segments included in the model and the flow of compliance costs through the economic system.

As shown in Figure 10.1-1, the compliance costs will be directly borne by engine manufacturers, equipment manufacturers, and petroleum refineries. Depending on market characteristics, some or all of these compliance costs will be passed on through the supply chain in the form of higher prices extending to producers and consumers in the application markets (i.e., construction, agriculture, and manufacturing). In this way the proposed rule indirectly affects producers and consumers in all of the related markets included in Figure 10.1-1. For example, the proposed rule will increase the cost of producing nonroad diesel engines. Engine manufacturers will attempt to pass these increased costs on to equipment manufacturers in the form of higher diesel engine prices. Similarly, equipment manufacturers will attempt to pass their direct compliance costs and the increased cost of engines to application manufacturers through higher diesel equipment prices. Petroleum refiners will also attempt to pass their direct compliance costs on to application manufacturers through higher prices for diesel fuel. Finally, application manufacturers will look to pass on the increased equipment and diesel fuel costs to consumers of final application products and services. The NDEIM explicitly models these linkages and estimates the behavioral responses that lead to new equilibrium prices and output for all related markets and the resulting distribution of social costs across affected stakeholders.

Figure 10.1-1
Market Linkages Included in Economic Model



10.1.3 What are the key features of the NDEIM?

The NDEIM is a computer model comprised of a series of spreadsheet modules that define the baseline characteristics of supply and demand for the relevant markets and the relationships between them. The basis for this analysis is provided in the EIA technical support document (RTI, 2003). The model methodology is firmly rooted in applied microeconomic theory and was developed following the *OAQPS Economic Analysis Resource Document* (EPA, 1999). Table 10.1-1 provides a summary of the markets included in the NDEIM, including their baseline characterization and behavioral response parameters (i.e., supply and demand elasticities). These market characteristics are described in more detail in Section 10.3. Based on the specified market linkages, shown in Figure 10.1-1, the model is shocked by applying the engineering compliance cost estimates to the appropriate market suppliers and then numerically solved using an iterative auctioneer approach by "calling out" new prices until a new equilibrium is reached in all markets simultaneously.

The NDEIM uses a multi-market partial equilibrium approach to track changes in price and quantity for 60 integrated product markets, as follows:

- 7 diesel engine markets (less than 25 hp, 26 to 50 hp, 51 to 75 hp, 76 to 100 hp, 101 to 175 hp, 176 to 600 hp, and greater than 600 hp)
- 42 diesel equipment markets (7 horsepower categories within 7 application categories: construction, agricultural, general industrial, pumps and compressors, generator and welder sets, refrigeration and air conditioning, and lawn and garden; there are 7 horsepower/application categories that did not have sales in 2000 and are not included in the model, so the total number of diesel equipment markets is 42, rather than 49)
- 3 application markets (construction, agriculture, and manufacturing)
- 8 nonroad diesel fuel markets (2 sulfur content levels of15 ppm and 500 ppm, for each of 4 PADDs; PADDs 1 and 3 are combined for the purpose of this analysis). It should be noted that PADD 5 includes Alaska and Hawaii.

The economic impacts of the proposed rule are largely determined by behavioral response parameters within the model (i.e., the supply and demand elasticities). For most markets, as summarized in Table 10.1-1, the supply and demand elasticities were either obtained from the professional literature or econometrically estimated. Details on sources and estimation method are provided in Section 10.3 and Appendix 10G. Demand responses in the equipment, engine, and diesel fuel markets are derived internally as a function of changes in output levels in the applications markets (i.e., derived demand specification). Therefore, parameter values are not required for demand elasticities in these markets.

The actual economic impacts of the proposed rule will be determined by the ways in which producers and consumers of the engines, equipment, and fuels affected by the proposal change their behavior in response to the costs incurred in complying with the standards. In the NDEIM, these behaviors are modeled by the demand and supply elasticities. Table 10.1-1 summarizes the sources of the demand and supply elasticities used in the model; more information can be found in section 10.3-5, below. As noted in Table 10.1-1, the supply elasticities for the engine and equipment markets and the demand elasticities for the application markets were estimated using econometric methods. The procedures and results are reported in Appendix 10.1 of this draft RIA. Literature-based estimates were used for the supply elasticities in the application and fuel markets. There are two ways to handle the demand elasticities for the engine, equipment, and fuel markets. The approach in NDEIM internally derives these elasticities based on the specified market linkages, i.e., the demand for engines, equipment, and fuel are modeled as directly related to the supply and demand of goods and services supplied by the final application markets. In other words, the supply of those goods and services determines the demand for equipment and fuel, and the supply of equipment determines the demand for engines. An alternative approach could be used in which the demand elasticities for the equipment, engine, and fuel markets are estimated outside the model.

The estimated supply and demand elasticities used in this analysis for the application markets and the supply elasticity for the diesel fuel market are inelastic or unit elastic. This means that the quantities of goods and services demanded/supplied are expected to be fairly insensitive to price changes (inelastic) or that the quantity demanded/supplied is expected to vary directly with changes in prices. In other words, price changes are not expected to have a large impact on the level of consumption in these application markets. For the agricultural application market, the inelastic supply and demand elasticities reflects the relatively constant demand for food products and the high fixed cost nature of food production. For the construction and manufacturing application markets, the estimated demand and supply elasticities are less inelastic, because consumers have more flexibility to substitute away from construction and manufactured products and producers have more flexibility to adjust production levels. The estimated supply elasticity for the diesel fuel market is also inelastic, because most refineries operate near capacity and are therefore less responsive to fluctuations in market prices. The supply elasticities used in this analysis for the engine and equipment markets, on the other hand, are fairly elastic. This means that quantities supplied in these markets are expected to be very responsive to price changes, that manufacturers are more likely (better able) to change production levels in response to price changes. The demand elasticities for the diesel engine and equipment markets and for the diesel fuel market are not explicitly specified because these demand levels are derived as part of the modeled outcomes for the application markets. It should be noted that these elasticities reflect intermediate run behavioral changes. In the long run, supply and demand are expected to be more elastic since more substitutes may become available.

Table 10.1-1
Summary of Markets in Nonroad Diesel Economic Impact Model (NDEIM)

Model Dimension	Markets (number)			
	Diesel Engines (7)	**Diesel Equipment (42)**	**Diesel Fuel (8)**	**Application (3)**
Geographic scope	National	National	Regional by PADDs	National
Product groupings	7 horsepower categories consistent with proposed standard[a]	7 horsepower categories within seven application categories[b,c]	2 diesel fuels by sulfur content (500, 15 ppm) for 4 regional markets[d]	Three broad commodity categories[e]
Market structure	Perfectly competitive	Perfectly competitive	Perfectly competitive	Perfectly competitive
Baseline population	Power Systems Research (PSR) database for 2000 as modified by EPA[f]	Assume one-to-one relationship with engine population	Based on Energy Information Administration (EIA) 2000 fuel consumption data	Value of shipments for 2000 from U.S. Census Bureau
Growth projections	EPA's nonroad model	Based on engine growth	Based on nonroad model and EIA	
Supply elasticity	Econometric estimate (elastic)	Econometric estimate (elastic)	Published econometric estimate (inelastic)	Published econometric estimate (inelastic)
Demand elasticity	Derived demand	Derived demand	Derived demand	Econometric estimate (inelastic)
Regulatory shock	Direct compliance costs cause shift in supply function	Direct compliance costs and higher diesel engine prices cause shift in supply function	Direct compliance costs cause shift in supply function	No direct compliance costs but higher prices for diesel equipment and fuel cause shift in supply function

[a] Horsepower categories are 0-25, 26-50, 51-75, 76-100, 101-175, 176-600, and 601 and greater; the EIA includes more horsepower categories than the standards, allowing more efficient use of the engine compliance cost estimates developed for this proposal.

[b] Engine categories are agricultural (SIC 3523), construction (SIC 3531), pumps and compressors (SIC 3561 and 3563), generator and welder sets (SIC 3548), refrigeration and air conditioning (SIC 3585), general industrial (SIC 3537), and lawn and garden (SIC 3524).

[c] There are seven horsepower/application categories that do not have sales in 2000 and are not included in the model. These are: agricultural equipment >600 hp; gensets & welders > 600 hp; refrigeration & A/C > 71 hp (4 hp categories); and lawn & garden >600 hp. Therefore, the total number of diesel equipment markets is 42 rather than 49.

[d] PADDs 1 and 3 are combined for the purpose of this analysis). It should be noted that PADD 5 includes Alaska and Hawaii.

[e] Application market categories are construction, agriculture, and manufacturing.

[f] See Section 8.1 in Chapter 8 of this draft RIA for an explanation of how the engines were allocated to the seven categories.

Because the elasticity estimates are a key input to the model, a sensitivity analysis for supply and demand elasticity parameters used in the model was also performed as part of this EIA. The results are presented in Appendix 10I. In general, varying the elasticity values across the range of values reported in the literature or using the upper and lower bounds of a 90 percent confidence interval around estimated elasticities has no impact on the magnitude of the total social costs, and only a minimal impact on the distribution of costs across stakeholders. This is because equipment and diesel fuel costs are a relatively small share of total production costs in the construction, agriculture, and manufacturing industries. As a result compliance costs are expected to have little influence on production in these application markets, and the derived demand for equipment, engines and fuel are minimally affected.

With regard to the compliance costs that are used to shock the model, the NDEIM uses the expected increase in variable costs associated with the proposed engine emission standards and the sum of variable and fixed costs associated with the fuel standards. Fixed costs associated with the engine emission standards are not included in the market analysis reported in Table 10.1-2. This is because in an analysis of competitive markets the industry supply curve is based on its marginal cost curve, and fixed costs are not reflected in changes in the marginal cost curve. In addition, fixed costs are primarily R&D costs associated with design and engineering changes, and firms in the affected industries currently allocate funds for these costs. Therefore, fixed costs are not likely to affect the prices of engines or equipment. This assumption is described in greater detail below in Section 10.2.3.3. R&D costs are a long-run concern, and decisions to invest or not invest in R&D are made in the long run. If funds have to be diverted from some other activity into R&D needed to meet the environmental regulations, then these costs represent a component of the social costs of the rule. Therefore, fixed R&D costs are included in the welfare impact estimates reported in Table 10.1-3 as additional costs on producers.

An alternative approach for R&D expenditures can be used, in which these costs are included in intermediate-run decision-making. This alternative assumes that manufacturers will change their behavior based on the R&D required for compliance with the standards. A sensitivity analysis is included in Chapter 10 of the draft RIA for this proposal that reflects this approach.

In addition to the variable and fixed costs described above, there are three additional costs components that are included in the total social cost estimates of the proposed regulation but that are not explicitly included in the NDEIM. These are operating savings (costs), fuel marker costs, and spillover from 15 ppm fuel to higher sulfur fuel.

Operating savings (costs) refers to changes in operating costs that are expected to be realized by users of both existing and new nonroad diesel equipment as a result of the reduced sulfur content of nonroad diesel fuel. These include operating savings (cost reductions) due to fewer oil changes, which accrue to nonroad engines, and marine and locomotive engines, that are already in use as well as new nonroad engines that will comply with the proposed standards. These savings (costs) also include any extra operating costs associated with the new PM emission control technology which may accrue to new engines that use this new technology. These savings (costs) are not included directly in the model because some of the savings accrue to existing engines and because these savings (costs) are not expected to affect consumer decisions with respect to new engines. Instead, they are added into the estimated welfare impacts as additional costs to the application markets, since it is the users of these engines that will see these savings (costs). Nevertheless, a sensitivity analysis was also performed in which these savings (costs) are included as inputs to the NDEIM, where they are modeled as benefits accruing to the application producers. The results of this analysis are presented in Appendix 10.I.

Fuel marker costs refers to costs associated with marking high sulfur diesel fuel in the locomotive, marine, and heating oil markets between 2007 and 2014. Marker costs are not included in the market analysis because locomotive, marine, and heating oil markets are not explicitly modeled in the NDEIM. Similar to the operating savings (costs), marker costs are added into the estimated welfare impacts separately.

The costs of fuel that spills over from the 15 ppm market to higher grade sulfur fuel are also not included in the NDEIM but, instead, are added into the estimated welfare impacts separately. As described in Chapter 7, refiners are expected to produce more 15 ppm fuel than is required for the nonroad diesel fuel market. This excess 15 ppm fuel will be sold into markets that allow fuel with a higher sulfur level (e.g., locomotive, marine diesel, or home heating fuel). Because this spillover fuel will meet the 15 ppm limit, it is necessary to count the costs of sulfur reduction processes against those fuels.

Consistent with the engine and equipment cost discussion in Chapter 6, this EIA does not include any cost savings associated with the proposed equipment transition flexibility program or the proposed nonroad engine ABT program. As a result, the results of this EIA can be viewed as somewhat conservative.

10.1.4 Summary of Economic Analysis

The economic analysis consists of two parts: a market analysis and welfare analysis. The market analysis looks at expected changes in prices and quantities for directly and indirectly affected market commodities as shown in Figure 10.1-1. The welfare analysis looks at economic impacts in terms of annual and present value changes in social costs. For this proposed rule, the social costs are computed as the sum of market surplus offset by operating cost savings. Market surplus is equal to the aggregate change in consumer and producer surplus based on the estimated market impacts associated with the proposed rule. Operating cost savings are associated with the decreased sulfur content of diesel fuel. These include maintenance savings (cost reductions) and changes in fuel efficiency. Increased maintenance costs may also be incurred for some technologies. Operating costs are not included in the market analysis but are instead listed as a separate category in the social cost results tables.

As noted in Chapter 6, engine and equipment costs vary over time because fixed costs are recovered over five to ten year periods while variable costs, despite learning effects that serve to reduce costs on a per unit basis, continue to increase in total at a rate consistent with new sales. Similarly, engine operating costs also vary over time because oil change maintenance savings, PM filter maintenance, and fuel economy effects, all of which are calculated on the basis of gallons of fuel consumed, change over time consistent with the growth in nationwide fuel consumption. Fuel related compliance costs (costs for refining and distributing the proposed fuels) also change over time. These changes are more subtle than the engine costs, however, as the fuel provisions are largely implemented in discrete steps instead of phasing in over time. The total fuel costs do increase as the demand for fuel increases. The variable operating costs are based on the natural gas cost of producing hydrogen and for heating diesel fuel for the new desulfurization equipment, and thus would fluctuate along with the price of natural gas. The distribution costs decrease in 2014 as it would no longer be necessary to use a marker.

Economic impact results for 2013, 2020, and 2030 are presented in this section. The first of these years, 2013, corresponds to the first year in which the standards affect all engines, equipment, and fuels. It should be noted that, as illustrated in Table 8-7-2, aggregate program costs peak in 2014; increases in costs after that year are due increases in the population of engines over time. The other years, 2020 and 2030, correspond to years analyzed in our benefits analysis. Detailed results for all years are included in Appendix 10E for this chapter.

10.1.4.1 What are the Expected Market Impacts of this Proposal?

The market impacts of this rule suggest that the overall economic impact of the proposed emission control program on society is expected be small, on average. According to this analysis, the average price of goods and services produced using equipment and fuel affected by the proposal is expected to increase by about 0.02 percent. The estimated price increases and quantity reductions for engines and equipment vary depending on compliance costs. In general, price increases would be expected to be higher (lower) as a result of a high (low) relative level of compliance costs to market price. The change in price would also be expected to be highest when compliance costs are highest.

This analysis indicates that most of the direct compliance costs for engine, equipment, and fuel producers will be passed through to the application markets in the form of higher prices to the consumers of final construction, agricultural, and manufactured goods and services. This is expected to occur because the demand for nonroad diesel equipment (and hence the derived demand for diesel engines and fuel) is estimated to be relatively price inelastic. The demand for nonroad diesel equipment is inelastic because of the following:

1) Nonroad diesel equipment and fuel expenditures are a relatively small share of total production costs for the products and services that use this equipment and fuel as inputs.
2) There are limited substitutes for nonroad diesel equipment and fuel.

The suppliers to the application markets are thus not expected to respond very much to increases in the price of nonroad diesel equipment and fuel because these factors represent a small share of total production costs. Furthermore, to the extent these increased costs might be significant enough to cause a response, there are few substitutes available to these suppliers. Therefore, the NDEIM predicts a small decrease in demand for diesel equipment and fuel. This would allow engine, equipment and fuel producers to pass through compliance costs in the form of higher prices.

The estimated market impacts for 2013, 2020, and 2030 are presented in Table 10.1-2. The market-level impacts presented in this table represent production-weighted averages of the individual market-level impact estimates generated by the model: the average expected price increase and quantity decrease across all of the units in each of the engine, equipment, fuel, and final application markets. For example, the model includes seven individual engine markets that reflect the different horsepower size categories. The 23 percent price change for engines shown in Table 10.1-2 for 2013 is an average price change across all engine markets weighted by the number of production units. Similarly, equipment impacts presented in Table 10.1-2 are weighted averages of 42 equipment-application markets, such as small (< 25hp) agricultural equipment and large (>600hp) industrial equipment. It should be noted that price increases and quantity decreases for specific types of engines, equipment, application sectors, or diesel fuel markets are likely to be different. But the data in this table provide a broad overview of the expected market impacts that is useful when considering the impacts of the proposal on the economy as a whole. Individual market-level impacts are presented in Appendix 10A through Appendix 10D.

Engine Market Results: Most of the variable costs associated with the proposed rule are passed along in the form of higher prices. The average price increase in 2013 for engines is estimated to be about 23 percent. This percentage is expected to decrease to about 19.5 percent for 2020 and later. This expected price increase varies by engine size because compliance costs are a larger share of total production costs for smaller engines. In 2013, the year of greatest compliance costs overall, the largest expected percent price increase is for engines between 25 and 50 hp: 34 percent or $852; the average price for an engine in this category is about $2,500. However, this price increase is expected to drop to 26 percent, or about $647, for 2016 and later. The smallest expected percent price increase in 2013 is for engines in the greater than 600 hp category. These engines are expected to see price increases of about 3 percent increase in 2013, increasing to about 5.6 percent in 2014 and beyond. The expected price increase for these engines is about $4,211 in 2013, increasing to about $6,950 in 2014 and later, for engines that cost on average about $125,000.

The market impact model predicts that even with these increase in engine prices, total demand is not expected to change very much. The expected average change in quantity is only about 69 engines per year in 2013, out of total sales of more than 500,000 engines. The estimated change in market quantity is small because as compliance costs are passed along the supply chain they become a smaller share of total production costs. In other words, firms that use these engines and equipment will continue to purchase them even at the higher cost because the increase in costs will not have a large impact on their total production costs. Diesel equipment is only one factor of production for their output of construction, agricultural, or manufactured goods. The average decrease in the quantity of all engines produced as a result of the regulation is estimated to be about 0.013 percent. This decrease ranges from 0.010 percent for engines less than 25 hp to 0.016 percent for engines 175 to 600 hp.

Equipment Market Results: Estimated price changes for the equipment markets reflect both the direct costs of the proposed standards on equipment production and the indirect cost through increased engine prices. In 2013, the average price increase for nonroad diesel equipment is estimated to be about 5.2 percent. This percentage is expected to decrease to about 4.5 percent for 2020 and beyond. The range of estimated price increases across equipment types parallels the share of engine costs relative to total equipment price, so the estimated percentage price increase among equipment types also varies. For example, the market price in 2013 for agricultural equipment between 175 and 600 hp is estimated to increase about 1.4 percent, or $1,835 for equipment with an average cost of $130,000. This compares with an estimated engine price increase of about $1,754 for engines of that size. The largest expected price increase in 2013 for equipment is $4,335, or 4.9 percent, for pumps and compressors over 600 hp. This compares with an estimated engine price increase of about $4,211 for engines of that size. The smallest expected price increase in 2013 for equipment is $125, or 3.6 percent, for construction equipment less than 25 hp. This compares with an estimated engine price increase of about $124 for engines of that size. The price changes for the equipment are less than that for engines because the engine is only one input in the production of equipment.

The output reduction for nonroad diesel equipment is estimated to be very small and to average about 0.014 percent for all years. This decrease ranges from 0.005 percent for general manufacturing equipment to 0.019 percent for construction equipment. The largest expected decrease in quantity in 2013 is 13 units of construction equipment per year for construction equipment between 100 and 175 hp, out of about 62,800 units. The smallest expected decrease in quantity in 2013 is less than one unit per year in all hp categories of pumps and compressors.

Table 10.1-2
Summary of Market Impacts ($2001)

Market	Engineering Cost	Change in Price		Change in Quantity	
	Per Unit	Absolute ($million)	Percent	Absolute	Percent
2013					
Engines	$1,087	$840	22.9	–69[a]	–0.013
Equipment	$1,021	$1,017	5.2	–118	–0.014
Application Markets[b]			0.02		–0.010
No. 2 Distillate Nonroad	$0.039	$0.038	4.1	–1.38[c]	–0.013
2020					
Engines	$1,028	$779	19.5	–79[a]	–0.013
Equipment	$1,018	$1,013	4.4	–135	–0.014
Application Markets[b]			0.02		–0.010
No. 2 Distillate Nonroad	$0.039	$0.039	4.1	–1.58[c]	–0.014
2030					
Engines	$1,027	$768	19.4	–92[a]	–0.013
Equipment	$1,004	$999	4.5	–156	–0.014
Application Markets[b]			0.02		–0.010
No. 2 Distillate Nonroad	$0.039	$0.039	4.1	–1.84[c]	–0.014

[a] The absolute change in the quantity of engines represents only engines sold on the market. Reductions in engines consumed internally by integrated engine/equipment manufacturers are not reflected in this number but are captured in the cost analysis. For this reason, the absolute change in the number of engines and equipment does not match.
[b] The model uses normalized commodities in the application markets because of the great heterogeneity of products. Thus, only percentage changes are presented.
[c] Units are in million of gallons.

Application Market Results: The estimated price increase associated with the proposed standards in all three of the application markets is very small and averages about 0.02 percent for all years. In other words, on average, the prices of goods and services produced using the engines, equipment, and fuel affected by this proposal are expected to increase only negligibly. This is because in all of the application markets the compliance costs passed on through price increases represent a very small share of total production costs. For example, the construction industry realizes an increase in production costs of approximately $468 million in 2013 because of the price increases for diesel equipment and fuel. However, this represents only 0.03 percent of the $1,392 billion value of shipments in the construction industry in 2001. The estimated average commodity price increase in 2013 ranges from 0.06 percent in the agricultural application market to about 0.01 percent in the manufacturing application market. The percentage change in output is also estimated to be very small and averages about 0.01 percent. This reduction ranges from less than a 0.01 percent decrease in manufacturing to about a 0.02 percent decrease in construction. Note that these estimated price increases and quantity decreases are average for these sectors and may vary for specific subsectors. Also, note that absolute changes in price and quantity are not provided for the application markets in Table 10.1-2 because normalized commodity values are used in the market model. Because of the great heterogeneity of manufactured or agriculture products, a normalized commodity ($1 unit) is used in the application markets. This has no impact on the estimated percentage change impacts but makes interpretation of the absolute changes less informative.

Fuel Markets Results: The estimated average price increase across all nonroad diesel fuel is about 4 percent for all years. For 15 ppm fuel, the estimated price increase for 2013 ranges from 3.2 percent in the East Coast region (PADD 1&3) to 9.3 percent in the mountain region (PADD 4). The average national output decrease for all fuel is estimated to be about 0.01 percent for all years, and is relatively constant across all four regional fuel markets.

10.1.4.2 What are the Expected Social Costs of this Proposal?

Social costs include the changes in market surplus estimated by the NDEIM and changes in operating costs and marker costs associated with the regulation. Table 10.1-3 shows the time series of engineering compliance costs and social cost estimates for 2007 through 2030. As shown, these estimates are of similar magnitude for each year of the analysis. However, the distribution of costs across the affected stakeholders is very different. This is highlighted by the comparison of Figure 10.1-3a and Figure 10.1-3b, which show the way in which the estimated engineering compliance costs and the estimated social costs are distributed across stakeholders, for 2013. Figure 10.1-3a shows that the direct compliance costs are borne relatively evenly across engine, equipment, and fuel producers, with each bearing about one-third of the costs. In contrast, as shown in Figure 10.1-3b, most of the social costs are borne by producers and consumers in the application markets (about 89 percent when the operating savings (costs) are not considered) due to the increased prices for diesel engines, equipment, and fuel. Engine producers are able to pass on 94 percent their compliance costs through higher prices. The remaining 6 percent are primarily fixed R&D costs that are internalized by engine manufacturers and not passed into the market. Equipment manufacturers retain a slightly higher share of compliance costs because they have greater fixed costs. Diesel fuel refiners pass over 98 percent of their compliance costs on to the application producers and consumers because, as discussed in Chapter 6, refiners pass both fixed and variable costs into the market.

Table 10.1-3
National Engineering Compliance Costs and
Social Costs Estimates for the Proposed Rule (2004 - 2030)
($2001; $Million)

Year	Engineering Compliance Costs	Total Social Costs
2004	$0.00	$0.00
2005	$0.00	$0.00
2006	$0.00	$0.00
2007	$39.61	$39.61
2008	$130.41	$130.40
2009	$132.25	$132.25
2010	$262.02	$262.01
2011	$641.12	$641.07
2012	$1,010.37	$1,010.27
2013	$1,202.52	$1,202.40
2014	$1,329.14	$1,329.01
2015	$1,260.74	$1,260.62
2016	$1,298.40	$1,298.27
2017	$1,318.75	$1,318.62
2018	$1,325.02	$1,324.89
2019	$1,339.30	$1,339.16
2020	$1,366.79	$1,366.66
2021	$1,351.08	$1,350.94
2022	$1,349.58	$1,349.44
2023	$1,365.53	$1,365.38
2024	$1,371.60	$1,371.45
2025	$1,395.98	$1,395.83
2026	$1,419.79	$1,419.64
2027	$1,442.91	$1,442.76
2028	$1,465.41	$1,465.26
2029	$1,487.68	$1,487.53
2030	$1,509.77	$1,509.61
NPV at 3%	$16,524.29	$16,522.66
NPV at 7%	$9,894.02	$9,893.06

Figure 10.1-2 shows the time series of total social costs from 2007 through 2030. Social costs increase rapidly between 2007 and 2013 as engine, equipment and fuel costs are phased into the regulation. Estimated net annual social costs (including operating savings (cost) and marker costs) in 2013 are about $1,202 million. After 2013, per unit compliance costs decrease as fixed costs are depreciated. However, due to growth in engine and equipment sales and related fuel consumption, net social costs are expected continue to increase, but at a slower rate, from 2014 to 2030. The estimated net present value of social costs over the time period 2004 through 2030 based on a social discount rate of 3 percent is reported in Table 10.1-3 and is about $16.5 billion. The present value over this same period based on a social discount rate of 7 percent is about $9.9 billion.

Figure 10.1-2
Total Social Costs (2004-2030)

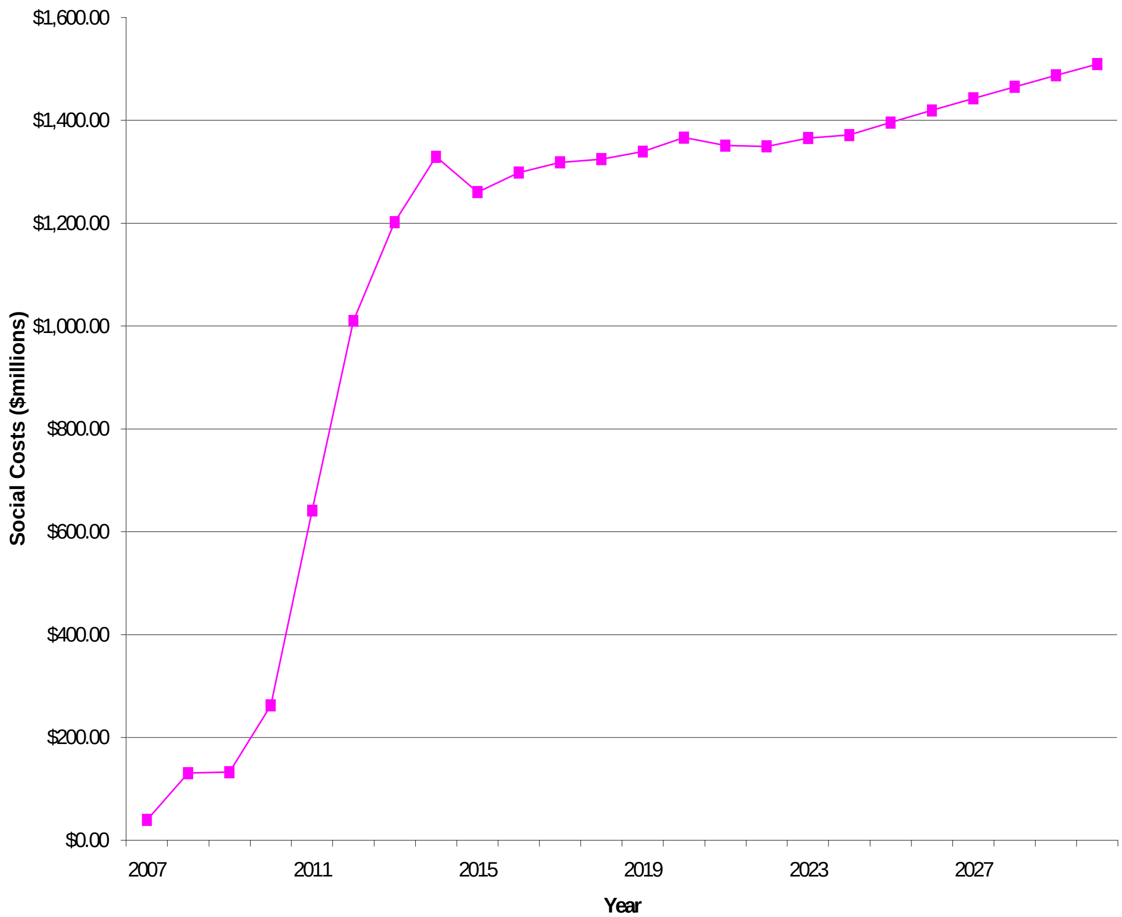
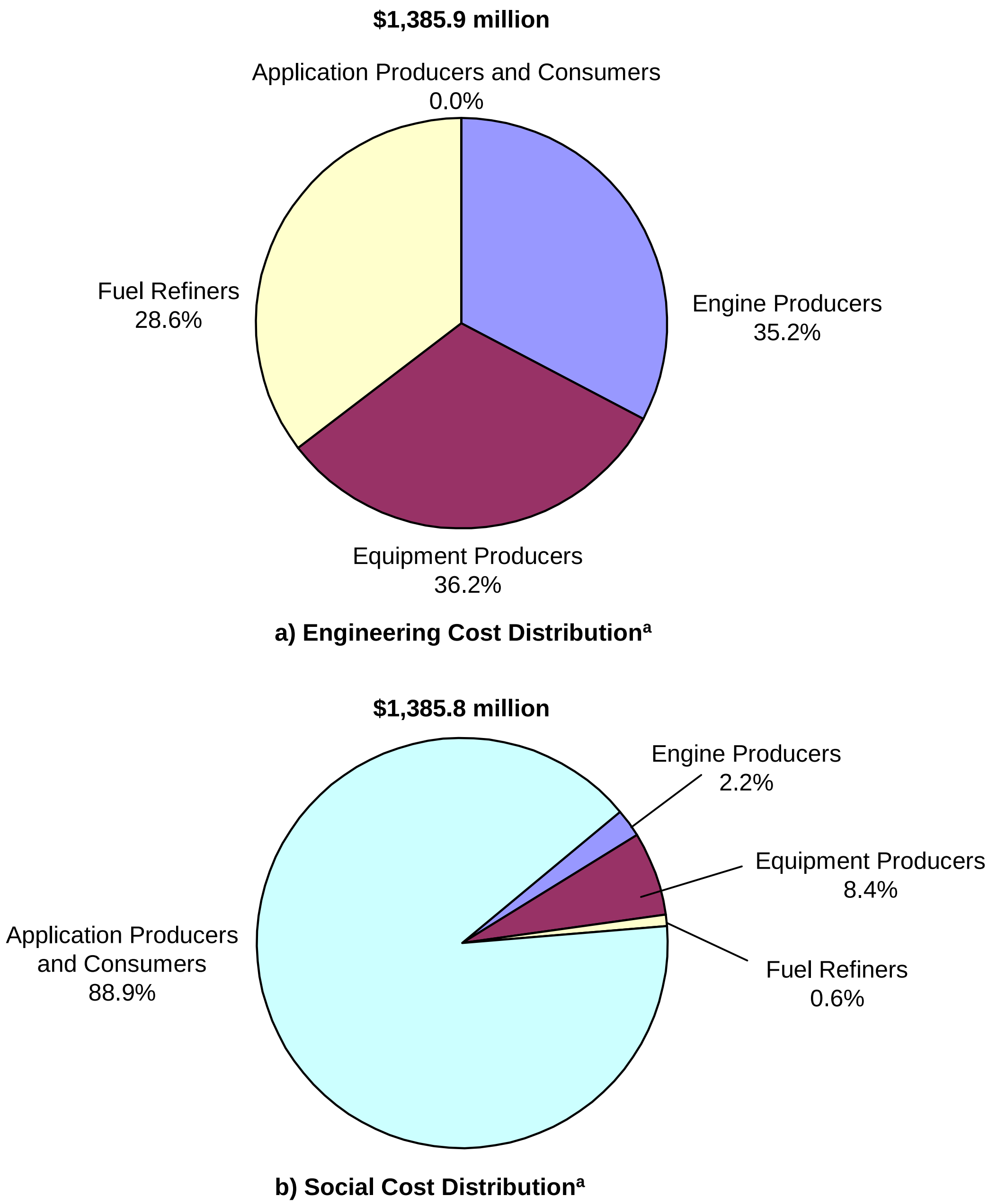


Figure 10.1-3
Comparison of the Distribution of Engineering Compliance
and Social Cost Estimates by Industry Segment (2013)



[a] Costs do not include operating cost savings, nonroad spillover, or marker costs, which represent negative 183.4 million in costs (i.e., benefits).

Estimated social costs are disaggregated by market in Table 10.1-4, for 2013, 2020, and 2030. A more detailed time series from 2007 to 2030 provided is in Appendix 10.E. The data in Table 10.1-4 shows that in 2013, social costs are expected to be about $1,202.4 million ($2001). About 82 percent of the total social costs is expected to be borne by producers and consumers in the application markets, indicating that the majority of the costs are expected to be passed on in the form of higher prices. When these estimated impacts are broken down, about 58 percent of the social costs are expected to be borne by consumers in the application markets and about 42 percent are expected to be borne by producers in the application markets. Equipment manufacturers are expected to bear about 10 percent of the total social costs. Engine manufacturers and diesel fuel refineries are expected to bear 2.5 percent and 0.5 percent, respectively. The remaining 5.0 percent is accounted for by fuel marker costs and the additional costs of 15 ppm fuel being sold in to markets such as marine diesel, locomotive, and home heating fuel that do not require it.

In 2030, the total social costs are projected to be about $1,509.6 million ($2001). The increase is due to the projected annual growth in the engine and equipment populations. As in earlier years, producers and consumers in the application markets are expected to bear the large majority of the costs, approximately 94 percent. This is consistent with economic theory, which states that, in the long run, all costs are passed on to the consumers of goods and services.

Table 10.1-4
Summary of Social Costs Estimates Associated with Primary Program: 2013, 2020, and 2030 ($million)[a,b]

	Maximum Cost Year (2013)				Year 2020				Final Year (2030)			
	Market Surplus ($$10^6$)	Operating Savings ($$10^6$)	Total	Percent	Market Surplus ($$10^6$)	Operating Savings ($$10^6$)	Total	Percent	Market Surplus ($$10^6$)	Operating Savings ($$10^6$)	Total	Percent
Engine Producers Total	$30.2		$30.2	2.5%	$0.1		$0.1	0.01%	$0.1		$0.1	0.0%
Equipment Producers Total	$116.1		$116.1	9.7%	$102.6		$102.6	7.5%	$5.3		$5.3	0.3%
Construction Equipment	$53.0		$53.0		$48.2		$48.2		$3.8		$3.8	
Agricultural Equipment	$39.9		$39.9		$33.2		$33.2		$1.3		$1.3	
Industrial Equipment	$23.2		$23.2		$21.2		$21.2		$0.2		$0.2	
Application Producers & Consumers Total	$1,231.8	($241.9)	$989.8	82.3%	$1,386.5	($190.1)	$1,196.3	87.5%	$1,598.9	($174.5)	$1,424.5	94.4%
Total Producer	*$515.7*				*$583.4*				*$672.9*			
Total Consumer	*$716.1*				*$803.1*				*$926.0*			
Construction	$468.3	($77.9)	$390.4		$550.4	($61.2)	$489.3		$635.7	($56.1)	$579.5	
Agriculture	$348.7	($44.7)	$304.0		$339.2	($35.2)	$364.0		$416.5	($32.3)	$429.2	
Manufacturing	$414.8	($119.3)	$295.5		$436.8	($93.8)	$343.0		$501.8	($86.0)	$415.7	
Fuel Producers Total	$7.8		$7.8	0.6%	$9.0		$9.0	0.7%	$10.5		$10.5	0.7%
PADD I&III	$3.6		$3.6		$4.1		$4.1		$4.8		$4.8	
PADD II	$2.9		$2.9		$3.3		$3.3		$3.9		$3.9	
PADD IV	$0.8		$0.8		$0.9		$0.9		$1.0		$1.0	
PADD V	$0.5		$0.5		$0.6		$0.6		$0.8		$0.8	
Nonroad Spillover		$51.2		$4.3		$58.6		$4.3		$69.2		4.6%
Marker Costs		$7.3		0.6%		–		0.0%		–		0.0%
Total	$1,385.8	($183.4)	$1,202.4	100%	$1,498.2	($131.5)	$1,366.7	100%	$1,614.9	($105.3)	$1,509.6	100%

[a] Figures are in 2001 dollars.
[b] Operating savings are shown as negative costs.

Table 10.1-5
Summary of Social Costs Estimates Associated with Primary Program:
NPV, 3%, 2004-2030 ($million)[a,b]

	Market Surplus ($$10^6$)	Fuel Maintenance ($$10^6$)	Total	Percent
Engine Producers Total	$190.0		$190.0	1.1%
Equipment Producers Total	$927.4		$927.4	5.6%
Construction Equipment	$433.6		$433.6	
Agricultural Equipment	$306.7		$306.7	
Industrial Equipment	$187.1		$187.1	
Application Producers & Consumers Total	$17,744.2	($3,402.4)	$14,341.8	86.8%
Total Producer	*$7,450.7*			
Total Consumer	*$10,293.5*			
Construction	$6,923.5	($1,094.9)	$5,828.6	
Agriculture	$5,050.4	($629.3)	$4,421.1	
Manufacturing	$5,770.3	($1,678.1)	$4,092.2	
Fuel Producers Total	$113.9		$113.9	0.7%
PADD I&III	$52.3		$52.3	
PADD II	$41.9		$41.9	
PADD IV	$11.5		$11.5	
PADD V	$8.1		$8.1	
Nonroad Spillover		$886.5		5.4%
Marker Costs		$63.0		0.4%
Total	$18,975.5	($2,452.8)	$16,522.7	100%

[a] Figures are in 2001 dollars.
[b] Operating savings are shown as negative costs.

10.2 Economic Methodology

Economic impact analysis uses a combination of theory and econometric modeling to evaluate potential behavior changes associated with a new regulatory program. As noted above, the goal is to estimate the impact of the regulatory program on producers and consumers. This is done by creating a mathematical model based on economic theory and populating the model using publically available price and quantity data. A key factor in this type of analysis is estimating the responsiveness of the quantity of engines, equipment, and fuels demanded by consumers or supplied by producers to a change in the price of that product. This relationship is called the elasticity of demand or supply. This section discusses the economic theory underlying the modeling for this EIA and several key issues that affect the way the model was developed.

10.2.1 Behavioral Economic Models

Models incorporating different levels of economic decision making can generally be categorized as *with*-behavior responses or *without*-behavior responses (engineering cost analysis). Engineering cost analysis is an example of the latter and provides detailed estimates of the cost of a regulation based on the projected number of affected units and engineering estimates of the annualized costs.

The behavioral approach builds on the engineering cost analysis and incorporates economic theory related to producer and consumer behavior to estimate changes in market conditions. Owners of affected plants are economic agents that can make adjustments, such as changing production rates or altering input mixes, that will generally affect the market environment in which they operate. As producers change their production levels in response to a regulation, consumers are typically faced with changes in prices that cause them to alter the quantity that they are willing to purchase. These changes in price and output from the market-level impacts are used to estimate the distribution of social costs between consumers and producers.

Generally, the behavioral approach and engineering cost approach yield approximately the same total cost impact. However, the advantage of the behavioral approach is that it illustrates how the costs flow through the economic system and identifies which stakeholders, producers, and consumers are most affected.

10.2.2 Conceptual Economic Approach

This EIA models basic economic relationships between supply and demand to estimate behavioral changes expected to occur as a result of the proposed regulation. An overview of the basic economic theory used to develop the model to estimate the potential effect of the proposed program on market outcomes is presented in this section. Following the *OAQPS Economic Analysis Resource Document* (EPA, 1999), standard concepts in microeconomics are used to model the supply of affected products and the impacts of the regulations on production costs and the operating decisions.

10.2.2.1 Types of Models: Partial vs. General Equilibrium Modeling Approaches

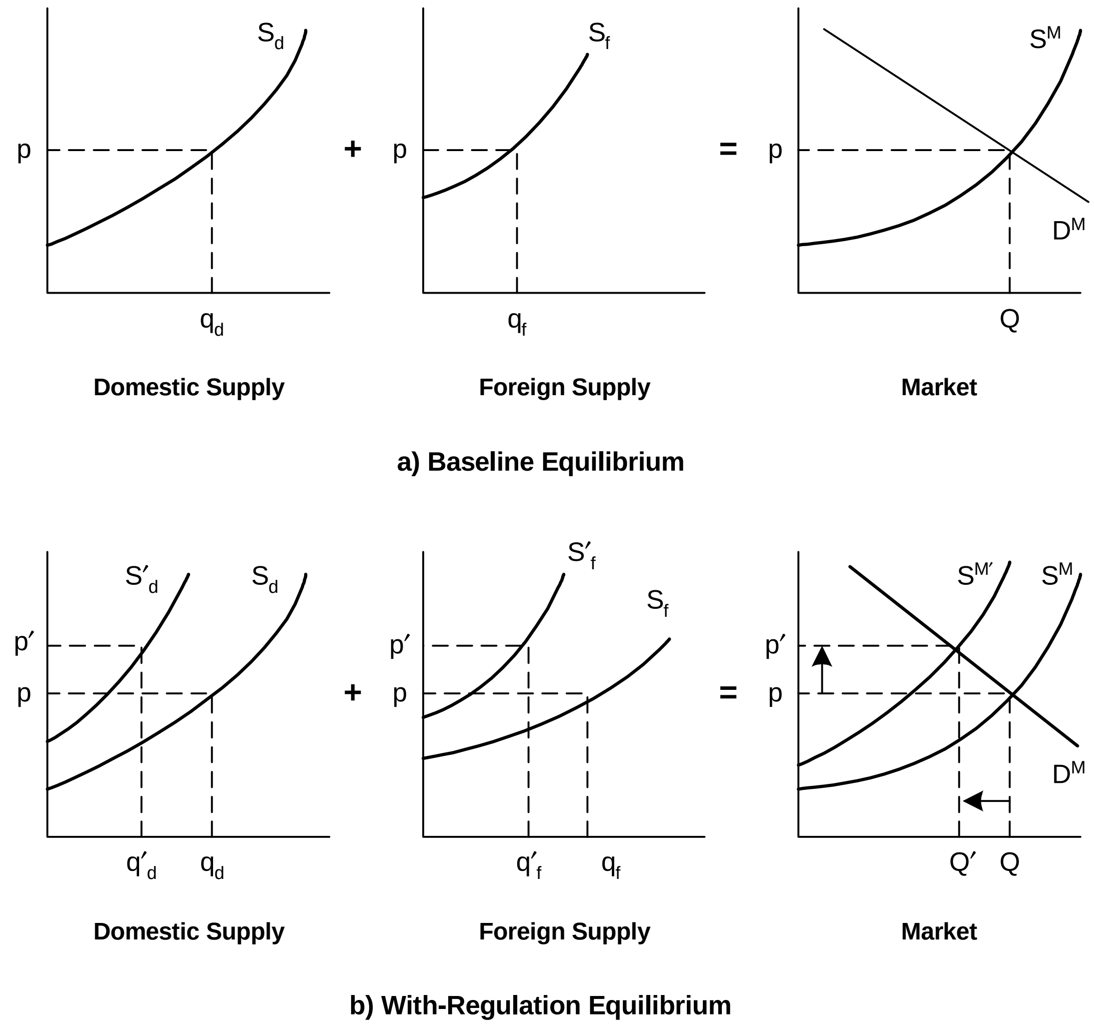
In the broadest sense, all markets are directly or indirectly linked in the economy; thus, the proposed regulation will affect all commodities and markets to some extent. The appropriate level of market interactions to be included in an EIA is determined by the number of industries directly affected by the requirements and the ability of affected firms to pass along the regulatory costs in the form of higher prices. Alternative approaches for modeling interactions between economic sectors can generally be divided into three groups:

- *Partial equilibrium model*—Individual markets are modeled in isolation. The only factor affecting the market is the cost of the regulation on facilities in the industry being modeled; there are no interaction effects with other markets.
- *General equilibrium model*—All sectors of the economy are modeled together, incorporating interaction effects between all sectors included in the model. General equilibrium models operationalize neoclassical microeconomic theory by modeling not only the direct effects of control costs but also potential input substitution effects, changes in production levels associated with changes in market prices across all sectors, and the associated changes in welfare economy-wide. A disadvantage of general equilibrium modeling is that substantial time and resources are required to develop a new model or tailor an existing model for analyzing regulatory alternatives.
- *Multimarket model*—A subset of related markets is modeled together, with sector linkages, and hence selected interaction effects, explicitly specified. This approach represents an intermediate step between a simple, single-market partial equilibrium approach and a full general equilibrium approach. This technique has most recently been referred to in the literature as "partial equilibrium analysis of multiple markets" (Berck and Hoffmann, 2002).

This analysis uses a behavioral multimarket framework because the benefits of increasing the dimensions of the model outweigh the cost associated with additional model detail. As Bingham and Fox (1999) note, this increased scope provides "a richer story" of the expected distribution of economic welfare changes across producers and consumers. Therefore, the NDEIM developed for this analysis consists of a spreadsheet model that links a series of standard partial equilibrium models by specifying the interactions between the supply and demand for products. Changes in prices and quantities are then solved across all markets *simultaneously*. The following markets were included in the model; their linkages are illustrated in Figure 10.2-1 and they are described in detail in Section 10.3.3 below:

- seven diesel engine markets categorized by engine size;
- 42 equipment markets, including construction, agriculture, refrigeration, lawn and garden, pumps and compressors, generators and welder sets, and general industrial equipment types—with five to seven horsepower size categories for each equipment type;
- eight fuel markets, four regions (PADDs) each with two nonroad diesel fuel markets (500 ppm and 15 ppm); and
- three application markets (construction, agriculture, and manufacturing).

Figure 10.2-1
Market Equilibrium without and with Regulation



10.2.2.2 Market Equilibrium in a Single Commodity Market

A graphical representation of a general economic competitive model of price formation, as shown in Figure 10.2-1(a), posits that market prices and quantities are determined by the intersection of the market supply and market demand curves. Under the baseline scenario, a market price and quantity (p,Q) are determined by the intersection of the downward-sloping market demand curve (D^M) and the upward-sloping market supply curve (S^M). The market supply curve reflects the sum of the domestic (S_d) and import (S_f) supply curves.

With the regulation, the costs of production increase for suppliers. The imposition of these regulatory control costs is represented as an upward shift in the supply curve for domestic and import supply, by the estimated compliance costs. As a result of the upward shift in the supply curve, the market supply curve will also shift upward as shown in Figure 10.2-1(b) to reflect the increased costs of production.

At baseline without the proposed rule, the industry produces total output, Q, at price, p, with domestic producers supplying the amount q_d and imports accounting for Q minus q_d, or q_f. With the regulation, the market price increases from p to p′, and market output (as determined from the market demand curve) declines from Q to Q′. This reduction in market output is the net result of reductions in domestic and import supply.

10.2.2.3 Incorporating Multimarket Interactions

The above description is typical of the expected market effects for a single product market (e.g., diesel engine manufacturers) considered in isolation. However, the modeling problem for this EIA is more complicated because of the need to investigate affected equipment manufacturers and fuel producers as well as engine manufacturers.

For example, the proposed Tier 4 standards will affect equipment producers in two ways. First, these producers are affected by higher input costs (increases in the price of diesel engines) associated with the rule. Second, the standards will also impose additional production costs on equipment producers associated with equipment changes necessary to accommodate changes in engine design.

The demand for diesel engines is directly linked to the production of diesel equipment. A single engine is typically used in each piece of equipment, and there are no substitutes (i.e., to make diesel equipment one needs a diesel engine). For this reason, it is reasonable to assume that the input-output relationship between the diesel engines and the equipment is strictly fixed and that the demand for engines varies directly with the demand for equipment.[A]

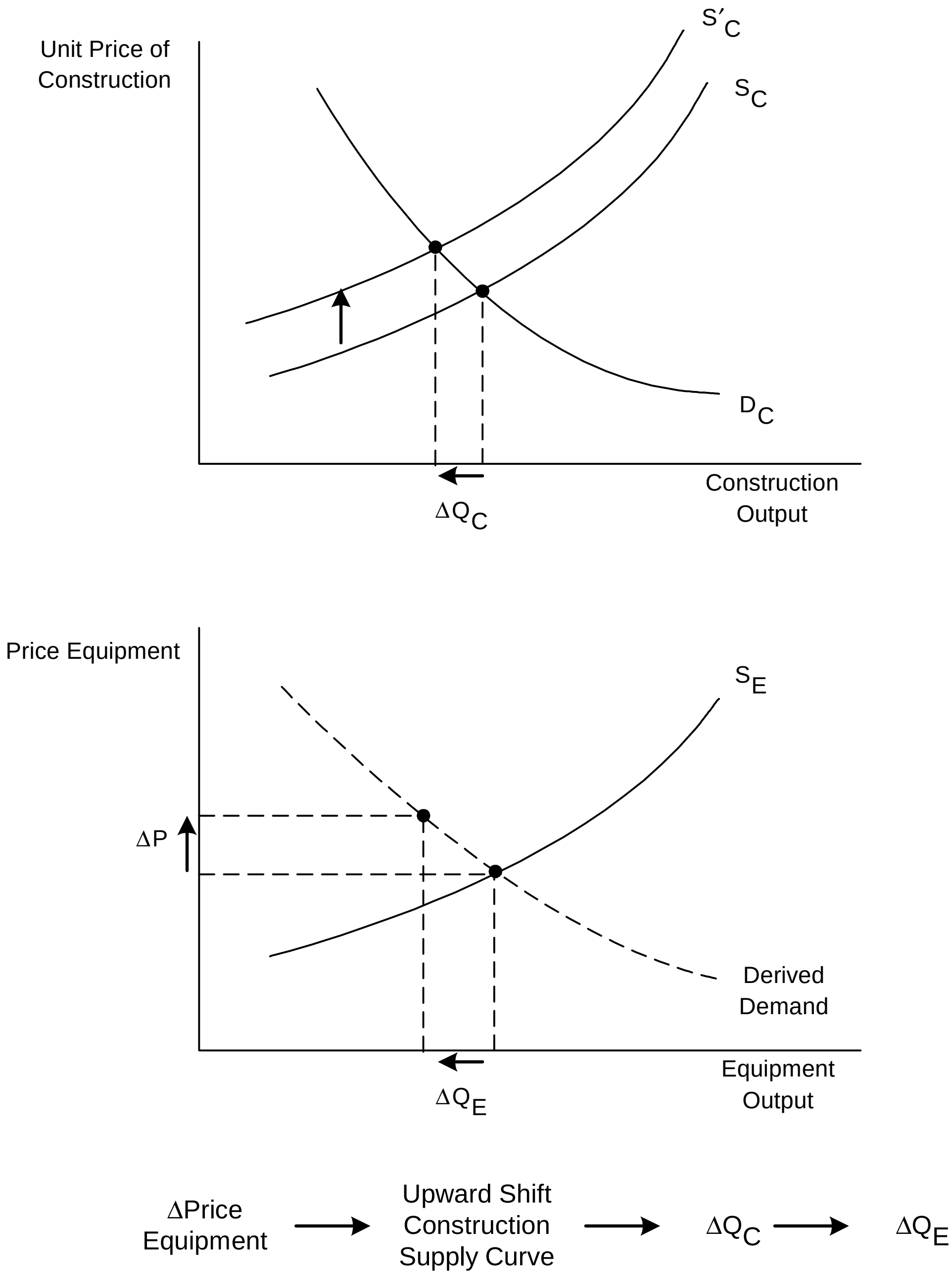
The demand for diesel equipment is directly linked to the production of final goods and services that use diesel equipment. For example, the demand for agricultural equipment depends on the final demand for agricultural products and the total price of supplying these products. Thus, any change in the price of agricultural equipment will shift the agriculture supply curve, leading to a decrease in agricultural production and hence decreased consumption of agricultural equipment. Assuming a fixed input-output relationship, the percentage change in agricultural production will equal the percentage change in agricultural equipment production.

These relationships link the demand for engines and equipment directly to the level of production of goods and services in the application markets. A demand curve specified in terms of its downstream consumption is referred to as a derived demand curve. Figure 10.2-2 graphically illustrates how a derived demand curve is identified. Consider an event in the

[A]This one-to-one relationship holds for engines sold on the market and for engines consumed internally by integrated engine/equipment manufacturers.

construction equipment market that causes the price of equipment to increase by ΔP (such as an increase in the price of engines). This increase in the price of equipment will cause the supply curve in the construction market to shift up, leading to a decreased quantity of construction activity (ΔQ_C). The change in construction activity leads to a decrease in the demand for construction equipment (ΔQ_E). The new point ($Q_E - \Delta Q_E$, $P - \Delta P$) traces out the derived demand curve. Note that the supply and demand curves in the construction applications market are needed to identify the derived demand in the construction equipment market. The construction application market supply and demand curves are functional form and elasticity parameters described in Appendix10F.

Figure 10.2-2
Derived Demand for Construction Equipment



Each point on the derived demand curve equals the construction industry's willingness to pay for the corresponding marginal input. This is typically referred to as the input's net value of marginal product (VMP), which is equal to the price of the output (P_x) times the input's marginal physical product (MPP). MPP is the incremental construction output attributable to a change in equipment inputs:

$$\text{Value Marginal Product (VMP)} = P_x * \text{MPP}.$$

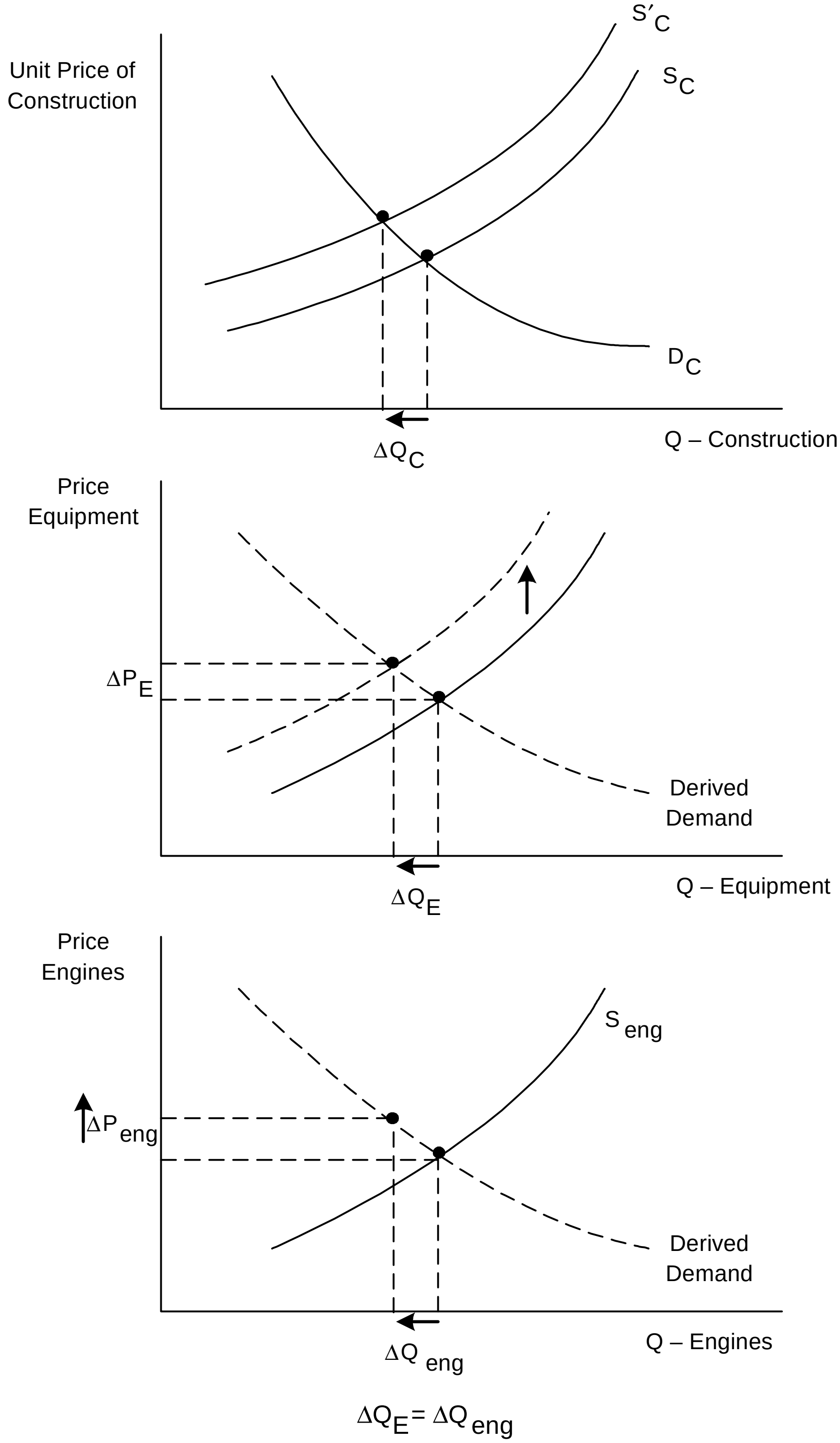
An increase in regulatory costs (c) associated with equipment will lower the VMP of all inputs, leading to a decrease in the net marginal product:

$$\text{Net Value Marginal Product} = (P_x - c) * \text{MPP}.$$

This decrease in the VMP of equipment, as price increases, is what leads the downward-sloping derived demand curve in the equipment market.

Similarly, derived demand curves are developed for the engine markets that supply the equipment markets. As shown in Figure 10.2-3, the increased price of engines resulting from regulatory costs shifts the supply curve for engines and leads to a shift in the supply curve for equipment. The resulting increased price of equipment leads to a shift in the supply curve for the construction industry, decreasing construction output. The decrease in construction output flows back through the equipment market, resulting in decreased demand for engines (ΔQeng).

Figure 10.2-3
Derived Demand for Engines



10.2.3 Key Modeling Elements

In addition to specifying the type of model used and the relationships between the markets, it is also necessary to specify several other key model characteristics. These characteristics include the degree of competition in each market, the time horizon of the analysis, and how fixed costs affect firms' production decisions. The specification of the industry/market characteristics and how regulatory costs are introduced into the model has an impact on the size and interpretation of the estimated economic impacts. These modeling issues are discussed below.

10.2.3.1 Perfect vs. Imperfect Competition

For all markets that are modeled, the analyst must characterize the degree of competition within each market. The discussion generally focuses on perfect competition (price-taking behavior) versus imperfect competition (the lack of price-taking behavior). The central issue is whether individual firms have sufficient market power to influence the market price.

Under imperfect (such as monopolistic) competition, firms produce products that have unique attributes that differentiate them from competitors' products. This allows them to limit supply, which in turn increases the market price, given the traditional downward-sloping demand curve. Decreasing the quantity produced increases the monopolist's profits but decreases total social surplus because a less than optimal amount of the product is being consumed. In the monopolistic equilibrium, the value society (consumers) places on the marginal product, the market price, exceeds the marginal cost to society (producers) of producing the last unit. Thus, social welfare would be increased by inducing the monopolist to increase production.

Social cost estimates associated with a proposed regulation are larger with monopolistic market structures because the regulation exacerbates an already social inefficiency of too little output from a social perspective. The Office of Management and Budget (OMB) explicitly mentions the need to consider these market power-related welfare costs in evaluating regulations under Executive Order 12866 (OMB, 1996).

However, as discussed in the industry profiles in Chapter 1, most of the diesel engine and equipment markets have significant levels of domestic and international competition. Even in markets where a few firms dominate the market, there is significant excess capacity enabling competitors to quickly respond to changes in price. For this reason, for the nonroad diesel rule analysis, it is assumed that within each modeled engine and equipment market the commodities of interest are similar enough to be considered homogeneous (e.g., perfectly substitutable) and that the number of buyers and sellers is large enough so that no individual buyer or seller has market power or influence on market prices (i.e., perfect competition). As a result of these conditions, producers and consumers take the market price as given when making their production and consumption choices.

With regard to the fuel market, the Federal Trade Commission (FTC) has developed an approach to ensure competitiveness in this sector. The FTC reviews oil company mergers and frequently requires divestiture of refineries, terminals, and gas stations to maintain a minimum level of competition. Therefore, it is reasonable to assume a competitive structure for this market. At the same time, however, there are several ways in which refiners may pass along their fuel compliance costs. This analysis explores three approaches. The primary modeling scenario is the average cost scenario, according to which the change in market price is driven by the average total (variable + fixed) regional cost of the regulation. The two other approaches are modeled in a sensitivity analysis and reflect the case in which the highest-cost producer sets the market price in a region. The first of these is the maximum variable cost scenario, according to which the market price is drive by the maximum variable regional cost of the regulation. The second is the maximum total (fixed + variable) regional cost of the regulation. The results of the sensitivity analyses for these two fuel scenarios are contained in Appendix 10I.

10.2.3.2 Short- vs. Long-Run Models

In developing the multimarket partial equilibrium model, the choices available to producers must be considered. For example, are producers able to increase their factors of production (e.g., increase production capacity) or alter their production mix (e.g., substitution between materials, labor, and capital)? These modeling issues are largely dependent on the time horizon for which the analysis is performed. Three benchmark time horizons are discussed below: the very short run, the long run, and the intermediate run. This discussion relies in large part on the material contained in the *OAQPS Economic Analysis Resource Guide* (U.S. EPA, 1999).

In the very short run, all factors of production are assumed to be fixed, leaving the directly affected entity with no means to respond to increased costs associated with the regulation. Within a very short time horizon, regulated producers are constrained in their ability to adjust inputs or outputs due to contractual, institutional, or other factors and can be represented by a vertical supply curve as shown in Figure 10.2-4. In essence, this is equivalent to the nonbehavioral model described earlier. Neither the price nor quantity change and the manufacturer’s compliance costs become fixed or sunk costs. Under this time horizon, the impacts of the regulation fall entirely on the regulated entity. Producers incur the entire regulatory burden as a one-to-one reduction in their profit. This is referred to as the “full-cost absorption” scenario and is equivalent to the engineering cost estimates. While there is no hard and fast rule for determining what length of time constitutes the very short run, it would be inappropriate to use this time horizon for this analysis because it assumes economic entities have no flexibility to adjust factors of production.

In the long run, all factors of production are variable, and producers can be expected to adjust production plans in response to cost changes imposed by a regulation. Figure 10.2-5 illustrates a typical, if somewhat simplified, long-run industry supply function. The function is horizontal, indicating that the marginal and average costs of production are constant with respect to output.[B] This horizontal slope reflects the fact that, under long-run constant returns to scale, technology and input prices ultimately determine the market price, not the level of output in the market.

[B]The constancy of marginal costs reflects an underlying assumption of constant returns to scale of production, which may or may not apply in all cases.

Figure 10.2-4
Full-Cost Absorption of Regulatory Costs

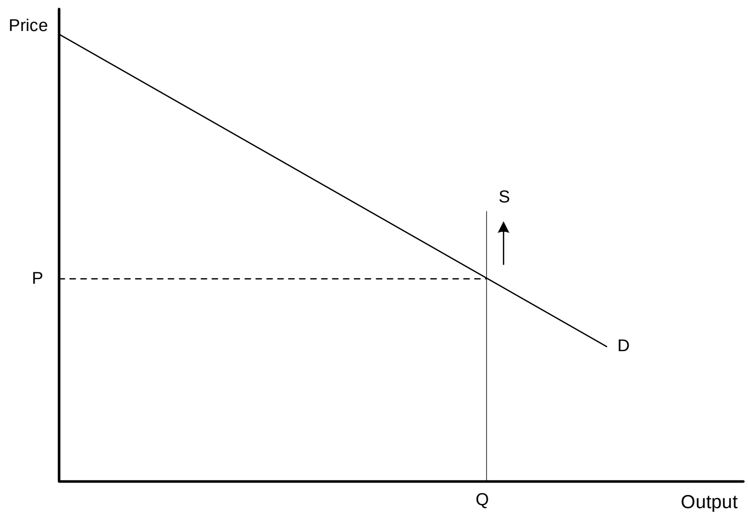


Figure 10.2-5
Full-Cost Pass-Through of Regulatory Costs

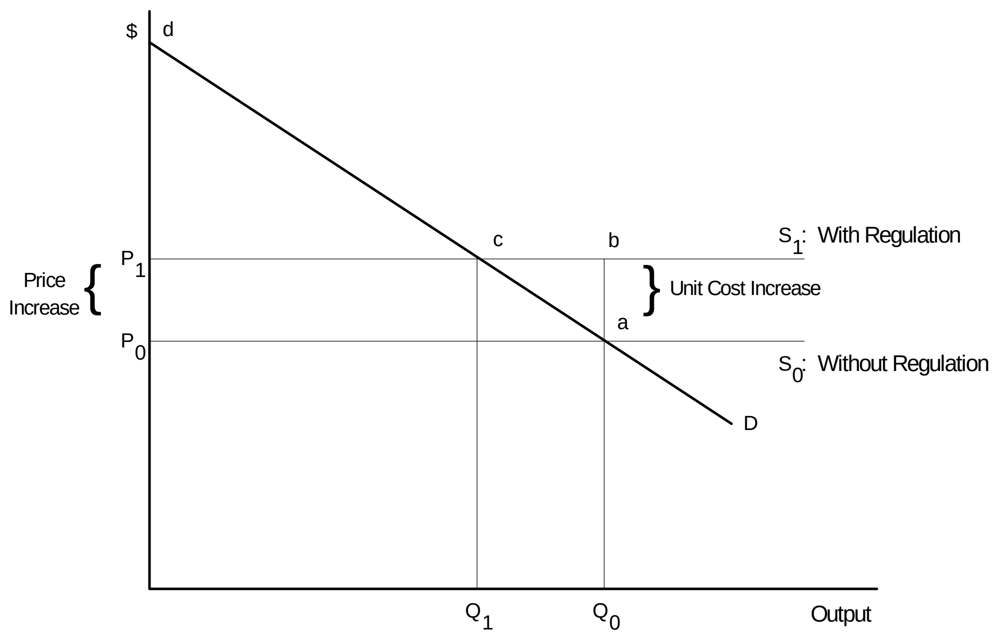
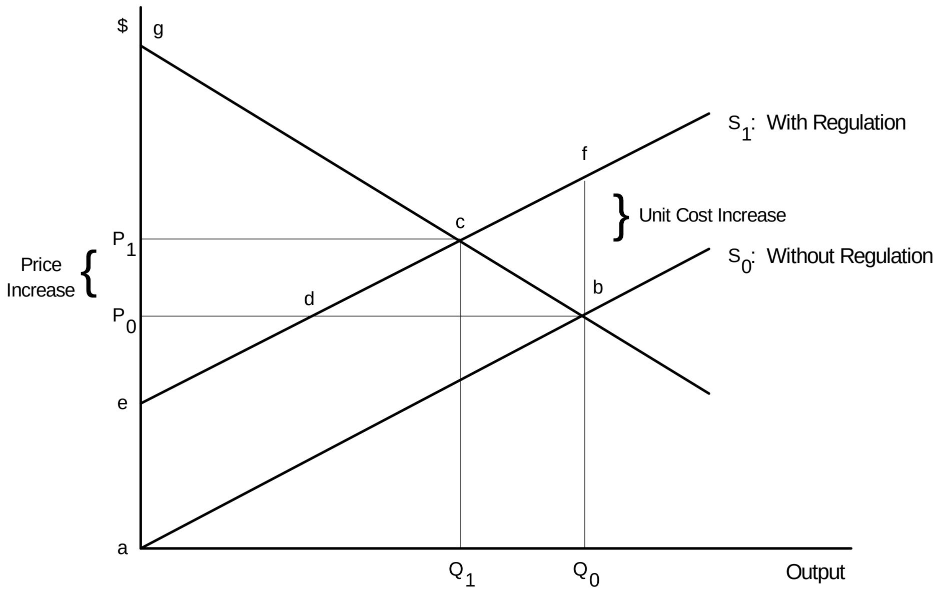


Figure 10.2-6
Partial Cost Pass-Through of Regulatory Costs



Market demand is represented by the standard downward-sloping curve. The market is assumed here to be perfectly competitive; equilibrium is determined by the intersection of the supply and demand curves. In this case, the upward parallel shift in the market supply curve represents the regulation's effect on production costs. The shift causes the market price to increase by the full amount of the per-unit control cost (i.e., from P_0 to P_1). With the quantity demanded sensitive to price, the increase in market price leads to a reduction in output in the new with-regulation equilibrium (i.e., Q_0 to Q_1). As a result, consumers incur the entire regulatory burden as represented by the loss in consumer surplus (i.e., the area P_0 ac P_1). In the nomenclature of EIAs, this long-run scenario is typically referred to as "full-cost pass-through," and is illustrated in Figure 10.2-5.

Taken together, impacts modeled under the long-run/full-cost-pass-through scenario reveal an important point: under fairly general economic conditions, a regulation's impact on producers is transitory. Ultimately, the costs are passed on to consumers in the form of higher prices. However, this does not mean that the impacts of a regulation will have no impact on producers of goods and services affected by a regulation. For example, the long run may cover the time taken to retire all of today's capital vintage, which could take decades. Therefore, transitory impacts could be protracted and could dominate long-run impacts in terms of present value. In addition, to evaluate impacts on current producers, the long-run is approach is not appropriate. Consequently an time horizon that falls between the very short-run/full-cost-absorption case and the long-run/full-cost-pass-through case is most appropriate for this EIA.

The intermediate run can best be defined by what it is not. It is not the very short run and it is not the long run. In the intermediate run, some factors are fixed; some are variable.[C] The existence of fixed production factors generally leads to diminishing returns to those fixed factors. This typically manifests itself in the form of a marginal cost (supply) function that rises with the output rate, as shown in Figure 10.2-6.

Again, the regulation causes an upward shift in the supply function. The lack of resource mobility may cause producers to suffer profit (producer surplus) losses in the face of regulation; however, producers are able to pass through some of the associated costs to consumers, to the extent the market will allow. As shown, in this case, the market-clearing process generates an increase in price (from P_0 to P_1) that is less than the per-unit increase in costs (fb), so that the regulatory burden is shared by producers (net reduction in profits) and consumers (rise in price). In other words there is a loss of both producer and consumer surplus.

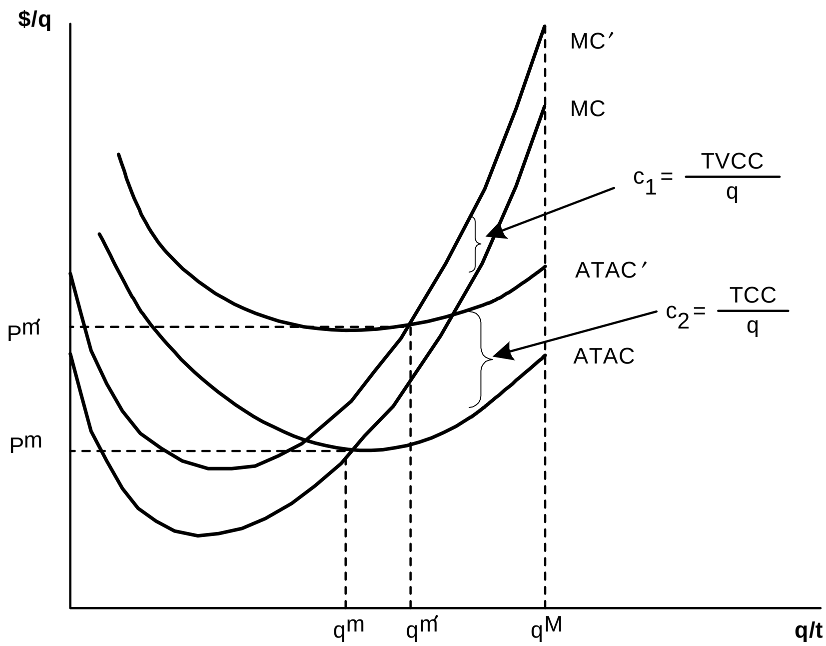
10.2.3.3 Variable vs. Fixed Regulatory Costs

Related to short-run versus long-run modeling issues is the question of how fixed and variable cost increases affect market prices and quantities. The engineering estimates of fixed R&D and capital costs and variable material and operating and maintenance (O&M) costs provide an initial measure of total annual compliance costs without accounting for behavioral responses. The starting point for assessing the market impacts of a regulatory action is to incorporate the regulatory compliance costs into the production decision of the firm.

In general, shifting the supply curve by the total cost per unit implies that both capital and operating costs vary with output levels. At least in the case of capital, this raises some questions. In the long run, all inputs (and their costs) can be expected to vary with output. But a short(er)-run analysis typically holds some capital factors fixed. For instance, to the extent that a market supply function is tied to existing facilities, there is an element of fixed capital (or one-time R&D). As indicated above, the current market supply function might reflect these fixed factors with an upward slope. As shown in Figure 10.2-7, the MC curve will only be affected, or shift upwards, by the per-unit variable compliance costs, while the ATAC curve will shift up by the per-unit total compliance costs (c_2). Thus, the variable costs will directly affect the production decision (optimal output rate), and the fixed costs will affect the closure decision by establishing a new higher reservation price for the firm (i.e., $P^{m'}$). In other words, the fixed costs are important in determining whether the firm will stay in this line of business (i.e., produce anything at all), and the variable costs determine the level (quantity) of production.

[C]As a semantical matter, the situation where some factors are variable and some are fixed is often referred to as the “short run” in economics, but the term “intermediate run” is used here to avoid any confusion with the term “very short run.”

Figure 10.2-7
Modeling Fixed Costs



(a) Upward-sloping supply function

In the EIA for this rule, it is assumed that only the variable cost influences the firm's production decision level and that the fixed costs are absorbed by the firm. Fixed costs associated with the engine emission standards are not included in the market analysis. This is because in an analysis of competitive markets the industry supply curve is based on its marginal cost curve, and fixed costs are not reflected in changes in the marginal cost curve. In addition, fixed costs are primarily R&D costs associated with design and engineering changes, and firms in the affected industries currently allocate funds for these costs (see below). These costs are still a cost to society because they displace other R&D activities that may improve the quality or performance of engines and equipment. However, in this example, the fixed costs would not influence the market price or quantity in the intermediate run. Therefore, fixed costs are not likely to affect the prices of engines or equipment.

R&D costs are a long-run concern, and decisions to invest or not invest in R&D are made in the long run. If funds have to be diverted from some other activity into R&D needed to meet the environmental regulations, then these costs represent a component of the social costs of the rule. Therefore, fixed R&D costs are included in the welfare impact estimates reported in Table 10.1-4 as unavoidable costs that reduce producer surplus. In other words, engine manufacturers budget for research and development programs and include these charges in their long-run strategies. In the absence of new standards, these resources would be focused on design changes to increase customer satisfaction. Engine manufacturers are expected to redirect these resources toward compliance with the standards, instead of adding additional resources to research and development programs.

Operationally, the model used in this EIA shifts the diesel engines' and equipment markets' supply curves by the variable cost per unit only. The fixed costs associated with the proposed regulation are calculated to reflect their opportunity costs and then added to the producer surplus decrease after the new market (with-regulation) equilibrium has been established.[D] The primary fixed costs in these markets are associated with one-time expenditures to redesign products and retool production lines to comply with the regulation. These fixed costs can be recovered as part of the industry's routine R&D budget and hence are not likely to lead to additional price increases. This assumption is supported by information received from a number of nonroad engine and equipment manufacturers, with whom EPA met to discuss redesign and equipment costs. The manufacturers indicated that their redesign budgets (for emissions or other product changes) are constrained by R&D budgets that are set annually as a percentage of annual revenues. While the decision to redesign may be driven by anticipated future revenues for an individual piece of equipment, the resources from with the redesign budget is allocated are determined from the current year's R&D budget. Thus redesigns to meet emission standards represent a reallocation of resources that would have been spent for other kinds of R&D (i.e., a lost opportunity cost). To account for the value to the company of this loss, the engineering cost analysis includes a 7 percent rate of return for all fixed costs which are "recovered" over a defined period for the emission compliant products.

An alternative approach for R&D expenditures can be used, in which these costs are included in intermediate-run decision-making. This alternative assumes that manufacturers will change their behavior based on the R&D required for compliance with the standards. A sensitivity analysis is included in Chapter 10 of the draft RIA for this proposal that reflects this approach.

Fixed costs on the refiner side are treated differently in the NDEIM. Unlike for engines and equipment where the fixed costs are primarily for up-front R&D, most of the petroleum refinery fixed costs are for production hardware. The decision to invest to increase, maintain, or decrease production capacity may be made in response to anticipated or actual changes in price. To reflect the different ways in which refiners can pass costs through to refiners, three scenarios were run for the following supply shifts in the diesel fuel markets:

- shift by average total (variable + fixed cost)
- shift by max total (variable + fixed cost)
- shift by max variable cost.

[D]The fixed R&D costs capture the lost opportunity of forgone investments to the firm.

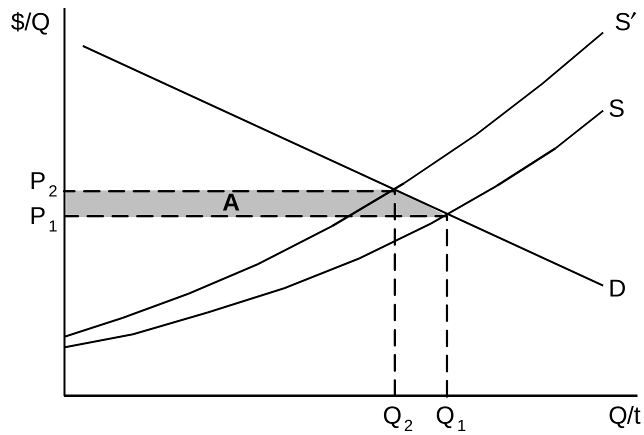
The first, shift by average total cost (variable + fixed), is the primary scenario and is included in the NDEIM. The other two are investigated using sensitivity analyses. These supply shifts are discussed further in sensitivity analysis presented in Appendix10I.

10.2.3.4 Estimation of Social Costs

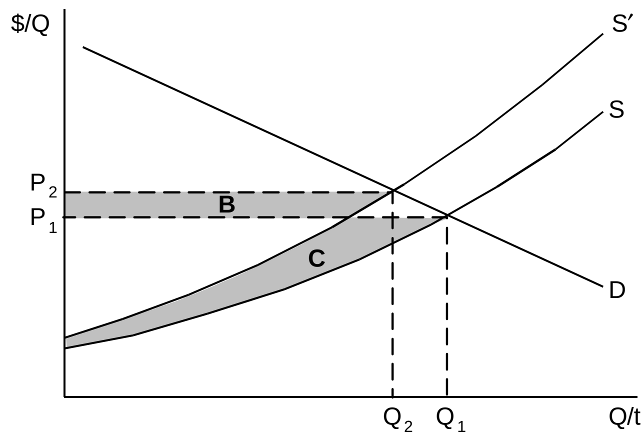
The economic welfare implications of the market price and output changes with the regulation can be examined by calculating consumer and producer net "surplus" changes associated with these adjustments. This is a measure of the negative impact of an environmental policy change and is commonly referred to as the "social cost" of a regulation. It is important to emphasize that this measure does not include the benefits that occur outside of the market, that is, the value of the reduced levels of air pollution with the regulations. Including this benefit will reduce the net cost of the regulation and even make it positive.

The demand and supply curves that are used to project market price and quantity impacts can be used to estimate the change in consumer, producer, and total surplus or social cost of the regulation (see Figure 10.2-8).

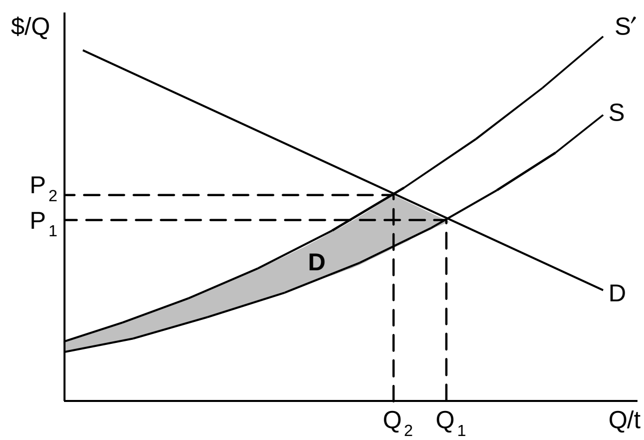
Figure 10.2-8
Market Surplus Changes with Regulation: Consumer and Producer Surplus



(a) Change in Consumer Surplus with Regulation



(b) Change in Producer Surplus with Regulation



(c) Net Change in Economic Welfare with Regulation

The difference between the maximum price consumers are willing to pay for a good and the price they actually pay is referred to as “consumer surplus.” Consumer surplus is measured as the area under the demand curve and above the price of the product. Similarly, the difference between the minimum price producers are willing to accept for a good and the price they actually receive is referred to as “producer surplus.” Producer surplus is measured as the area above the supply curve below the price of the product. These areas can be thought of as consumers’ net benefits of consumption and producers’ net benefits of production, respectively.

In Figure 10.2-8, baseline equilibrium occurs at the intersection of the demand curve, D, and supply curve, S. Price is P_1 with quantity Q_l. The increased cost of production with the regulation will cause the market supply curve to shift upward to S'. The new equilibrium price of the product is P_2. With a higher price for the product there is less consumer welfare, all else being unchanged. In Figure 10.2-8(a), area A represents the dollar value of the annual net loss in consumers’ welfare associated with the increased price. The rectangular portion represents the loss in consumer surplus on the quantity still consumed due to the price increase, Q_2, while the triangular area represents the foregone surplus resulting from the reduced quantity consumed, $Q_l – Q_2$.

In addition to the changes in consumers’ welfare, there are also changes in producers’ welfare with the regulatory action. With the increase in market price, producers receive higher revenues on the quantity still purchased, Q_2. In Figure 10.2-8(b), area B represents the increase in revenues due to this increase in price. The difference in the area under the supply curve up to the original market price, area C, measures the loss in producer surplus, which includes the loss associated with the quantity no longer produced. The net change in producers’ welfare is represented by area B – C.

The change in economic welfare attributable to the compliance costs of the regulations is the sum of consumer and producer surplus changes, that is, – (A) + (B–C). Figure 10.2-8(c) shows the net (negative) change in economic welfare associated with the regulation as area D.[E]

If not all the costs of the regulation are reflected in the supply shift, then the producer and consumer surplus changes reflected in Figure 10.2-5 will not capture the total social costs of the regulation. As discussed earlier, fixed R&D and capital costs are not included in the supply curve shift for the engine and equipment markets. The fixed costs in these instances are assumed to be borne totally by the producers in that none of these costs are passed on to consumers in the form of higher prices. The costs are added to the producer surplus estimates generated from the market analysis so that the accounting accurately reflects the total social cost of the regulation.

[E]However, it is important to emphasize that this measure does not include the benefits that occur outside the market, that is, the value of the reduced levels of air pollution with the regulations. Including this benefit may reduce the net cost of the regulation or even make it positive.

In addition, two additional compliance cost components are included in the total social cost estimates but not integrated in to the market analysis:

- *Operating Costs*: Changes in operating costs are expected to be realized by diesel equipment users, for both existing and new equipment, as a result of the reduced sulfur content of nonroad diesel fuel. These include operating savings (cost reductions) due to fewer oil changes, which accrue to nonroad engines that are already in use as well as those that will comply with the proposed standards. These savings (costs) also include any extra operating costs associated with the new PM emission control technology which may accrue to new engines that use this new technology.
- *Marker costs*: Costs associated with marking high sulfur diesel fuel in the locomotive, marine, and heating oil markets between 2007 and 2014.

Operating costs are not included directly in the model because some of the savings accrue to existing engines and because these savings (costs) are not expected to affect consumer decisions with respect to new engines. Instead, they are added into the estimated welfare impacts as additional costs to the application markets, since it is the users of these engines that will see these savings (costs). Marker costs are not include in the market analysis because locomotive, marine, and heating oil markets are not explicitly modeled in the NDEIM. Similar to the operating savings (costs), marker costs are added into the estimated welfare impacts separately. Nevertheless, a sensitivity analysis was also performed in which these savings (costs) are included as inputs to the NDEIM, where they are modeled as benefits accruing to the application producers. The results of this analysis are presented in Appendix 10.I.

10.3 Economic Impact Modeling

The impact of a regulatory action can be measured by the change in social costs that it generates. Producers will experience economic impacts due to changes in production costs (direct regulatory costs and indirect input price changes) and changes in the market price they receive for their products. Consumers will experience economic impacts due to the adjustments in market prices and their consumption levels.

The previous section described the economic theory that underpins this EIA. This section focuses on the markets and linkages included in the NDEIM. This is followed by a description of the supply and demand elasticities used in the model and an overview of the baseline population data used in the analysis. Finally, the steps used to operationalize the computer model are presented.

10.3.1 Operational Economic Model

The Nonroad Diesel Economic Impact Model simulates the economic impacts using a computer model comprising a series of spreadsheet modules that:

- define the baseline characteristics of the supply and demand of affected commodities and specify the intermarket relationships;
- introduce a policy "shock" into the model based on estimated compliance costs that shift the supply functions;
- use a solution algorithm to determine an estimated new, with-regulation equilibrium price and quantity for all markets; and
- estimate the change in producer and consumer surplus in all markets included in the model.

Supply responses and market adjustments can be conceptualized as an interactive process. Producers facing increased production costs due to compliance are willing to supply smaller quantities at the baseline price. This reduction in market supply leads to an increase in the market price that all producers and consumers face, which leads to further responses by producers and consumers and thus new market prices, and so on. The new with-regulation equilibrium is the result of a series of iterations in which price is adjusted and producers and consumers respond, until a set of stable market prices arises where total market supply equals market demand. Market price adjustment takes place based on a price revision rule, described below, that adjusts price upward (downward) by a given percentage in response to excess demand (excess supply).

The remainder of this section describes elements of the NDEIM including baseline characteristics, compliance cost inputs, model elasticity parameters, and the model solution algorithm.

10.3.2 Baseline Economic Data

This section describes the data needed to run the model. The major components are the baseline data needed to establish the without-regulation equilibrium and the engineering compliance costs that are used to "shock" the model to estimate the with-regulation equilibrium.

10.3.2.1 Baseline Population

The PSR sales data were the primary source for the population for diesel engines used in domestically consumed nonroad diesel equipment (See Chapter 1). Sales data is used as a proxy for production data in the NDEIM because detailed production data by horsepower and equipment application are not available. In addition, modeling inventory decisions of engine and equipment manufacturers is beyond the scope of the NDEIM. EPA adjusted the Power Systems Research (PSR) population to reflect the population units affected by the regulation.[F] Table 10.3-1 lists sales data for affected diesel nonroad equipment consumed domestically in 2000 by engine horsepower and equipment type. The population distribution by size and application is the same

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[F]See Section 8.1 in Chapter 8 of this draft RIA for an explanation of how the engines were allocated to the seven categories.

for engines and equipment because of the one-to-one relationship between engines and equipment.

Baseline nonroad diesel fuel consumption is provided in Table 10.3-2. Fuel consumption is broken out by region (PADD) and application market (construction, agriculture, and manufacturing). Nonroad diesel fuel consumption is further disaggregated into spillover and nonspillover (referred to hereafter as simply nonroad). As described below, spillover fuel is highway grade diesel fuel consumed by nonroad equipment. Spillover fuel is affected by the diesel highway rule and is not affected by this regulation. The economic impact associated with lowering the sulfur content of spillover fuel consumed by nonroad diesel equipment is calibrated into the baseline prior to estimating the economic impacts of the nonroad regulation.[G]

[G]Spillover and nonspillover fuels consumed by nonroad diesel equipment are modeled as two commodities and markets. Thus, in calibrating the baseline, the increased costs associated with the highway rule are used to shock the supply curve for spillover diesel fuel. This results in an increased cost of production in the application markets leading to a slight decrease in application market output. This in turn ripples through the supply chain leading to a very small adjustment (decrease) in the baseline equipment and engine output. The impact of the nonroad rule is then estimated relative to this adjusted baseline.

Table 10.3-1
Engine/Equipment Sales in 2000

Engine Market	Construction	Agricultural Equipment	General Industrial	Generator Sets and Welders	Lawn and Garden	Pumps and Compressors	Refrigeration/Air Condition	Grand Total
0<hp<25	17,043	13,195	3,173	54,971	17,118	4,980	8,677	119,159
25≤hp<50	30,233	38,303	6,933	32,540	10,323	4,254	10,394	132,981
50≤hp<75	30,919	19,156	7,074	13,234	1,456	3,930	18,145	93,914
75≤hp<100	30,146	11,788	14,204	5,567	2,722	4,238		68,665
100≤hp<175	49,503	35,226	17,757	7,313	1,556	985		112,340
175≤hp<600	42,126	41,678	8,327	1,813	509	1,494	—	95,947
hp > 600 hp	4,945	—	576	1	—	16	—	5,538
Grand Total	204,915	159,347	58,044	115,440	33,684	19,898	37,215	628,543

Table 10.3-2
Nonroad Diesel Equipment, Locomotive and Marine Fuel Consumption in 2001

		Construction (million gallons)	Agriculture (million gallons)	Manufacturing (million gallons)	Total (million gallons)
PADD I&III	Nonroad	1,700	449	2,778	4,927
	Spillover	359	95	1,180	1,634
PADD II	Nonroad	622	992	1,338	2,952
	Spillover	222	355	928	1,505
PADD IV	Nonroad	124	92	164	380
	Spillover	142	105	400	647
PADD V	Nonroad	268	59	373	700
	Spillover	59	13	151	223
Total	Nonroad	2,714	1,592	4,653	8,959
	Spillover	782	568	2,659	4,008

10.3.2.2 Baseline Prices

Prototypical engine and equipment prices were collected for engines by hp size and for diesel equipment by application and horsepower size. Average prices were developed by the Agency based on a review of publicly available market transactions and information listed in the PSR database. Table 10.3-3 provides the prices for the seven engine categories, and Table 10.3-4 provides prices for the 42 diesel equipment categories used in the model.

Table 10.3-3
Baseline Engine Prices

Power Range	Estimated Price
$0<hp<25$	$1,500
$25\leq hp<50$	$2,500
$50\leq hp<75$	$3,000
$75\leq hp<100$	$4,000
$100\leq hp<175$	$5,500
$175\leq hp<600$	$20,000
hp > 600 hp	$125,000

Table 10.3-4
Baseline Prices of Nonroad Diesel Equipment

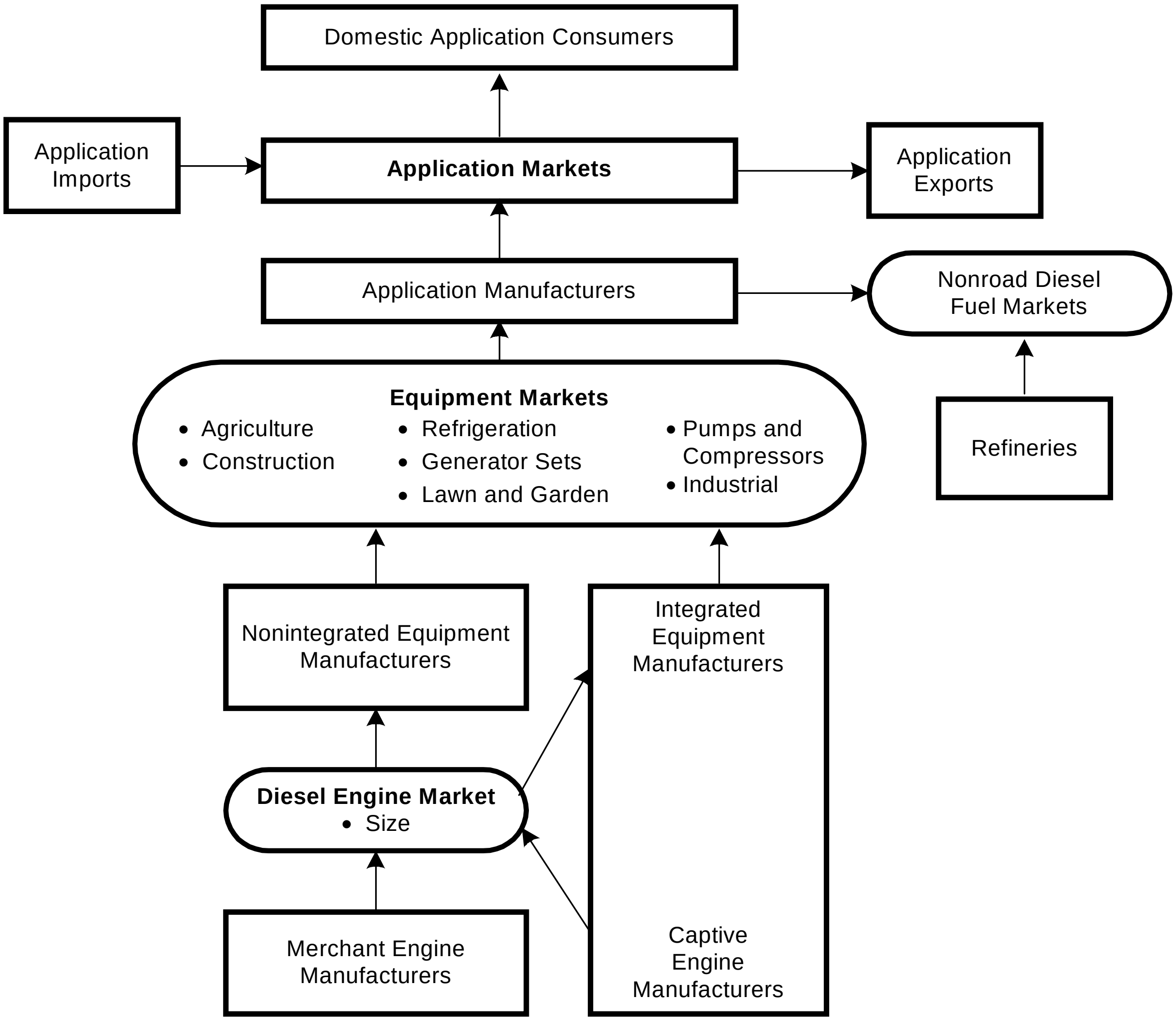
Application	<25 hp	26-50 hp	51-75 hp	76-100 hp	101-175 hp	176-600 hp	>600 hp
Construction Equip	$3,500	$13,500	$25,000	$50,000	$100,000	$575,000	$700,000
Agricultural Equip	$3,000	$6,000	$23,500	$47,000	$70,000	$130,000	N/A
Pumps & Compressors	$1,500	$3,000	$11,000	$21,500	$32,000	$60,000	$88,000
GenSets & Welders	$3,500	$6,000	$25,000	$50,000	$75,000	$140,000	N/A
Refrigeration & A/C	$1,500	$3,000	$11,000	N/A	N/A	N/A	N/A
General Industrial	$3,500	$13,500	$25,000	$50,000	$100,000	$575,000	$700,000
Lawn & Garden	$3,000	$6,000	$23,500	$47,000	$70,000	$130,000	N/A

10.3.3 Market Linkages

Figure 10.3-1 illustrates the sectoral linkages and the market interactions between producers and consumers that are explicitly accounted for in the NDEIM. This section provides a brief discussion of each of these related markets and important linkages. A detailed description of the market model equations (supply and demand functions, equilibrium conditions) is provided in Appendix 10F.

One of the key features of the NDEIM is that a subset of related markets is modeled together, with sector linkages; hence, selected interaction effects, are explicitly specified and accounted for in the model. A brief discussion of the markets and important linkages are highlighted in this section. Detailed specifications of the market model equations (supply and demand functions, equilibrium conditions) are provided in Appendix 10F.

Figure 10.3-1
Multimarket Linkages in the Engine/Equipment/Fuel Supply Chain



10.3.3.1 Engine Markets

The engine markets are the markets associated with the production and consumption of engines. Seven separate engine markets were modeled segmented by engine size in horsepower (the EIA includes more horsepower categories than the standards, allowing more efficient use of the engine compliance cost estimates developed for this proposal):

- less than 25 hp,
- 26 to 50 hp,
- 51 to 75 hp,
- 76 to 100 hp,
- 101 to 175 hp,

- 176 to 600 hp, and
- greater than 601 hp.

An important feature of the engine and equipment markets is that many equipment manufacturers also produce engines. These equipment manufacturers are referred to as integrated manufacturers, and their facilities produce engines to consume internally (in the nonroad equipment they produce) and to supply to the engine markets (to other equipment manufacturers). An important modeling distinction is that all compliance costs for internally consumed engines are absorbed into the equipment costs of integrated suppliers. In contrast, nonintegrated equipment suppliers pay some portion of the engine compliance costs that is determined by the incremental market price for engines. As long as engine demand is not perfectly inelastic, the increased market price for engines will reflect only a partial pass through of engine compliance costs. For the purposes of this analysis, engines sold on the market are referred to as “merchant” engines, and engines consumed internally are referred to as “captive” engines.

Because the impact of the regulation is not directly proportional to engine price, the relative supply shift in each of the engine size markets varies. For example, the ratio of control costs to market price for small engines (less than 25 hp) is approximately 12 percent, and the ratio of control costs to market price for large engines (greater than 600 hp) is approximately 8 percent. These different ratios lead to different relative shifts in the supply curves and larger percentage changes in market price and quantity in the small engine markets. The impacts on the engine market and engine manufacturers can be found in Appendix 10A.

10.3.3.2 Equipment Markets

The equipment markets are the markets associated with the production and consumption of equipment that use nonroad diesel engines. Seven equipment types were modeled:

- construction,
- agricultural,
- pumps and compressors,
- generators and welder sets,
- refrigeration and air conditioning,
- general industrial, and
- lawn and garden.

These categories were identified by reviewing the “application” field in the PSR database. Approximately 60 different equipment “applications” are listed in the database. These were aggregated into these seven equipment categories to obtain a manageable number of individual markets to be included in the NDEIM.[H] For each of these equipment types, up to seven

[H]See Section 8.1 in Chapter 8 of this draft RIA for an explanation of how the engines were allocated to the seven categories.

horsepower size category markets are included in the model, for a total of 42 individual equipment markets.[I]

Equipment manufacturers consume engines in their production processes and then supply diesel equipment to the application markets. The demand for engines is determined by the production levels in the application markets. Equipment is assumed to be a fixed factor of production in the application markets. Thus, for example, a 1 percent decrease in agricultural output will lead to a 1 percent decrease in the demand for agricultural equipment (and fuel). The relationship between the percentage increase on equipment price and the percentage change in equipment demand (the elasticity of demand) is determined by the input share of diesel equipment relative to other inputs in the application markets and the supply and demand elasticities in the application markets. The impacts on the equipment market and manufacturers can be found in Appendix 10B.

10.3.3.3 Application Markets

The application markets consist of the producers and consumers of products and services that employ the diesel engines, equipment, and fuel affected by this proposal. Therefore, these economic entities are indirectly affected by the proposal, through potential changes in equipment and fuel prices. For the purpose of this analysis, application markets are grouped into three categories:
- construction
- agricultural, and
- manufacturing.

These three application markets were selected because they encompass the majority of the final products and services that incorporate diesel engines in their production process. In addition, these three application markets represent a manageable number of markets to be included in the NDEIM and have well-established census data. The impacts on the equipment market and manufacturers can be found in Appendix 10C.

The seven equipment categories are mapped into the three application markets as described in Table 10.3-5.

[I]There are seven horsepower/application categories that do not have sales in 2000 and are not included in the model. These are: agricultural equipment >600 hp; gensets & welders > 600 hp; refrigeration & A/C > 71 hp (4 hp categories); and lawn & garden >600 hp. Therefore, the total number of diesel equipment markets is 42 rather than 49.

Table 10.3-5
Mapping from Equipment Markets to Application Markets

Application Market	Equipment Market
Construction	Construction equipment Pumps and compressors Gen sets and welding equipment
Agricultural	Agricultural equipment
Manufacturing	Refrigeration Lawn and garden General industrial

For example, mining equipment is included in the general industrial equipment categories. This is linked to the manufacturing applications market.[J]

10.3.3.4 Diesel Fuel Markets

The analysis estimates the economic impact of increasing the cost of production for nonroad diesel, locomotive, and marine fuels. Nonroad diesel fuel cost increases are linked to application markets (users of diesel engines and equipment) to estimate how the compliance costs on refineries are linked to the application markets. For example, although locomotive and commercial marine engines and equipment are not directly affected by the proposed rule, the users of this equipment in the application markets are affected by the higher diesel fuel costs, and these impacts are included in the model.

As shown in Figure 10.2-8, equipment users are the suppliers in the application markets and are also the demanders of nonroad diesel fuel. Thus, the fuel markets are linked with the engine and equipment markets through the application markets using the derived-demand framework described above.

One can think of these relationships as the conceptual equivalent of the derived-demand relationship between equipment and engines. For example, the demand for No. 2 distillate will be specified as a function of the production and consumption decisions made in the construction, agricultural, and manufacturer application markets. In this way increased equipment costs decrease the demand for fuel, and increased fuel costs decrease the demand for equipment because both increase the costs of production in the application markets. This in turn leads to a

[J]A full mapping from PSR applications to the NDEIM equipment categories and then to the NDEIM application markets can be found in a Memorandum from M. Gallaher, RTI, to Todd Sherwood, Clarifications on Several Modeling Issues (March 24, 2003).

decrease in production in the application markets and hence a decrease in the demand for inputs (fuel and equipment).

Eight nonroad diesel fuel markets were modeled: two distinct nonroad diesel fuel commodities in four regional markets. The two fuels are:

- 500 ppm nonroad diesel fuel, and
- 15 ppm nonroad diesel fuel.

The four regional nonroad diesel fuel markets are
- PADD 1 and 3,
- PADD 2,
- PADD 4, and
- PADD 5 (includes Alaska and Hawaii)

Separate compliance costs are estimated for each 500 ppm and 15 ppm regional fuel market. As a result, the price and quantify impacts, as well as the changes in producer surplus, vary across the eight fuel markets. PADD 1 and PADD 3 are combined because of the high level of interregional trade. Regional imports and exports across the remaining four regions included in the model are not included in the analysis. The impacts on the nonroad fuel market can be found in Appendix 10D.

As discussed in Section 10.2, all the engine and equipment markets are modeled as competitive: it is assumed that no individual firm can affect the market price. In this case the average compliance cost is used to shift the market supply curve. In this scenario, the fuel markets are also modeled as competitive, and each regional supply curve is shifted by the average total (variable + fixed) regional cost of the regulation. This fuel market scenario (referred to as average total cost) is also used when presenting disaggregated market results in Appendices 10.A through 10.D and sensitivity analysis results in Appendix 10I.

However, in some fuel regions, it may be more appropriate to let the “high cost” refinery’s compliance cost drive the new market price. Under this assumption it is the high cost producer’s dollars per gallon compliance cost increase that determines the new price. This is referred to as the max cost scenario and no longer reflects perfect competition because now individual firms have direct influence on market price. Two max cost scenarios are explored in the sensitivity analysis presented in Appendix 10I: one in which the high-cost refinery’s total (variable + fixed) compliance costs determine price, and a second in which only the high-cost refinery’s variable compliance costs determine price.

Locomotive and Marine Diesel. Locomotive and marine fuels are modeled as being consumed by the manufacturers. Thus, these fuels are included in the total volume of diesel fuel consumed by the manufacturing application market and their per unit (gallon) costs are included in the refinery supply function shifts. Inclusion of locomotive and marine diesel fuel in the market analysis has two main impacts:

- It affects the magnitude of the supply shift because their per unit costs are slightly different from the nonroad diesel per-unit fuel costs
- It increases the quantity of affected diesel fuel purchased by the manufacturing market and thus increases the total compliance costs passed into the manufacturing sector from refiners. This leads to a greater shift of the supply curve in the manufacturing application market and thus a larger decrease in quantity in the manufacturing market that ripples back through the fuel, equipment, and engine markets.

10.3.3.5 Calibrating the Spillover Baseline (Impacts Relative to Highway Rule)

The economic impact of the nonroad diesel rule is measured relative to the highway diesel rule. The highway rule is scheduled to be phased in prior to the nonroad rule. Thus, the effect of the highway rule must be incorporated into the baseline prior to modeling the impact of the nonroad rule. The main factor to be addressed is “spillover” fuel from the highway market. The Agency estimates that approximately one-third of nonroad equipment currently uses highway grade fuel because of access and distribution factors. Nonroad equipment currently using highway diesel will experience increased fuel costs as a result of the highway rule, but not as a result of the nonroad rule. These costs have already been captured in the highway rule analysis; thus, it is important to discount “spillover” fuel in the nonroad market to avoid double counting of cost impacts.

In the model, the increased cost of “spillover” fuel consumed by nonroad equipment is built into the baseline. In effect, current market projections are “shocked” by the highway rule and a new set of baseline prices and quantities is estimated for all linked markets. This then becomes the new baseline from which the incremental impact of the nonroad rule is estimated. When this adjustment is performed, increasing the cost of producing spillover fuel leads to a slight increase in the cost of producing goods and services in the application markets, and a decrease in application quantity ripples through the derived-demand curves of the equipment and engine markets, slightly reducing the baseline equipment and engine population. We assume that there are no substitutions between spillover diesel fuel consumption and nonroad diesel fuel consumption as prices change because demand is primarily driven by availability constraints.

10.3.4 Compliance Costs

Social costs capture the full range of economic impacts associated with the proposed regulation. For this economic analysis, the sources of compliance costs are grouped in to the following categories:

- Fixed and variable costs for diesel engines
- Fixed and variable costs for diesel equipment
- Fixed and variable costs for nonroad diesel fuel
- Changes in operating costs of diesel equipment
- Marker costs for locomotive and marine diesel fuel and heating oil.

All of the above compliance impact are included in the social cost estimates. The majority are included in the market analysis using the NDEIM. However, as discussed above, not all of the compliance costs are incorporated in to the market analysis. Table 10.3-6 identifies which compliance costs are used as shocks in the market analysis and which are added to the social cost estimates after changes in market prices and quantifies have been determined.

Table 10.3-6
How Compliance Costs are Accounted for in the Economic Analysis

Compliance Costs used to Shock the Market Model	Compliance Costs added after Market Analysis
• Variable costs for diesel engines • Variable costs for diesel equipment • Fixed and variable costs for nonroad diesel fuel	• Fixed costs for diesel engines • Fixed costs for diesel equipment • Changes in operating costs of diesel equipment • Marker costs for locomotive and marine diesel fuel and heating oil

The compliance costs described in Chapters 6 and 7 were used to determine the regulation's impacts on each industry sector. The compliance cost per unit varied over time and by industry sector (engine, equipment, or fuel producer). All costs are presented in 2001 dollars and most are broken out by variable and fixed costs.

10.3.4.1 Engine and Equipment Compliance Costs

For diesel engines, the projected compliance costs are largely due to using new technologies, such as advanced emissions control technologies and low-sulfur diesel fuel, to meet the proposed Tier 4 emissions standards. Compliance costs for engines are broken out by horsepower category and impact year. The per unit compliance costs are weighted average costs within the appropriate horsepower range (refer to Chapter 6 for how we have estimated engine and equipment costs; refer to Chapter 8 for aggregate costs and projected sales; per unit costs within each horsepower range are the engine and equipment aggregate costs for that horsepower range divided by the projected sales for that horsepower range). As shown in Table 10.3-7, the fixed cost per engine typically decreases after 5 years as these annualized costs are depreciated. The regulation's market impacts are driven primarily by the per-engine variable costs that remain relatively constant over time. In 2013, there is a projected fourfold cost increase for engines in the range of 25 hp to less than 75 hp, which then decreases over time. Because these engines represent over 35 percent of the overall engine population, this cost increase contributes to the year 2013 having the largest average cost per unit impact.

For nonroad equipment, the majority of the projected compliance cost increases are due to the need to redesign the equipment. The fixed cost consists of the redesign cost to accommodate new emissions control devices. The variable cost consists of the cost of new or modified equipment hardware and of labor to install the new emissions control devices. The per unit compliance costs are weighted average costs within the appropriate horsepower range.

The equipment sector compliance costs are broken out by horsepower category and impact year in Table 10.3-8. The majority of costs per piece of equipment are the fixed costs. The overall compliance costs per piece of equipment are less than half the overall costs associated with the same horsepower category engine. Table 10.3-8 shows a significant compliance cost increase for equipment in the range of 25 hp to less than 75 hp in the year 2013.

10.3.4.2 Nonroad Diesel Fuel Compliance Costs

In the fuel market, the desulfurization (compliance) costs per gallon of diesel fuel differ according to PADD and according to impact year as shown in Table 10.3-9a,b,c. Sulfur fuel requirements are phased in a two-step process. From 2007 to 2010, both the nonroad sector and the locomotive and marine sectors are required to meet the sulfur standard of 500ppm. The costs for this combined 500ppm market are shown in Table 10.3-9a. Variable and fixed costs per gallon are presented for the average cost refiner and the maximum cost refiner in each PADD.

Beginning in 2010, the costs diverge between these two groups. 2010 is the target year set for nonroad diesel fuel to meet a 15 ppm capacity sulfur standard, while the sulfur standard for marine and locomotive diesel fuel will remain at 500 ppm. Therefore, nonroad diesel fuel is estimated to experience a higher increase in cost than locomotive and marine diesel fuel, after 2010, as shown in Tables 10.3-9b and 10.3-9c, respectively.

Table 10.3-7
Compliance Costs per Engine[a]

HP Category	Cost Types	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
0<hp<25	Variable	$131	$131	$124	$124	$124	$124	$124	$124	$124	$124	$124
	Fixed	$30	$29	$29	$28	$27	$0	$0	$0	$0	$0	$0
	Total	$161	$161	$153	$152	$152	$124	$124	$124	$124	$124	$124
25≤hp<50	Variable	$149	$149	$141	$141	$141	$852	$852	$457	$647	$647	$647
	Fixed	$47	$46	$45	$44	$43	$61	$60	$59	$58	$57	$0
	Total	$196	$195	$186	$185	$184	$913	$912	$516	$705	$704	$647
50≤hp<75	Variable	$171	$171	$161	$161	$161	$845	$845	$642	$642	$642	$642
	Fixed	$48	$47	$46	$45	$44	$62	$61	$60	$59	$58	$0
	Total	$218	$217	$207	$206	$205	$9073	$906	$702	$701	$700	$642
75≤hp<100	Variable	$0	$0	$0	$0	$1,150	$1,150	$1,139	$1,139	$1,139	$1,139	$1,139
	Fixed	$0	$0	$0	$0	$53	$52	$70	$69	$55	$18	$17
	Total	$0	$0	$0	$0	$1,2046	$1,203	$1,209	$1,208	$1,194	$1,157	$1,157
100≤hp<175	Variable	$0	$0	$0	$0	$1,410	$1,410	$1,384	$1,384	$1,384	$1,384	$1,384
	Fixed	$0	$0	$0	$0	$52	$51	$68	$67	$53	$17	$17
	Total	$0	$0	$0	$0	$1,461	$1,461	$1,452	$1,450	$1,436	$1,401	$1,400
175≤hp<600	Variable	$0	$0	$0	$2,266	$1,265	$1,755	$2,209	$2,209	$2,208	$2,207	$2,206
	Fixed	$0	$0	$0	$199	$188	$185	$240	$236	$66	$56	$55
	Total	$0	$0	$0	$2,466	$2,453	$1,939	$2,450	$2,445	$2,2742	$2,262	$2,261
hp≥600hp	Variable	$0	$0	$0	$5,402	$5,402	$4,216	$6,952	$6,952	$6,953	$6,953	$6,953
	Fixed	$0	$0	$0	$904	$825	$813	$1,222	$1,205	$479	$403	$398
	Total	$0	$0	$0	$6,306	$6,228	$5,030	$8,175	$8,157	$7,432	$7,356	$7,351

(continued)

Table 10.3-7 (continued)
Compliance Costs per Engine[a]

HP Category	Cost Types	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
0<hp<25	Variable	$124	$124	$124	$124	$124	$124	$124	$124	$124	$124	$124	$124
	Fixed	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total	$124	$124	$124	$124	$124	$124	$124	$124	$124	$124	$124	$124
25≤hp<50	Variable	$647	$647	$647	$647	$647	$647	$647	$647	$647	$647	$647	$647
	Fixed	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total	$647	$647	$647	$647	$647	$647	$647	$647	$647	$647	$647	$647
50≤hp<75	Variable	$642	$642	$642	$642	$642	$642	$642	$642	$642	$642	$642	$642
	Fixed	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total	$642	$642	$642	$642	$642	$642	$642	$642	$642	$642	$642	$642
75≤hp<100	Variable	$1,139	$1,139	$1,139	$1,139	$1,139	$1,139	$1,139	$1,139	$1,139	$1,139	$1,139	$1,139
	Fixed	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total	$1,139	$1,139	$1,139	$1,139	$1,139	$1,139	$1,139	$1,139	$1,139	$1,139	$1,139	$1,139
100≤hp<175	Variable	$1,384	$1,384	$1,384	$1,384	$1,384	$1,384	$1,384	$1,384	$1,384	$1,384	$1,384	$1,384
	Fixed	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total	$1,384	$1,384	$1,384	$1,384	$1,384	$1,384	$1,384	$1,384	$1,384	$1,384	$1,384	$1,384
175≤hp<600	Variable	$2,205	$2,204	$2,203	$2,202	$2,202	$2,201	$2,200	$2,200	$2,199	$2,198	$2,198	$2,197
	Fixed	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total	$2,205	$2,2042	$2,203	$2,202	$2,202	$2,201	$2,200	$2,200	$2,199	$2,198	$2,198	$2,197
hp≥600hp	Variable	$6,953	$6,953	$6,953	$6,953	$6,953	$6,953	$6,953	$6,953	$6,953	$6,953	$6,953	$6,954
	Fixed	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total	$6,953	$6,953	$6,953	$6,953	$6,953	$6,953	$6,953	$6,953	$6,953	$6,953	$6,953	$6,954

[a] 2001 dollars

Table 10.3-8
Costs per Piece of Equipment

HP Category	Cost Types	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
0<hp<25	Variable	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Fixed	$10	$10	$10	$9	$9	$9	$9	$9	$8	$8	$0
	Total	$10	$10	$10	$9	$9	$9	$9	$9	$8	$8	$0
25≤hp<50	Variable	$0	$0	$0	$0	$0	$18	$18	$18	$18	$18	$18
	Fixed	$12	$12	$12	$11	$11	$41	$40	$39	$38	$38	$27
	Total	$12	$12	$12	$11	$11	$58	$58	$57	$56	$56	$45
50≤hp<75	Variable	$0	$0	$0	$0	$0	$18	$18	$18	$18	$18	$18
	Fixed	$12	$12	$12	$12	$12	$45	$44	$43	$43	$42	$31
	Total	$12	$12	$12	$12	$12	$62	$62	$61	$60	$60	$48
75≤hp<100	Variable	$0	$0	$0	$0	$55	$55	$55	$55	$55	$55	$55
	Fixed	$0	$0	$0	$0	$90	$89	$109	$107	$105	$104	$102
	Total	$0	$0	$0	$0	$145	$143	$164	$162	$160	$159	$157
100≤hp<175	Variable	$0	$0	$0	$0	$55	$55	$55	$55	$55	$55	$55
	Fixed	$0	$0	$0	$0	$140	$138	$170	$167	$164	$162	$159
	Total	$0	$0	$0	$0	$196	$193	$225	$223	$220	$217	$215
175≤hp<600	Variable	$0	$0	$0	$92	$91	$91	$91	$91	$91	$91	$91
	Fixed	$0	$0	$0	$322	$317	$312	$384	$379	$373	$368	$362
	Total	$0	$0	$0	$414	$409	$404	$476	$470	$464	$459	$453
hp≥600hp	Variable	$0	$0	$0	$125	$125	$125	$181	$181	$181	$181	$181
	Fixed	$0	$0	$0	$743	$732	$721	$1,071	$1,056	$1,041	$1,026	$1,012
	Total	$0	$0	$0	$868	$857	$846	$1,252	$1,237	$1,222	$1,207	$1,193

(continued)

Table 10.3-8 (continued)
Costs per Piece of Equipment

HP Category	Cost Types	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
0<hp<25	Variable	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Fixed	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
25≤hp<50	Variable	$18	$18	$18	$18	$18	$18	$18	$18	$18	$18	$18	$18
	Fixed	$27	$26	$26	$25	$0	$0	$0	$0	$0	$0	$0	$0
	Total	$44	$44	$44	$43	$18	$18	$18	$18	$18	$18	$18	$18
50≤hp<75	Variable	$18	$18	$18	$18	$18	$18	$18	$18	$18	$18	$18	$18
	Fixed	$30	$30	$29	$29	$0	$0	$0	$0	$0	$0	$0	$0
	Total	$48	$48	$47	$47	$18	$18	$18	$18	$18	$18	$18	$18
75≤hp<100	Variable	$55	$55	$55	$55	$55	$55	$55	$55	$55	$55	$55	$55
	Fixed	$101	$99	$98	$19	$19	$0	$0	$0	$0	$0	$0	$0
	Total	$155	$154	$152	$74	$74	$55	$55	$55	$55	$55	$55	$55
100≤hp<175	Variable	$55	$55	$55	$55	$55	$55	$55	$55	$55	$55	$55	$55
	Fixed	$157	$155	$153	$30	$30	$0	$0	$0	$0	$0	$0	$0
	Total	$213	$210	$208	$86	$85	$55	$55	$55	$55	$55	$55	$55
175≤hp<600	Variable	$91	$91	$91	$91	$90	$90	$90	$90	$90	$90	$90	$90
	Fixed	$357	$352	$69	$69	$68	$0	$0	$0	$0	$0	$0	$0
	Total	$448	$443	$160	$159	$158	$90	$90	$90	$90	$90	$90	$90
hp≥600hp	Variable	$181	$181	$181	$181	$181	$181	$181	$181	$181	$181	$181	$181
	Fixed	$998	$985	$327	$323	$319	$0	$0	$0	$0	$0	$0	$0
	Total	$1,180	$1,166	$508	$504	$500	$181	$181	$181	$181	$181	$181	$181

Table 10.3-9a
Desulfurization Costs for Nonroad, Locomotive, and Marine Diesel Fuel by PADD Prior 2010

	Average Cost		Maximum Cost	
	Variable Costs ($/gallon)	Fixed Costs ($/gallon)	Variable Costs ($/gallon)	Fixed Costs ($/gallon)
PADD I and III	0.0089	0.0063	0.0129	0.0207
PADD II	0.0143	0.0158	0.0228	0.0254
PADD IV	0.0144	0.0268	0.0174	0.0403
PADD V	0.0089	0.0165	0.0097	0.0296

Table 10.3-9b
Desulfurization Costs for Nonroad Diesel Fuel by PADD Starting in 2010

	Average Cost		Maximum Cost	
	Variable Costs ($/gallon)	Fixed Costs ($/gallon)	Variable Costs ($/gallon)	Fixed Costs ($/gallon)
PADD I and III	0.0184	0.0117	0.0251	0.0287
PADD II	0.0247	0.0364	0.0285	0.0459
PADD IV	0.0280	0.0611	0.0301	0.0624
PADD V	0.0194	0.0391	0.0191	0.0649

Table 10.3-9c
Desulfurization Costs for Marine and Locomotive Diesel Fuel by PADD Starting in 2010

	Average Cost		Maximum Cost	
	Variable Costs ($/gallon)	Fixed Costs ($/gallon)	Variable Costs ($/gallon)	Fixed Costs ($/gallon)
PADD I and III	0.0088	0.0071	0.0089	0.0247
PADD II	0.0169	0.0188	0.0228	0.0254
PADD IV	0.0111	0.0225	0.0114	0.0254
PADD V	0.0080	0.0137	0.0064	0.0154

10.3.4.3 Changes in Operating Costs

Changes in operating costs are expected to be realized by all diesel equipment users as a result of the reduced sulfur content of nonroad diesel fuel. Equipment operating saving are generated as a result of the decreased sulfur content of diesel fuel. These savings will accrue to all equipment users that use 500 ppm or 15 ppm sulfur fuel, regardless of whether the equipment has a compliant engine or not. In addition, there may be some operating costs associated with the new PM emission reduction technology. These costs will accrue to engines that use these new technologies. Both of these impacts are discussed in more detail in Chapter 4 and 5. These costs are not included in the market analysis and are instead listed as a separate category in the social cost results tables. In Appendix 10I, a sensitivity analysis is presented where operating cost savings are introduced into the market analysis as a downward shift in the application supply functions.

The net impact is projected to be operating savings of between 1 to 17 cents per gallon consumed by nonroad diesel equipment. Operating savings vary depending on the horsepower size of the equipment (smaller engines have greater savings) and whether the equipment has emission controls (existing noncontrolled fleet will have greater savings). Table 10.3-10 lists the new operating savings by horsepower category and by existing versus new (emission controls) fleet. Average cost savings per gallon for nonroad applications will vary by year as the existing fleet of diesel equipment is replaced over time. EPA estimates that approximately 90 percent of the existing fleet will be replaced by 2030.

Table 10.3-10
Net Change in Operating Cost[a]

Engine Size/Type	Net Operating Cost Per Gallon—Existing Fleet	Net Operating Cost Per Gallon—New Fleet
0<hp<25	–$0.160	–$0.175
25≤hp<50	–$0.076	–$0.041
50≤hp<75	–$0.066	–$0.036
75≤hp<175	–$0.030	–$0.014
175≤hp<600	–$0.017	–$0.010
hp≥600	–$0.011	–$0.006
Locomotive	–$0.011	N/A
Marine	–$0.011	N/A

[a]Changes in operating costs are shown as negative values to indicate savings (benefits).

10.3.4.4 Fuel Marker Costs

Fuel marker costs will be needed to identify high-sulfur diesel fuel in the locomotive, marine, and heating oil markets as the proposed regulation is phased in between 2007 and 2014. These are also added as a separate category in the social cost result tables. Marker costs are estimated to be 0.2 cents per gallon. The affected fuel volume is presented in Table 10.3-11.

Table 10.3-11
Fuel Volume Affected by Marker Costs of 0.2 Cents per Gallon

Year	Locomotive and Marine (MMgals/yr)	Heating Oil (MMgals/yr)
2007		4371
2008		7563
2009		7633
2010	2082	3210
2011	3621	
2012	3647	
2013	3670	
2014	1539	

10.3.5 Supply and Demand Elasticity Estimates

To operationalize the market model, supply and demand elasticities are needed to represent the behavior adjustments that are likely to be made by market participants. The following parameters are needed:

- supply and demand price elasticities for application markets (construction, agriculture, and manufacturing),
- supply elasticities for equipment markets,
- supply elasticities for engine markets, and
- supply elasticities for diesel fuel markets.

Note that, for the equipment, engine, and diesel fuel markets, demand-specific elasticity estimates are not needed because they are derived internally as a function of changes in output levels in the applications markets.

Tables 10.3-12 and 10.3-13 provides a summary of the demand and supply elasticities used to estimate the economic impact of the proposed rule. Most elasticities were derived econometrically using publicly available data, with the exception of the supply elasticities for the construction and agricultural application markets and the diesel fuel supply elasticity, which were obtained from previous studies.[K] The general methodologies for estimating the supply and demand elasticities are discussed below. The specific regression results are presented in Appendix 10G. It should be noted that these elasticities reflect intermediate run behavioral

[K]A supply function was estimated as part of the simultaneous equations approach used for the construction and manufacturing application markets. However, the supply elasticity estimates were not statistically significant and were negative, which is inconsistent with generally accepted economic theory. For this reason, literature estimates were used for the supply elasticities in the construction and manufacturing application markets.

changes. In the long run, supply and demand are expected to be more elastic since more substitutes may become available.

Table 10.3-12
Summary of Market Demand Elasticities Used in the NDEIM

Market	Estimate	Source	Method	Input Data Summary
Applications				
Construction	–0.96	EPA econometric estimate	Simultaneous equation (log-log) approach	Annual time series from 1958 – 1995 developed by Jorgenson et al. (Jorgenson, 1990; Jorgenson, Gollop, and Fraumeni, 1987)
Agriculture	–0.20	EPA econometric estimate	Productivity shift approach (Morgenstern, Pizer, and Shih, 2002)	Annual time series from 1958 – 1995 developed by Jorgenson et al. (Jorgenson, 1990; Jorgenson, Gollop, and Fraumeni, 1987)
Manufacturing	–0.58	EPA econometric estimate	Simultaneous equation (log-log) approach.	Annual time series from 1958 – 1995 developed by Jorgenson et al. (Jorgenson, 1990; Jorgenson, Gollop, and Fraumeni, 1987)
Equipment				
Construction		Derived demand	In the derived demand approach, • compliance costs increase prices and decrease demand for products and services in the application markets; • this in turn leads to reduced demand for diesel equipment, engines and fuel, which are inputs into the production of products and services in the application markets	
Agriculture		Derived demand		
Pumps/ compressors		Derived demand		
Generators and Welders		Derived demand		
Refrigeration		Derived demand		
Industrial		Derived demand		
Lawn and Garden		Derived demand		
Engines		Derived demand		
Diesel fuel		Derived demand		

Table 10.3-13
Summary of Market Supply Elasticities Used in the NDEIM

Markets	Estimate	Source	Method	Input Data Summary
Applications				
Construction	1.0	Literature-based estimate	Based on Topel and Rosen, (1988).[a]	Census data, 1963 – 1983
Agriculture	0.32	Literature-based estimate	Production-weighted average of individual crop estimates ranging from 0.27 to 0.55. (Lin et al., 2000)	Agricultural Census data 1991 – 1995
Manufacturing	1.0	Literature-based estimate	Literature estimates are not available so assumed same value as for Construction market	Not applicable
Equipment				
Construction	3.31	EPA econometric estimate	Cobb-Douglas production function	Census data 1958-1996; SIC 3531
Agriculture	2.14	EPA econometric estimate	Cobb-Douglas production function	Census data 1958-1996; SIC 3523
Pumps/ compressors	2.83	EPA econometric estimate	Cobb-Douglas production function	Census data 1958-1996; SIC 3561 and 3563
Generators/ Welder Sets	2.91	EPA econometric estimate	Cobb-Douglas production function	Census data 1958-1996; SIC 3548
Refrigeration	2.83	EPA econometric estimate		Assumed same as pumps/compressors
Industrial	5.37	EPA econometric estimate	Cobb-Douglas production function	Census data 1958-1996; SIC 3537
Lawn and Garden	3.37	EPA econometric estimate	Cobb-Douglas production function	Census data 1958-1996; SIC 3524
Engines	3.81	EPA econometric estimate	Cobb-Douglas production function	Census data 1958-1996; SIC 3519
Diesel fuel	0.24	Literature based estimate	Based on Considine (2002).[b]	From Energy Intelligence Group (EIG); 1987-2000

[a] Most other studies estimate ranges that encompass 1.0, including DiPasquale (1997) and DiPasquale and Wheaton (1994).

[b] Other estimates range from 0.02 to 1.0 (Greene and Tishchishyna, 2000). However, Considine (2002) is one of the few studies that estimates a supply elasticity for refinery operations. Most petroleum supply elasticities also include extraction.

10.3.6 Model Solution Algorithm

The algorithm for determining with-regulation equilibria can be summarized by six recursive steps:

1. Impose the control costs on affected supply segments, thereby affecting their supply decisions.
2. Recalculate the market supply in each market. Excess demand currently exists.
3. Determine the new prices via a price revision rule. We use a rule similar to the factor price revision rule described by Kimbell and Harrison (1986). P_i is the market price at iteration i, q_d is the quantity demanded, and q_s is the quantity supplied. The parameter z influences the magnitude of the price revision and speed of convergence. The revision rule increases the price when excess demand exists, lowers the price when excess supply exists, and leaves the price unchanged when market demand equals market supply. The price adjustment is expressed as follows:

$$P_{i+1} = P_1 \bullet \left(\frac{q_d}{q_s}\right)^z \tag{10.1}$$

4. Recalculate market supply with new prices, accounting for fuel-switching choices associated with new energy prices.
5. Compute market demand in each market.
6. Compare supply and demand in each market. If equilibrium conditions are not satisfied, go to Step 3, resulting in a new set of market prices. Repeat until equilibrium conditions are satisfied (i.e., the ratio of supply and demand is arbitrarily close to one). When the ratio is appropriately close to one, the market-clearing condition of supply equals demand is satisfied.

Section 10.1 presents a summary of the results of this modeling. More detailed information is presented in the appendices to this chapter.

References for Chapter 10

Berck, P., and S. Hoffmann. 2002. "Assessing the Employment Impacts." *Environmental and Resource Economics* 22:133-156.

Bingham, T.H., and T.J. Fox. 1999. "Model Complexity and Scope for Policy Analysis." *Public Administration Quarterly* 23(3).

Charles River Associates, Inc. and Baker and O'Brien, Inc. 2000. An Assessment of the Potential Impacts of Proposed Environmental Regulations on U.S. Refinery Supply of Diesel Fuel. CRA No. 002316-00 (August 2000). A copy of this document is available in Docket A-2001-28, Document No. II-A-17.

Considine, Timothy J. 2002. "Inventories and Market Power in the World Crude Oil Market." Working paper, Department of Energy, Environmental, and Mineral Economics, The Pennsylvania State University, University Park, PA. A copy of this document is available at http://www.personal.psu.edu/faculty/c/p/cpw/resume/InventoriesMarketPowerinCrudeOilMarkets.pdf. A copy is also available in Docket A-2001-28, Document No. II-A-25.

DiPasquale, Denise. 1997. "Why Don't We Know More about Housing Supply?" Working paper, University of Chicago. A copy of this document is available at http://www.cityresearch.com/pubs/supply.pdf. A copy of this document is also available in Docket A-2001-28, Document No. II-A-24.

DiPasquale, Denise and William C. Wheaton. 1994. "Housing Market Dynamics and the Future of Housing Prices." *Journal of Urban Economics* 35(1):1-27.

Federal Trade Commission. 2001. Final Report of the Federal Trade Commission: Midwest Gasoline Price Investigation (March 29, 2001). A copy of this document is available at http://www.ftc.gov/os/2001/03/mwgasrpt.htm. This document is also available in Docket A-2001-28, Document No. II-A-23.

Finizza, Anthony. 2002. Economic Benefits of Mitigating Refinery Disruptions: A Suggested Framework and Analysis of a Strategic Fuels Reserve. Study conducted for the California Energy Commission pursuant to California State Assembly Bill AB 2076. (P600-02-018D, July 4, 2002). A copy of this document is available at http://www.energy.ca.gov/reports/2002-07-08_600-02-018D.PDF. A copy is also available in Docket A-2001-28, Document No. II-A-18.

M. Gallaher, 2003. Memorandum to Todd Sherwood, regarding Clarifications on Several Modeling Issues (March 24, 2003). A copy of this memorandum can be found in Docket A-2001-28, Document No. II-A-37.

Greene, D.L. and N.I. Tishchishyna. 2000. Costs of Oil Dependence: A 2000 Update. Study prepared by Oak Ridge National Laboratory for the U.S. Department of Energy under contract DE-AC05-00OR22725 (O RNL/TM-2000/152, May 2000). This document can be accessed at http://www.ornl.gov/~webworks/cpr/v823/rpt/107319.pdf. A copy of this document is also available in Docket A-2001-28, Document No. II-A-21.

Jorgenson, Dale W. 1990. "Productivity and Economic Growth." In *Fifty Years of Economic Measurement: The Jubilee Conference on Research in Income and Wealth*. Ernst R. Berndt and Jack E. Triplett (eds.). Chicago, IL: University of Chicago Press.

Jorgenson, Dale W., Frank M. Gollop, and Barbara M. Fraumeni. 1987. *Productivity and U.S. Economic Growth*. Cambridge, MA: Harvard University Press.

Kimbell, L.J., and G.W. Harrison. 1986. "On the Solution of General Equilibrium Models." *Economic Modeling* 3:197-212.

Lin, William, Paul C. Westcott, Robert Skinner, Scott Sanford, and Daniel G. De La Torre Ugarte. 2000. Supply Response under the 1996 Farm Act and Implications for the U.S. Field Crops Sector. U.S. Department of Agriculture, Economics Research Service, Technical Bulletin No. 1888 (July 2000). A copy of this document is available at http://www.ers.usda.gov/publications/tb1888/tb1888.pdf. A copy is also available in Docket A-2001-28, Document No. II-A-20.

MathPro, Inc. 2002. Prospects for Adequate Supply of Ultra Low Sulfur Diesel Fuel in the Transition Period (2006-2007): An Analysis of Technical and Economic Driving Forces for Investment in ULSD Capacity in the U.S. Refining Sector. Study prepared for The Alliance of Automobile Manufacturers and The Engine Manufacturers Association (February 26, 2002). A copy of this study is available at http://www.autoalliance.org/ulsd_study.pdf. A copy is also available in Docket A-2001-28, Document No. II-A-19.

Morgenstern, Richard D., William A. Pizer, and Jhih-Shyang Shih. 2002. "Jobs Versus the Environment: An Industry-Level Perspective." *Journal of Environmental Economics and Management* 43:412-436.

NBER-CES. National Bureau of Economic Research and U.S. Census Bureau, Center for Economic Research. 2002. NBER-CES Manufacturing Industry Database, 1958 - 1996. http://www.nber.org/nberces/nbprod96.htm A copy of this document is available in Docket A-2001-28.

Office Management and Budget (OMB). 1996. Executive Analysis of Federal Regulations Under Executive Order 12866. Executive Office of the President, Office Management and Budget. January 11, 1996. A copy of this document is available at http://www.whitehouse.gov/omb/inforeg/print/riaguide.html. A copy is also available in Docket A-2001-28, Document No. II-A-22.

Pizer, Bill. Communications between Mike Gallaher and Bill Pizer on November 5, 2002. Docket A-2001-28, Document No. II-B-18.

Poterba, James M. 1984. "Tax Subsidies to Owner Occupied Housing: An Asset Market Approach," *Quarterly Journal of Economics* 99:4, pp. 729-52.

RTI. 2002. Economic Analysis of Air Pollution Regulations: Boilers and Process Heaters. Final Report. Prepared for the U.S. Environmental Protection Agency by RTI (November 2002). EPA Contract No. 68-D-99-024; RTI Project No. 7647-004-385. A copy of this document is available at http://www.epa.gov/ttn/ecas/regdata/economicimpactsanalysis.pdf. A copy is also available in Docket A-2001-28, Document No. II-A-16.

RTI. 2003. Economic Impact Analysis for Nonroad Diesel Tier 4 Rule. Prepared for the U.S. Environmental Protection Agency by RTI (April 2003). EPA Contract No. 68-D-99-024. A copy of this document is available in Docket A-2001-28.

Topel, Robert and Sherwin Rosen. 1988. "Housing Investment in the United States." *Journal of Political Economy* 96(4):718-40.

U.S. Census Bureau, 2002. "Annual Value of Construction Put in Place," C30 Table 101. As accessed on November 12, 2002. <http://www.census.gov/pub/const/ C30/tab101.txt>. Docket A-2001-28, Document No. II-B-17.

U.S. Environmental Protection Agency. 1999. *OAQPS Economic Analysis Resource Document*. Research Triangle Park, NC: EPA. A copy of this document can be found at http://www.epa.gov/ttn/ecas/econdata/6807-305.pdf. A copy can also be found in Docket A-2001-28, Document No. II-A-14.

U.S. Environmental Protection Agency. 2000. Regulatory Impact Analysis, Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements (EPA420-R-00-026). A copy of this document is available at http://www.epa.gov/otaq/diesel.htm#documents. A copy is also available in Docket A-2001-28, Document No. II-A-01.

APPENDIX 10A: Impacts on the Engine Market and Engine Manufacturers

This appendix provides the time series of impacts from 2007 through 2030 for the engine markets. Seven separate engine markets were modeled segmented by engine size in horsepower (the EIA includes more horsepower categories than the standards, allowing more efficient use of the engine compliance cost estimates developed for this proposal):

- less than 25 hp,
- 26 to 50 hp,
- 51 to 75 hp,
- 76 to 100 hp,
- 101 to 175 hp,
- 176 to 600 hp, and
- greater than 601 hp.

Tables 10A-1 through 10A-7 provide the time series of impacts for the seven horsepower markets included in the analysis. Each table includes the following:

- average engine price,
- average engineering costs (variable and fixed) per engine,
  - Note that in the engineering cost analysis, fixed costs for engine manufacturers are recovered in the first five years (see Chapter 6)
- absolute change in the market price ($),
  - Note that the estimated absolute change in market price is based on variable costs only; see Appendix I for a sensitivity analysis including fixed costs as well
- relative change in market price (%),
- relative change in market quantity (%),
- total engineering (regulatory) costs for merchant engines ($), and
- change in producer surplus from merchant engine manufacturers.

As described in Section 10.3.3.1, approximately 65 percent of engines are sold on the market and these are referred to as “merchant” engines. The remaining 35 percent are consumed internally by integrated equipment manufacturers and are referred to as “captive” engines. The total engineering costs and changes in producer surplus presented in this appendix include only merchant engines because captive engines never pass through the engines markets. Fixed and variable engineering costs and changes in producer surplus associated with captive engines are included in equipment manufacture impact estimates presented in Appendix 10B.

All prices and costs are presented in $2001, and real engine prices are assumed to be constant. The engineering cost per engine typically decreases after 5 years as the annualized fixed costs are depreciated. The price increase after that time is driven by the per-engine variable costs and remains relatively constant over time. We did the cost analysis using a 3% discount rate. We will also be conducting a similar analysis using a 7% discount rate and including this information in the docket.

For all the engine size categories, the majority of the cost of the regulation is passed along through increased engine prices. Price increases range from $125 (8.3% increase) for small (<25hp) engines to $6,950 (5.6% increase) for large (>600hp) engines. Even though the cost per engine and market impacts (in terms of percentage change in price and quantity) stabilize in the later years of the regulation, the engineering costs and producer surplus changes continue to gradually increase because the projected baseline population of engines increases over time.

Table 10A-1. Impacts on the Engine Market and Engine Manufacturers: ≤25hp
(Average Price per Engine = $1,500)[a]

	Engine (≤25Hp)					
Year	Engineering Cost/Unit	Absolute Change in Price	Change in Price (%)	Change in Quantity (%)	Total Engineering Costs (10^3)	Change in Producer Surplus for Engine Manufacturers (10^3)
2007	—	–$0.01	0.00%	–0.002%	$–	–$1.0
2008	$161.48	$131.33	8.76%	–0.003%	$19,922.9	–$3,720.4
2009	$160.69	$131.33	8.76%	–0.003%	$20,361.4	–$3,720.4
2010	$153.07	$124.45	8.30%	–0.004%	$19,906.8	–$3,721.1
2011	$152.35	$124.45	8.30%	–0.006%	$20,322.4	–$3,722.4
2012	$151.67	$124.44	8.30%	–0.009%	$20,738.0	–$3,723.8
2013	$124.47	$124.43	8.30%	–0.010%	$17,434.5	–$5.5
2014	$124.47	$124.43	8.30%	–0.010%	$17,850.1	–$5.9
2015	$124.47	$124.43	8.30%	–0.010%	$18,265.7	–$5.6
2016	$124.47	$124.43	8.30%	–0.010%	$18,681.3	–$5.9
2017	$124.47	$124.43	8.30%	–0.010%	$19,096.9	–$6.0
2018	$124.47	$124.43	8.30%	–0.010%	$19,512.5	–$6.1
2019	$124.47	$124.43	8.30%	–0.010%	$19,928.1	–$6.3
2020	$124.47	$124.43	8.30%	–0.010%	$20,343.7	–$6.4
2021	$124.47	$124.43	8.30%	–0.010%	$20,759.3	–$6.5
2022	$124.47	$124.43	8.30%	–0.010%	$21,174.9	–$6.6
2023	$124.47	$124.43	8.30%	–0.010%	$21,590.5	–$6.8
2024	$124.47	$124.43	8.30%	–0.010%	$22,006.1	–$6.9
2025	$124.47	$124.43	8.30%	–0.010%	$22,421.7	–$7.0
2026	$124.47	$124.43	8.30%	–0.010%	$22,837.3	–$7.1
2027	$124.47	$124.43	8.30%	–0.010%	$23,252.8	–$7.3
2028	$124.47	$124.43	8.30%	–0.010%	$23,668.4	–$7.4
2029	$124.47	$124.43	8.30%	–0.010%	$24,084.0	–$7.5
2030	$124.47	$124.43	8.30%	–0.010%	$24,499.6	–$7.6
NPV[b]					$308,900.8	–$15,668.6

[a] Figures are in 2001 dollars.
[b] Net present values are calculated using a social discount rate of 3 percent over the 2004 to 2030 time period.

Table 10A-2. Impacts on the Engine Market and Engine Manufacturers: 26–50hp (Average Price per Engine = $2,500)[a]

	Engine (26hp to 50hp)					
Year	**Engineering Cost/Unit**	**Absolute Change in Price**	**Change in Price (%)**	**Change in Quantity (%)**	**Total Engineering Costs (10^3)**	**Change in Producer Surplus for Engine Manufacturers (10^3)**
2007	—	–$0.02	0.00%	–0.002%	$–	–$2.0
2008	$196.04	$149.22	5.97%	–0.003%	$26,120.5	–$6,238.9
2009	$195.05	$149.22	5.97%	–0.003%	$26,553.3	–$6,238.9
2010	$186.18	$141.30	5.65%	–0.005%	$25,887.0	–$6,240.5
2011	$185.27	$141.28	5.65%	–0.008%	$26,296.9	–$6,244.0
2012	$184.39	$141.26	5.65%	–0.012%	$26,706.8	–$6,247.3
2013	$913.48	$852.28	34.09%	–0.013%	$134,957.6	–$9,042.7
2014	$912.31	$852.27	34.09%	–0.014%	$137,429.7	–$9,043.7
2015	$516.20	$457.31	18.29%	–0.013%	$79,257.9	–$9,043.0
2016	$704.91	$647.10	25.88%	–0.013%	$110,276.3	–$9,043.6
2017	$703.86	$647.10	25.88%	–0.013%	$112,153.3	–$9,043.8
2018	$647.19	$647.10	25.88%	–0.013%	$105,000.1	–$13.8
2019	$647.19	$647.10	25.88%	–0.013%	$106,877.1	–$14.1
2020	$647.19	$647.10	25.88%	–0.013%	$108,754.1	–$14.3
2021	$647.19	$647.10	25.88%	–0.013%	$110,631.1	–$14.5
2022	$647.19	$647.10	25.88%	–0.013%	$112,508.1	–$14.8
2023	$647.19	$647.10	25.88%	–0.013%	$114,385.1	–$15.0
2024	$647.19	$647.10	25.88%	–0.013%	$116,262.1	–$15.3
2025	$647.19	$647.10	25.88%	–0.013%	$118,139.1	–$15.5
2026	$647.19	$647.10	25.88%	–0.013%	$120,016.1	–$15.7
2027	$647.19	$647.10	25.88%	–0.013%	$121,893.1	–$16.0
2028	$647.19	$647.10	25.88%	–0.013%	$123,770.1	–$16.2
2029	$647.19	$647.10	25.88%	–0.013%	$125,647.0	–$16.5
2030	$647.19	$647.10	25.88%	–0.013%	$127,524.0	–$16.7
NPV[b]					$1,363,271.2	–$58,965.6

[a] Figures are in 2001 dollars.
[b] Net present values are calculated using a social discount rate of 3 percent over the 2004 to 2030 time period.

Table10.A-3. Impacts on the Engine Market and Engine Manufacturers: 51–75hp
(Average Price per Engine = $3,000)[a]

	Engine (51hp to 75hp)					
Year	Engineering Cost/Unit	Absolute Change in Price	Change in Price (%)	Change in Quantity (%)	Total Engineering Costs (10^3)	Change in Producer Surplus for Engine Manufacturers (10^3)
2007	—	–$0.02	0.00%	–0.002%	—	–$1.5
2008	$218.10	$170.53	5.68%	–0.003%	$18,456.1	–$4,025.4
2009	$217.24	$170.53	5.68%	–0.003%	$18,723.8	–$4,025.4
2010	$206.87	$160.99	5.37%	–0.005%	$18,155.5	–$4,026.7
2011	$206.07	$160.96	5.37%	–0.009%	$18,408.3	–$4,029.4
2012	$205.29	$160.93	5.36%	–0.012%	$18,661.1	–$4,032.0
2013	$907.16	$844.59	28.15%	–0.013%	$83,885.0	–$5,785.8
2014	$906.11	$844.58	28.15%	–0.014%	$85,210.9	–$5,786.6
2015	$702.27	$641.75	21.39%	–0.013%	$67,144.2	–$5,786.0
2016	$701.29	$641.75	21.39%	–0.014%	$68,151.8	–$5,786.4
2017	$700.35	$641.75	21.39%	–0.014%	$69,159.3	–$5,786.6
2018	$641.85	$641.75	21.39%	–0.014%	$64,390.8	–$10.8
2019	$641.85	$641.75	21.39%	–0.014%	$65,398.3	–$10.9
2020	$641.85	$641.75	21.39%	–0.014%	$66,405.8	–$11.1
2021	$641.85	$641.74	21.39%	–0.014%	$67,413.4	–$11.2
2022	$641.85	$641.74	21.39%	–0.014%	$68,420.9	–$11.4
2023	$641.85	$641.74	21.39%	–0.014%	$69,428.4	–$11.6
2024	$641.85	$641.74	21.39%	–0.014%	$70,435.9	–$11.7
2025	$641.85	$641.74	21.39%	–0.014%	$71,443.5	–$11.9
2026	$641.85	$641.74	21.39%	–0.014%	$72,451.0	–$12.1
2027	$641.84	$641.74	21.39%	–0.014%	$73,458.5	–$12.2
2028	$641.84	$641.74	21.39%	–0.014%	$74,466.0	–$12.4
2029	$641.84	$641.74	21.39%	–0.014%	$75,473.6	–$12.5
2030	$641.84	$641.73	21.39%	–0.014%	$76,481.1	–$12.7
NPV[b]					$855,626.8	–$37,885.0

[a] Figures are in 2001 dollars.
[b] Net present values are calculated using a social discount rate of 3 percent over the 2004 to 2030 time period.

Table10A-4. Impacts on the Engine Market and Engine Manufacturers: 76–100hp (Average Price per Engine = $4,000)[a]

	Engine (76hp to 100hp)					
Year	Engineering Cost/Unit	Absolute Change in Price	Change in Price (%)	Change in Quantity (%)	Total Engineering Costs (10^3)	Change in Producer Surplus for Engine Manufacturers (10^3)
2007	—	–$0.02	0.00%	–0.002%	—	–$1.3
2008	—	–$0.03	0.00%	–0.003%	—	–$1.7
2009	—	–$0.03	0.00%	–0.003%	—	–$1.7
2010	—	–$0.05	0.00%	–0.005%	—	–$2.8
2011	—	–$0.09	0.00%	–0.009%	—	–$5.1
2012	$1,203.59	$1,150.18	28.75%	–0.012%	$68,915.0	–$3,058.0
2013	$1,202.69	$1,150.17	28.75%	–0.013%	$70,054.5	–$3,058.9
2014	$1,209.39	$1,139.20	28.48%	–0.014%	$71,643.2	–$4,158.0
2015	$1,208.24	$1,139.22	28.48%	–0.013%	$72,771.9	–$4,157.6
2016	$1,194.15	$1,139.22	28.48%	–0.014%	$73,105.8	–$3,363.2
2017	$1,157.02	$1,139.22	28.48%	–0.014%	$71,978.6	–$1,107.4
2018	$1,156.74	$1,139.22	28.48%	–0.014%	$73,107.3	–$1,107.6
2019	$1,139.37	$1,139.22	28.48%	–0.014%	$73,137.5	–$9.3
2020	$1,139.37	$1,139.23	28.48%	–0.014%	$74,266.2	–$9.4
2021	$1,139.37	$1,139.23	28.48%	–0.014%	$75,394.9	–$9.5
2022	$1,139.37	$1,139.23	28.48%	–0.014%	$76,523.6	–$9.7
2023	$1,139.38	$1,139.23	28.48%	–0.014%	$77,652.3	–$9.8
2024	$1,139.38	$1,139.23	28.48%	–0.014%	$78,781.0	–$9.9
2025	$1,139.38	$1,139.24	28.48%	–0.014%	$79,909.7	–$10.1
2026	$1,139.38	$1,139.24	28.48%	–0.014%	$81,038.4	–$10.2
2027	$1,139.38	$1,139.24	28.48%	–0.014%	$82,167.0	–$10.4
2028	$1,139.39	$1,139.24	28.48%	–0.014%	$83,295.7	–$10.5
2029	$1,139.39	$1,139.24	28.48%	–0.014%	$84,424.4	–$10.6
2030	$1,139.39	$1,139.25	28.48%	–0.014%	$85,553.1	–$10.8
NPV[b]					$882,138.1	–$14,777.3

[a] Figures are in 2001 dollars.
[b] Net present values are calculated using a social discount rate of 3 percent over the 2004 to 2030 time period.

Table 10A-5. Impacts on the Engine Market and Engine Manufacturers: 101–175hp (Average Price per Engine = $15,500)[a]

	Engine (101hp to 175hp)					
Year	Engineering Cost/Unit	Absolute Change in Price	Change in Price (%)	Change in Quantity (%)	Total Engineering Costs (10^3)	Change in Producer Surplus for Engine Manufacturers (10^3)
2007	—	–$0.04	0.00%	–0.002%	—	–$2.0
2008	—	–$0.04	0.00%	–0.003%	—	–$2.6
2009	—	–$0.05	0.00%	–0.003%	—	–$2.7
2010	—	–$0.07	0.00%	–0.005%	—	–$4.5
2011	—	–$0.14	0.00%	–0.010%	—	–$8.6
2012	$1,461.38	$1,409.45	25.63%	–0.014%	$91,426.0	–$3,248.7
2013	$1,460.54	$1,409.44	25.63%	–0.015%	$92,886.1	–$3,250.0
2014	$1,451.52	$1,383.48	25.15%	–0.016%	$93,816.2	–$4,397.7
2015	$1,450.45	$1,383.50	25.15%	–0.015%	$95,249.4	–$4,397.0
2016	$1,436.25	$1,383.49	25.15%	–0.015%	$95,804.6	–$3,519.5
2017	$1,400.64	$1,383.49	25.15%	–0.015%	$94,879.5	–$1,161.4
2018	$1,400.38	$1,383.49	25.15%	–0.015%	$96,312.7	–$1,161.6
2019	$1,383.71	$1,383.49	25.15%	–0.015%	$96,599.4	–$15.3
2020	$1,383.71	$1,383.49	25.15%	–0.015%	$98,032.6	–$15.5
2021	$1,383.71	$1,383.49	25.15%	–0.015%	$99,465.8	–$15.7
2022	$1,383.71	$1,383.49	25.15%	–0.015%	$100,899.1	–$15.9
2023	$1,383.71	$1,383.49	25.15%	–0.015%	$102,332.3	–$16.2
2024	$1,383.71	$1,383.49	25.15%	–0.015%	$103,765.5	–$16.4
2025	$1,383.71	$1,383.49	25.15%	–0.015%	$105,198.8	–$16.6
2026	$1,383.71	$1,383.49	25.15%	–0.015%	$106,632.0	–$16.8
2027	$1,383.71	$1,383.49	25.15%	–0.015%	$108,065.2	–$17.0
2028	$1,383.71	$1,383.49	25.15%	–0.015%	$109,498.4	–$17.3
2029	$1,383.71	$1,383.49	25.15%	–0.015%	$110,931.7	–$17.5
2030	$1,383.71	$1,383.49	25.15%	–0.015%	$112,364.9	–$17.7
NPV[b]					$1,161,715.6	–$15,656.9

[a] Figures are in 2001 dollars.
[b] Net present values are calculated using a social discount rate of 3 percent over the 2004 to 2030 time period.

Table 10A-6. Impacts on the Engine Market and Engine Manufacturers: 176–600hp (Average Price per Engine = $20,000)[a]

	Engine (176hp to 600hp)					
Year	Engineering Cost/Unit	Absolute Change in Price	Change in Price (%)	Change in Quantity (%)	Total Engineering Costs (10^3)	Change in Producer Surplus for Engine Manufacturers (10^3)
2007	—	$0.13	0.00%	–0.003%	—	–$5.0
2008	—	$0.17	0.00%	–0.003%	—	–$6.4
2009	—	$0.17	0.00%	–0.003%	—	–$6.6
2010	—	$0.28	0.00%	–0.005%	—	–$11.2
2011	$2,465.89	$2,265.86	11.33%	–0.010%	$99,063.4	–$8,035.8
2012	$2,452.90	$2,264.55	11.32%	–0.015%	$100,109.1	–$7,687.3
2013	$1,939.41	$1,753.89	8.77%	–0.016%	$80,391.8	–$7,690.4
2014	$2,449.55	$2,208.60	11.04%	–0.017%	$103,103.5	–$10,142.1
2015	$2,445.00	$2,207.69	11.04%	–0.016%	$104,474.2	–$10,140.4
2016	$2,273.55	$2,206.73	11.03%	–0.016%	$98,601.2	–$2,897.9
2017	$2,262.31	$2,205.82	11.03%	–0.016%	$99,559.5	–$2,486.1
2018	$2,260.63	$2,204.94	11.02%	–0.016%	$100,930.2	–$2,486.6
2019	$2,204.93	$2,204.08	11.02%	–0.016%	$99,852.3	–$38.4
2020	$2,204.09	$2,203.25	11.02%	–0.016%	$101,223.0	–$38.9
2021	$2,203.28	$2,202.43	11.01%	–0.016%	$102,593.7	–$39.5
2022	$2,202.49	$2,201.64	11.01%	–0.016%	$103,964.4	–$40.0
2023	$2,201.72	$2,200.87	11.00%	–0.016%	$105,335.1	–$40.5
2024	$2,200.97	$2,200.13	11.00%	–0.016%	$106,705.8	–$41.0
2025	$2,200.24	$2,199.40	11.00%	–0.016%	$108,076.5	–$41.6
2026	$2,199.53	$2,198.69	10.99%	–0.016%	$109,447.2	–$42.1
2027	$2,198.84	$2,197.99	10.99%	–0.016%	$110,817.9	–$42.6
2028	$2,198.16	$2,197.32	10.99%	–0.016%	$112,188.6	–$43.2
2029	$2,197.50	$2,196.66	10.98%	–0.016%	$113,559.4	–$43.7
2030	$2,196.86	$2,196.02	10.98%	–0.016%	$114,930.1	–$44.2
NPV[b]					$1,280,605.9	–$39,033.9

[a] Figures are in 2001 dollars.
[b] Net present values are calculated using a social discount rate of 3 percent over the 2004 to 2030 time period.

Table 10A-7. Impacts on the Engine Market and Engine Manufacturers: ≥601hp (Average Price per Engine = $125,000)[a]

	Engine (≥601hp)					
Year	Engineering Cost/Unit	Absolute Change in Price	Change in Price (%)	Change in Quantity (%)	Total Engineering Costs (10^3)	Change in Producer Surplus for Engine Manufacturers (10^3)
2007	—	–$0.80	0.00%	–0.002%	—	–$1.2
2008	—	–$1.00	0.00%	–0.003%	—	–$1.6
2009	—	–$1.00	0.00%	–0.003%	—	–$1.6
2010	—	–$1.65	0.00%	–0.005%	—	–$2.6
2011	$6,305.92	$5,399.16	4.32%	–0.009%	$10,293.4	–$1,480.2
2012	$6,227.66	$5,397.83	4.32%	–0.013%	$10,320.1	–$1,375.2
2013	$5,029.76	$4,211.73	3.37%	–0.014%	$8,459.7	–$1,375.9
2014	$8,174.82	$6,947.29	5.56%	–0.016%	$13,952.2	–$2,095.1
2015	$8,157.40	$6,947.67	5.56%	–0.015%	$14,124.8	–$2,094.7
2016	$7,432.01	$6,947.66	5.56%	–0.015%	$13,053.0	–$850.7
2017	$7,356.03	$6,947.74	5.56%	–0.015%	$13,102.0	–$727.2
2018	$7,350.56	$6,947.82	5.56%	–0.015%	$13,274.6	–$727.3
2019	$6,952.78	$6,947.90	5.56%	–0.015%	$12,728.6	–$8.9
2020	$6,952.86	$6,947.98	5.56%	–0.015%	$12,901.2	–$9.0
2021	$6,952.93	$6,948.05	5.56%	–0.015%	$13,073.7	–$9.2
2022	$6,953.00	$6,948.13	5.56%	–0.015%	$13,246.3	–$9.3
2023	$6,953.07	$6,948.20	5.56%	–0.015%	$13,418.9	–$9.4
2024	$6,953.13	$6,948.27	5.56%	–0.015%	$13,591.4	–$9.5
2025	$6,953.20	$6,948.33	5.56%	–0.015%	$13,764.0	–$9.6
2026	$6,953.26	$6,948.40	5.56%	–0.015%	$13,936.5	–$9.7
2027	$6,953.33	$6,948.46	5.56%	–0.015%	$14,109.1	–$9.9
2028	$6,953.39	$6,948.53	5.56%	–0.015%	$14,281.7	–$10.0
2029	$6,953.45	$6,948.59	5.56%	–0.015%	$14,454.2	–$10.1
2030	$6,953.50	$6,948.65	5.56%	–0.015%	$14,626.8	–$10.2
NPV[b]					$160,049.3	–$8,057.4

[a] Figures are in 2001 dollars.
[b] Net present values are calculated using a social discount rate of 3 percent over the 2004 to 2030 time period.

APPENDIX 10B: Impacts on Equipment Market and Equipment Manufacturers

This appendix provides the time series of impacts from 2007 through 2030 for the equipment markets. The equipment markets are the markets associated with the production and consumption of equipment that use nonroad diesel engines. Seven equipment types were modeled:

- construction,
- agricultural,
- pumps and compressors,
- generators and welder sets,
- refrigeration and air conditioning,
- general industrial, and
- lawn and garden.

Forty-two equipment markets were modeled, representing 7 horsepower categories within 7 application categories. There are 7 horsepower/application categories that did not have sales in 2000 and are not included in the model, so the total number of diesel equipment markets is 42 rather than 49.

Tables 10B-1 through 10B-7 provide the time series of impacts for the seven equipment markets included in the analysis. Each table includes the following:

- average equipment price,
- average engineering costs (variable and fixed) per piece of equipment,
  - Note that in the engineering cost analysis, fixed costs for equipment manufacturers are recovered in the first ten years (see Chapter 6)
- absolute change in the equipment market price ($),
  - Note that the estimated absolute change in market price is based on variable costs only; see Appendix I for a sensitivity analysis including fixed costs as well
- relative change in the equipment market price (%),
- relative change in the equipment market quantity (%),
- total engineering (regulatory) costs associated with each equipment market ($), and
- change in producer surplus for all equipment manufacturers in the market.

As described in Section 10.3.3.1, approximately 65 percent of engines are sold on the market and these are referred to as “merchant” engines. The remaining 35 percent are consumed internally by integrated equipment manufacturers and are referred to as “captive” engines. The engineering costs and changes in producer surplus presented in this appendix include total equipment costs as well as captive engine costs. Because captive engines never pass through the engines markets, they therefore present an additional cost for integrated equipment producers.

All prices and costs are presented in \$2001, and real equipment prices are assumed to be constant. The engineering cost per piece of equipment peak around 2013 as the fixed cost per equipment are phased in and then are depreciated over the next several years.

A greater percentage of the cost of the regulation is borne by the various equipment markets than is borne by the engine market. However, a substantial percentage of the cost is still passed along through increased equipment prices. Price increases range from an average increase of 1.84 percent in the general industrial equipment market to 9.37 percent in the refrigeration and air-conditioning market. Even though the cost per piece of equipment and market impacts (in terms of percentage change in price and quantity) stabilize after the initial years of the regulation, the engineering costs and produce surplus changes continue to gradually increase because the projected baseline population of equipment increases over time.

Table 10B-1. Impacts on Agricultural Equipment Market and Manufacturers (Average Price per Equipment = $55,396)[a]

	Agricultural Equipment					Change in Producer Surplus for Equipment Manufacturers (10^3)
Year	Engineering Cost/Unit	Absolute Change in Price	Change in Price (%)	Change in Quantity (%)	Total Engineering Costs (10^3)	
2007	–$0.01	–$0.71	0.00%	–0.003%	$–	–$129.1
2008	$80.60	$67.81	1.09%	–0.003%	$6,411.0	–$2,412.3
2009	$80.52	$67.96	1.09%	–0.003%	$6,499.3	–$2,415.8
2010	$76.73	$63.67	1.04%	–0.006%	$6,353.8	–$2,560.5
2011	$796.90	$658.43	1.49%	–0.013%	$132,042.2	–$27,655.9
2012	$1,242.25	$1,060.42	2.13%	–0.017%	$196,410.2	–$36,985.4
2013	$1,386.50	$1,193.96	5.41%	–0.019%	$199,850.0	–$39,869.9
2014	$1,533.64	$1,300.28	5.49%	–0.020%	$231,071.2	–$49,179.7
2015	$1,405.61	$1,176.51	3.76%	–0.019%	$224,459.1	–$49,121.5
2016	$1,409.97	$1,222.04	4.55%	–0.019%	$222,759.7	–$40,985.7
2017	$1,396.93	$1,220.45	4.55%	–0.019%	$223,659.0	–$39,136.9
2018	$1,380.70	$1,218.91	4.56%	–0.019%	$223,742.8	–$36,472.6
2019	$1,362.36	$1,217.42	4.56%	–0.019%	$223,224.0	–$33,205.5
2020	$1,358.70	$1,215.97	4.57%	–0.019%	$225,988.3	–$33,221.7
2021	$1,286.32	$1,214.58	4.57%	–0.019%	$212,477.8	–$16,963.0
2022	$1,252.67	$1,213.22	4.58%	–0.019%	$207,735.7	–$9,472.8
2023	$1,241.18	$1,211.91	4.58%	–0.019%	$208,148.7	–$7,137.7
2024	$1,215.51	$1,210.63	4.58%	–0.019%	$204,967.8	–$1,208.5
2025	$1,214.27	$1,209.39	4.59%	–0.019%	$207,732.1	–$1,224.7
2026	$1,213.06	$1,208.19	4.59%	–0.019%	$210,496.4	–$1,240.8
2027	$1,211.88	$1,207.02	4.59%	–0.019%	$213,260.7	–$1,256.9
2028	$1,210.74	$1,205.88	4.60%	–0.019%	$216,025.0	–$1,273.1
2029	$1,209.63	$1,204.78	4.60%	–0.019%	$218,789.4	–$1,289.2
2030	$1,208.55	$1,203.71	4.60%	–0.019%	$221,553.7	–$1,305.3
NPV[b]			3.76%		$2,632,706.9	–$306,693.1

[a] Figures are in 2001 dollars.
[b] Net present values are calculated using a social discount rate of 3 percent over the 2004 to 2030 time period.

Table 10.B-2. Impacts on Construction Equipment Market and Manufacturers (Average Price per Equipment = $166,086)[a]

Year	Construction Equipment: Engineering Cost/Unit	Absolute Change in Price	Change in Price (%)	Change in Quantity (%)	Total Engineering Costs (10^3)	Change in Producer Surplus for Equipment Manufacturers (10^3)
2007	–$0.02	–$1.57	0.00%	–0.003%	—	–$366.2
2008	$66.22	$58.01	0.61%	–0.004%	$2,983.7	–$1,985.4
2009	$66.23	$58.14	0.61%	–0.004%	$3,011.4	–$1,994.8
2010	$62.97	$53.39	0.58%	–0.007%	$2,954.9	–$2,409.1
2011	$785.33	$648.33	0.68%	–0.014%	$139,136.4	–$35,069.1
2012	$1,359.19	$1,166.79	1.38%	–0.020%	$230,575.9	–$50,141.3
2013	$1,452.08	$1,252.19	2.60%	–0.021%	$221,136.2	–$53,022.7
2014	$1,647.81	$1,396.67	2.62%	–0.023%	$266,895.3	–$67,782.3
2015	$1,551.03	$1,304.51	2.05%	–0.022%	$267,893.0	–$67,679.2
2016	$1,537.78	$1,331.79	2.27%	–0.022%	$260,863.2	–$57,507.7
2017	$1,523.40	$1,330.14	2.27%	–0.022%	$261,235.8	–$54,852.6
2018	$1,512.99	$1,328.54	2.28%	–0.022%	$262,618.9	–$53,208.1
2019	$1,491.27	$1,326.99	2.28%	–0.022%	$260,590.1	–$48,151.8
2020	$1,487.37	$1,325.50	2.28%	–0.022%	$263,663.6	–$48,197.6
2021	$1,414.60	$1,324.04	2.28%	–0.022%	$245,876.8	–$27,383.1
2022	$1,372.58	$1,322.63	2.29%	–0.022%	$236,856.8	–$15,335.5
2023	$1,362.50	$1,321.27	2.29%	–0.022%	$237,399.6	–$12,850.7
2024	$1,331.08	$1,319.94	2.29%	–0.022%	$231,100.5	–$3,524.0
2025	$1,329.77	$1,318.65	2.29%	–0.022%	$234,174.0	–$3,569.9
2026	$1,328.51	$1,317.40	2.29%	–0.022%	$237,247.5	–$3,615.7
2027	$1,327.27	$1,316.18	2.29%	–0.022%	$240,321.0	–$3,661.6
2028	$1,326.07	$1,315.00	2.30%	–0.022%	$243,394.5	–$3,707.4
2029	$1,324.91	$1,313.85	2.30%	–0.022%	$246,468.0	–$3,753.2
2030	$1,323.77	$1,312.73	2.30%	–0.022%	$249,541.6	–$3,799.0
NPV[b]			1.89%		$3,006,380.6	–$433,600.5

[a] Figures are in 2001 dollars.
[b] Net present values are calculated using a social discount rate of 3 percent over the 2004 to 2030 time period.

Table 10B-3. Impacts on Pumps and Compressor Equipment Market and Manufacturers (Average Price per Equipment = $13,198)[a]

	Pumps and Compressors					Change in Producer Surplus for Equipment Manufacturers (10^3)
Year	Engineering Cost/Unit	Absolute Change in Price	Change in Price (%)	Change in Quantity (%)	Total Engineering Costs (10^3)	
2007	–$0.03	–$0.12	0.00%	–0.002%	—	–$2.1
2008	$107.28	$99.50	3.69%	–0.002%	$183.9	–$186.7
2009	$107.24	$99.63	3.70%	–0.002%	$183.9	–$186.7
2010	$101.82	$94.34	3.51%	–0.003%	$183.9	–$187.3
2011	$296.63	$265.84	3.81%	–0.003%	$949.8	–$785.9
2012	$637.09	$581.71	5.18%	–0.005%	$1,968.1	–$1,442.0
2013	$900.62	$833.50	11.57%	–0.006%	$2,506.4	–$1,782.1
2014	$940.17	$862.60	11.61%	–0.006%	$2,836.5	–$2,099.1
2015	$813.80	$737.70	8.43%	–0.006%	$2,848.8	–$2,098.3
2016	$851.85	$777.12	9.80%	–0.006%	$2,861.0	–$2,098.8
2017	$849.14	$775.75	9.80%	–0.006%	$2,873.2	–$2,098.9
2018	$840.21	$774.42	9.81%	–0.006%	$2,701.6	–$1,915.1
2019	$837.80	$773.14	9.81%	–0.006%	$2,713.8	–$1,915.2
2020	$835.47	$771.91	9.82%	–0.006%	$2,726.0	–$1,915.4
2021	$813.71	$770.71	9.82%	–0.006%	$2,140.5	–$1,317.7
2022	$790.85	$769.56	9.82%	–0.006%	$1,498.3	–$663.3
2023	$778.71	$768.44	9.83%	–0.006%	$1,172.3	–$325.3
2024	$767.62	$767.35	9.83%	–0.006%	$867.7	–$8.6
2025	$766.57	$766.30	9.83%	–0.006%	$880.0	–$8.7
2026	$765.55	$765.29	9.84%	–0.006%	$892.2	–$8.8
2027	$764.57	$764.30	9.84%	–0.006%	$904.4	–$8.9
2028	$763.61	$763.35	9.84%	–0.006%	$916.6	–$9.1
2029	$762.68	$762.42	9.85%	–0.006%	$928.9	–$9.2
2030	$761.78	$761.52	9.85%	–0.006%	$941.1	–$9.3
NPV[b]			8.29%		$24,133.3	–$14,701.0

[a] Figures are in 2001 dollars.
[b] Net present values are calculated using a social discount rate of 3 percent over the 2004 to 2030 time period.

Table 10.B-4. Impacts on Generator Sets and Welding Equipment Market and Manufacturers (Average Price per Equipment = $14,483)[a]

Year	Generator Sets and Welders: Engineering Cost/Unit	Absolute Change in Price	Change in Price (%)	Change in Quantity (%)	Total Engineering Costs (10^3)	Change in Producer Surplus for Equipment Manufacturers (10^3)
2007	–$0.01	–$0.11	0.00%	–0.002%	—	–$13.5
2008	$143.56	$124.60	2.61%	–0.002%	$7,583.3	–$2,696.7
2009	$143.18	$124.66	2.62%	–0.002%	$7,697.0	–$2,696.9
2010	$136.20	$118.07	2.48%	–0.003%	$7,536.0	–$2,700.7
2011	$175.95	$152.11	2.51%	–0.003%	$11,229.4	–$3,630.6
2012	$330.33	$292.14	2.74%	–0.005%	$25,160.7	–$5,944.6
2013	$607.35	$559.14	6.37%	–0.006%	$40,598.4	–$7,666.3
2014	$614.82	$562.28	6.37%	–0.006%	$42,375.4	–$8,531.3
2015	$482.77	$431.32	4.48%	–0.006%	$37,298.3	–$8,526.4
2016	$530.87	$482.22	5.34%	–0.006%	$39,279.4	–$8,225.8
2017	$527.13	$481.18	5.34%	–0.006%	$39,499.6	–$7,924.0
2018	$510.92	$480.17	5.34%	–0.006%	$37,501.4	–$5,403.8
2019	$508.22	$479.21	5.34%	–0.006%	$37,816.3	–$5,196.6
2020	$506.76	$478.28	5.34%	–0.006%	$38,339.1	–$5,197.4
2021	$501.54	$477.38	5.34%	–0.006%	$38,153.4	–$4,489.7
2022	$490.14	$476.51	5.33%	–0.006%	$36,762.9	–$2,577.2
2023	$479.37	$475.68	5.33%	–0.006%	$35,418.0	–$710.3
2024	$475.15	$474.87	5.33%	–0.006%	$35,285.3	–$55.7
2025	$474.37	$474.09	5.33%	–0.006%	$35,808.1	–$56.4
2026	$473.62	$473.34	5.33%	–0.006%	$36,330.8	–$57.2
2027	$472.89	$472.61	5.33%	–0.006%	$36,853.6	–$58.0
2028	$472.18	$471.90	5.33%	–0.006%	$37,376.3	–$58.8
2029	$471.50	$471.22	5.33%	–0.006%	$37,899.1	–$59.5
2030	$470.83	$470.55	5.33%	–0.006%	$38,421.8	–$60.3
NPV[b]			4.59%		$461,276.2	–$59,177.6

[a] Figures are in 2001 dollars.
[b] Net present values are calculated using a social discount rate of 3 percent over the 2004 to 2030 time period.

Table 10B-5. Impacts on Refrigeration and Air-Conditioning Equipment Market and Manufacturers (Average Price per Equipment = $6,314)[a]

	Refrigeration and Air Conditioning					Change in Producer Surplus for Equipment Manufacturers (10^3)
Year	Engineering Cost/Unit	Absolute Change in Price	Change in Price (%)	Change in Quantity (%)	Total Engineering Costs (10^3)	
2007	–$0.02	–$0.06	0.00%	–0.002%	—	–$1.9
2008	$166.67	$154.86	4.28%	–0.002%	$528.8	–$531.3
2009	$166.37	$154.80	4.29%	–0.002%	$528.8	–$531.3
2010	$157.66	$146.32	4.07%	–0.003%	$528.8	–$531.9
2011	$157.36	$146.24	4.08%	–0.003%	$528.8	–$532.6
2012	$157.08	$146.14	4.09%	–0.005%	$528.8	–$534.1
2013	$712.79	$678.12	13.88%	–0.006%	$2,382.7	–$1,726.8
2014	$711.32	$677.31	13.88%	–0.006%	$2,394.6	–$1,727.0
2015	$504.88	$471.52	9.34%	–0.006%	$2,406.5	–$1,726.3
2016	$556.92	$524.16	11.11%	–0.006%	$2,418.4	–$1,726.7
2017	$555.81	$523.64	11.12%	–0.006%	$2,430.4	–$1,726.8
2018	$545.06	$523.14	11.12%	–0.006%	$1,913.4	–$1,198.1
2019	$544.20	$522.66	11.12%	–0.006%	$1,925.4	–$1,198.2
2020	$543.37	$522.19	11.12%	–0.006%	$1,937.3	–$1,198.3
2021	$542.56	$521.74	11.13%	–0.006%	$1,949.2	–$1,198.4
2022	$541.78	$521.31	11.13%	–0.006%	$1,961.1	–$1,198.5
2023	$521.01	$520.88	11.13%	–0.006%	$782.0	–$7.7
2024	$520.60	$520.48	11.13%	–0.006%	$794.0	–$7.8
2025	$520.21	$520.08	11.14%	–0.006%	$805.9	–$7.9
2026	$519.82	$519.70	11.14%	–0.006%	$817.8	–$8.0
2027	$519.45	$519.32	11.14%	–0.006%	$829.7	–$8.1
2028	$519.09	$518.96	11.14%	–0.006%	$841.6	–$8.2
2029	$518.74	$518.61	11.14%	–0.006%	$853.5	–$8.3
2030	$518.40	$518.27	11.15%	–0.006%	$865.4	–$8.4
NPV[b]			9.37%		$20,342.3	–$12,244.8

[a] Figures are in 2001 dollars.
[b] Net present values are calculated using a social discount rate of 3 percent over the 2004 to 2030 time period.

Table 10.B-6. Impacts on General Industrial Equipment Market and Manufacturers (Average Price per Equipment = $132,972)[a]

	General Industrial					
Year	Engineering Cost/Unit	Absolute Change in Price	Change in Price (%)	Change in Quantity (%)	Total Engineering Costs (10^3)	Change in Producer Surplus for Equipment Manufacturers (10^3)
2007	–$0.04	–$0.51	0.00%	–0.002%	—	–$31.7
2008	$51.50	$46.14	0.44%	–0.002%	$606.1	–$366.3
2009	$51.51	$46.25	0.44%	–0.002%	$611.4	–$366.9
2010	$48.95	$43.66	0.42%	–0.003%	$600.4	–$375.5
2011	$485.64	$425.67	0.49%	–0.003%	$7,449.8	–$4,335.3
2012	$1,289.38	$1,159.24	1.52%	–0.005%	$27,094.6	–$9,575.1
2013	$1,387.46	$1,251.01	2.51%	–0.006%	$29,136.6	–$10,216.5
2014	$1,496.25	$1,329.31	2.52%	–0.006%	$32,268.0	–$12,715.2
2015	$1,418.49	$1,254.49	2.06%	–0.006%	$32,185.8	–$12,703.7
2016	$1,434.64	$1,277.00	2.24%	–0.006%	$32,218.8	–$12,414.3
2017	$1,426.31	$1,275.92	2.24%	–0.006%	$32,152.6	–$12,038.9
2018	$1,418.48	$1,274.87	2.24%	–0.006%	$32,104.6	–$11,681.6
2019	$1,412.32	$1,273.86	2.24%	–0.006%	$32,174.9	–$11,442.5
2020	$1,409.22	$1,272.88	2.24%	–0.006%	$32,485.8	–$11,444.0
2021	$1,362.03	$1,271.92	2.24%	–0.006%	$29,031.1	–$7,680.1
2022	$1,305.18	$1,270.99	2.25%	–0.006%	$24,618.3	–$2,958.0
2023	$1,297.20	$1,270.10	2.25%	–0.006%	$24,349.5	–$2,380.0
2024	$1,270.65	$1,269.22	2.25%	–0.006%	$22,405.9	–$127.2
2025	$1,269.80	$1,268.37	2.25%	–0.006%	$22,716.8	–$128.8
2026	$1,268.97	$1,267.55	2.25%	–0.006%	$23,027.6	–$130.4
2027	$1,268.17	$1,266.75	2.25%	–0.006%	$23,338.4	–$132.0
2028	$1,267.39	$1,265.97	2.25%	–0.006%	$23,649.3	–$133.6
2029	$1,266.63	$1,265.21	2.25%	–0.006%	$23,960.1	–$135.2
2030	$1,265.89	$1,264.47	2.26%	–0.006%	$24,271.0	–$136.8
NPV[b]			1.84%		$333,923.8	–$85,851.8

[a] Figures are in 2001 dollars.
[b] Net present values are calculated using a social discount rate of 3 percent over the 2004 to 2030 time period.

Table 10.B-7. Impacts on Lawn and Garden Equipment Market and Manufacturers (Average Price per Equipment = $12,394)[a]

Year	Lawn and Garden					Change in Producer Surplus for Equipment Manufacturers (10^3)
	Engineering Cost/Unit	Absolute Change in Price	Change in Price (%)	Change in Quantity (%)	Total Engineering Costs (10^3)	
2007	–$0.01	–$0.08	0.00%	–0.002%	—	–$2.9
2008	$138.80	$120.56	3.07%	–0.002%	$2,233.4	–$760.0
2009	$138.46	$120.64	3.08%	–0.002%	$2,271.9	–$760.1
2010	$131.75	$114.32	2.92%	–0.003%	$2,228.9	–$760.9
2011	$168.43	$146.92	2.95%	–0.003%	$2,520.4	–$960.6
2012	$333.59	$299.74	3.23%	–0.005%	$3,435.9	–$1,545.1
2013	$574.91	$536.55	6.96%	–0.006%	$5,502.4	–$1,789.2
2014	$581.20	$539.53	6.96%	–0.006%	$5,774.8	–$1,984.8
2015	$454.05	$413.26	4.97%	–0.006%	$4,984.6	–$1,983.7
2016	$508.37	$468.39	5.91%	–0.006%	$5,470.2	–$1,984.3
2017	$506.56	$467.36	5.90%	–0.006%	$5,538.9	–$1,984.5
2018	$494.69	$466.36	5.90%	–0.006%	$5,085.3	–$1,462.3
2019	$493.20	$465.40	5.90%	–0.006%	$5,154.1	–$1,462.5
2020	$491.76	$464.48	5.90%	–0.006%	$5,222.8	–$1,462.7
2021	$486.74	$463.59	5.90%	–0.006%	$5,092.9	–$1,264.2
2022	$475.01	$462.74	5.90%	–0.006%	$4,579.5	–$682.3
2023	$465.57	$461.91	5.89%	–0.006%	$4,172.9	–$207.1
2024	$461.32	$461.11	5.89%	–0.006%	$4,046.5	–$12.1
2025	$460.55	$460.34	5.89%	–0.006%	$4,115.2	–$12.3
2026	$459.81	$459.60	5.89%	–0.006%	$4,183.9	–$12.4
2027	$459.09	$458.88	5.89%	–0.006%	$4,252.6	–$12.6
2028	$458.39	$458.18	5.89%	–0.006%	$4,321.4	–$12.8
2029	$457.71	$457.51	5.89%	–0.006%	$4,390.1	–$12.9
2030	$457.06	$456.85	5.88%	–0.006%	$4,458.8	–$13.1
NPV[b]			5.11%		$63,452.9	–$15,141.2

[a] Figures are in 2001 dollars.
[b] Net present values are calculated using a social discount rate of 3 percent over the 2004 to 2030 time period.

APPENDIX 10C: Impacts on Application Market Producers and Consumers

This appendix provides the time series of impacts from 2007 through 2030 for the product and service application markets included in the model. There are 3 application markets: construction, agriculture, and manufacturing.

Tables 10C-1 through 10C-3 provide the time series of impacts for the three application markets. Each table includes the following:

- relative change in market price (%),
- relative change in market quantity (%), and
- change in producer and consumer surplus for each application market.

Price increases range from an average of 0.01 percent in the manufacturing sector to 0.05 percent in the agricultural sector. Even though the cost per engine and market impacts (in terms of percentage change in price and quantity) stabilize in the later years of the regulation, the engineering costs and producer surplus changes continue to gradually increase because the projected consumption by producers and consumers within each application market increases over time.

Table 10C-1. Impacts on Agricultural Application Market and Agricultural Producers and Consumers[a]

Year	Agriculture: Change in Price (%)	Agriculture: Change in Quantity (%)	Change in Producer and Consumer Surplus ($$10^3$)
2007	0.009%	–0.002%	–$43,960.9
2008	0.012%	–0.002%	–$57,864.1
2009	0.012%	–0.002%	–$59,188.4
2010	0.021%	–0.004%	–$108,934.7
2011	0.044%	–0.009%	–$229,431.7
2012	0.059%	–0.012%	–$315,186.7
2013	0.064%	–0.013%	–$348,696.5
2014	0.068%	–0.014%	–$377,452.5
2015	0.063%	–0.013%	–$357,954.7
2016	0.065%	–0.013%	–$374,252.1
2017	0.065%	–0.013%	–$380,487.4
2018	0.065%	–0.013%	–$386,722.8
2019	0.065%	–0.013%	–$392,958.1
2020	0.065%	–0.013%	–$399,193.5
2021	0.065%	–0.013%	–$405,428.8
2022	0.065%	–0.013%	–$411,664.1
2023	0.065%	–0.013%	–$417,899.4
2024	0.065%	–0.013%	–$424,134.7
2025	0.065%	–0.013%	–$430,370.0
2026	0.065%	–0.013%	–$436,592.0
2027	0.065%	–0.013%	–$442,814.0
2028	0.065%	–0.013%	–$449,036.0
2029	0.065%	–0.013%	–$455,257.9
2030	0.065%	–0.013%	–$461,479.9
	AVG	AVG	NPV[b]
	0.055%	–0.011%	–$5,050,376.0

[a] Figures are in 2001 dollars.
[b] Net present values are calculated using a social discount rate of 3 percent over the 2004 to 2030 time period.

Table 10C-2. Impacts on Construction Application Market and Construction Producers and Consumers[a]

Year	Construction: Change in Price (%)	Construction: Change in Quantity (%)	Change in Producer and Consumer Surplus ($$10^3$)
2007	0.003%	–0.003%	–$58,654.6
2008	0.004%	–0.004%	–$74,356.5
2009	0.004%	–0.004%	–$76,058.2
2010	0.007%	–0.007%	–$143,107.9
2011	0.015%	–0.014%	–$297,490.6
2012	0.021%	–0.020%	–$437,573.1
2013	0.022%	–0.021%	–$468,250.1
2014	0.024%	–0.023%	–$515,649.1
2015	0.023%	–0.022%	–$499,896.0
2016	0.023%	–0.022%	–$516,309.7
2017	0.023%	–0.022%	–$524,842.8
2018	0.023%	–0.022%	–$533,375.9
2019	0.023%	–0.022%	–$541,909.0
2020	0.023%	–0.022%	–$550,442.1
2021	0.023%	–0.022%	–$558,975.1
2022	0.023%	–0.022%	–$567,508.0
2023	0.023%	–0.022%	–$576,041.0
2024	0.023%	–0.022%	–$584,573.9
2025	0.023%	–0.022%	–$593,106.8
2026	0.023%	–0.022%	–$601,622.0
2027	0.023%	–0.022%	–$610,137.1
2028	0.023%	–0.022%	–$618,652.2
2029	0.023%	–0.022%	–$627,167.4
2030	0.023%	–0.022%	–$635,682.5
	AVG	AVG	NPV[b]
	0.020%	–0.019%	–$6,923,515.6

[a] Figures are in 2001 dollars.
[b] Net present values are calculated using a social discount rate of 3 percent over the 2004 to 2030 time period.

Table 10C-3. Impacts on Manufacturing Application Market and Manufacturing Producers and Consumers[a]

Year	Manufacturing: Change in Price (%)	Manufacturing: Change in Quantity (%)	Change in Producer and Consumer Surplus ($$10^3$)
2007	0.003%	–0.002%	–$111,732.2
2008	0.004%	–0.002%	–$148,130.8
2009	0.004%	–0.002%	–$150,298.2
2010	0.004%	–0.003%	–$181,349.6
2011	0.005%	–0.003%	–$222,767.7
2012	0.008%	–0.004%	–$316,540.3
2013	0.010%	–0.006%	–$414,805.7
2014	0.010%	–0.006%	–$428,962.5
2015	0.009%	–0.005%	–$388,563.0
2016	0.009%	–0.005%	–$412,018.5
2017	0.009%	–0.005%	–$418,249.7
2018	0.009%	–0.005%	–$424,459.7
2019	0.009%	–0.005%	–$430,700.7
2020	0.009%	–0.005%	–$436,821.7
2021	0.009%	–0.005%	–$443,264.9
2022	0.009%	–0.005%	–$449,719.9
2023	0.009%	–0.005%	–$456,187.1
2024	0.009%	–0.005%	–$462,666.7
2025	0.009%	–0.005%	–$469,158.8
2026	0.009%	–0.005%	–$475,656.2
2027	0.009%	–0.005%	–$482,166.5
2028	0.009%	–0.005%	–$488,690.2
2029	0.009%	–0.005%	–$495,227.3
2030	0.009%	–0.005%	–$501,778.2
	AVG	AVG	NPV[b]
	0.008%	–0.005%	–$5,770,293.9

[a] Figures are in 2001 dollars.
[b] Net present values are calculated using a social discount rate of 3 percent over the 2004 to 2030 time period.

APPENDIX 10D: Impacts on the Nonroad Fuel Market

This appendix provides the time series of impacts from 2007 through 2030 for the nonroad diesel fuel market. Eight nonroad diesel fuel markets were modeled: 2 sulfur content levels (15 ppm and 500 ppm) for each of 4 PADDs (PADDs 1&3, PADD 2, PADD 4, and PADD 5). It should be noted that PADD 5 includes Alaska and Hawaii.

Tables 10D-1 through 10D-4 provide the time series of impacts for the diesel fuel market for the four regional fuel markets. Each table includes the following:

- average price per gallon,
- average engineering costs (variable and fixed) per gallon,
- absolute change in the PADDs' nonroad diesel price ($),
  - Note that the estimated absolute change in market price is based on average variable and fixed costs; see Appendix I for sensitivity analyses reflecting maximum total costs and maximum variable costs
- relative change in the PADDs' nonroad diesel price (%),
- relative change in the PADDs' nonroad diesel quantity (%),
- total engineering (regulatory) costs associated with each PADD's fuel market ($), and
- change in producer surplus for all fuel producers.

About 60 to 65 percent of high-sulfur diesel fuel is consumed by nonroad diesel equipment, the other 35 to 40 percent is consumed by marine equipment and locomotive engines. The engineering costs and changes in producer surplus presented in this appendix include both of these diesel fuel segments.

All prices and costs are presented in $2001, and the real per-gallon prices are assumed to be constant within each regional fuel market. Initially, nonroad diesel equipment, locomotive, and marine engines are included in the 500 ppm market. As the proposed rule phases in 2010, nonroad equipment switches to the 15 ppm market. The engineering compliance costs are greater to refine 15 ppm (4.6 cents/gal) compared to 500 ppm (2.6 cents/gal), thus the price change in the 15 ppm market is greater than in the 500 ppm market.

For each regional fuel market, the majority of the cost of the regulation is passed along through increased fuel prices. Price increases for the 15 ppm market are about an average of 6.24 percent per gallon in each regional fuel market. Even though the cost per engine and market impacts (in terms of percentage change in price and quantity) stabilize within the first few years of the regulation, the engineering costs and producer surplus changes continue to gradually increase because the projected consumption of diesel fuel increases over time.

Table 10D-1. Impacts on the Nonroad Fuel Market in PADD 1&3 (Average Price per Gallon = $0.9199)[a]

	15ppm PADD 1&3					500ppm PADD 1&3					Change in Producer Surplus for Fuel Producers ($10^6^)
Year	Engineering Cost/Unit	Absolute Change in Price	Change in Price (%)	Change in Quantity (%)	Total Engineering Costs ($10⁶)	Engineering Cost/Unit	Absolute Change in Price	Change in Price (%)	Change in Quantity (%)	Total Engineering Costs ($10⁶)	
2007		—	0.00%	0.000%	—	$0.0209	$0.02	1.64%	–0.002%	$69.8	–$0.4
2008		—	0.00%	0.000%	—	$0.0209	$0.02	1.64%	–0.003%	$71.1	–$0.5
2009		—	0.00%	0.000%	—	$0.0209	$0.02	1.64%	–0.003%	$72.4	–$0.6
2010	$0.0301	$0.03	3.25%	–0.006%	$97.9	$0.0159	$0.02	1.72%	–0.003%	$25.4	–$0.9
2011	$0.0301	$0.03	3.23%	–0.011%	$100.1	$0.0159	$0.02	1.71%	–0.003%	$25.8	–$1.6
2012	$0.0301	$0.03	3.21%	–0.016%	$102.2	$0.0159	$0.02	1.71%	–0.005%	$26.0	–$2.4
2013	$0.0301	$0.03	3.20%	–0.017%	$104.4	$0.0159	$0.02	1.70%	–0.006%	$26.1	–$2.7
2014	$0.0301	$0.03	3.20%	–0.018%	$106.6	$0.0159	$0.02	1.70%	–0.006%	$26.3	–$2.9
2015	$0.0301	$0.03	3.20%	–0.017%	$108.8	$0.0159	$0.02	1.70%	–0.006%	$26.5	–$2.8
2016	$0.0301	$0.03	3.20%	–0.018%	$111.0	$0.0159	$0.02	1.70%	–0.006%	$26.8	–$2.9
2017	$0.0301	$0.03	3.20%	–0.018%	$113.1	$0.0159	$0.02	1.70%	–0.006%	$27.0	–$2.9
2018	$0.0301	$0.03	3.20%	–0.018%	$115.3	$0.0159	$0.02	1.70%	–0.006%	$27.2	–$3.0
2019	$0.0301	$0.03	3.20%	–0.018%	$117.4	$0.0159	$0.02	1.70%	–0.006%	$27.4	–$3.0
2020	$0.0301	$0.03	3.20%	–0.018%	$119.6	$0.0159	$0.02	1.70%	–0.006%	$27.6	–$3.1
2021	$0.0301	$0.03	3.20%	–0.018%	$121.8	$0.0159	$0.02	1.70%	–0.006%	$27.9	–$3.1
2022	$0.0301	$0.03	3.20%	–0.018%	$123.9	$0.0159	$0.02	1.70%	–0.006%	$28.2	–$3.2
2023	$0.0301	$0.03	3.20%	–0.018%	$126.1	$0.0159	$0.02	1.70%	–0.006%	$28.4	–$3.2
2024	$0.0301	$0.03	3.20%	–0.018%	$128.3	$0.0159	$0.02	1.70%	–0.006%	$28.7	–$3.3
2025	$0.0301	$0.03	3.20%	–0.018%	$130.4	$0.0159	$0.02	1.70%	–0.006%	$29.0	–$3.3
2026	$0.0301	$0.03	3.20%	–0.018%	$132.6	$0.0159	$0.02	1.70%	–0.006%	$29.3	–$3.4
2027	$0.0301	$0.03	3.20%	–0.018%	$134.7	$0.0159	$0.02	1.70%	–0.006%	$29.6	–$3.4
2028	$0.0301	$0.03	3.20%	–0.018%	$136.9	$0.0159	$0.02	1.70%	–0.006%	$29.9	–$3.5
2029	$0.0301	$0.03	3.20%	–0.018%	$139.0	$0.0159	$0.02	1.70%	–0.006%	$30.2	–$3.5
2030	$0.0301	$0.03	3.20%	–0.018%	$141.2	$0.0159	$0.02	1.70%	–0.006%	$30.5	–$3.6
NPV[b]			2.802%		$1,559.2			1.697%		$555.7	–$39.0

[a] Figures are in 2001 dollars.

[b] Net present values are calculated using a social discount rate of 3 percent over the 2004 to 2030 time period.

Table 10D-2. Impacts on the Nonroad Fuel Market in PADD 2 (Average Price per Gallon = $0.9399)[a]

	15ppm PADD 2					500ppm PADD 2					
Year	**Engineering Cost/Unit**	**Absolute Change in Price**	**Change in Price (%)**	**Change in Quantity (%)**	**Total Engineering Costs ($10⁶)**	**Engineering Cost/Unit**	**Absolute Change in Price**	**Change in Price (%)**	**Change in Quantity (%)**	**Total Engineering Costs ($10⁶)**	**Change in Producer Surplus for Fuel Producers ($10⁶)**
2007		—	0.00%	0.000%	—	$0.0415	$0.03	3.19%	–0.002%	$96.6	–$0.3
2008		—	0.00%	0.000%	—	$0.0415	$0.03	3.19%	–0.003%	$98.3	–$0.4
2009		—	0.00%	0.000%	—	$0.0415	$0.03	3.19%	–0.003%	$100.1	–$0.4
2010	$0.0611	$0.06	6.48%	–0.006%	$132.8	$0.0357	$0.04	3.79%	–0.003%	$43.2	–$0.6
2011	$0.0611	$0.06	6.45%	–0.012%	$135.7	$0.0357	$0.04	3.78%	–0.003%	$43.9	–$1.2
2012	$0.0611	$0.06	6.43%	–0.016%	$138.7	$0.0357	$0.04	3.78%	–0.005%	$44.2	–$1.7
2013	$0.0611	$0.06	6.43%	–0.018%	$141.7	$0.0357	$0.04	3.77%	–0.006%	$44.5	–$1.9
2014	$0.0611	$0.06	6.42%	–0.019%	$144.6	$0.0357	$0.04	3.77%	–0.006%	$44.7	–$2.1
2015	$0.0611	$0.06	6.43%	–0.018%	$147.6	$0.0357	$0.04	3.77%	–0.006%	$45.1	–$1.9
2016	$0.0611	$0.06	6.43%	–0.018%	$150.5	$0.0357	$0.04	3.77%	–0.006%	$45.5	–$2.0
2017	$0.0611	$0.06	6.43%	–0.018%	$153.4	$0.0357	$0.04	3.77%	–0.006%	$45.9	–$2.1
2018	$0.0611	$0.06	6.43%	–0.018%	$156.4	$0.0357	$0.04	3.77%	–0.006%	$46.3	–$2.1
2019	$0.0611	$0.06	6.43%	–0.018%	$159.3	$0.0357	$0.04	3.77%	–0.006%	$46.7	–$2.1
2020	$0.0611	$0.06	6.43%	–0.018%	$162.3	$0.0357	$0.04	3.77%	–0.006%	$47.0	–$2.2
2021	$0.0611	$0.06	6.43%	–0.018%	$165.2	$0.0357	$0.04	3.77%	–0.006%	$47.4	–$2.2
2022	$0.0611	$0.06	6.43%	–0.018%	$168.1	$0.0357	$0.04	3.77%	–0.006%	$47.9	–$2.2
2023	$0.0611	$0.06	6.43%	–0.018%	$171.1	$0.0357	$0.04	3.77%	–0.006%	$48.4	–$2.3
2024	$0.0611	$0.06	6.43%	–0.018%	$174.0	$0.0357	$0.04	3.77%	–0.006%	$48.9	–$2.3
2025	$0.0611	$0.06	6.43%	–0.018%	$176.9	$0.0357	$0.04	3.77%	–0.006%	$49.4	–$2.4
2026	$0.0611	$0.06	6.43%	–0.018%	$179.8	$0.0357	$0.04	3.77%	–0.006%	$49.9	–$2.4
2027	$0.0611	$0.06	6.43%	–0.018%	$182.8	$0.0357	$0.04	3.77%	–0.006%	$50.4	–$2.4
2028	$0.0611	$0.06	6.43%	–0.018%	$185.7	$0.0357	$0.04	3.77%	–0.006%	$50.9	–$2.5
2029	$0.0611	$0.06	6.43%	–0.018%	$188.6	$0.0357	$0.04	3.77%	–0.006%	$51.4	–$2.5
2030	$0.0611	$0.06	6.43%	–0.018%	$191.5	$0.0357	$0.04	3.77%	–0.006%	$51.9	–$2.5
NPV[b]			5.626%		$2,115.0			3.702%		$885.1	–$27.7

[a] Figures are in 2001 dollars.

[b] Net present values are calculated using a social discount rate of 3 percent over the 2004 to 2030 time period.

Table 10D-3. Impacts on the Nonroad Fuel Market in PADD 4 (Average Price per Gallon = $0.9499)[a]

	15ppm PADD 4					500ppm PADD 4					
Year	Engineering Cost/Unit	Absolute Change in Price	Change in Price (%)	Change in Quantity (%)	Total Engineering Costs ($10^6)	Engineering Cost/Unit	Absolute Change in Price	Change in Price (%)	Change in Quantity (%)	Total Engineering Costs ($10^6)	Change in Producer Surplus for Fuel Producers ($10^6)
2007		—	0.00%	0.000%	—	$0.0371	$0.04	4.33%	–0.002%	$34.0	–$0.1
2008		—	0.00%	0.000%	—	$0.0371	$0.04	4.33%	–0.003%	$34.4	–$0.1
2009		—	0.00%	0.000%	—	$0.0371	$0.04	4.33%	–0.003%	$34.9	–$0.1
2010	$0.0891	$0.09	9.35%	–0.006%	$25.3	$0.0336	$0.03	3.52%	–0.003%	$19.3	–$0.1
2011	$0.0891	$0.09	9.33%	–0.012%	$25.9	$0.0336	$0.03	3.52%	–0.003%	$19.5	–$0.2
2012	$0.0891	$0.09	9.31%	–0.017%	$26.4	$0.0336	$0.03	3.52%	–0.005%	$19.7	–$0.3
2013	$0.0891	$0.09	9.30%	–0.018%	$27.0	$0.0336	$0.03	3.51%	–0.006%	$19.8	–$0.4
2014	$0.0891	$0.09	9.30%	–0.020%	$27.6	$0.0336	$0.03	3.51%	–0.006%	$19.9	–$0.4
2015	$0.0891	$0.09	9.30%	–0.019%	$28.1	$0.0336	$0.03	3.51%	–0.006%	$20.1	–$0.4
2016	$0.0891	$0.09	9.30%	–0.019%	$28.7	$0.0336	$0.03	3.51%	–0.006%	$20.3	–$0.4
2017	$0.0891	$0.09	9.30%	–0.019%	$29.2	$0.0336	$0.03	3.51%	–0.006%	$20.5	–$0.4
2018	$0.0891	$0.09	9.30%	–0.019%	$29.8	$0.0336	$0.03	3.51%	–0.006%	$20.6	–$0.4
2019	$0.0891	$0.09	9.30%	–0.019%	$30.4	$0.0336	$0.03	3.51%	–0.006%	$20.8	–$0.4
2020	$0.0891	$0.09	9.30%	–0.019%	$30.9	$0.0336	$0.03	3.51%	–0.006%	$20.9	–$0.4
2021	$0.0891	$0.09	9.30%	–0.019%	$31.5	$0.0336	$0.03	3.51%	–0.006%	$21.1	–$0.4
2022	$0.0891	$0.09	9.30%	–0.019%	$32.0	$0.0336	$0.03	3.51%	–0.006%	$21.4	–$0.4
2023	$0.0891	$0.09	9.30%	–0.019%	$32.6	$0.0336	$0.03	3.51%	–0.006%	$21.6	–$0.4
2024	$0.0891	$0.09	9.30%	–0.019%	$33.2	$0.0336	$0.03	3.51%	–0.006%	$21.8	–$0.4
2025	$0.0891	$0.09	9.30%	–0.019%	$33.7	$0.0336	$0.03	3.51%	–0.006%	$22.0	–$0.4
2026	$0.0891	$0.09	9.30%	–0.019%	$34.3	$0.0336	$0.03	3.51%	–0.006%	$22.2	–$0.4
2027	$0.0891	$0.09	9.30%	–0.019%	$34.8	$0.0336	$0.03	3.51%	–0.006%	$22.5	–$0.4
2028	$0.0891	$0.09	9.30%	–0.019%	$35.4	$0.0336	$0.03	3.51%	–0.006%	$22.7	–$0.5
2029	$0.0891	$0.09	9.30%	–0.019%	$35.9	$0.0336	$0.03	3.51%	–0.006%	$22.9	–$0.5
2030	$0.0891	$0.09	9.30%	–0.019%	$36.5	$0.0336	$0.03	3.51%	–0.006%	$23.1	–$0.5
NPV[b]			8.142%		$403.0			3.615%		$369.3	–$5.2

[a] Figures are in 2001 dollars.

[b] Net present values are calculated using a social discount rate of 3 percent over the 2004 to 2030 time period.

Table 10D-4. Impacts on the Nonroad Fuel Market in PADD 5 (Average Price per Gallon = $0.9599)[a]

	15ppm PADD 5					500ppm PADD 5					Change in Producer Surplus for Fuel Producers ($10^6^)
Year	Engineering Cost/Unit	Absolute Change in Price	Change in Price (%)	Change in Quantity (%)	Total Engineering Costs ($$10^6$)	Engineering Cost/Unit	Absolute Change in Price	Change in Price (%)	Change in Quantity (%)	Total Engineering Costs ($$10^6$)	
2007		—	0.00%	0.000%	—	$0.0344	$0.03	2.64%	–0.002%	$15.7	–$0.1
2008		—	0.00%	0.000%	—	$0.0344	$0.03	2.63%	–0.003%	$16.0	–$0.1
2009		—	0.00%	0.000%	—	$0.0344	$0.03	2.63%	–0.003%	$16.3	–$0.1
2010	$0.0586	$0.06	6.08%	–0.006%	$27.3	$0.0217	$0.02	2.25%	–0.003%	$4.1	–$0.1
2011	$0.0586	$0.06	6.06%	–0.012%	$27.9	$0.0217	$0.02	2.25%	–0.003%	$4.1	–$0.3
2012	$0.0586	$0.06	6.03%	–0.017%	$28.5	$0.0217	$0.02	2.24%	–0.005%	$4.2	–$0.4
2013	$0.0586	$0.06	6.03%	–0.018%	$29.1	$0.0217	$0.02	2.23%	–0.006%	$4.2	–$0.4
2014	$0.0586	$0.06	6.02%	–0.019%	$29.7	$0.0217	$0.02	2.23%	–0.006%	$4.2	–$0.4
2015	$0.0586	$0.06	6.03%	–0.018%	$30.3	$0.0217	$0.02	2.24%	–0.006%	$4.2	–$0.4
2016	$0.0586	$0.06	6.03%	–0.019%	$30.9	$0.0217	$0.02	2.24%	–0.006%	$4.3	–$0.4
2017	$0.0586	$0.06	6.03%	–0.019%	$31.5	$0.0217	$0.02	2.24%	–0.006%	$4.3	–$0.4
2018	$0.0586	$0.06	6.03%	–0.019%	$32.1	$0.0217	$0.02	2.24%	–0.006%	$4.4	–$0.5
2019	$0.0586	$0.06	6.03%	–0.019%	$32.7	$0.0217	$0.02	2.24%	–0.006%	$4.4	–$0.5
2020	$0.0586	$0.06	6.03%	–0.019%	$33.3	$0.0217	$0.02	2.24%	–0.006%	$4.4	–$0.5
2021	$0.0586	$0.06	6.03%	–0.019%	$33.9	$0.0217	$0.02	2.24%	–0.006%	$4.5	–$0.5
2022	$0.0586	$0.06	6.03%	–0.019%	$34.5	$0.0217	$0.02	2.24%	–0.006%	$4.5	–$0.5
2023	$0.0586	$0.06	6.03%	–0.019%	$35.1	$0.0217	$0.02	2.24%	–0.006%	$4.6	–$0.5
2024	$0.0586	$0.06	6.03%	–0.019%	$35.7	$0.0217	$0.02	2.24%	–0.006%	$4.6	–$0.5
2025	$0.0586	$0.06	6.03%	–0.019%	$36.3	$0.0217	$0.02	2.24%	–0.006%	$4.6	–$0.5
2026	$0.0586	$0.06	6.03%	–0.019%	$36.9	$0.0217	$0.02	2.24%	–0.006%	$4.7	–$0.5
2027	$0.0586	$0.06	6.03%	–0.019%	$37.5	$0.0217	$0.02	2.24%	–0.006%	$4.7	–$0.5
2028	$0.0586	$0.06	6.03%	–0.019%	$38.1	$0.0217	$0.02	2.24%	–0.006%	$4.8	–$0.5
2029	$0.0586	$0.06	6.03%	–0.019%	$38.7	$0.0217	$0.02	2.24%	–0.006%	$4.8	–$0.5
2030	$0.0586	$0.06	6.03%	–0.018%	$39.3	$0.0217	$0.02	2.24%	–0.006%	$4.9	–$0.5
NPV[b]			5.278%		$434.3			2.287%		$101.1	–$6.0

[a] Figures are in 2001 dollars.

[b] Net present values are calculated using a social discount rate of 3 percent over the 2004 to 2030 time period.

APPENDIX 10E: Time Series of Social Cost

This appendix provides a time series of the estimated social costs for the proposed program for the period 2007 through 2030. Costs are presented in 2001 dollars.

Table 10E-1. Time Series of Market Impacts

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Engine Producers Total	$0.0	$14.0	$14.0	$14.0	$23.5	$29.4	$30.2	$35.6	$35.6	$25.5	$20.3	$5.5
Equipment Producers Total	$0.5	$8.9	$9.0	$9.5	$73.0	$106.2	$116.1	$144.0	$143.8	$124.9	$119.8	$111.3
Construction Equipment	$0.4	$2.0	$2.0	$2.4	$35.1	$50.1	$53.0	$67.8	$67.7	$57.5	$54.9	$53.2
Agricultural Equipment	$0.1	$2.4	$2.4	$2.6	$27.7	$37.0	$39.9	$49.2	$49.1	$41.0	$39.1	$36.5
Industrial Equipment	$0.1	$4.5	$4.5	$4.6	$10.2	$19.0	$23.2	$27.1	$27.0	$26.4	$25.8	$21.7
Application Producers & Consumers Total	$214.3	$280.4	$285.5	$433.4	$749.7	$1,069.3	$1,231.8	$1,322.1	$1,246.4	$1,302.6	$1,323.6	$1,344.6
Total Producer	*$86.7*	*$113.0*	*$115.2*	*$178.6*	*$315.7*	*$451.7*	*$515.7*	*$555.1*	*$525.1*	*$548.0*	*$556.9*	*$565.7*
Total Consumer	*$127.7*	*$167.3*	*$170.4*	*$254.8*	*$434.0*	*$617.6*	*$716.1*	*$767.0*	*$721.3*	*$754.6*	*$766.7*	*$778.8*
Construction	$58.7	$74.4	$76.1	$143.1	$297.5	$437.6	$468.3	$515.6	$499.9	$516.3	$524.8	$533.4
Agriculture	$44.0	$57.9	$59.2	$108.9	$229.4	$315.2	$348.7	$377.5	$358.0	$374.3	$380.5	$386.7
Manufacturing	$111.7	$148.1	$150.3	$181.3	$222.8	$316.5	$414.8	$429.0	$388.6	$412.0	$418.2	$424.5
Fuel Producers Total	$1.2	$1.5	$1.6	$2.6	$4.8	$6.9	$7.8	$8.4	$8.0	$8.4	$8.5	$8.7
PADD 1&3	$0.5	$0.7	$0.7	$1.2	$2.2	$3.2	$3.6	$3.9	$3.7	$3.9	$3.9	$4.0
PADD 2	$0.4	$0.6	$0.6	$0.9	$1.8	$2.6	$2.9	$3.1	$2.9	$3.1	$3.1	$3.2
PADD 4	$0.1	$0.2	$0.2	$0.3	$0.5	$0.7	$0.8	$0.9	$0.8	$0.8	$0.9	$0.9
PADD 5	$0.1	$0.1	$0.1	$0.2	$0.3	$0.5	$0.5	$0.6	$0.6	$0.6	$0.6	$0.6
Change in Market Surplus ($\$10^6$/yr)	$216.1	$304.8	$310.0	$459.5	$851.0	$1,211.8	$1,385.8	$1,510.1	$1,433.9	$1,461.4	$1,472.2	$1,470.1
NR Spillover	$44.8	$45.8	$46.9	$48.0	$49.0	$50.1	$51.2	$52.3	$53.3	$54.4	$55.5	$56.5
Operating and Marker Costs ($\$10^6$/yr)	–$221.3	–$220.3	–$224.7	–$245.5	–$259.0	–$251.6	–$234.6	–$233.4	–$226.6	–$217.5	–$209.0	–$201.7
Social Costs ($\$10^6$/yr)	$39.6	$130.4	$132.2	$262.00	$641.1	$1,010.3	$1,202.4	$1,329.0	$1,260.6	$1,298.3	$1,318.6	$1,324.9

(continued)

Table 10E-1. Time Series of Market Impacts (continued)

	2019	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Engine Producers Total	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1
Equipment Producers Total	$102.6	$102.6	$60.3	$32.9	$23.6	$4.9	$5.0	$5.1	$5.1	$5.2	$5.3	$5.3
Construction Equipment	$48.2	$48.2	$27.4	$15.3	$12.9	$3.5	$3.6	$3.6	$3.7	$3.7	$3.8	$3.8
Agricultural Equipment	$33.2	$33.2	$17.0	$9.5	$7.1	$1.2	$1.2	$1.2	$1.3	$1.3	$1.3	$1.3
Industrial Equipment	$21.2	$21.2	$16.0	$8.1	$3.6	$0.2	$0.2	$0.2	$0.2	$0.2	$0.2	$0.2
Application Producers & Consumers Total	$1,365.6	$1,386.5	$1,407.7	$1,428.9	$1,450.1	$1,471.4	$1,492.6	$1,513.9	$1,535.1	$1,556.4	$1,577.7	$1,598.9
Total Producer	*$574.6*	*$583.4*	*$592.3*	*$601.3*	*$610.2*	*$619.2*	*$628.2*	*$637.1*	*$646.1*	*$655.1*	*$664.0*	*$672.9*
Total Consumer	*$791.0*	*$803.1*	*$815.3*	*$827.6*	*$839.9*	*$852.2*	*$864.5*	*$876.8*	*$889.1*	*$901.4*	*$913.7*	*$926.0*
Construction	$541.9	$550.4	$559.0	$567.5	$576.0	$584.6	$593.1	$601.6	$610.1	$618.7	$627.2	$635.7
Agriculture	$393.0	$399.2	$405.4	$411.7	$417.9	$424.1	$430.4	$436.6	$442.8	$449.0	$455.3	$461.5
Manufacturing	$430.7	$436.8	$443.3	$449.7	$456.2	$462.7	$469.2	$475.7	$482.2	$488.7	$495.2	$501.8
Fuel Producers Total	$8.8	$9.0	$9.1	$9.3	$9.4	$9.6	$9.7	$9.9	$10.0	$10.2	$10.3	$10.5
PADD 1&3	$4.1	$4.1	$4.2	$4.3	$4.3	$4.4	$4.5	$4.5	$4.6	$4.7	$4.7	$4.8
PADD 2	$3.2	$3.3	$3.4	$3.4	$3.5	$3.5	$3.6	$3.6	$3.7	$3.7	$3.8	$3.9
PADD 4	$0.9	$0.9	$0.9	$0.9	$0.9	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0	$1.0
PADD 5	$0.6	$0.6	$0.7	$0.7	$0.7	$0.7	$0.7	$0.7	$0.7	$0.7	$0.7	$0.8
Change in Market Surplus ($\$10^6$/yr)	$1,477.1	$1,498.2	$1,477.2	$1,471.2	$1,483.3	$1,486.0	$1,507.5	$1,528.9	$1,550.4	$1,571.9	$1,593.4	$1,614.9
NR Spillover	$57.6	$58.6	$59.7	$60.8	$61.8	$62.9	$63.9	$65.0	$66.0	$67.1	$68.1	$69.2
Operating and Marker Costs ($\$10^6$/yr)	–$195.5	–$190.1	–$185.9	–$182.5	–$179.7	–$177.4	–$175.6	–$174.3	–$173.7	–$173.7	–$174.0	–$174.5
Social Costs ($\$10^6$/yr)	$1,339.2	$1,366.7	$1,350.9	$1,349.4	$1,365.4	$1,371.5	$1,395.8	$1,419.6	$1,442.8	$1,465.3	$1,487.5	$1,509.6

APPENDIX 10F: Model Equations

To enhance understanding of the economic model EPA used in this report, additional details about the model's structure are provided in this appendix. The equations describing supply, final demand, and intermediate (i.e., derived) demand relationships are presented below along with a brief description of the solution algorithm.

10F.1 Model Equations

A constant-elasticity functional form was selected for all supply and final demand functions. The general form and description of these equations are presented below:

$$\text{Supply Equation: } Q_x = a(P_x - \Delta c - \Delta c_y)^{\varepsilon} \tag{10F.1}$$

$$\text{Final Demand Equation: } Q_x = aP_x^{\eta} \tag{10F.2}$$

where

x	=	production output,
y	=	production input,
Q_x	=	quantity of output (x) supplied or demanded,
P_x	=	market price for output (x),
a	=	constant,
Δc	=	direct supply shift ($/$Q_x$),
Δc_y	=	indirect supply shift resulting from change in the price of input y, and
ε,η	=	these parameters can be interpreted as the own-price elasticity of supply/demand for the economic agent (see Tables 10.3-12 and 10.3-13 for values of these parameters).

With this choice of functional form, the supply and demand elasticities are assumed to remain constant over the range of output affected by the regulation. This can be demonstrated by applying the definition of own-price elasticity of demand:

$$\frac{dq}{dp} \bullet \frac{p}{q} = \mathrm{E}ap^{(1-\varepsilon)} \bullet \frac{p^{(1-\varepsilon)}}{a} = \varepsilon. \tag{10F.3}$$

The intermediate input (Q_y) demands is specified within the supply chain as a function of output (Q_x). The subscript "0" denotes baseline and the subscript "1" denotes with regulation.

$$\text{Derived Demand Equation: } Q_y = f(Q_x) \tag{10F.4a}$$

$$Q_{y1} = Q_{y0}(1+\Delta Q_x/Q_x) \tag{10F.4b}$$

Computing Supply/Demand Function Constants. Using the baseline price, quantity, and elasticity parameter, the value of the constants can be computed. For example, supply function constants can be calculated as follows:

$$\text{Constant Calibration: } a = \frac{Q_{x0}}{(P_{x0})^{\varepsilon}} \qquad (10F.5)$$

Direct Supply Shift (Dc). The direct upward shift in the supply function is calculated by using the annualized compliance cost estimates provided by the engineering cost analysis. Computing the supply shift in this manner treats the compliance costs as the conceptual equivalent of a unit tax on output.

Indirect Supply Shift (Dc_y). The indirect upward shift in the supply function is calculated by using the change in input (y) prices (i.e., engines, equipment, and/or fuel) that result from the direct compliance costs introduced into the model. Only two types of suppliers are affected by these changes: equipment producers that use diesel engines and application markets that use equipment with diesel engines and diesel fuel. The term Dc_y is computed as follows:

$$\Delta c_y = \frac{\Delta P_y \bullet Q_{y0}}{Q_{x0}}. \qquad (10F.6)$$

10F.2 Engine Markets

As described in Section 10.3.3.1, seven separate engine markets were modeled segmented by engine size in horsepower (the EIA includes more horsepower categories than the standards, allowing more efficient use of the engine compliance cost estimates developed for this proposal):

- less than 25 hp,
- 26 to 50 hp,
- 51 to 75 hp,
- 76 to 100 hp,
- 101 to 175 hp,
- 176 to 600 hp, and
- greater than 601 hp.

In each of these engine markets, there are three types of suppliers: captive suppliers (engines are consumed internally by integrated equipment manufacturers), merchant suppliers (engines are sold on the open market), and foreign suppliers. These supply segments are represented by upward-sloping supply functions. On the demand side, consumers of engines include integrated and nonintegrated equipment manufacturers[L] and are represented by derived demand functions (Eqs. [104a] and [10F.4b]).

Captive Domestic Supply Equation: $$S_{engcap} = a_1(p - c)^{\varepsilon} \qquad (10F.7)$$

Merchant Domestic Supply Equation: $$S_{engmer} = a_2(p - c)^{\varepsilon} \qquad (10F.8)$$

[L]Note that engines sold to foreign equipment manufacturers are not included in the domestic engine market because they are subject to different (foreign) environmental regulations and hence are considered different products.

Import Supply Equation: $M_{eng} = a(p - c)^{\varepsilon}$ (10F.9)

Integrated Demand Equation: $D_I = S\,(S_{equip})$ (10F.10)

Nonintegrated Demand Equation: $D_{NI} = S(S_{equip})$ (10F.11)

Market Clearing Condition: $S_{engcap} + S_{engmer} + M_{eng} = D_I + D_{NI}$ (10F.12)

10F.3 Equipment Markets

As described in Section 10.3.3.2, integrated and nonintegrated equipment manufacturers supply their products into a series of 42 equipment markets (7 horsepower categories within 7 application categories; there are 7 horsepower/application categories that did not have sales in 2000 and are not included in the model,[M] so the total number of diesel equipment markets is 42, not 49). The equipment types are:

- construction
- agricultural,
- refrigeration
- generators and welder sets
- lawn and garden
- pumps and compressors
- general industrial

Each individual equipment market is comprised of two aggregate suppliers groups: (1) domestic integrated suppliers that produce and consume their own engines (captive engines) and (2) domestic nonintegrated suppliers that purchase engines from the open market to be used in their equipment (merchant engines).

On the demand side, each of the 42 equipment markets is linked to one of three application markets (construction, agricultural, and manufacturers) is represented by derived demand functions (Eq. [10F.4a and 10F.4b])

Domestic Integrated Supply Equation: $S_{eqI} = a(p - c)^{\varepsilon}$ (10F.13)

Domestic Nonintegrated Supply Equation: $S_{eqNI} = a(p - c - c_y)^{\varepsilon}$ (10F.14)

Domestic Demand Equation: $D_{eq} = \sum Q_{eq}\left(1 + \frac{\Delta Q_{qpp}}{Q_{qpp0}}\right)$ (10F.15)

Market Clearing Condition: $S_{eqI} + S_{eqNI} = D_{eq}$ (10F.16)

10F.4 Application Markets

As described in Section 10.3.3.3, there are three application markets that supply products and services to consumers:

[M] These are: agricultural equipment >600 hp; gensets & welders > 600 hp; refrigeration & A/C > 71 hp (4 hp categories); and lawn & garden >600 hp.

- construction
- agricultural, and
- manufacturing.

The supply in each of these three application markets is the sum of a domestic supply and an foreign (import) supply. The consumers in the application markets are represented by a domestic demand and a foreign (export) demand function.

Supply Equation: $S_{app} = a(p_{app} - \beta_0 \Delta \mathbf{P}_{eq} - \beta_1 \Delta P_{fuel})^{\varepsilon}$ (10F.17)

Foreign (Import) Supply Equation: $M_{app} = ap_{app}\varepsilon$ (10F.18)

Domestic Demand Equation: $D_{app} = ap^{\eta}$ (10F.19)

Foreign (Export) Demand Equation: $X_{app} = ap^{\eta}$ (10F.20)

Market Clearing Condition: $S_{app} + M_{app} = D_{app} + X_{app}$ (10F.21)

β_0 and β_1 are the baseline input shares of equipment $\left(\frac{Q_{eq0}}{Q_{app0}}\right)$ and fuel $\left(\frac{Q_{fuel0}}{Q_{app0}}\right)$.

10F.5 Fuel Markets

As described in Section 10.3.3.4, eight nonroad diesel fuel markets were modeled: two distinct nonroad diesel fuel commodities in four regional markets. The two fuels are:

- 500 ppm nonroad diesel fuel, and
- 15 ppm nonroad diesel fuel.

The four regional nonroad diesel fuel markets are
- PADD 1 and 3,
- PADD 2,
- PADD 4, and
- PADD 5 (includes Alaska and Hawaii)

The supply and demand for nonroad diesel fuel is specified for the model for four regional diesel fuel markets. Derived demand of diesel fuel comes from three application markets. The equations for PADD district j are specified below:

Supply Equation: $S_j = a(P_j - \Delta c)\varepsilon$ (10F.22)

Derived Demand Equation: $D_j = \Sigma Q_{j0}\left(1 + \frac{\Delta Q_{app}}{Q_{app0}}\right)$ (10F.23)

Market Clearing Condition: $S_j = D_j$ (10F.24)

10F.6 Market-Clearing Process and Equations

Supply responses and market adjustments can be conceptualized as an interactive process. Producers facing increased production costs due to compliance with the control program are willing to supply smaller quantities at the baseline price. This reduction in market supply leads to an increase in the market price that all producers and consumers face, which leads to further responses by producers and consumers and thus new market prices, and so on. The new with-regulation equilibrium is the result of a series of iterations in which price is adjusted and producers and consumers respond, until a set of stable market prices arises where total market supply equals market demand.

$$\text{Market-Clearing Equation: Total Supply} = \text{Total Demand.} \qquad (10F.25)$$

The algorithm for determining with-regulation equilibria can be summarized by six recursive steps:

1. Impose the control costs on affected supply segments, thereby affecting their supply decisions.
2. Recalculate the market supply in each market. Excess demand currently exists.
3. Determine the new prices via a price revision rule. A rule similar to the factor price revision rule described by Kimbell and Harrison (1986) is used. P_i is the market price at iteration i, q_d is the quantity demanded, and q_s is the quantity supplied. The parameter z influences the magnitude of the price revision and speed of convergence. The revision rule increases the price when excess demand exists, lowers the price when excess supply exists, and leaves the price unchanged when market demand equals market supply. The price adjustment is expressed as follows:

$$P_{i+1} = P_1 \bullet \left(\frac{q_d}{q_s}\right)^z \qquad (10F.26)$$

4. Recalculate market supply with new prices, accounting for fuel-switching choices associated with new energy prices.
5. Compute market demand in each market.
6. Compare supply and demand in each market. If equilibrium conditions are not satisfied, go to Step 3, resulting in a new set of market prices. Repeat until equilibrium conditions are satisfied (i.e., the ratio of supply and demand is arbitrarily close to one).

APPENDIX 10G: Elasticity Parameters for Economic Impact Modeling

The Nonroad Diesel Economic Impact Model (NDEIM) relies on elasticity parameters to estimate the behavioral response of consumers and producers to the implementation of the proposed rule and its associated costs. To operationalize the market model, supply and demand elasticities are needed to represent the behavioral adjustments that are likely to be made by market participants. The following parameters are needed:

- supply and demand elasticities for application markets (construction, agriculture, and manufacturing),
- supply elasticities for equipment markets,
- supply elasticities for engine markets, and
- supply elasticities for diesel fuel markets.

Note that demand elasticities for the equipment, engine, and diesel fuel markets are not estimated because they are derived internally in the model. They are a function of changes in output levels in the applications markets.

Tables 10G-1 and 10G-2 contains the demand and supply elasticities used to estimate the economic impact of the proposed rule. Two methods were used to obtain the supply and demand elasticities used in the NDEIM. First, the professional literature was surveyed to identify elasticity estimates used in published studies. Second, when literature estimates were not available for specific markets, established econometric techniques were used to estimate supply and demand elasticity parameters directly. Specifically, the supply elasticities for the construction and agricultural application markets and the supply elasticity for the diesel fuel market were obtained from the literature. The supply elasticity for the manufacturing market is assumed to be the same as for the construction market. The supply elasticities for all of the application markets and for equipment and engine markets were estimated econometrically.

This appendix discusses the literature for elasticities based on existing studies and presents the data sources and estimation methodology and regression results for the econometric estimation.

Finally, it should be noted that these elasticities reflect intermediate run behavioral changes. In the long run, supply and demand are expected to be more elastic since more substitutes may become available.

Table 10G-1
Summary of Market Demand Elasticities Used in the NDEIM

Market	Estimate	Source	Method	Input Data Summary
Applications				
Construction	–0.96	EPA econometric estimate	Simultaneous equation (log-log) approach	Annual time series from 1958 – 1995 developed by Jorgenson et al. (Jorgenson, 1990; Jorgenson, Gollop, and Fraumeni, 1987)
Agriculture	–0.20	EPA econometric estimate	Productivity shift approach (Morgenstern, Pizer, and Shih, 2002)	Annual time series from 1958 – 1995 developed by Jorgenson et al. (Jorgenson, 1990; Jorgenson, Gollop, and Fraumeni, 1987)
Manufacturing	–0.58	EPA econometric estimate	Simultaneous equation (log-log) approach.	Annual time series from 1958 – 1995 developed by Jorgenson et al. (Jorgenson, 1990; Jorgenson, Gollop, and Fraumeni, 1987)
Equipment				
Construction		Derived demand	In the derived demand approach, • compliance costs increase prices and decrease demand for products and services in the application markets; • this in turn leads to reduced demand for diesel equipment, engines and fuel, which are inputs into the production of products and services in the application markets	
Agriculture		Derived demand		
Pumps/ compressors		Derived demand		
Generators and Welders		Derived demand		
Refrigeration		Derived demand		
Industrial		Derived demand		
Lawn and Garden		Derived demand		
Engines		Derived demand		
Diesel fuel		Derived demand		

Table 10G-2
Summary of Market Supply Elasticities Used in the NDEIM

Markets	Estimate	Source	Method	Input Data Summary
Applications				
Construction	1.0	Literature-based estimate	Based on Topel and Rosen, (1988).[a]	Census data, 1963 – 1983
Agriculture	0.32	Literature-based estimate	Production-weighted average of individual crop estimates ranging from 0.27 to 0.55. (Lin et al., 2000)	Agricultural Census data 1991 – 1995
Manufacturing	1.0	Literature-based estimate	Literature estimates are not available so assumed same value as for Construction market	Not applicable
Equipment				
Construction	3.31	EPA econometric estimate	Cobb-Douglas production function	Census data 1958-1996; SIC 3531
Agriculture	2.14	EPA econometric estimate	Cobb-Douglas production function	Census data 1958-1996; SIC 3523
Pumps/ compressors	2.83	EPA econometric estimate	Cobb-Douglas production function	Census data 1958-1996; SIC 3561 and 3563
Generators/ Welder Sets	2.91	EPA econometric estimate	Cobb-Douglas production function	Census data 1958-1996; SIC 3548
Refrigeration	2.83	EPA econometric estimate		Assumed same as pumps/compressors
Industrial	5.37	EPA econometric estimate	Cobb-Douglas production function	Census data 1958-1996; SIC 3537
Lawn and Garden	3.37	EPA econometric estimate	Cobb-Douglas production function	Census data 1958-1996; SIC 3524
Engines	3.81	EPA econometric estimate	Cobb-Douglas production function	Census data 1958-1996; SIC 3519
Diesel fuel	0.24	Literature based estimate	Based on Considine (2002).[b]	From Energy Intelligence Group (EIG); 1987-2000

[a] Most other studies estimate ranges that encompass 1.0, including DiPasquale (1997) and DiPasquale and Wheaton (1994).

[b] Other estimates range from 0.02 to 1.0 (Greene and Tishchishyna, 2000). However, Considine (2002) is one of the few studies that estimates a supply elasticity for refinery operations. Most petroleum supply elasticities also include extraction.

10G.1 Application Markets - Demand Elasticities

There are three application markets in the NDEIM: construction, agricultural, and manufacturing. Demand elasticities for the construction and manufacturing application markets were estimated using a simultaneous equation (two-stage least squares) method. This approach was also investigated for the agricultural application market; however, the estimated demand elasticity parameter for that market was not statistically significant. For this reason, a production function approach (Morgenstern, Pizer and Shih, 2002) was employed for the agricultural application market. Publicly available data developed by Dale Jorgenson and his associates (Jorgenson, 1990; Jorgenson, Gollop, and Fraumeni, 1987) were used in the regression analysis. A time series of 38 observations, from 1958 to 1995, was used to estimate the demand elasticities in both the two-stage least squares and production function approach. Both of these techniques are described below.

10G.1.1 Construction and Manufacturing Demand Elasticities

10G.1.1.1 Description of Simultaneous Equation Method

The demand elasticities for the construction and manufacturing application markets were estimated using a simultaneous equation (two-stage least squares) approach. The methodology is described below and the individual regression results are presented in Appendix 10F.

In a partial equilibrium model, supply and demand are represented by a series of simultaneous interdependent equations, in which the price and quantity produced of a product are simultaneously determined by the interaction of producers and consumers in the market. In simultaneous equations models, where one variable feeds back in to the other equations, the error terms are correlated with the endogenous variable. As a result, estimating parameter values using the ordinary least squares (OLS) regression method for each individual equation yields biased and inconsistent parameter estimates. Therefore, OLS is not an appropriate estimation technique.

Instead, a simultaneous equations approach is used. In the simultaneous equations approach both the supply and demand equations for the market are specified and parameters for the two-equation system are estimated simultaneously.

The log-log version of the model is specified as follows:

$$\text{Supply: } Q_{ts} = a_0 + a_1P_t + a_2PL_t + a_3PK_t + a_4PM_t + e_t \qquad (10G.1a)$$

$$\text{Demand: } Q_{td} = b_0 + b_1P_t + b_2HH_t + b_3I_t + v_t \qquad (10G.1b)$$

where

Q_t = log of quantity of the market product in year t
P_t = log of price of the market product in year t

PL_t = log of cost of labor inputs in year t
PK_t = log of cost of capital inputs in production in year t
PM_t = log of cost of material inputs in production in year t
HH_t = log of number of households in year t
I_t = average income per household in year t
e_t, v_t = error terms in year t

The parameter estimates $\hat{a}_1$ and $\hat{b}_1$ are the estimated price elasticity of supply and price elasticity of demand, respectively.

The first equation defines quantity supplied in each year as a function of the product price and the cost of inputs: labor, capital and materials. The second equation defines the quantity demanded in each year as a function of the production price, the number of households, and the average income per household. The equilibrium condition is that supply equals demand

$$\text{equilibrium: } Q_{ts} = Q_{td}$$

Application of this two-stage least square regression approach was successful for estimating the demand elasticity parameters for use here but was unsuccessful for estimating the supply elasticities. The supply elasticity estimates were negative and not statistically significant. Therefore, as noted above, literature estimates were used for the supply elasticities for the three application markets in the NDEIM.

To estimate the demand elasticities using this two-stage least squares approach, it is necessary to first estimate the reduced-form equation for price using OLS. The reduced-form equation expresses price as a function of all exogenous variables in the system:

$$P_t = fn(PL_t , PK_t , PM_t , HH_t , I_t)$$

The results of this regression are used to develop fitted values of the dependent price variable P_t (this is a new instrumental variable for price). The fitted values by construction will be independent of error terms in the demand equation. In the second stage regression, the fitted price variable P_t (the instrumental variable) is used as a replacement for P_t, in the demand equation. An OLS is performed on this equation, which produces a consistent, unbiased estimate of the demand elasticity b_1.

10G.1.1.2 Construction Application Market Demand Elasticity

The results of the simultaneous equation method for the construction demand elasticity are presented in Table 10G-3. The estimated demand elasticity is −0.96 and is statistically significant with a t-statistic of –3.83. This inelastic estimate implies that a 1 percent increase in price will lead to a 0.96 percent decrease in demand for construction, and means that the quantity of goods and services demanded is expected to be fairly insensitive to price changes.

Table 10G-3. Construction Demand Elasticity

Number of Observations = 29
R squared = 0.78
Adjusted R squared = 0.75

Variable	Estimated Coefficients	t-statistic
intercept	18.83	5.19
In price	–0.96	–3.83
In number of households	–1.73	–3.37
In average income per household	–1.67	5.34

10G.1.1.3 Manufacturing Application Market Demand Elasticity

The results of the simultaneous equation method for the manufacturing market are presented in Table 10G-4. The estimated demand elasticity is –0.58 and is statistically significant with a t-statistic of –2.24. This inelastic estimate implies that a 1 percent increase in price will lead to a 0.58 percent decrease in the demand for manufactured products, and means that the quantity of goods and services demanded is expected to be fairly insensitive to price changes.

Table 10G-4. Manufacturing Demand Elasticity

Number of Observations = 29
R squared = 0.83
Adjusted R squared = 0.81

Variable	Estimated Coefficients	t-statistic
intercept	6.16	0.84
In price	–0.58	–2.24
In number of households	0.19	0.23
In average income per household	0.62	1.49

10G.1.2 Agricultural Application Market Demand Elasticity

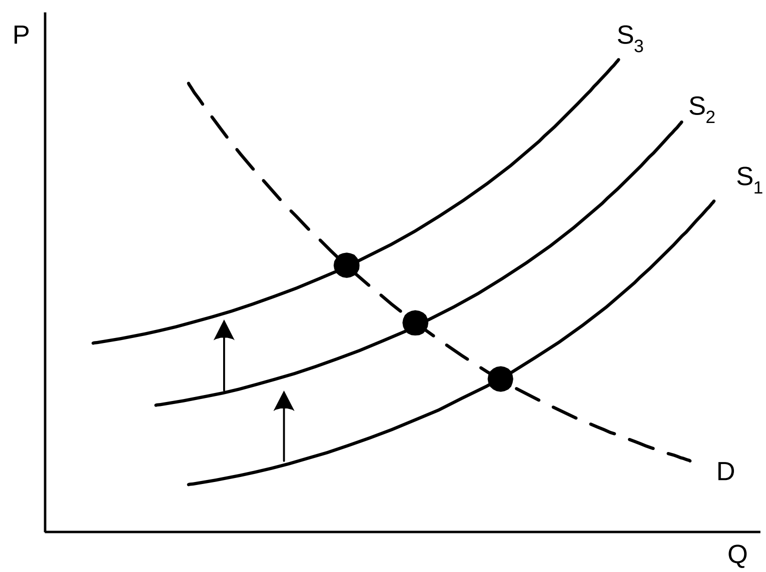
10G.1.2.1: Description of Productivity Shift Approach

When the simultaneous equation method was attempted for the agricultural application market, the resulting demand elasticity parameter estimate was not statistically significant. Thus, the demand elasticity for the agricultural market was estimated using the productivity shift approach.

This is a technique that regresses historical data for aggregate output on industry productivity (Morgenstern, Pizer, and Shih, 2002).

As shown in Figure 10G-1, changes in industry productivity represent shifts in the supply curve. The supply curve shifts in conjunction with the known output values trace-out the demand curve and enables the estimation of the demand elasticity. Because the agricultural sector is relatively small compared to the entire economy, it is reasonable to assume that the productivity changes do not shift the demand curve through income effects.

Figure 10G-1
Productivity Shifts Trace-Out Demand Curve



The demand elasticity (ξd) is estimated through a simple regression of the annual change in the natural log of outputs on change in the natural log of productivity:

$$\vartriangle \ln output_t = \xi_d \vartriangle \ln prod_t + \varepsilon_t$$

where
$output_t$ = output t is the industry output in year t,
$prod_t$ = industry productivity in year t, and
ε_t = random error term.

The change in the natural log of productivity is computed as the log difference between the annual change in input price and the annual change in output price:

$$\triangle \ln prod_t = \sum_{sh} \frac{(\upsilon_{sh,t}+\upsilon_{sh,t-1})}{\partial} (\ln P_{sh,t}-\ln P_{sh,t-1}) - (\ln PO_t-\ln PO_{t-1}) \qquad (10.G\text{-}2)$$

where

P = input prices,

PO = output prices, and

υ = input shares.

Eq. (10G.2) is a similar to a standard quantity-based definition of productivity (output divided by input), but expressed in terms of input and output prices. Under a competitive market with zero-profit assumptions, revenue equals cost, and the price of output must equal the price of input divided by the standard definition of productivity:

$$P_O = P_I (Q_I / Q_O)$$

Thus,

$$P_I / P_O = Q_O / Q_I$$

Where

Q_O = quantity of output

Q_I = quantity of input

Since Q_O / Q_I is a quantity based productivity, P_I / P_O is an equivalent measure of productivity according to the above equation. The difference in logged changes in P_I and P_O is a valid measure of productivity growth (Pizer, 2002).

10G.1.2.2 Agricultural Application Market Demand Elasticity

The results of the estimated agricultural model are presented in Table 10G-5. The demand elasticity estimate is −0.20 and is statistically significant with a t-statistic of 2.31. This implies that a 1 percent increase in price will lead to a 0.2 percent decrease in demand, and means that the quantity of goods and services demanded is expected to be fairly insensitive to price changes.

Table 10G-5. Agricultural Demand Elasticity

Number of Observations = 38
R squared = 0.13
Adjusted R squared = 0.11

Variable	Estimated Coefficients	t-statistic
intercept	0.02	3.49
ln productivity t	–0.20	2.31

10G.2 Application Market - Supply Elasticities

Professional literature sources were used to obtain supply elasticity estimates for the applications markets. These literature sources used are described below.

It should be noted that both of the econometric estimation methods described above, the simultaneous equation approach and the production function approach, were also attempted for the supply elasticities. However, because of the great variety of the production processes in these aggregate industry sectors (heterogeneity), parameter estimates were either not statistically significant or did not conform with standard microeconomic theory (i.e., estimates were not upward sloping).

10G.2.1 Agricultural Application Market Supply Elasticity

Obtaining reasonable estimates of supply response in agriculture has been a persistent problem since the inception of farm price support programs in the 1930s. The nonrecourse marketing loans, deficiency payments, and conservation set-asides that make up the current farm price support system distort equilibrium prices to the point that any econometric estimates are difficult to formulate or support.

A recent study by economists at the USDA’s Economic Research Service provides an approach to estimating agricultural demand elasticities (Lin et al., 2000). Taking into account recent changes in the 1996 Farm Bill, the authors measure nationwide acreage price elasticity values for the seven major agricultural crops, obtaining values ranging from 0.269 for soybeans to 0.550 for sorghum. Although a composite number for all farm output is not reported, an average value of 0.32 can be obtained by weighting the reported values by the acreage planted for each crop. This value was used for the supply elasticity in the agriculture application market. This estimated elasticity is inelastic, which means that the quantity of goods and services supplied is expected to be fairly insensitive to price changes.

Although the literature estimates vary, this estimate conforms closely to historical evidence and economic theory of small but positive supply elasticities. This determination of price having little impact on supply (referred to as inelastic supply) is consistent with a historical observation that total acreage cultivated varies little from year to year. Between 1986 and 2001, for instance, U.S. cropland harvested has ranged from 289 to 318 million acres, with an average of 305 million acres over that 15-year period. A low supply elasticity is also supported by the fact that there are few alternative uses (except in the very long run) for cropland, capital, and labor employed in farming. Abandonment or redeployment of farm assets is an often irreversible decision, and one not greatly affected by annual price swings.

10G.2.2 Construction Application Market Supply Elasticity

Although the construction market does not suffer from government-induced distortions to prices and quantities, the evidence on supply elasticity is even more varied than that for agriculture. Estimates of supply elasticity ranging from near zero to infinity have been reported in credible papers on housing construction published during the past 20 to 30 years. A literature survey paper by DiPasquale (1997) describes the methodological issues that have led to this variety of responses. A key issue is the conceptual problem of distinguishing between increases in the stock the of housing (or other structures) through new construction and changes in the flow of housing services, which can also include renovation, apartment or condominium conversion, and abandonment.

DiPasquale cites a number of published studies that suggest that a value of 1.0 for supply elasticity is appropriate. In the study that most closely matches the analysis for this regulation, Poterba (1984) estimated elasticity of new construction with respect to real house prices ranging from 0.5 to 2.3, depending on the specification. A study by Topel and Rosen investigating asset-markets and also found a short-run elasticity value of 1.0 (Topel and Rosen, 1988). Finally, DiPasquale cites one of her own papers that estimated values of 1.0 to 1.2 for the price elasticity of construction (DiPasquale and Wheaton, 1994). Based on these studies, a value of 1.0 was used for the supply elasticity in the construction application market. This unit elastic elasticity means that the quantity supplied is expected to vary directly with changes in prices.

Estimates of supply response for other portions of the construction market, namely nonresidential buildings and nonbuilding (roads and bridges, water and sewer systems, etc.), are not available in the literature. However, the similarity between technologies employed in construction of residential and other nonindustrial buildings suggests that supply elasticities should be comparable. In addition, residential construction accounts for a significant portion of construction activity. According to the Census Bureau’s most recent Annual Value of Construction Put in Place report, residential and nonindustrial buildings accounted for about 77 percent of the $842 billion in construction spending in 2001, with new residential housing making up about 33 percent (U.S. Census Bureau, 2002).

10G.2.3 Manufacturing Application Market Supply Elasticity

No supply elasticity estimates were available in the professional literature for the aggregate manufacturing sector. For this reason, a unitary supply elasticity of 1.0 was used in the model. This unit elastic elasticity means that the quantity supplied is expected to vary directly with changes in prices. A sensitivity analysis for this assumed elasticity is presented in Appendix I.

10G.3 Engine and Equipment Markets Supply Elasticity

Published sources for the price elasticity of supply for diesel engine and diesel equipment markets were not available. Therefore, the supply elasticities used in the model were estimated econometrically using a production function cost minimization approach.

10G.3.1 Production Function Cost Minimization Approach

The production function cost minimization approach for econometrically estimating the supply elasticities is based on the cost-minimizing behavior of the firm subject to production function constraints. The production function describes the relationship between output and inputs. For this analysis, a Cobb-Douglas, or multiplicative form, was used as the functional form of the production function:

$$Q_t = A\ k_t^{\alpha k}\ L_t^{\alpha L}\ M_t^{\alpha k}\ t^{\lambda} \qquad (10G\text{-}3)$$

where

Q_t = output in year t,
K_t = real capital consumed in production in year t,[N]
L_t = quantify of labor used in year t,
M_t = material inputs in year t, and
t = a time trend variable to reflect technology changes.

This equation can be written in linear form by taking the natural logarithms of each side of the equation. The parameters of this model, α_K, α_L, α_M, can then be estimated using linear regression techniques:

$$\ln Q_t = \ln A + \alpha_k \ln k_t + \alpha \ln L_t + \alpha_m \ln M_t + \lambda \ln t.$$

Under the assumptions of a competitive market and perfect competition, the elasticity of supply with respect to the price of the final product can be expressed in terms of the parameters of the production function:

$$\text{Supply Elasticity} = (\alpha_l + \alpha_m) / (1 - \alpha_l - \alpha_m) \qquad (10G\text{-}4)$$

This underlying relationship is derived from the technical production function and the behavioral profit maximization conditions. The derivation for equation (106) is provided in Appendix 10H.

[N]Capital consumed is defined as the value added minus labor expenditures, divided by the price index for capital.

In a competitive market, a firm will supply output as long as the marginal cost (MC) of producing the next unit does not exceed the marginal revenue (MR, i.e., the price). In a short-run analysis, where capital stock is assumed to be fixed (or a sunk cost of production), the firm will adjust its variable inputs of labor and material to minimize the total cost of producing a given level of output.

The supply function is estimated by minimization, subject to the technical constraints of the production function, and then setting the MC = P to determine the quantity produced as a function of market price. To maintain the desired properties of the Cobb-Douglas production function, it is necessary to place restrictions on the estimated coefficients. For example, if $\alpha_L + \alpha_M = 1$, then the supply elasticity will be undefined. Alternatively, if $\alpha_L + \alpha_M > 1$, this yields a negative supply elasticity. Thus, a common assumption is that $\alpha_K + \alpha_L + \alpha_M = 1$. This implies constant returns to scale, which is consistent with most empirical studies.

10G.3.2 Data for Estimating Engine and Equipment Supply Elasticities

The data for the supply elasticity estimation were obtained from the National Bureau of Economic Research-Center for Economic Studies (NBER-CES). All nominal values were deflated into $1987, using the appropriate price index. The following variables were used:

- value of shipments
- price index of value shipments
- production worker wages
- implicit GDP deflators
- cost of materials
- price index for materials
- real capital stock
- investment
- price index for investment
- value added
- price index for capital

The capital (k) variable used in the Cobb-Douglas regression analysis is calculated as:

$$K = (\text{Value Added} - \text{Labor Costs}) / \text{Price Index for Capital}$$

This provides a measure of capital consumed as opposed to using a measure of total capital stock in place at the firm.

10G.3.3 Engine Supply Elasticity Regression Results

The results of the estimated production function is presented in Table 10G-6. All parameter estimates are statistically significant at the 95 percent confidence level and the supply elasticity is calculated to be 3.81. This elastic elasticity estimate means that the quantities supplied in this market are expected to be very responsive to price changes.

Table 10G-6. Engine Supply Elasticity

Supply Elasticity = 3.81
Number of Observations = 33
R-squared = 0.9978
Goldfeld-Quandt F = 1.88
Note: F(14,14) = 2.46.

Variable	Estimated Coefficients	t-statistic
Intercept	0.954	24.76
ln K	0.2081	4.77
ln T	0.0215	2.37
ln M	0.5909	13.40
ln L	0.201	5.55

10G.3.4 Equipment Supply Elasticity Regression Results

The results of the estimated production functions are presented in Tables 10G-7 through 10G-12. The supply elasticities are calculated from the estimated coefficients for lnM and lnL as described in Equation G10-4. The supply elasticities range from approximately 1.0 for refrigeration to 5.4 for general industrial equipment. The average supply elasticity is 3.6. These elastic elasticity estimates means that the quantities supplied in this market are expected to be responsive to price changes.

Table 10G-7. Agricultural Supply Elasticity

Supply Elasticity = 2.14
Number of Observations = 33
R-squared = 0.9969
Goldfeld-Quandt F = 2.01
Note: F(14,14) = 2.46.

Variable	Estimated Coefficients	t-statistic
Intercept	1.1289	20.81
ln K	0.3189	11.12
ln T	–0.0241	–3.10
ln M	0.4952	10.29
ln L	0.1858	4.64

Table 10G-8. Construction Supply Elasticity

Supply Elasticity = 3.31
Number of Observations = 33
R-squared = 0.9926
Goldfeld-Quandt F = 1.76
Note: F(14,14) = 2.46.

Variable	Estimated Coefficients	t-statistic
Intercept	1.172	28.54
ln K	0.2318	5.83
ln T	–0.0617	–7.08
ln M	0.1511	4.54
ln L	0.6172	13.97

Table 10G-9. Industrial Supply Elasticity

Supply Elasticity = 5.37
Number of Observations = 33
R-squared = 0.9949
Goldfeld-Quandt F = 1.23
Note: F(14,14) = 2.46

Variable	Estimated Coefficients	t-statistic
Intercept	0.6927	18.29
ln K	0.157	3.47
ln T	–0.00739	–0.76
ln M	0.0412	0.96
ln L	0.8018	21.90

Table 10G-10. Garden

Supply Elasticity = 3.37
Number of Observations = 33
R-squared = 0.9963
Goldfeld-Quandt F = 1.18
Note: F(14,14) = 2.46

Variable	**Estimated Coefficients**	**t-statistic**
Intercept	0.6574	13.34
ln K	0.2287	3.75
ln T	0.0413	2.78
ln M	0.0644	1.72
ln L	0.7069	11.23

Table 10G-11. Gensets

Supply Elasticity = 2.91
Number of Observations = 33
R-squared = 0.9909
Goldfeld-Quandt F = 1.16
Note: F(14,14) = 2.46.

Variable	**Estimated Coefficients**	**t-statistic**
Intercept	1.1304	11.09
ln K	0.2557	3.60
ln T	0.0325	2.73
ln M	0.3797	4.67
ln L	0.3646	4.51

Table 10G-12. Pumps

Supply Elasticity = 2.83
Number of Observations = 33
R-squared = 0.9979
Goldfeld-Quandt F = 1.40
Note: F(14,14) = 2.46

Variable	Estimated Coefficients	t-statistic
Intercept	0.9367	19.01
ln K	0.2608	4.45
ln T	–0.207	–1.74
ln M	0.0891	1.57
ln L	0.6501	14.48

10G.4 Diesel Fuel Supply Elasticity: Literature Estimate

Very few studies have attempted to quantify supply responsiveness for individual refined products, such as diesel fuel. For example, a study for the California Energy Commission stated "There do not seem to be credible estimates of gasoline supply elasticity" (Finizza, 2002). However, sources agree that refineries have little or no ability to change output in response to price: high fixed costs compel them to operate as close to their capacity limit as possible. The Federal Trade Commission (FTC) analysis made this point explicitly (FTC, 2001).

Greene and Tishchishyna (2000) reviewed supply elasticity estimates available in the literature. The supply elasticity values cited in most of these studies were for "petroleum" or "oil" production in the United States, which includes exploration, distribution and refining activities. The lowest short-term numbers cited were 0.02 to 0.05, with long-run values ranging from 0.4 to 1.0. It seems likely that these extremely low numbers are influenced by the limited domestic supply of crude petroleum and the difficulty of extraction.

A recent paper by Considine (2002) provides one of the few supply elasticity estimates for refining production (excluding extraction and distribution) based on historical price and quantity data. In this study, Considine estimates a refining production supply elasticity of 0.24. This estimate is for aggregate refinery production and includes distillate and nondistillate fuels. Because petroleum products are made in strict proportion and refineries have limited ability to adjust output mix in the short to medium run, it is reasonable to assume that supply is relatively inelastic and similar across refinery products. This value of 0.24 was used for the supply elasticity for this market. This estimated elasticity is inelastic, which means that the quantity of goods and services supplied is expected to be fairly insensitive to price changes.

APPENDIX 10H: Derivation of Supply Elasticity

This appendix derives the underlying relationship for the supply elasticity used in the production function approach described in Appendix 10G.

Cobb-Douglas:

$Q = L^{\alpha} k^{1-\alpha}$ where Q = output
L = labor input
k = capital input

Cost Minimization:

Marginal Revenue Product of Labor = Wage Rate

$MRP_L = P \bullet MP_L = w$

$$MP_L = \frac{\partial Q}{\partial L} = \alpha L^{\alpha-1} k^{1-\alpha}$$

$$P \bullet MP_L = P\alpha\, L^{\alpha-1} k^{1-\alpha} = w$$

$$L^{\alpha-1} = \frac{w}{P\alpha k^{1-\alpha}}$$

$$L^{1-\alpha} = \frac{P\alpha k^{1-\alpha}}{w}$$

$$L = \left(\frac{P\alpha k^{1-\alpha}}{w}\right)^{\frac{1}{1-\alpha}} = \left(\frac{P\alpha}{w}\right)^{\frac{1}{1-\alpha}} k$$

Substitute Back into Cobb-Douglas:

$$y = \left[\left(\frac{P\alpha}{w}\right)^{\frac{1}{1-\alpha}} k\right]^{\alpha} k^{1-\alpha}$$

$$y = \left(\frac{P\alpha}{w}\right)^{\frac{\alpha}{1-\alpha}} k = p^{\frac{\alpha}{1-\alpha}} \left(\frac{\alpha}{w}\right)^{\frac{\alpha}{1-\alpha}} k$$

$$\ln y = \frac{\alpha}{1-\alpha} \ln P + \frac{\alpha}{1-\alpha} \ln\left(\frac{\alpha}{w}\right) + \ln k$$

$$\boxed{\frac{\partial \ln y}{\partial \ln P} = \frac{\alpha}{1-\alpha} = \text{Supply Elasticity}}$$

APPENDIX 10I: Sensitivity Analysis

The Economic Impact Analysis presented in this Chapter 10 is based on the Nonroad Diesel Economic Impact Model (NDEIM) developed for this analysis. The NDEIM reflects certain assumptions about behavioral responses (modeled by supply and demand elasticities) and how costs are treated by producers. This Appendix presents a sensitivity analysis for several model components by varying how they are treated. Five model components are examined:

- Scenario 1: alternative market supply and demand elasticity parameters
- Scenario 2: alternative ways to treat fuel market costs
- Scenario 3: alternative way to treat operating costs
- Scenario 4: alternatives way to treat engine and equipment fixed costs
- Scenario 5: alternative discount rates

The results of these sensitivity analyses are presented below. All of the results are presented for 2013 only. Also, the application market results are presented without adjusting by the operating savings. Instead, these are added into the welfare changes separately.

In general, varying the model parameters does not significantly change the results of the economic impact assessment analysis presented above. Total social costs are about the same across all sensitivity analysis scenarios, $1,202.4 million, with the exception of Scenario 2 (alternative ways to treat fuel market costs). The base case models fuel market costs based on average variable + fixed costs. Two alternatives were considered: maximum total costs and maximum variable costs. In both of these alternatives, the social costs of the rule (less operating savings and fuel marker and spillover costs) would increase by about 2 percent, to about $1,229 million.

In addition, varying these model parameters does not significantly affect the way the social costs are borne. In all cases, the application markets bear the majority of the burden (about 82 percent), although there are small differences in the way the costs are borne among the markets. There are also differences in the way the application market costs are shared among producers and consumers in that market, especially for Scenario 1. The exception is Scenario 2, the fuel cost scenario. In the maximum total cost scenario, the share of the social costs borne by the application market exceeds the social costs of the rule ($1,412.1 million versus $1,229.3 million for the rule), indicating that the refiners would gain from the proposal (about $146.3 million). In the maximum variable cost scenario, the share borne by the refiners would increase from $7.8 million to $200.9 million, and the share borne by the application market would decrease from $1,231.8 million to $1,066 million.

With regard to the market analysis, expected price and quantity changes are about the same as in the base case. The expected change in engine prices is the same except in Scenario 4 (includes engine and equipment fixed costs), in which the expected engine price increase goes up about 6 percent (from 22.88 percent to 24.22 percent). The expected change in equipment prices is also similar across scenarios with the exception of Scenario 4, in which the expected equipment price increase goes up about 11 percent (from 5.23 percent to 5.83 percent). For the application market, the expected price increase remains between 0.01 percent and 0.02 percent. Expected fuel price changes are somewhat more volatile across the scenarios, ranging from a 1.77 percent increase to a 4.54 increase, compared to 3.09 percent increase in the base case. Finally, expected decreases in the quantities produced do not change much. The largest expected quantity decrease is 0.019 for the equipment market in Scenario1; the smallest is 0.006 for the application markets in Scenario 1.

10I.1 Model Elasticity Parameters

Key model parameters include supply and demand elasticity estimates used by the model to characterize behavioral responses of producers and consumers in each market.

Consumer demand and producer supply responsiveness to changes in the commodity prices are referred to by economists as "elasticity." The measure is typically expressed as the percentage change in quantity (demanded or supplied) brought about by a percent change in own price. A detailed discussion regarding the estimation and selection of the elasticities used in the NDEIM are discussed in Appendix 10G. This component of the sensitivity analysis examines the impact of changes in selected elasticity values, holding other parameters constant. The goal is to determine whether alternative elasticity values significantly alter conclusions in this report.

10I.1.1 Application Markets (Supply and Demand Elasticity Parameters)

The choice of supply and demand elasticities for the *application market* is important because changes in quantities in the application markets are the key drivers in the derived demand functions used to link impacts in the engine, equipment, and fuel markets. In addition, the distribution of regulatory costs depends on the *relative supply and demand elasticities* used in the analysis. For example, consumers will bear less of the regulatory burden if they are more responsive to price changes than producers.

Table 10I-1 reports the upper- and lower-bound values of the application market elasticity parameters (supply and demand) used in the sensitivity analysis. The variation in estimates reported in the literature were used for supply elasticity ranges. For the manufacturing market, an assumed elasticity of 1.0 was used. For the purpose of this sensitivity analysis, the same upper and lower bounds were used as for the construction market. For demand elasticity values, a 90 percent confidence interval was computed using the coefficient and standard error values reported in the econometric analysis (see Appendix 10G).

Table 10I-1. Sensitivity Analysis of the Supply and Demand Elasticities for the Application Markets

Parameter/Market	Elasticity Source	Upper Bound	Base Case	Lower Bound
Supply elasticity				
Construction	Literature estimate	2.3	1.00	0.50
Agriculture	Literature estimate	0.55	0.32	0.027
Manufacturing	Assumed value	2.3	1.00	0.50
Demand elasticity				
Construction	EPA estimate	–1.39	–0.96	–0.534
Agriculture	EPA estimate	–0.35	–0.20	–0.054
Manufacturing	EPA estimate	–1.02	–0.58	–0.140

Note: For literature estimates, the variations in estimates reported were used to develop elasticity ranges. In contrast, EPA computed upper- and lower-bound estimates using the coefficient and standard error values associated with its econometric analysis and reflect a 90 percent confidence interval.

The results of the NDEIM using these alternative elasticity values are reported in Tables 10I-2 and 10I-3. As can be seen in those tables, market price and quantity increases vary negligibly across the upper- and lower-bound sensitivity scenarios.

The change in total social surplus for 2013 also remains essentially unchanged across all scenarios and is approximately the same as for the proposed program ($1,202.5 million). However, consumers in the application market bear a *smaller* share of the social costs when they are more responsive to price changes relative to producers (supply lower bound and demand upper bound scenarios). As shown, consumers bear approximately 33 and 46 percent, respectively, in these scenarios compared to 58 percent in the base case. In contrast, they bear a *higher* share (up to 78 percent) when they are less responsive to price changes relative to producers (supply upper bound and demand lower bound scenarios). While the burden of the fuel market changes slightly, it always remain below 1 percent of the social costs.

Table 10I-2. Application Market Sensitivity Analysis for Supply Elasticities[a,b]

Scenario	Base Case Absolute	Base Case Relative	Supply Upper Bound Absolute	Supply Upper Bound Relative	Supply Lower Bound Absolute	Supply Lower Bound Relative
Application Markets						
Price ($/q)	NA	0.02%	NA	0.02%	NA	0.01%
Quantity (q/yr)	NA	–0.010%	NA	–0.014%	NA	–0.007%
Change in Consumer Surplus ($$10^6$/yr)	$716.1	NA	$914.1	NA	$412.1	NA
Change in Producer Surplus ($$10^6$/yr)	$515.6	NA	$313.2	NA	$825.0	NA
Change in Total Surplus ($$10^6$/yr)	$1,231.7	NA	$1,227.3	NA	$1,237.1	NA
Equipment Markets						
Price ($/q)	$1,016.49	5.23%	$1,041.63	5.23	$1,018.68	5.23%
Quantity (units/yr)	–118	–0.014%	–161	–0.019%	–63	–0.008%
Change in Producer Surplus ($$10^6$/yr)	$116.1	NA	$117.6	NA	$114.3	NA
Engine Markets						
Price ($/q)	$839.71	22.88%	$839.65	22.88%	$839.78	22.88%
Quantity (units/yr)	–69	–0.013%	–95	–0.017%	–40	–0.007%
Change in Producer Surplus ($$10^6$/yr)	$30.2	NA	$30.2	NA	$30.2	NA
Fuel Markets						
Price ($/q)	$0.03	3.09%	$0.03	3.07%	$0.03	3.12%
Quantity (gal/yr)	–293,593	–0.014%	–401,456	–0.020%	–163,005	–0.008%
Change in Producer Surplus ($$10^6$/yr)	$7.8	NA	$10.6	NA	$4.3	NA
Change in Market Surplus ($$10^6$/yr)	$1,385.7	NA	$1,385.7	NA	$1,385.8	NA
NR Spillover	$51.2	NA	$51.2	NA	$5.12	NA
Operating and Marker Cost ($$10^6$/yr)	–$234.6	NA	–$234.6	NA	–$234.6	NA
Social Costs ($$10^6$/yr)	$1,202.4	NA	$1,202.3	NA	$1,202.4	NA

[a] Sensitivity analysis is presented for 2013.
[b] Figures are in 2001 dollars.

Table 10I-3. Application Market Sensitivity Analysis for Demand Elasticities[a,b]

Scenario	Base Case		Demand Upper Bound		Demand Lower Bound	
	Absolute	Relative	Absolute	Relative	Absolute	Relative
Application Markets						
Price ($/q)	NA	0.02%	NA	0.01%	NA	0.02%
Quantity (q/yr)	NA	–0.010%	NA	–0.013%	NA	–0.006%
Change in Consumer Surplus ($$10^6$/yr)	$716.1	NA	$566.7	NA	$970.9	NA
Change in Producer Surplus ($$10^6$/yr)	$515.6	NA	$662.4	NA	$265.3	NA
Change in Total Surplus ($$10^6$/yr)	$1,231.7	NA	$1,229.0	NA	$1,236.1	NA
Equipment Markets						
Price ($/q)	$1,016.49	5.23%	$1,015.45	5.23%	$1,018.19	5.23%
Quantity (units/yr)	–118	–0.014%	–145	–0.018%	–72	–0.009%
Change in Producer Surplus ($$10^6$/yr)	$116.1	NA	$116.9	NA	$114.7	NA
Engine Markets						
Price ($/q)	$839.71	22.88%	$839.67	22.88%	$839.78	22.88%
Quantity (units/yr)	–69	–0.013%	–86	–0.016%	–42	–0.008%
Change in Producer Surplus ($$10^6$/yr)	$30.2	NA	$30.2	NA	$30.2	NA
Fuel Markets						
Price ($/q)	$0.03	3.09%	$0.03	3.08%	$0.03	3.11%
Quantity (gal/yr)	–293,593	–0.014%	–359,059	–0.018%	–184,642	–0.009%
Change in Producer Surplus ($$10^6$/yr)	$7.8	NA	$9.5	NA	$4.8	NA
Change in Market Surplus ($$10^6$/yr)	$1,385.7	NA	$1,385.7	NA	$1,385.8	NA
NR Spillover	$51.2	NA	$51.2	NA	$51.2	NA
Operating and Marker Cost ($$10^6$/yr)	–$234.6	NA	–$234.6	NA	–$234.6	NA
Social Costs ($$10^6$/yr)	$1,202.4	NA	$1,202.3	NA	$1,202.4	NA

[a] Sensitivity analysis is presented for 2013.
[b] Figures are in 2001 dollars.

10I.1.2 Equipment, Engine and Diesel Fuel Markets (Supply Elasticity Parameters)

Sensitivity analysis was also conducted for the engine, equipment, and diesel fuel market supply elasticities. The range of elasticity values evaluated for each market are provided in Table 10I-4. The engine and equipment market supply elasticities are derived econometrically.

Therefore, the upper and lower bound values were computed using the coefficient and standard error values associated with the econometric analysis and reflect a 90 percent confidence interval (see Appendix 10G).

The fuel market supply elasticity was obtained from the literature. The value for the lower bound for the sensitivity analysis is based on the range of available estimates. The value for the upper bound was derived from a set of regulatory studies of the petroleum refining industry that were conducted using a techno-economic method to estimate supply costs at the individual refinery level (EPA, 2000; CRA/BOB, 2000; MathPro, 2002). Synthetic industry supply curves (i.e., marginal cost curves) were developed from these studies and yielded supply elasticities ranging from 0.2 to 2.0. Therefore, the sensitivity analysis uses 2.0 as an upper bound for the supply elasticity of nonroad diesel fuel.

Three sets of sensitivity results are presented in Tables 10I-5, 10I-6, and 10I-7, where supply elasticities are changed in the equipment, engines, and fuel markets, respectively.

Table 10I-4
Engine, Equipment, and Diesel Fuel Market Sensitivity Analysis for Supply Elasticity Parameters

Market	Elasticity Source	Upper Bound	Base Case	Lower Bound
Supply				
Engines	EPA Estimate	7.64	3.81	2.33
Equipment				
Construction	EPA Estimate	6.06	3.31	2.09
Agriculture	EPA Estimate	3.72	2.14	1.31
Refrigeration	EPA Estimate	5.62	2.83	1.62
Industrial	EPA Estimate	12.93	5.37	2.90
Garden	EPA Estimate	7.96	3.37	1.82
Generator	EPA Estimate	12.14	2.91	1.12
Pumps	EPA Estimate	5.62	2.83	1.62
Diesel fuel	Literature Estimate	2.00	0.20	0.04

Note: For literature estimates, the variations in estimates reported were used to develop elasticity ranges. In contrast, EPA computed upper- and lower-bound estimates using the coefficient and standard error values associated with its econometric analysis and reflect a 90 percent confidence interval.

For the engine and equipment markets (Tables 10I-5 and 10I-6), all quantitative estimates for both market impacts (price and quantity changes) and social impacts (how the burden is shared across markets) remain essentially unchanged when compared to the proposed program, across both the upper and lower bound supply elasticity scenarios for equipment and engines. These results imply that the results presented in Section 10.1 are not sensitive to the supply elasticity values used in the engine and equipment markets. This is because the derived demand for engines and equipment is highly inelastic (it is a function of the inelastic demand and supply in the application markets), and so almost all of the compliance costs are passed on to the application markets through price increases.

For the fuel market (Table 10I-7), there is some variation in impacts. As the fuel market supply elasticity becomes more elastic (supply upper bound; producers become more sensitive to price changes), the change in fuel prices increases from 3.09 percent in the base case to 3.14 percent in the supply upper bound case, and producer welfare losses fall from $7.8 million to about $1.0 million. In contrast, as the fuel market supply elasticity becomes less elastic (supply lower bound; producers become less responsive to price changes), the change in fuel prices decreases from 3.09 percent in the base case to 2.78 percent in the lower bound case, and producer welfare losses increase from $7.8 million to $47.7 million.

It should be remembered that the demand elasticities for the equipment and engine diesel fuel markets are derived as part of the model, and therefore sensitivity analysis was not conducted on those parameters.[O] In other words, the change in the application market quantities determines the demand responsiveness in the engine, equipment, and diesel fuel markets. As a result, the demand sensitivity analysis for these markets is indirectly shown in Table 10I-2. Nonroad diesel equipment and fuel expenditures are relatively small shares of total production costs for the application markets. Therefore changes in these input prices do not significantly alter input demand (i.e., demand in these markets is highly inelastic).

[O]For a discussion of the concept of derived demand, see Section 10.2.2.3 Incorporating Multimarket Interactions.

Table 10I-5. Equipment Market Supply Elasticity Sensitivity Analysis[a,b]

	Base Case		Supply Upper Bound		Supply Lower Bound	
Scenario	Absolute	Relative	Absolute	Relative	Absolute	Relative
Application Markets						
Price ($/q)	NA	0.02%	NA	0.02%	NA	0.02%
Quantity (q/yr)	NA	–0.010%	NA	–0.010%	NA	–0.010%
Change in Consumer Surplus ($$10^6$/yr)	$716.1	NA	$717.1	NA	$714.7	NA
Change in Producer Surplus ($$10^6$/yr)	$515.6	NA	$516.5	NA	$514.5	NA
Change in Total Surplus ($$10^6$/yr)	$1,231.7	NA	$1,233.5	NA	$1,229.2	NA
Equipment Markets						
Price ($/q)	$1,016.49	5.23%	$1,018.73	5.23%	$1,013.48	5.22%
Quantity (units/yr)	–118	–0.014%	–118	–0.014%	–118	–0.014%
Change in Producer Surplus ($$10^6$/yr)	$116.1	NA	$114.2	NA	$118.6	NA
Engine Markets						
Price ($/q)	$839.71	22.88%	$839.72	22.88%	$839.71	22.88%
Quantity (units/yr)	–69	–0.013%	–67	–0.012%	–70	–0.013%
Change in Producer Surplus ($$10^6$/yr)	$30.2	NA	$30.2	NA	$30.2	NA
Fuel Markets						
Price ($/q)	$0.03	3.09%	$0.03	3.09%	$0.03	3.09%
Quantity (gal/yr)	–293,593	–0.014%	–294,171	–0.014%	–292,828	–0.014%
Change in Producer Surplus($$10^6$/yr)	$7.8	NA	$7.8	NA	$7.7	NA
Change in Market Surplus ($$10^6$/yr)	$1,385.7	NA	$1,385.7	NA	$1,385.7	NA
NR Spillover	$51.2	NA	$51.2	NA	$51.2	NA
Operating and Marker Cost ($$10^6$/yr)	–$234.6	NA	–$234.6	NA	–$234.6	NA
Social Costs ($$10^6$/yr)	$1,202.4	NA	$1,202.4	NA	$1,202.4	NA

[a] Sensitivity analysis is presented for 2013.
[b] Figures are in 2001 dollars.

Table 10I-6. Engine Market Supply Elasticity Sensitivity Analysis[a,b]

	Base Case		Supply Upper Bound		Supply Lower Bound	
Scenario	**Absolute**	**Relative**	**Absolute**	**Relative**	**Absolute**	**Relative**
Application Markets						
Price ($/q)	NA	0.02%	NA	0.02%	NA	0.02%
Quantity (q/yr)	NA	–0.010%	NA	–0.010%	NA	–0.010%
Change in Consumer Surplus ($$10^6$/yr)	$716.1	NA	$716.1	NA	$716.0	NA
Change in Producer Surplus ($$10^6$/yr)	$515.6	NA	$515.6	NA	$515.6	NA
Change in Total Surplus ($$10^6$/yr)	$1,231.7	NA	$1,231.7	NA	$1,231.6	NA
Equipment Markets						
Price ($/q)	$1,016.49	5.23%	$1,016.55	5.23%	$1,016.43	5.23%
Quantity (units/yr)	–118	–0.014%	–118	–0.014%	–118	–0.014%
Change in Producer Surplus ($$10^6$/yr)	$116.1	NA	$116.1	NA	$116.1	NA
Engine Markets						
Price ($/q)	$839.71	22.88%	$839.80	22.88%	$839.61	22.88%
Quantity (units/yr)	–69	–0.013%	–70	–0.013%	–69	–0.013%
Change in Producer Surplus ($$10^6$/yr)	$30.2	NA	$30.2	NA	$30.3	NA
Fuel Markets						
Price ($/q)	$0.03	3.09%	$0.03	3.09%	$0.03	3.09%
Quantity (gal/yr)	–293,593	–0.014%	–293,603	–0.014%	–293,580	–0.014%
Change in Producer Surplus ($$10^6$/yr)	$7.8	NA	$7.8	NA	$7.8	NA
Change in Market Surplus ($$10^6$/yr)	$1,385.7	NA	$1,385.7	NA	$1,385.7	NA
NR Spillover	$51.2	NA	$51.2		$51.2	
Operating and Marker Cost ($$10^6$/yr)	–$234.6	NA	–$234.6	NA	–$234.6	NA
Social Costs ($$10^6$/yr)	$1,202.4	NA	$1,202.4	NA	$1,202.4	NA

[a] Sensitivity analysis is presented for 2013.
[b] Figures are in 2001 dollars.

Table 10I-7. Fuel Market Supply Elasticity Sensitivity Analysis[a,b]

Scenario	Base Case Absolute	Base Case Relative	Supply Upper Bound Absolute	Supply Upper Bound Relative	Supply Lower Bound Absolute	Supply Lower Bound Relative
Application Markets						
Price ($/q)	NA	0.02%	NA	0.02%	NA	0.02%
Quantity (q/yr)	NA	–0.010%	NA	–0.010%	NA	–0.010%
Change in Consumer Surplus ($$10^6$/yr)	$716.1	NA	$720.0	NA	$692.8	NA
Change in Producer Surplus ($$10^6$/yr)	$515.6	NA	$518.5	NA	$499.2	NA
Change in Total Surplus ($$10^6$/yr)	$1,231.7	NA	$1,238.5	NA	$1,191.9	NA
Equipment Markets						
Price ($/q)	$1,016.49	5.23%	$1,016.46	5.23%	$1,016.66	5.23%
Quantity (units/yr)	–118	–0.014%	–119	–0.014%	–114	–0.014%
Change in Producer Surplus ($$10^6$/yr)	$116.1	NA	$116.1	NA	$115.9	NA
Engine Markets						
Price ($/q)	$839.71	22.88%	$839.71	22.88%	$839.72	22.88%
Quantity (units/yr)	–69	–0.013%	–70	–0.013%	–67	–0.012%
Change in Producer Surplus ($$10^6$/yr)	$30.2	NA	$30.2	NA	$30.2	NA
Fuel Markets						
Price ($/q)	$0.03	3.09%	$0.03	3.14%	$0.03	2.78%
Quantity (gal/yr)	–293,593	–0.014%	–295,287	–0.014%	–283,979	–0.014%
Change in Producer Surplus ($$10^6$/yr)	$7.8	NA	$0.9	NA	$47.7	NA
Change in Market Surplus ($$10^6$/yr)	$1,385.7	NA	$1,385.7	NA	$1,385.8	NA
NR Spillover	$51.2	NA	$51.2	NA	$51.2	NA
Operating and Marker Cost ($$10^6$/yr)	–$234.6	NA	–$234.6	NA	–$234.6	NA
Social Costs ($$10^6$/yr)	$1,202.4	NA	$1,202.4	NA	$1,202.4	NA

[a] Sensitivity analysis is presented for 2013.
[b] Figures are in 2001 dollars.

10.I.2 Fuel Market Supply Shift Alternatives

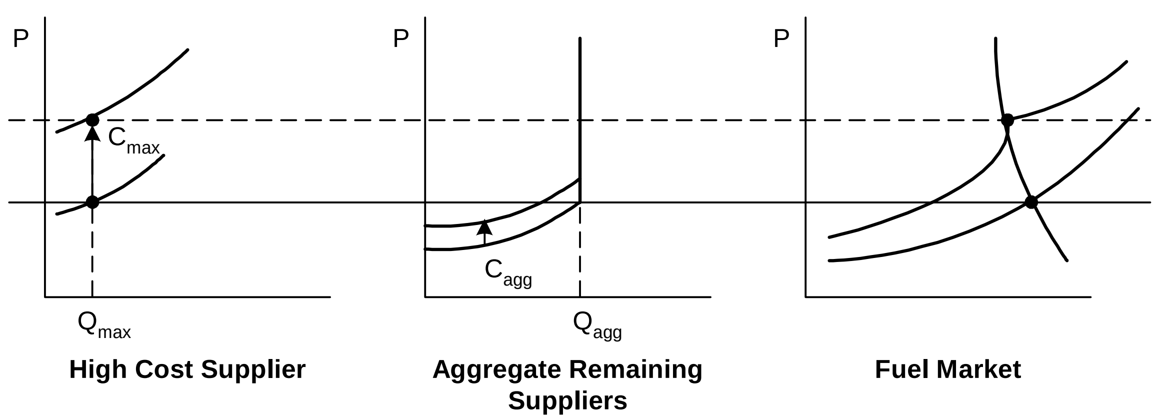
Section 10.2 discusses alternative approaches to shifting the supply curve in the market model. Three alternatives for the fuel market supply shift are investigated in this sensitivity analysis:

- Total average (variable + fixed) cost shift—the results presented in Section 10.1 and the appendices are generated using this cost shift.
- Total maximum (variable + fixed) cost shift
- Variable maximum cost shift

To model the total and variable maximum cost scenarios, the high-cost producer is represented by a separate supply curve as shown in Figure 10I-1. The remainder of the market is represented as a single aggregate supplier. The high-cost producer's supply curve is then shifted by C_{max} (either total or variable), and the aggregate supply curve is shifted by C_{agg}. Using this structure, the high-cost producer will determine price as long as

- the decrease in market quantity does not shut down the high-cost producer, and
- the supply from aggregate producers is highly inelastic (i.e., remaining producers are operating close to capacity); thus, the aggregate producers cannot expand output in response to the price increase.

Figure 10I-1
High Cost Producer Drives Price Increases



Note that the aggregate supply curve is no longer shifted by the average compliance costs but slightly less than the average because the high-cost producer has been removed. The adjusted average aggregate cost shift (C_{agg}) is calculated from the following:

$$C_{ave} * Q_{tot} = C_{max} * Q_{max} + C_{agg} * Q_{agg} \qquad (10I.2)$$

where C_{ave} is the average control cost for the total population; Q_{max}, C_{max}, and Q_{agg}, C_{agg} are the baseline output and cost shift for the maximum cost producer; and the baseline output and cost shift for the remaining aggregate producers, respectively.

The results of this sensitivity analysis are reported in Table 10I-8.

Table 10I-8
Sensitivity Analysis to Cost Shifts in the Diesel Fuel Market

	Average Total Scenario		Maximum Total Scenario		Maximum Variable Scenario	
Scenario	**Absolute Change**	**Relative Change (%)**	**Absolute Change**	**Relative Change (%)**	**Absolute Change**	**Relative Change (%)**
Application Markets						
Price ($/q)	NA	0.02%	NA	0.02%	NA	0.01%
Quantity (q/yr)	NA	–0.010%	NA	–0.012%	NA	–0.009%
Change in Consumer Surplus ($$10^6$/yr)	$716.1	NA	$814.7	NA	$612.3	NA
Change in Producer Surplus ($$10^6$/yr)	$515.6	NA	$597.4	NA	$453.7	NA
Change in Total Surplus ($$10^6$/yr)	$1,231.7	NA	$1,412.1	NA	$1,066.0	NA
Equipment Markets						
Price ($/q)	$1,016.49	5.23%	$1,015.75	5.23%	$1,017.06	5.23%
Quantity (units/yr)	–118	–0.014%	–136	–0.016%	–104	–0.013%
Change in Producer Surplus ($$10^6$/yr)	$116.1	NA	$116.7	NA	$115.6	NA
Engine Markets						
Price ($/q)	$839.71	22.88%	$839.69	22.88%	$839.73	22.88%
Quantity (units/yr)	–69	–0.013%	–80	–0.015%	–61	–0.011%
Change in Producer Surplus ($$10^6$/yr)	$30.2	NA	$30.2	NA	$30.2	NA
Fuel Markets						
Price ($/q)	$0.03	3.09%	$0.04	4.54%	$0.02	1.77%
Quantity (gal/yr)	–293,593	–0.014%	–337,228	–0.017%	–259,056	–0.013%
Change in Producer Surplus ($$10^6$/yr)	$7.8	NA	$–146.3	NA	$200.9	NA
Change in Market Surplus ($$10^6$/yr)	$1,385.7	NA	$1,412.7	NA	$1,412.8	NA
NR Spillover	$51.2	NA	$51.2	NA	$51.2	NA
Operating and Marker Cost ($$10^6$/yr)	–$234.6	NA	–$234.6	NA	–$234.6	NA
Social Costs ($$10^6$/yr)	$1,202.4	NA	$1,229.3	NA	$1,229.4	NA

[a] Sensitivity analysis is presented for 2013.
[b] Figures are in 2001 dollars.

The total and variable maximum cost shift scenarios lead to different conclusions for two important variables: the estimated market price increase for diesel fuel and the estimated welfare impact for affected refineries. Under the base case (total average cost scenario), refiners pass most of the average compliance costs on to the application markets, and the net decrease in producer surplus for refiners is relatively small (about $7.8 million, or 0.6 percent of total social costs), and prices are expected to increase about 3.09 percent. Note that these are industry averages, and individual refiners will gain or lose because compliance costs vary across individual refineries.

In the total maximum cost scenario, the highest operating cost refinery determines the new market price through the impacts on both fixed and variable costs. This refinery has the highest per-unit supply shift, which leads to a higher price increase relative to the average cost scenario. As a result, all refiners except the highest cost refiner would be expected to benefit from the rule, by about $146.3 million. This is because the change in market price would exceed the additional per-unit compliance costs for most of the refineries (i.e., most refiners have costs less than the costs for the highest operating cost refinery). Consequently, in this scenario the producers and consumers in the application market are expected to bear a larger share of the total cost of the program ($1,412.1 million, compared to $1,231.7 million for the welfare costs of the proposed program less the operating savings).

The variable maximum cost scenario is similar to the total maximum cost scenario because the highest cost refinery determines the with-regulation market price. However, the variable maximum cost scenario leads to an expected price increase that is smaller than the total maximum cost scenario because the refiner supply shift includes only variable compliance costs. In other words, the refiners do not pass along any fixed costs; they absorb the fixed costs. Thus, in this scenario, the expected refinery welfare loss is greater than for the propose program, increasing from $7.8 million to $200.9 million. Similarly, the expected welfare loss to the application markets (without considering the operating savings) decreases from $1,412.1 million to $1,066 million

The results of this sensitivity analysis suggest that the expected impacts on producers and consumers in the application markets and on refiners is affected by how refinery costs are modeled. The NDEIM models these costs based on the average (variable + fixed) cost scenario, reflecting a competitive market situation in all regional markets. However, if the highest cost refinery drives the new market price, then prices are expected to increase more, although output does not contract. In this case, consumers and producers in the application market would be expected to bear more than the cost of the rule. However, if only the highest cost refinery's variable costs drive the new market price, then prices are expected to increase less, and producers and consumer will bear less of the burden, with refiners bearing more.

10I.3 Operating Cost Scenario

Changes in operating costs resulting from lower sulfur content nonroad diesel fuel are included in the social cost estimates presented in Section 10.1. However, because of the uncertainty of how these savings will effect individual equipment purchase decisions, operating savings were not included in the market and analysis and were added to social costs after changes in price and quantity were estimated. The results of this analysis are included in Table 10I.9.

In this sensitivity analysis, operating saving are modeled as a cost reduction (benefit) for producers in the application markets. To allow comparison of the results to the base case, the base case is adjusted by adding all the operating savings to the producer surplus, making it $273.7 million. This is because application market producers are the users of diesel equipment and therefore it makes intuitive sense that these benefits accrue to them. In this scenario, operating cost savings are treated as negative supply shift for the application supply curves. When the operating costs are included in the total welfare costs, the social costs for this scenario are about the same as the base case (about $1,202 million). The burden across the markets is also unchanged. The price increase and quantity decrease in the application markets is expected to be smaller. This is because by including operating savings in the supply shift, the magnitude of the shift decreases. This leads to a smaller price and quantity change in the application market.

At the same time, the distribution of costs between producers and consumers in the application market changes when operating costs are treated differently in the model. In the NDEIM, application consumers bear 72 percent of the burden of the loss of welfare surplus in the application market, while producers bear the other 28 percent. This is because this scenario assumes that application market consumers do not make market decisions based on operating costs, and that they expect to run their equipment as before. Producers are not expected to pass along operating savings to their customers. When the operating savings are included in the model, the way the cost burden is shared changes 58 percent for the application market consumers and 42 percent for the application market producers. Prices increase less and output decreases less. In other words, the impacts of the operating savings are shared among the producers and consumers.

Table 10I-9
Operating Savings Included in the Market Analysis[a]

Scenario	Base Case (2013) Absolute Change	Base Case (2013) Relative Change (%)	Adding Operating Savings To App Absolute Change	Adding Operating Savings To App Relative Change (%)
Application Markets				
Price ($/q)	NA	0.02%	NA	0.01%
Quantity (q/yr)	NA	–0.010%	NA	–0.008%
Change in Consumer Surplus ($$10^6$/yr)	$716.1	NA	$577.6	NA
Change in Producer Surplus ($$10^6$/yr)	$273.7	NA	$414.7	NA
Change in Total Surplus ($$10^6$/yr)	$989.8	NA	$992.2	NA
Equipment Markets				
Price ($/q)	$1,016.49	5.23%	$1,017.50	5.23%
Quantity (units/yr)	–118	–0.014%	–95	–0.011%
Change in Producer Surplus ($$10^6$/yr)	$116.1	NA	$115.3	NA
Engine Markets				
Price ($/q)	$839.71	22.88%	$839.75	22.88%
Quantity (units/yr)	–69	–0.013%	–56	–0.010%
Change in Producer Surplus ($$10^6$/yr)	$30.2	NA	$30.2	NA
Fuel Markets				
Price ($/q)	$0.03	3.09%	$0.03	3.10%
Quantity (gal/yr)	–293,593	–0.014%	–235,921	–0.012%
Change in Producer Surplus ($$10^6$/yr)	$7.8	NA	$6.2	NA
NR Spillover	$51.2	NA	$51.2	NA
Marker Cost	$7.3	NA	$7.3	NA
Total Social Cost	$1,202.4	NA	$1,202.5	NA

[a] Sensitivity analysis is presented for 2013.

10I.4 Engine and Equipment Fixed Cost Shift Scenario

As discussed in Section 10.3 only the variable costs are used to shift the supply curve in the engines and equipment markets. Fixed costs are assumed to be R&D costs that are absorbed by engine and equipment markets over a 5-year period and hence do not affect market prices or quantities. As a result, producers are not able to pass any of these costs on and bear all fixed costs as a decrease in producer surplus.

In this scenario, the supply shift for engine producers includes the fixed and variable compliance costs. The results are presented in Table 10I-10. In this scenario, engine producers are able to pass along the majority of the fixed compliance costs to the downstream markets rather than absorb them as a one-to-one reduction in profits. As expected, this scenario leads to a higher projected price increases for the engine and equipment markets (from 5.2 percent in the baseline case to 5.8 percent for equipment markets and from 22.9 percent in the baseline case to 24.2 percent for engine markets). These costs are passed on to the application markets, and their expected share of the compliance burden increases from 90 percent to 99 percent. However, the total social costs of the regulation are not expected to change measurably as the higher prices lead to almost no change in the demand for equipment and engines.

Table 10I-10 Fixed Costs Added to Supply Shift in Engine and Equipment Markets[a]

Scenario	Base Case (2013) Absolute Change	Base Case (2013) Relative Change (%)	Shocking Engine and Equipment Markets by Total Costs Absolute Change	Shocking Engine and Equipment Markets by Total Costs Relative Change (%)
Application Markets				
Price ($/q)	NA	0.02%	NA	0.02%
Quantity (q/yr)	NA	–0.010%	NA	–0.011%
Change in Consumer Surplus ($$10^6$/yr)	$716.1	NA	$796.9	NA
Change in Producer Surplus ($$10^6$/yr)	$515.6	NA	$575.4	NA
Change in Total Surplus ($$10^6$/yr)	$1,231.7	NA	$1,372.3	NA
Equipment Markets				
Price ($/q)	$1,016.49	5.23%	$1,187.23	5.83%
Quantity (units/yr)	–118	–0.014%	–132	–0.016%
Change in Producer Surplus ($$10^6$/yr)	$116.1	NA	$4.6	NA
Engine Markets				
Price ($/q)	$839.71	22.88%	$894.93	24.22%
Quantity (units/yr)	–69	–0.013%	–78	–0.014%
Change in Producer Surplus ($$10^6$/yr)	$30.2	NA	$0.1	NA
Fuel Markets				
Price ($/q)	$0.03	3.09%	$0.03	3.08%
Quantity (gal/yr)	–293,593	–0.014%	–329,511	–0.016%
Change in Producer Surplus ($$10^6$/yr)	$7.8	NA	$8.7	NA
Change in Market Surplus ($$10^6$/yr)	$1,385.7	NA	$1,385.7	NA
NR Spillover	$51.2	NA	$51.2	NA
Operating and Marker Cost ($$10^6$/yr)	–$234.6	NA	–$234.6	NA
Social Costs ($$10^6$/yr)	$1,202.4	NA	$1,202.3	NA

[a] Sensitivity analysis is presented for 2013.

10I.5 Alternative Social Discount Rates

Future benefits and costs are commonly discounted to account for the time value of money. The market and economic impact estimates presented in Section 10.1 calculate the present value of economic impacts using a social discount rate of 3 percent, yielding a total social cost of $16.5 billion. The 3 percent discount rate reflects the commonly used substitution rate of consumption over time. An alternative is the OMB-recommended discount rate of 7 percent that reflects the commonly used real private rate of investment. Table 10I-11 shows the present value calculated over 2004 to 2030 using a 7 percent social discount rate. With the 7 percent social discount rate, the present value of total social costs decreases from $18.9 billion to $9.2 billion.

Table 10I-11. Net Present Values[a]

	NPV (3%)			NPV (7%)		
	Market Surplus (10^6)	**Operating Cost Savings (10^6)**	**Total**	**Market Surplus (10^6)**	**Operating Cost Savings (10^6)**	**Total**
Engine Producers Total	$190.0		$190.0	$135.4		$135.4
Equipment Producers Total	$927.4		$927.4	$595.2		$595.2
Construction Equipment	$433.6		$433.6	$276.2		$276.2
Agricultural Equipment	$306.7		$306.7	$198.0		$198.0
Industrial Equipment	$187.1		$187.1	$120.9		$120.9
Application Total	$17,744.2	–$3,402.4	$14,341.8	$10,066.8	–$2,204.9	$7,861.9
Total Consumer	*$7,450.7*			*$4,222.6*		
Total Producer	*$10,293.5*			*$5,844.1*		
Construction	$6,923.5	–$1,094.9	$5,828.6	$3,895.1	–$709.6	$3,185.6
Agriculture	$5,050.4	–$629.3	$4,421.1	$2,847.5	–$407.8	$2,439.7
Manufacturing	$5,770.3	–$1,678.1	$4,092.2	$3,324.1	–$1,087.5	$2,236.6
Fuel Producers Total	$113.9		$113.9	$64.2		$64.2
PADD 1&3	$52.3		$52.3	$29.5		$29.5
PADD 2	$41.9		$41.9	$23.6		$23.6
PADD 4	$11.5		$11.5	$6.5		$6.5
PADD 5	$8.1		$8.1	$4.6		$4.6
NR Spillover		$886.48			$538.2	
Marker Cost		$63.0			$50.93	
Total	$18,975.5	–$2,452.8	$16,522.7	$10,861.6	–$1,615.8	$9,245.9

[a] Figures are in 2001 dollars.