Draft Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder

Chapter 5
Engineering Cost Estimates

Assessment and Standards Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

United States
Environmental Protection
Agency

EPA420-D-07-001
March 2007

CHAPTER 5: Engineering Cost Estimates

This chapter presents the engine and equipment engineering costs we have estimated for meeting the new engine emissions standards.[a] Section 5.1 includes a brief outline of the methodology used to estimate the engine and equipment costs. Sections 5.2 and 5.3 present the projected costs of the individual technologies we expect manufacturers to use to comply with the new emissions standards, along with a discussion of fixed costs such as research, tooling, certification, and equipment/vessel redesign. Section 5.4 presents our estimate of changes in the operating costs that would result from the proposed program and section 5.5 presents costs associated with the locomotive remanufacturing program. Section 5.6 summarizes these costs and presents the total program costs. Section 5.7 presents costs associated with a possible marine remanufacturing program, although this program is not being proposed.

To maintain consistency in the way our emission reductions, costs, and cost-effectiveness estimates are calculated, our cost methodology relies on the same projections of new locomotive and marine engine growth as those used in our emissions inventory projections. Our emission inventory analyses for marine engines and for locomotives include estimates of future engine populations that are consistent with the future engine sales used in this cost analysis.

Note that the costs here do not reflect changes to the fuel used to power locomotive and marine engines. Our Nonroad Tier 4 rule controlled the sulfur level in all nonroad fuel, including that used in locomotives and marine engines.[b] The sulfur level in the fuel is a critical element of the proposed locomotive and marine program. However, since the costs of controlling locomotive and marine fuel sulfur have been considered in our Nonroad Tier 4 rule, they are not considered here. This analysis considers only those costs associated with the proposed locomotive and marine program.

Additionally, the costs presented here do not reflect any savings that are expected to occur because of the engine ABT program and the various flexibilities included in the program. These program features have the potential to provide savings for both engine and locomotive/vessel manufacturers. While we fully expect companies to use them to reduce compliance costs, we do not factor them into the cost analysis because they are voluntary programs. This analysis of compliance costs

[a] We use the term “engineering costs” to differentiate from “social costs.” Social costs are discussed in Chapter 7 of this draft RIA. For simplicity, the terms “cost” and “costs” throughout the discussion in this Chapter 5 should be taken as referring to “engineering costs.”

[b] See the Regulatory Impact Analysis for the Nonroad Tier 4 final rule, EPA420-R-04-007, May 2004.

relates to regulatory requirements that are part of the proposed rule for Tiers 3 and 4 emissions standards for locomotive and marine engines. Unless noted otherwise, all costs are in 2005 dollars ($2005).

5.1 Methodology for Estimating Engine and Equipment Engineering Costs

This analysis makes several simplifying assumptions regarding how manufacturers will comply with the new emission standards. First, for each tier of emissions standards within a given category of engine, we assume a single technology recipe. For example, all Tier 4 engines in the locomotive category are estimated to be fitted with a selective catalytic reduction (SCR) system, a diesel particulate filter (DPF), and a diesel oxidation catalyst (DOC). However, we expect that each manufacturer will evaluate all possible technology avenues to determine how to best balance costs while ensuring compliance. As noted, for developing cost estimates, we have assumed that the industry does not make use of the averaging, banking, and trading program, even though this program offers industry the opportunity for significant cost reductions. Given these simplifying assumptions, we believe the projections presented here overestimate the costs associated with different compliance approaches manufacturers may ultimately take.

Through our background work for this locomotive and marine rule, our past locomotive and marine rules, and our recent highway and nonroad diesel rules, we have sought input from a large section of the regulated community regarding the future costs of applying the emission control technologies expected for diesel engines within the context of this proposed program. Under contract with EPA, ICF International (formerly ICF Consulting) provided questions to several engine and parts manufacturers regarding costs associated with emission control technologies for diesel engines. The responses to these questions were used to estimate costs for “traditional” engine technologies such as EGR, fuel-injection systems, and for marinizing systems for use in a marine environment.[1,2]

Costs for exhaust emission control devices (e.g., catalyzed DPFs, SCR systems, and DOCs) were estimated using the methodology used in our 2007 heavy-duty highway rulemaking. In that rulemaking effort, surveys were provided to nine engine manufacturers seeking information relevant to estimating the costs for and types of emission-control technologies that might be enabled with low-sulfur diesel fuel. The survey responses were used as the first step in estimating the costs for advanced emission control technologies anticipated for meeting the 2007 heavy-duty highway standards. We then built upon these costs based on input from members of the Manufacturers of Emission Controls Association (MECA). We also used this approach as the basis for estimating costs for our recent nonroad tier 4 (NRT4) rulemaking effort. Because the anticipated emission control technologies for use on locomotive and marine engines are the same as, or similar to, those expected for highway and nonroad engines, and because the suppliers of the technologies are the same for of these engines, we have used that analysis as the basis for estimating the costs of these technologies in this rulemaking.[3]

Costs of control include variable costs (for new hardware, its assembly, and associated markups) and fixed costs (for tooling, research, redesign efforts, and certification). For technologies sold by a supplier to the engine manufacturers, costs are either estimated based on a direct cost to manufacture the system components plus a 29 percent markup to account for the supplier's overhead and profit or, when available, based on estimates from suppliers on expected total costs to the manufacturers (inclusive of markups).[4] Estimated variable costs for new technologies include a markup to account for increased warranty costs. Variable costs are additionally marked up to account for both manufacturer and dealer overhead and carrying costs. The manufacturer carrying cost—estimated to be four percent of the direct costs—accounts for the capital cost of the extra inventory and the incremental costs of insurance, handling, and storage. The dealer carrying cost—estimated to be three percent of their direct costs—accounts for the cost of capital tied up in extra inventory. We adopted this same approach to markups in the 2007 heavy-duty highway rule and the NRT4 rule, based on industry input.[5]

We have also identified various factors that cause costs to decrease over time, making it appropriate to distinguish between near-term and long-term costs. Research on the costs of manufacturing has consistently shown that, as manufacturers gain experience in production, they are able to apply innovations to simplify machining and assembly operations, use lower cost materials, and reduce the number or complexity of component parts. This analysis incorporates the effects of this learning curve as described in Section 5.2.2.[6]

Fixed costs for engine research are estimated to be incurred over the five-year period preceding introduction of the engine. Fixed costs for engine tooling and certification are estimated to be incurred one year ahead of initial production. Fixed costs for equipment redesign are also estimated to be incurred one year ahead of production. We have also included lifetime operating costs where applicable. These include costs associated with fuel consumption impacts and urea use, and increased maintenance demands resulting from the addition of new emission-control hardware. We have also included incremental costs associated with an increase in remanufacturing costs due to the inclusion of additional hardware as part of the remanufactured engine.

A simplified overview of the methodology used to estimate engine and equipment costs is as follows:

- For engine research, we have estimated the total dollars that we believe each engine manufacturer will spend on research to make DPF and SCR systems work together. We refer to such efforts as corporate research. Also for engine research, we have estimated the dollars spent to tailor the corporate research to each individual engine line in the manufacturer's product mix. We refer to such efforts as engine-line research.

- For engine-related tooling costs, we have estimated the dollars that we believe each engine manufacturer will spend on tooling for each of its engine lines. This amount varies depending on whether the manufacturer makes only locomotive and/or marine engines or also makes highway and/or nonroad engines. This amount also varies depending on the emissions standards to which the engine line is certified (i.e., Tier 3 or 4).

- For engine variable costs (i.e., emission-control hardware), we use a three-step approach:

  - First, we estimate the cost per piece of technology/hardware. As described in detail in Section 5.2.2, emission-control hardware costs tend to be directly related to engine characteristics—for example, most emission control devices are sized according to engine displacement so costs vary by displacement. Because of this relationship, we are able to determine a variable cost equation as a function of engine displacement.

  - Second, we determine a sales weighted baseline technology package using a database from Power Systems Research of all locomotive and marine engines sold in the United States.[7] That database lists engine characteristics for every one of over 40,000 locomotive and marine engines sold in the United States in any given year. Using the baseline engine characteristics of each engine, the projected technology package for that engine, and the variable cost equations described in Section 5.2.2, we calculate a variable cost for the sales weighted average engine in each of several different engine categories.

  - Third, this weighted average variable cost is multiplied by the appropriate projected sales in each year after the new standards take effect to give total annual costs for each engine category. The sum total of the annual costs for all engines gives the fleetwide variable costs per year.

- Equipment related costs—i.e., marine vessels or locomotives—are generated using the same methodology to estimate the fixed costs for equipment redesign efforts and the variable costs for new brackets, bolts, and sheet metal that we expect will be required.

This chapter addresses a number of costs including: Engine costs – fixed costs then variable costs; equipment costs – fixed costs then variable costs; and, operating costs – urea, maintenance, and fuel consumption impacts; and, remanufacturing program costs. A summation of these costs is presented in Section 5.6. Variable cost estimates for both engines and equipment represent an expected incremental cost of the engine or piece of equipment in the model year of introduction. Variable costs per engine decrease in subsequent years as a result of several factors, as described below, although these factors do not apply to equipment variable costs. All costs are presented in 2005 dollars.

5.2 Engine-Related Engineering Costs for New Engines

5.2.1 New Engine Fixed Engineering Costs

Engine fixed costs consist of research, tooling, and certification. For these costs, we have made a couple of simplifying assumptions with regard to the timing of marine-related expenditures due to the complexity of the roll out of the marine engine standards. We have estimated that, in general, the marine engine fixed costs would be incurred during the years prior to 2012 (for Tier 3 related costs) and 2016 (for Tier 4 related costs). While this approach impacts the timing of marine-related expenditures and, thus, the annual costs during the early years of implementation, it has no impact on the total costs we would estimate in association with the proposed standards. However, while having no impact on the total costs we estimate would be incurred, this approach does have a very minor impact on the net present value of costs since some early costs (e.g., those for <75 kW Tier 3 engines and >3,700 kW Tier 4 NO_x) are effectively pushed back a couple of years. We believe that the approach taken makes it easier to follow the presentation of costs while having no impact on the results of the analysis.

5.2.1.1 Engine and Emission Control Device Research

As noted, we estimate costs for two types of engine research—corporate research, or that research conducted by manufacturers using test engines to learn how NO_x and PM control technologies work and how they work together in a system; and, engine line research, or that research done to tailor the corporate knowledge to each particular engine line. For the Tier 3 standards, we are estimating no corporate research since the technologies expected for Tier 3 are “existing” technologies and are well understood. However, we have estimated engine-line research associated with Tier 3 since those technologies will still need to be tailored to each engine-line. For Tier 4, we have estimated considerable corporate research since the technologies expected for Tier 4 are still considered “new” technologies in the diesel engine market. We have also estimated more engine-line research for Tier 4 so that the corporate research may be tailored to each engine.

We start this discussion with the more global corporate research. The technologies described in Chapter 4 represent those technologies we believe will be used to comply with the proposed emission standards. These technologies are also part of an ongoing research and development effort geared toward compliance with the 2007 heavy-duty highway and the nonroad Tier 4 standards and, to some extent, the current and future light-duty diesel vehicle standards in the US and Europe. Those engine manufacturers making research expenditures toward compliance with either highway or nonroad emission standards will have to undertake some research effort to transfer emission-control technologies to engines they wish to sell into the locomotive and/or marine markets. These research efforts will allow engine manufacturers to develop and optimize these new technologies for maximum emission control effectiveness, while continuing to design engines with good performance, durability, and fuel efficiency characteristics. However, many engine manufacturers are not part of the ongoing research effort toward compliance with highway and/or nonroad emission standards because they do not sell engines into the highway or nonroad markets. These manufacturers–i.e., the locomotive/marine-only manufacturers–are expected to learn from the research work that has already occurred and will continue through the coming years through their contact with highway and nonroad manufacturers, emission-control device manufacturers, and the independent engine research laboratories conducting relevant research. Despite these opportunities for learning, we expect the research expenditures for these loco/marine-only manufacturers to be higher than for those manufacturers already conducting research in response to the highway and nonroad rules.

We are projecting that SCR systems and DPFs will be the most likely technologies used to meet the new Tier 4 emission standards. Because these technologies are being researched for implementation in the highway and nonroad markets well before the locomotive and marine emission standards take effect, and because engine manufacturers will have had several years complying with the highway and nonroad standards, we believe that the technologies used to comply with the locomotive and marine Tier 4 standards will have undergone significant development before reaching locomotive and marine production. This ongoing research will likely lead to reduced costs in three ways. First, we expect research will lead to enhanced effectiveness for individual technologies, allowing manufacturers to use simpler packages of emission-control technologies than we would predict today, given the current state of development. Second, we anticipate that the continuing efforts to improve the emission-control technologies will include innovations that allow lower-cost production. And finally, we believe manufacturers will focus research efforts on any drawbacks, such as fuel economy impacts or maintenance costs, in an effort to minimize or overcome any potential negative effects.

We anticipate that manufacturers will introduce a combination of primary technology upgrades to meet the new emission standards. Achieving very low NO_x emissions requires basic research on NO_x emission-control technologies and improvements in engine management. Manufacturers are expected to address this challenge by optimizing the engine and exhaust emission-control system to realize the best overall performance. This will entail optimizing the engine and emission control system for both emissions and fuel economy performance in light of the presence of the new exhaust emission control devices and their ability to control pollutants previously controlled only via in-cylinder means or with exhaust gas recirculation. The NO_x control technology in particular is expected to benefit from re-optimization of the engine management system to better match the NO_x catalyst's performance characteristics. The majority of the dollars we have estimated for corporate engine research is expected to be spent on developing this synergy between the engine and NO_x exhaust emission-control systems. Therefore, for engines where we project use of exhaust aftertreatment devices, we have attributed two-thirds of the research expenditures to NO_x+NMHC control, and one-third to PM control. This approach is consistent with that taken in our 2007 heavy-duty highway and NRT4 rules.

To estimate corporate research costs, we begin with our 2007 heavy-duty highway rule. In that rule, we estimated that each engine manufacturer would expend $35 million for corporate research toward successfully implementing diesel particulate filters (DPF) and NO_x control catalysts. For this locomotive/marine analysis, we express all monetary values in 2005 dollars which means our starting point equates to just under $39 million.[8] For their locomotive/marine research efforts, engine manufacturers that also sell into the highway and/or nonroad markets will incur some level of research expense but not at the level incurred for the highway rule. In many cases, the engines used by highway/nonroad manufacturers in marine products are based on the same engine platform as those engines used in their highway/nonroad products. This is also true for locomotive switchers. However, power and torque characteristics are often different, so manufacturers will need to expend some effort to accommodate those differences. For these manufacturers, we assume that they will incur an average corporate research expense of roughly $4 million. This $4 million expense allows for the transfer of learning from highway/nonroad research to their locomotive/marine engines. For reasons noted above, two-thirds of this money is attributed to NO_x+NMHC control and one-third to PM control.

For those engine manufacturers that sell engines only into the locomotive and/or marine markets, and where those engines will be meeting the proposed Tier 4 standards, we believe they will incur a corporate research expense approaching that incurred by highway manufacturers for the 2007 highway rule although not quite at the same level. These manufacturers will be able to learn from the research efforts already underway for both the 2007 highway and nonroad Tier 4 rules (66 FR 5002 and 69 FR 38958, respectively), and for the Tier 2 light-duty highway rule (65 FR 6698) and analogous rules in Europe. This learning may come from seminars, conferences, technical publications regarding diesel engine technology (e.g., Society of Automotive Engineers technical papers), and contact with highway manufacturers, emission-control device manufacturers, and the independent engine research laboratories conducting relevant research. In the NRT4 rule, we estimated that this learning would result in nonroad-only manufacturers incurring 70 percent of the expenditures as highway manufacturers for the 2007 highway rule. Similarly, we would expect that locomotive/marine-only manufacturers would incur 70 percent of the expenditures incurred by nonroad-only manufacturers for the NRT4 rule. Therefore, we have assumed that locomotive/marine-only manufacturers will incur 49 percent of that spent by highway manufacturers in their highway efforts. This lower number—roughly $19 million versus $39 million in the highway rule—reflects the transfer of knowledge to locomotive/marine-only manufacturers from the many stakeholders in the diesel industry. Two-thirds of this corporate research is attributed to NO_x+NMHC control and one-third to PM control.

The $4 million and $19 million estimates represent our estimate of the average corporate research expenditures for engine manufacturers. Each manufacturer may incur more or less than these average figures.

These corporate research estimates are outlined in Table 5-1.

Table 5-1 Estimated Corporate Research Expenditures by Type of Engine Manufacturer Totals per Manufacturer over Five Years ($Million)

	Manufacturer sells only Tier 3 engines	Manufacturer sells Tier 4 engines
Manufacturer sells into highway and/or nonroad markets	$0	$4
Manufacturer sells only into locomotive and/or marine markets	$0	$19
% allocated to PM	n/a	33%
% allocated to NO_X+NMHC	n/a	67%

Note: Since we expect that the majority of the dollars we have estimated for corporate engine research would be spent on developing the synergy between the engine and NO_X exhaust emission-control systems, we have attributed two-thirds of the corporate research expenditures to NO_X+NMHC control and one-third to PM control.

The PSR database shows that there were 47 engine manufacturers that sold engines into the locomotive and marine markets in 2002. Of these 47, 12 sold engines into the market segments proposed to meet the Tier 4 standards (i.e., proposed to need exhaust aftertreatment devices and, therefore, need to conduct this research). Of those 12, three sold exclusively into the locomotive and/or marine markets, while the other nine sold engines into the highway and/or nonroad markets in addition to the locomotive and/or marine markets. As a result, we estimate that three manufacturers will need to spend the full $19 million conducting research and nine will spend $4 million, for a total corporate research expenditure of just over $92 million.

Further, six of these 12 manufacturers sold into both the locomotive and marine markets and, therefore, will spend a portion of their corporate research dollars during the five years prior to 2015 (for DPF research to support locomotive engines), a portion during the five years prior to 2016 (for SCR and DPF research to support marine engines) and the remaining portion during the five years prior to 2017 (for SCR research to support locomotive engines). Of the six remaining manufacturers, five sold only into the marine market so will spend their dollars during the five years prior to 2016 (for SCR and DPF research to support marine engines). The remaining manufacturer sold only into the locomotive market and will spend a portion of its corporate research dollars during the five years prior to 2015 (for DPF research) and the remaining portion during the five years prior to 2017 (for SCR research). Further allocation of corporate research into marine C1, marine C2, locomotive switcher, and locomotive line-haul segments based on the segments into which each manufacturer sold in 2002 results in the total corporate research expenditures by market segment shown in Table 5-2.[c] We then spread these costs over the five years in advance of the applicable standards to get the annual costs shown in Table 5-3.

Table 5-2 Estimated Corporate Research Expenditures Allocated by Market Segment ($Million)

Market Segment	Total Corporate Research Expenditure	PM	NO_x+NMHC
Locomotive Switcher/Passenger	$ 10.4	$ 3.4	$ 7.0
Locomotive Line-Haul	$ 19.1	$ 6.3	$ 12.8
Marine C1	$ 37.3	$ 12.3	$ 25.0
Marine C2	$ 25.6	$ 8.4	$ 17.1
Total Industry Expenditure	$ 92.3	$ 30.5	$ 61.8

Notes: Since we expect that the majority of the dollars we have estimated for corporate engine research would be spent on developing the synergy between the engine and NO_x exhaust emission-control systems, we have attributed two-thirds of the corporate research expenditures to NO_x+NMHC control and one-third to PM control. Marine C1 includes recreational marine $\geq$ 2000 kW.

[c] Note that, throughout this discussion of costs, recreational marine engines over 2000 kW are included in the C1 marine category unless otherwise noted. As such, when referring to the recreational marine category, we mean recreational marine engines less than 2000 kW unless otherwise noted.

Table 5-3 Estimated Corporate Research Expenditures by Year ($Millions)

Calendar Year	Locomotive Switchers			Locomotive Line-Haul			Marine C1			Marine C2			Totals		
	PM	NO_X+ NMHC	Subtotal	PM	NO_X+ NMHC	Subtotal	PM		Subtotal	PM	NO_X+ NMHC	Subtotal	Total Spent	PM	NO_X+ NMHC
2006	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2007	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2008	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2009	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2010	$0.7	$ -	$0.7	$1.3	$ -	$1.3	$ -	$ -	$ -	$ -	$ -	$ -	$1.9	$1.9	$ -
2011	$0.7	$ -	$0.7	$1.3	$ -	$1.3	$2.5	$5.0	$7.5	$1.7	$3.4	$5.1	$14.5	$6.1	$8.4
2012	$0.7	$1.4	$2.1	$1.3	$2.6	$3.8	$2.5	$5.0	$7.5	$1.7	$3.4	$5.1	$18.5	$6.1	$12.4
2013	$0.7	$1.4	$2.1	$1.3	$2.6	$3.8	$2.5	$5.0	$7.5	$1.7	$3.4	$5.1	$18.5	$6.1	$12.4
2014	$0.7	$1.4	$2.1	$1.3	$2.6	$3.8	$2.5	$5.0	$7.5	$1.7	$3.4	$5.1	$18.5	$6.1	$12.4
2015	$ -	$1.4	$1.4	$ -	$2.6	$2.6	$2.5	$5.0	$7.5	$1.7	$3.4	$5.1	$16.5	$4.1	$12.4
2016	$ -	$1.4	$1.4	$ -	$2.6	$2.6	$ -	$ -	$ -	$ -	$ -	$ -	$3.9	$ -	$3.9
2017	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2018	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2019	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2020	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2021	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2022	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2023	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2024	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2025	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2026	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2027	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2028	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2029	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2030	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2031	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2032	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2033	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2034	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2035	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2036	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2037	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2038	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2039	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2040	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total	$3.4	$7.0	$10.4	$6.3	$12.8	$19.1	$12.3	$25.0	$37.3	$8.4	$17.1	$25.6	$92.3	$30.5	$61.8
NPV at 7%	$2.1	$3.8	$5.9	$3.9	$7.0	$10.9	$7.2	$14.6	$21.8	$4.9	$10.0	$15.0	$53.6	$18.2	$35.4
NPV at 3%	$2.8	$5.3	$8.1	$5.1	$9.8	$14.9	$9.7	$19.7	$29.4	$6.7	$13.5	$20.2	$72.7	$24.3	$48.4

As shown in Table 5-3, the net present value of the corporate research is estimated at $73 million using a three percent discount rate, and $54 million using a seven percent discount rate.[d] We can estimate these expenditures on a per engine basis considering the time value of money and engine sales for 2006 through 2040, as shown in Table 5-4.

Table 5-4 Estimated Corporate Research per Engine

	Estimated Cost Allocation ($Millions)	Estimated Sales from 2006 to 2040	$/engine
Locomotive Switcher/Passenger	$ 8.1	3,212	$ 2,530
Locomotive Line Haul	$ 14.9	19,258	$ 780
Marine C1 >600 kW	$ 29.4	25,597	$ 1,150
Marine C2	$ 20.2	6,647	$ 3,040
Total	$ 72.7	54,715	$ 1,330

Note: Marine C1 >600 kW includes recreational marine $\geq$ 2000 kW. Net present values of sales are calculated using zero as the sales figure for 2006.

For engine line research—those engine research efforts done to tailor the corporate research to each particular engine line—we have first determined the number of engine lines by considering that, typically, the same basic diesel engine design can be increased or decreased in size by simply adding or subtracting cylinders. As a result, a four-, six-, or eight-cylinder engine may be produced from the same basic engine design. While these engines have different total displacement, they each have the same displacement per cylinder. Using the PSR database, we grouped each engine manufacturer's engines into distinct engine lines using increments of 0.5 liters per cylinder. This way, engines having similar displacements per cylinder are grouped together and are considered to be one engine line. Doing this, we found there to be 88 engine lines that will need Tier 3 engine line research and 31 engine lines that will need Tier 4 engine line research. Of the 88 Tier 3 engine lines, eight are locomotive switcher lines, two are locomotive line haul lines, 13 are C2 marine lines, and 65 are other marine lines which, due to their size, generally span at least two of the three categories of C1 marine, recreational, and small marine. For these 65 marine lines, we have weighted each manufacturer's estimated engine line research costs according to total engine lines sold into each of these three categories

[d] Throughout Chapter 5 of this draft RIA, net present value (NPV) calculations are based on the period 2006-2040, reflecting the period when the analysis was completed. This has the consequence of discounting the current year costs, 2007, and all subsequent years are discounted by an additional year. The result is a smaller stream of engineering costs than by calculating the NPV over 2007-2040 (3% smaller for 3% NPV and 7% smaller for 7% NPV).

by the particular manufacturer. Of the 31 Tier 4 engine lines, four engine lines had sales in both the locomotive and the marine markets, so we have split evenly the engine line research between the appropriate segments; two of these four were marine-C1/locomotive-switcher engine lines, while the other two were marine-C2/locomotive-line haul engine lines.

Consistent with our NRT4 rule, for those engine lines adding aftertreatment devices (i.e., the Tier 4 engine lines) we have estimated the engine line research at $3.2 million per line for those engines under 600 kW and $6.5 million per line for engines over 600 kW range. For engine line research associated with the Tier 3 standards, we have estimated the expenditure per engine line at $1.6 million. This value is lower than the amount estimated for Tier 4 since the Tier 3 effort should amount to recalibration work which is less costly than the work expected for Tier 4 engine lines. The estimated engine line research expenditures by type of engine manufacturer are shown in Table 5-5 and by market segment for Tier 3 in Table 5-6 and for Tier 4 in Table 5-7.

Table 5-5 Estimated Engine Line Research Expenditures by Type of Engine Manufacturer Totals per Engine Line for Tiers 3 & 4 ($Million)

	Tier 3 engine line	Tier 4 engine line <600 kW	Tier 4 engine line >600 kW
Manufacturer sells into highway and/or nonroad markets	$ 1.6	$ 3.2	$ 6.5
Manufacturer sells only into locomotive and/or marine markets	$ 1.6	$ 3.2	$ 6.5
% allocated to PM	33%	33%	33%
% allocated to NO_x+NMHC	67%	67%	67%

Note: Since we expect that the majority of the dollars we have estimated for engine line research would be spent on developing the synergy between the engine and NO_x exhaust emission-control systems, we have attributed two-thirds of the engine line research expenditures to NO_x+NMHC control and one-third to PM control.

Table 5-6 Tier 3 Engine Line Research Expenditures by Market Segment ($Million)

Segment	Engine Lines <600 kW	Engine Lines >600 kW	Tier 3 $/line	Total
Small Marine	65		$ 1.6	$ 104
Recreational Marine				
Marine C1				
Marine C2	0	13	$ 1.6	$ 20.8
Locomotive Switcher/Passenger	6*	2	$ 1.6	$ 12.8
Locomotive Line Haul	0	2	$ 1.6	$ 3.2
Total	63	25		$ 140.8

* Note that we have developed hardware costs for switchers based on a single large engine of, generally, over 2000 hp. However, many switchers are powered by several nonroad engines placed in series to arrive at a large horsepower locomotive. Perhaps it would have been more appropriate to assume research costs for those engines to be $0 since the effort is, presumably, being done for the nonroad Tier 4 rule. However, to be conservative, we have included engine line research costs for these engines.

Table 5-7 Tier 4 Engine Line Research Expenditures by Market Segment ($Million)

Segment	Engine Lines <600 kW	Engine Lines >600 kW	Tier 4 $/line	Total
Marine C1	n/a	10	$ 6.5	$ 65.0
Marine-C1/Loco-Switcher/Passenger	0	2	$ 6.5	$ 13.0
Locomotive Switcher/Passenger	6*	0	$ 3.2	$ 19.2
Marine C2	0	11	$ 6.5	$ 71.5
Marine-C2/Loco-LineHaul	0	2	$ 6.5	$ 13.0
Locomotive Line Haul	0	0	$ 6.5	$ 0
Total	6	25		$ 181.7

* Note that we have developed hardware costs for switchers based on a single large engine of, generally, over 2000 hp. However, many switchers are powered by several nonroad engines placed in series to arrive at a large horsepower locomotive. We could have assumed research costs for those engines to be $0 since the effort is, presumably, being done for the nonroad Tier 4 rule. However, to be conservative, we have included engine line research costs for these engines.

We estimate that these engine line research expenditures will be made over a five year period in advance of the standard for which the cost is incurred. Spreading the costs this way results in the annual cost streams shown in Table 5-8 for Tier 3 and Table 5-9 for Tier 4 and Table 5-10 for the proposed program (i.e., Tiers 3 and 4). [e]

[e] Note that we show the Tier 3 engine-line research costs beginning in calendar year 2007 even though this rule will not be final until the end of 2007 at the earliest. While we usually do not account for investments made prior to a rule being finalized, we understand that manufacturers have

Table 5-8 Estimated Tier 3 Engine Line Research Expenditures by Year ($Millions)

Calendar Year	Locomotive Switchers			Locomotive Line Haul			Marine C1; Rec; small			Marine C2			Totals		
	PM	NO_X+ NMHC	Subtotal	PM	NO_X+ NMHC	Subtotal	PM		Subtotal	PM	NO_X+ NMHC	Subtotal	Total Spent	PM	NO_X+ NMHC
2006	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2007	$0.8	$1.7	$2.6	$0.2	$0.4	$0.6	$6.9	$13.9	$20.8	$1.4	$2.8	$4.2	$28.2	$9.3	$18.9
2008	$0.8	$1.7	$2.6	$0.2	$0.4	$0.6	$6.9	$13.9	$20.8	$1.4	$2.8	$4.2	$28.2	$9.3	$18.9
2009	$0.8	$1.7	$2.6	$0.2	$0.4	$0.6	$6.9	$13.9	$20.8	$1.4	$2.8	$4.2	$28.2	$9.3	$18.9
2010	$0.8	$1.7	$2.6	$0.2	$0.4	$0.6	$6.9	$13.9	$20.8	$1.4	$2.8	$4.2	$28.2	$9.3	$18.9
2011	$0.8	$1.7	$2.6	$0.2	$0.4	$0.6	$6.9	$13.9	$20.8	$1.4	$2.8	$4.2	$28.2	$9.3	$18.9
2012	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2013	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2014	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2015	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2016	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2017	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2018	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2019	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2020	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2021	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2022	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2023	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2024	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2025	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2026	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2027	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2028	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2029	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2030	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2031	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2032	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2033	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2034	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2035	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2036	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2037	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2038	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2039	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2040	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total	$4.2	$8.6	$12.8	$1.1	$2.1	$3.2	$34.3	$69.7	$104.0	$6.9	$13.9	$20.8	$140.8	$46.5	$94.3
NPV at 7%	$3.2	$6.6	$9.8	$0.8	$1.6	$2.5	$26.3	$53.4	$79.7	$5.3	$10.7	$15.9	$107.9	$35.6	$72.3
NPV at 3%	$3.8	$7.6	$11.4	$0.9	$1.9	$2.8	$30.5	$62.0	$92.5	$6.1	$12.4	$18.5	$125.2	$41.3	$83.9

Table 5-9 Estimated Tier 4 Engine Line Research Expenditures by Year ($Millions)

Calendar Year	Locomotive Switchers			Locomotive Line Haul			Marine C1 > 600 kW			Marine C2			Totals		
	PM	NO_X+ NMHC	Subtotal	PM	NO_X+ NMHC	Subtotal	PM		Subtotal	PM	NO_X+ NMHC	Subtotal	Total Spent	PM	NO_X+ NMHC
2006	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2007	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2008	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2009	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2010	$1.7	$ -	$1.7	$0.4	$ -	$0.4	$ -	$ -	$ -	$ -	$ -	$ -	$2.1	$2.1	$ -
2011	$1.7	$ -	$1.7	$0.4	$ -	$0.4	$4.7	$9.6	$14.3	$5.1	$10.5	$15.6	$32.0	$12.0	$20.0
2012	$1.7	$3.4	$5.1	$0.4	$0.9	$1.3	$4.7	$9.6	$14.3	$5.1	$10.5	$15.6	$36.3	$12.0	$24.3
2013	$1.7	$3.4	$5.1	$0.4	$0.9	$1.3	$4.7	$9.6	$14.3	$5.1	$10.5	$15.6	$36.3	$12.0	$24.3
2014	$1.7	$3.4	$5.1	$0.4	$0.9	$1.3	$4.7	$9.6	$14.3	$5.1	$10.5	$15.6	$36.3	$12.0	$24.3
2015	$ -	$3.4	$3.4	$ -	$0.9	$0.9	$4.7	$9.6	$14.3	$5.1	$10.5	$15.6	$34.2	$9.9	$24.3
2016	$ -	$3.4	$3.4	$ -	$0.9	$0.9	$ -	$ -	$ -	$ -	$ -	$ -	$4.3	$ -	$4.3
2017	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2018	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2019	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2020	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2021	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2022	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2023	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2024	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2025	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2026	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2027	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2028	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2029	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2030	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2031	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2032	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2033	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2034	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2035	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2036	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2037	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2038	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2039	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2040	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total	$8.5	$17.2	$25.7	$2.1	$4.4	$6.5	$23.6	$47.9	$71.5	$25.7	$52.3	$78.0	$181.7	$60.0	$121.7
NPV at 7%	$5.3	$9.4	$14.7	$1.3	$2.4	$3.7	$13.8	$28.0	$41.8	$15.0	$30.6	$45.6	$105.8	$35.5	$70.4
NPV at 3%	$6.9	$13.2	$20.1	$1.7	$3.3	$5.1	$18.6	$37.8	$56.5	$20.3	$41.3	$61.6	$143.3	$47.6	$95.7

Table 5-10 Estimated Tier 3 & Tier 4 Engine Line Research Expenditures by Year ($Millions)

Calendar Year	Locomotive Switchers			Locomotive Line Haul			Marine C1; Rec; small			Marine C2			Totals		
	PM	NO_X+ NMHC	Subtotal	PM	NO_X+ NMHC	Subtotal	PM		Subtotal	PM	NO_X+ NMHC	Subtotal	Total Spent	PM	NO_X+ NMHC
2006	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2007	$0.8	$1.7	$2.6	$0.2	$0.4	$0.6	$6.9	$13.9	$20.8	$1.4	$2.8	$4.2	$28.2	$9.3	$18.9
2008	$0.8	$1.7	$2.6	$0.2	$0.4	$0.6	$6.9	$13.9	$20.8	$1.4	$2.8	$4.2	$28.2	$9.3	$18.9
2009	$0.8	$1.7	$2.6	$0.2	$0.4	$0.6	$6.9	$13.9	$20.8	$1.4	$2.8	$4.2	$28.2	$9.3	$18.9
2010	$2.5	$1.7	$4.3	$0.6	$0.4	$1.1	$6.9	$13.9	$20.8	$1.4	$2.8	$4.2	$30.3	$11.4	$18.9
2011	$2.5	$1.7	$4.3	$0.6	$0.4	$1.1	$11.6	$23.5	$35.1	$6.5	$13.2	$19.8	$60.2	$21.3	$38.9
2012	$1.7	$3.4	$5.1	$0.4	$0.9	$1.3	$4.7	$9.6	$14.3	$5.1	$10.5	$15.6	$36.3	$12.0	$24.3
2013	$1.7	$3.4	$5.1	$0.4	$0.9	$1.3	$4.7	$9.6	$14.3	$5.1	$10.5	$15.6	$36.3	$12.0	$24.3
2014	$1.7	$3.4	$5.1	$0.4	$0.9	$1.3	$4.7	$9.6	$14.3	$5.1	$10.5	$15.6	$36.3	$12.0	$24.3
2015	$ -	$3.4	$3.4	$ -	$0.9	$0.9	$4.7	$9.6	$14.3	$5.1	$10.5	$15.6	$34.2	$9.9	$24.3
2016	$ -	$3.4	$3.4	$ -	$0.9	$0.9	$ -	$ -	$ -	$ -	$ -	$ -	$4.3	$ -	$4.3
2017	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2018	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2019	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2020	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2021	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2022	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2023	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2024	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2025	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2026	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2027	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2028	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2029	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2030	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2031	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2032	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2033	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2034	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2035	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2036	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2037	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2038	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2039	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2040	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total	$12.7	$25.8	$38.5	$3.2	$6.5	$9.7	$57.9	$117.6	$175.5	$32.6	$66.2	$98.8	$322.5	$106.4	$216.1
NPV at 7%	$8.5	$16.0	$24.5	$2.2	$4.0	$6.2	$40.1	$81.4	$121.5	$20.3	$41.2	$61.5	$213.8	$71.1	$142.7
NPV at 3%	$10.7	$20.8	$31.5	$2.7	$5.2	$7.9	$49.2	$99.8	$149.0	$26.4	$53.7	$80.1	$268.5	$88.9	$179.6

Table 5-10 shows the total estimated costs associated with engine line research. This table combines the costs for Tier 3 (Table 5-8) and Tier 4 (Table 5-9). As shown in Table 5-10, the net present value of the engine line research is estimated at $269 million using a three percent discount rate and $214 million using a seven percent discount rate. We can estimate these expenditures on a per engine basis considering the time value of money and engine sales for 2006 through 2040, as shown in Table 5-11.

Table 5-11 Estimated Engine Line Research per Engine

	Estimated Cost Allocation ($Millions)	Estimated Sales from 2006 to 2040	$/engine
Locomotive Switcher/Passenger	$ 31.5	3,212	$ 9,800
Locomotive Line Haul	$ 7.9	19,258	$ 410
Small Marine	$ 7.1	324,403	$ 20
Recreational Marine	$ 23.8	432,523	$ 60
Marine C1 <600 kW	$ 44.5	303,024	$ 150
Marine C1 >600 kW	$ 73.6	25,597	$ 2,870
Marine C2	$ 80.1	6,647	$12,050
Total	$ 268.5	1,114,666	$ 240

Note: Marine C1 >600 kW includes recreational marine $\geq$ 2000 kW. Net present values of sales are calculated using zero as the sales figure for 2006.

5.2.1.2 Engine-Related Tooling Costs

Once engines are ready for production, new tooling will be required to accommodate the assembly of the new engines. In the 2007 heavy-duty highway rule, we estimated approximately $1.6 million per engine line for tooling costs associated with DPF/NO_x aftertreatment systems. For the NRT4 rule, we estimated that a manufacturer that sold only into the landbased nonroad market would incur the same amount – $1.65 million expressed in 2002 dollars – for each engine line that required a DPF/NO_x aftertreatment system. In this rule, we estimate the same level of tooling costs associated with DPF/NO_x aftertreatment for those manufacturers selling only into the locomotive/marine markets, or $1.8 million in 2005 dollars. We have estimated the same level of tooling costs as in the 2007 highway and NRT4 rules because we expect new locomotive/marine engines to use technologies with similar tooling needs (i.e., a DPF and a NO_x aftertreatment device). For those manufacturers that sell into the highway and/or nonroad markets and have, therefore, already made considerable tooling investments, we have estimated an expenditure of 25 percent of this amount, or $450,000, for those engine lines that will require DPF/NO_x aftertreatment systems for the locomotive/marine market. These costs are assigned equally to NO_x+NMHC control and PM control since the tooling for one should be no more costly than that for the other.

The tooling estimates discussed above represent our estimates, per engine line, for engine lines expected to meet the Tier 4 requirements. As noted above in our discussion of engine line research, we estimate 31 engine lines that will incur these costs. Of those 31 lines, we estimate that five belong to manufacturers selling exclusively into the locomotive and/or marine markets. The remaining 26 lines belong to manufacturers that also sell into the highway and/or nonroad markets. The resultant tooling expenditures associated with the Tier 4 standards are then $22.1 million.

For meeting the Tier 3 requirements, we have estimated lower costs per line because the engines will require far less in terms of new hardware and, in fact, are expected only to require upgrades to existing hardware (i.e., new fuel systems). As such, we have estimated that those manufacturers selling exclusively into the locomotive and/or marine markets will spend $450,000 per engine line, while manufacturers that also sell into the highway and/or nonroad markets will spend $180,000 per engine line. The PSR database shows 88 engine lines that we expect to meet the Tier 3 standards, 13 of which belong to manufacturers that sell only into the locomotive and/or marine markets. The resultant tooling expenditures associated with the Tier 3 standards are then $19.4 million. As with the Tier 4 tooling costs, these costs are assigned equally to NO_x control and PM control.

We have applied tooling costs by engine line assuming that engines in the same line are produced on the same production line. Typically, the same basic diesel engine design can be increased or decreased in size by simply adding or subtracting cylinders. As a result, a four-, six-, or eight-cylinder engine may be produced from the same basic engine design. While these engines have different total displacement, they each have the same displacement per cylinder. Using the PSR database, we grouped each engine manufacturer’s engines into distinct engine lines using increments of 0.5 liters per cylinder. This way, engines having similar displacements per cylinder are grouped together and are considered to be built on the same production line. Note that a tooling expenditure for a single engine line may cover engines over several market segments. To allocate the tooling expenditure for a given production line to a specific market segment, we have divided costs equally among the segments (i.e., an engine line used in both the marine C1 and the locomotive switchers segments would have its tooling costs split evenly between those two segments).

We estimate that the tooling expenditures would be made one year in advance of meeting the standards for which the money is spent. A summary of the tooling costs per manufacturer are shown in Table 5-12. The tooling costs by market segment are shown in Table 5-13 and the annual cost streams are shown in Table 5-14.

Table 5-12 Estimated Tooling Expenditures by Type of Engine Manufacturer
Totals per Engine Line ($Million)

	Tier 3 engine lines	Tier 4 engine lines
Manufacturer sells into highway and/or nonroad markets	$ 0.18	$ 0.45
Manufacturer sells only into locomotive and/or marine markets	$ 0.45	$ 1.8
% allocated to PM	50%	50%
% allocated to NO_x+NMHC	50%	50%

Note: We have arbitrarily attributed the tooling costs equally to NO_x+NMHC and PM control because we have no reason to believe that the tooling costs would be greater for one than the other.

Table 5-13 Estimated Engine Tooling Expenditures by Market Segment and Tier ($Million)

Segment	Tier 3	Tier 4	Total
Marine C1 <600 kW	$ 7.9	$ 0	$ 7.9
Marine C1 >600 kW	$ 1.9	$ 7.8	$ 9.7
Marine C2	$ 2.6	$ 8.9	$ 11.5
Marine Recreational	$ 4.2	$ 0	$ 4.2
Marine Small	$ 1.2	$ 0	$ 1.2
Locomotive Switcher	$ 1.0	$ 3.1	$ 4.1
Locomotive Line Haul	$ 0.6	$ 2.3	$ 2.8
Total	$ 19.4	$ 22.1	$ 41.4

Note: Marine C1 >600 kW includes recreational marine $\geq$ 2000 kW.

Table 5-14 Estimated Tier 3 and Tier 4 Engine Tooling Expenditures by Year ($Millions)

Calendar Year	Locomotive			Marine					Totals		
	Switchers	Line-Haul	Subtotal	Marine C1				Subtotal	Total Spent	PM	NO_X+ NMHC
2006	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2007	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2008	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2009	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2010	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2011	$1.0	$0.6	$1.6	$9.8	$2.6	$4.2	$1.2	$17.8	$19.4	$9.7	$9.7
2012	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2013	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2014	$1.6	$1.1	$2.7	$ -	$ -	$ -	$ -	$ -	$2.7	$2.7	$ -
2015	$ -	$ -	$ -	$7.8	$8.9	$ -	$ -	$16.7	$16.7	$8.3	$8.3
2016	$1.6	$1.1	$2.7	$ -	$ -	$ -	$ -	$ -	$2.7	$ -	$2.7
2017	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2018	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2019	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2020	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2021	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2022	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2023	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2024	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2025	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2026	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2027	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2028	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2029	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2030	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2031	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2032	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2033	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2034	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2035	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2036	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2037	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2038	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2039	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2040	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total	$4.1	$2.8	$6.9	$17.6	$11.5	$4.2	$1.2	$34.5	$41.4	$20.7	$20.7
NPV at 7%	$2.3	$1.5	$3.8	$10.5	$6.2	$2.8	$0.8	$20.3	$24.1	$12.1	$12.0
NPV at 3%	$3.2	$2.1	$5.3	$14.0	$8.8	$3.5	$1.0	$27.3	$32.6	$16.4	$16.2

As shown in Table 5-14, the net present value of the engine tooling expenditures are estimated at $33 million using a three percent discount rate, and $24 million using a seven percent discount rate. We can estimate these expenditures on a per engine basis considering the time value of money and engine sales for 2006 through 2040, as shown in Table 5-15.

Table 5-15 Estimated Engine Tooling Costs per Engine

	Estimated Cost Allocation ($Millions)	Estimated Sales from 2006 to 2040	$/engine
Locomotive Switcher/Passenger	$ 3.2	3,212	$ 980
Locomotive Line Haul	$ 2.1	19,258	$ 110
Small Marine	$ 1.0	324,403	$ 3
Recreational Marine	$ 3.5	432,523	$ 10
Marine C1 <600 kW	$ 8.2	303,024	$ 30
Marine C1 >600 kW	$ 5.8	25,597	$ 230
Marine C2	$ 8.8	6,647	$ 1,320
Total	$ 32.6	1,114,666	$ 30

Note: Net present values of sales are calculated using zero as the sales figure for 2006.

5.2.1.3 Engine Certification Costs

Manufacturers would incur more than the normal level of certification costs during the first few years of implementation because all engines would need to be fully certified to the new emission standards rather than using the normal practice of carrying certification data over from prior years.[f] Consistent with our past locomotive and marine standard setting regulations, we have estimated engine certification costs as shown in Table 5-16. These costs are consistent with past rulemakings, but have been updated to 2005 dollars. Certification costs (for engines in all market segments) apply equally to all engine families for all manufacturers regardless of the markets into which the manufacturer sells.

[f] Note that all engines are certified every year, but most annual certifications involve carrying over test data from prior years since the engine being certified has not changed in an "emissions-meaningful" way. Since new standards preclude use of carry-over data, we estimate new certification costs for all engines. Note that this is, effectively, a conservative estimate since some engines would have changed sufficiently absent our new standards to require new certification data.

Table 5-16 Certification Costs per Engine Family

	$/engine family	# of engine families
Locomotive	$ 42,000	46
Small marine	$ 32,000	24
Marine C1 0.9<L/cyl<1.2	$ 32,000	7
Marine C1 1.2<L/cyl<2.5	$ 43,000	19
Marine C1 L/cyl>2.5	$ 54,000	13
Marine C2 L/cyl>5	$ 54,000	5

To determine the number of engine families to be certified, we looked at our certification databases for the 2004 model year. For marine engines, our database provides the number of engine families, the liters per cylinder for each, and specifies whether it is certified as a C1 or a C2 engine. For locomotive engines, the database provides the engine displacement. We have also split the Marine C1 certification costs evenly between the C1 Marine and Recreational Marine market segments in the Tier 3 timeframe. In the Tier 4 timeframe, only those C1 Marine engines over 600 kW, including those recreational marine engines over 2000 kW, would incur certification costs since those C1 engines under 600 kW and the remaining recreational marine engines will not be meeting the Tier 4 standards. For the small marine segment, we have estimated the number of engine families at 24 based on an estimated two families per each of 10 manufacturers selling into that market, and then another four families sold by marinizers. The costs for small marine would be incurred only in the Tier 3 timeframe since they will not be meeting the Tier 4 standards. Similarly, the locomotive certification costs have been split evenly between locomotive switchers and locomotive line haul for both Tiers 3 and 4. The resultant annual cost streams are shown in Table 5-17. As shown in the table, the Tier 3 certification costs are estimated at $4.7 million, while the Tier 4 certification costs are estimated at around $4.5 million. Despite fewer engines being certified in the Tier 4 timeframe, the costs are roughly equal to the Tier 3 costs because, for the Tier 4 standards, we have estimated that locomotive engines are certified twice, once for the new PM standard and a second time two years later for the new NO_x standard.

The total certification expenditures are estimated at $9.3 million, or $7.3 million at a three percent discount rate and $5.5 million at a seven percent discount rate. The table also makes clear what portion of costs are allocated to NO_x+NMHC and PM, with a 50/50 allocation associated with the Tier 3 standards and the marine Tier 4 standards. The locomotive Tier 4 certification cost allocations align with the Tier 4 standards (PM costs first and NO_x+NMHC costs two years later).

We can estimate these expenditures on a per engine basis considering the time value of money and engine sales for 2006 through 2040, as shown in Table 5-18.

Table 5-17 Estimated Engine Certification Costs by Year ($Millions)

Calendar Year	Locomotive		Marine				Totals		
	Switchers	Line-Haul	Marine C2	Marine C1	Recreational	Small	Total Spent	PM	NO_X+ NMHC
2006	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2007	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2008	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2009	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2010	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2011	$1.0	$1.0	$0.3	$0.9	$0.9	$0.8	$4.7	$2.4	$2.4
2012	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2013	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2014	$1.0	$1.0	$ -	$ -	$ -	$ -	$1.9	$1.9	$ -
2015	$ -	$ -	$0.3	$0.4	$ -	$ -	$0.7	$0.4	$0.4
2016	$1.0	$1.0	$ -	$ -	$ -	$ -	$1.9	$ -	$1.9
2017	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2018	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2019	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2020	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2021	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2022	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2023	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2024	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2025	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2026	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2027	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2028	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2029	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2030	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2031	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2032	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2033	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2034	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2035	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2036	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2037	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2038	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2039	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2040	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total	$2.9	$2.9	$0.5	$1.3	$0.9	$0.8	$9.3	$4.6	$4.6
NPV at 7%	$1.6	$1.6	$0.3	$0.8	$0.6	$0.5	$5.5	$2.8	$2.7
NPV at 3%	$2.2	$2.2	$0.4	$1.1	$0.7	$0.6	$7.3	$3.7	$3.6

Table 5-18 Estimated Engine Certification Costs per Engine

	Estimated Total Cost Allocation ($Millions)	Estimated Sales from 2006 to 2040	$/engine
Locomotive Switcher/Passenger	$ 2.2	3,212	$ 700
Locomotive Line Haul	$ 2.2	19,258	$ 120
Small Marine	$ 0.6	324,403	$ 2
Recreational Marine	$ 0.7	432,523	$ 2
Marine C1	$ 1.1	328,621	$ 3
Marine C2	$ 0.4	6,647	$ 60
Total	$ 7.3	1,114,666	$ 10

Note: Net present values of sales are calculated using zero as the sales figure for 2006.

Note that these certification costs may overestimate actual costs because they assume all engines would be certified as a result of the proposed new emission standards. However, some engines would have been scheduled for new certification independent of the proposed new standards due to design changes or power increases among other possible reasons. For such engines, the incremental certification cost would be zero. However, to remain conservative, here we have applied the certification costs to all engine families.

5.2.2 New Engine Variable Engineering Costs

Engine variable costs are those costs for new hardware required to meet the new Tier 4 emission standards. We have estimated no incremental hardware costs associated with the Tier 3 standards. Unlike the Tier 4 standards, the proposed Tier 3 standards are not based on the introduction of new emission control technologies on locomotive or marine diesel engines. Rather, the Tier 3 standards represent the largest level of emission reductions possible from the emission control systems we project that locomotive and marine engines will already have in the timeframe of Tier 3 implementation. For example, the marine Tier 3 standards are predicated on the use of the most modern nonroad Tier 4 base engine technologies without the use of the nonroad Tier 4 aftertreatment based emission solutions. While these base engines may represent significant technical advances from the marine Tier 2 engines they replace—having better high pressure fuel systems, better injectors, improved turbochargers, and more sophisticated electronic control units—we do not expect the manufacturing costs for these individual components to increase over the cost of the Tier 2 components they will replace. In fact, the shift from the Tier 2 engine's electronic unit pump system to the Tier 3 engine's common rail fuel system may actually result in a fuel system that is cheaper to produce, not more expensive. Similarly, while the processing power of the Tier 3 engine control computer may increase significantly, the cost of the computer chip that makes this possible is likely to be lower. This does not mean that the Tier 3 emission controls come for free. We project there will be costs incurred to optimize the control strategies to meet the stringent Tier 3 standards and further to test and certify these engines. These costs are accounted for as fixed costs described further in section 5.2.1 of this draft RIA.[g]

[g] To clarify, we have analyzed the fixed costs associated with the switch from unit injectors to common rail fuel systems reflecting our belief that this transition will come in part because of our regulation. Because we estimate that common rail fuel systems will be no more expensive than unit injector systems, and may in fact be cheaper, we have made no estimate of an incremental increase in variable costs due to this switch. Similarly, we have not made an estimate of what savings (if any) might be realized from this switch.

For the variable cost estimates presented here, we have used the same methodology to estimate costs as was used in our 2007 highway and our NRT4 rules. Because of the wide variation of engine sizes in the locomotive and marine markets, we have chosen an approach that results not in a specific cost per engine for engines within a given power range or market segment, but rather a set of equations that can be used to determine the variable costs for any engine provided its displacement and number of cylinders are known. Using the equations presented in this section, we have then estimated the engine variable costs for the sales weighted average engine in different power ranges within each market segment.[h]

The discussion here considers both near-term and long-term cost estimates. We believe there are factors that cause hardware costs to decrease over time, making it appropriate to distinguish between near-term and long-term costs. Research in the costs of manufacturing has consistently shown that as manufacturers gain experience in production, they are able to apply innovations to simplify machining and assembly operations, use lower cost materials, and reduce the number or complexity of component parts, all of which allows them to lower the per-unit cost of production. These effects are often described as the manufacturing learning curve.[9]

The learning curve is a well documented phenomenon dating back to the 1930s. The general concept is that unit costs decrease as cumulative production increases. Learning curves are often characterized in terms of a progress ratio, where each doubling of cumulative production leads to a reduction in unit cost to a percentage “p” of its former value (referred to as a “p cycle”). Organizational learning, which brings about a reduction in total cost, is caused by improvements in several areas. Areas involving direct labor and material are usually the source of the greatest savings. Examples include, but are not limited to, a reduction in the number or complexity of component parts, improved component production, improved assembly speed and processes, reduced error rates, and improved manufacturing process. These all result in higher overall production, less scrappage of materials and products, and better overall quality. As each successive p cycle takes longer to complete, production proficiency generally reaches a relatively stable plateau, beyond which increased production does not necessarily lead to markedly decreased costs.

Companies and industry sectors learn differently. In a 1984 publication, Dutton and Thomas reviewed the progress ratios for 108 manufactured items from 22 separate field studies representing a variety of products and services.[10] The distribution of these progress ratios is shown in Figure 5-1. Except for one company that saw increasing costs as production continued, every study showed cost savings of at least five percent for every doubling of production volume. The average progress ratio for the whole data set falls between 81 and 82 percent. Other studies (Alchian 1963, Argote and Epple 1990, Benkard 1999) appear to support the commonly used p

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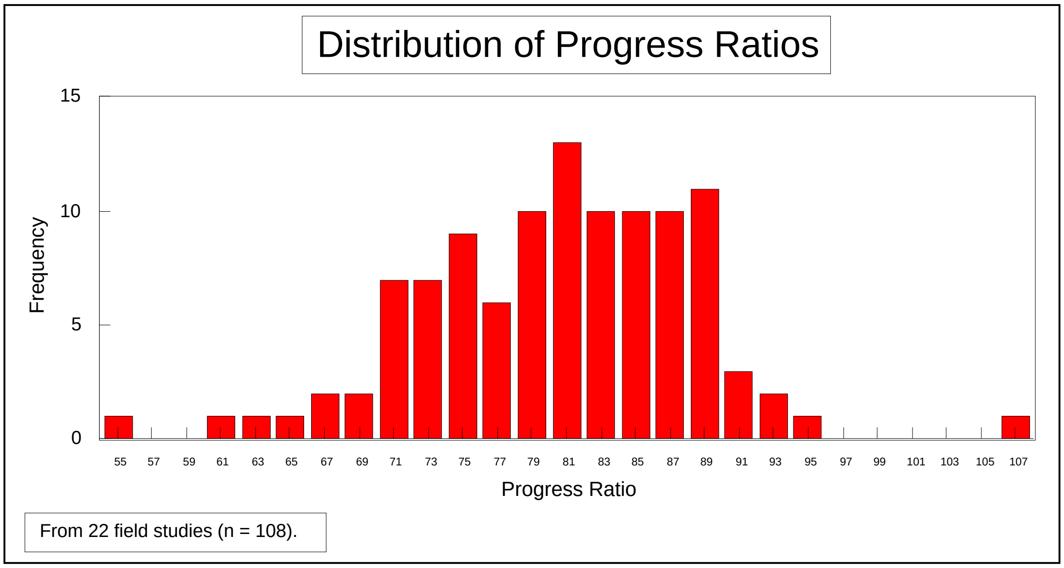
[h] For example, if two engines are sold with one being 100 hp and having 5 sales, the other being 200 hp and having 20 sales, the sales weighted horsepower of engines sold would not be 150 hp but would instead be 180 hp (100x5 + 200x20 = 4,500; 4,500/25 = 180).

value of 80 percent, i.e., each doubling of cumulative production reduces the former cost level by 20 percent.

Figure 5-1 Distribution of Progress Ratios (Dutton and Thomas 1984)



The learning curve is not the same in all industries. For example, the effect of the learning curve seems to be less in the chemical industry and the nuclear power industry where a doubling of cumulative output is associated with 11 percent decrease in cost (Lieberman 1984, Zimmerman 1982). The effect of learning is more difficult to decipher in the computer chip industry (Gruber 1992).

We believe the learning curve is appropriate to consider in assessing the cost impact of diesel engine emission controls. The learning curve applies to new technology, new manufacturing operations, new parts, and new assembly operations. Neither locomotive nor marine diesel engines currently use any form of NO_x or PM aftertreatment except in very limited retrofit applications. Therefore, these are new technologies for these engines and will involve some new manufacturing operations, new parts, and new assembly operations beyond those anticipated in response to the 2007 highway and NRT4 rules. Since this will be a new product, we believe this is an appropriate situation for the learning curve concept to apply. Opportunities will exist to reduce unit labor and material costs and increase productivity as discussed above. We believe a similar opportunity exists for the new control systems that will integrate the function of the engine and emission-control technologies. While impacted diesel engines beginning with Tier 3 compliance are expected to have the basic components of this system—advanced engine control modules (computers), advanced engine air management systems (cooled EGR, and variable geometry turbocharging), and advanced electronic fuel systems including common rail systems—they will be applied in some new ways in response to the Tier 4 standards. Additionally some new components will be applied for the first time. These new parts and new assemblies will involve new manufacturing operations. As manufacturers gain experience with these new systems, comparable learning is expected to occur with respect to unit labor and material costs. These changes require manufacturers to start new production procedures, which will improve with experience.

We have applied a p value of 80 percent beginning with the first year of introduction of any new technology. That is, variable costs were reduced by 20 percent for each doubling of cumulative production following the year in which the technology was first introduced in a given market segment. Because the timing of the emission standards in this final rule follows that of the 2007 highway and NRT4 rules, we have used the first stage of learning done via those rules collectively as the starting point of learning for locomotive and marine engines. In other words, one learning phase is factored into the baseline costs for locomotive/marine engines. We have then applied one additional learning step from that baseline. In the 2007 highway rule, we applied a second learning step following the second doubling of production estimated to occur at the end of the 2010 model year. We could have chosen that point as our baseline case for this rule and then applied a single learning curve effect from there. Instead, to remain conservative, we have chosen to use only the first learning step from the highway/nonroad rules. The approach taken here is consistent with the approaches taken in our Tier 2 light-duty highway rule and the 2007 highway rule for heavy-duty gasoline engines. There, compliance was being met through improvements to existing technologies rather than the development of new technologies. We argued in those rules that, with existing technologies, there is less opportunity for lowering production costs. For that reason, we applied only one learning curve effect. The situation is similar for locomotive and marine engines. Because these will be existing technologies by the time they are introduced into the market, there would arguably be less opportunity for learning than there will be for the highway engines on which the technologies were first introduced.

Another factor that plays into our near-term and long-term cost estimates is that for warranty claim rates. In our 2007 highway rule, we estimated a warranty claim rate of one percent. Subsequent to that rule, we learned from industry that repair rates can be as much as two to three times higher during the initial years of production for a new technology relative to later years.[11] As a result, in our NRT4 rule, we applied a three percent warranty claim rate during the first two years and then one percent warranty claim rate thereafter. We have used the same approach here as used in the NRT4 rule. This difference in warranty claim rates, in addition to the learning effects discussed above, is reflected in the different long-term costs relative to near-term costs.

5.2.2.1 SCR System Costs

The NO_x aftertreatment system anticipated for the Tier 4 standards is the selective catalytic reduction (SCR) system. For the SCR system to function properly, a systems approach that includes a reductant metering system and control of engine-out NO_x emissions is necessary. Many of the new air handling and electronic system technologies developed to meet past locomotive and marine standards, and past highway and nonroad standards can be applied to accomplish the SCR system control functions as well. Some additional hardware for exhaust NO_x or oxygen sensing may also be required.

We have used the same methodology to estimate costs associated with SCR systems as was used in our 2007 highway and NRT4 rulemakings for other aftertreatment devices. The basic components of the SCR system are well known and include the following material elements:

- a ceramic substrate upon which a NO_x catalyst washcoating is applied;
- a can to hold and support the substrate;
- a urea dosing unit (urea injector and control computer);
- a urea storage tank and associated brakets; and,
- an exhaust gas sensor (e.g., a NO_x sensor) used for control.

Examples of these material costs are summarized in Table 5-19 and represent costs to the engine manufacturers inclusive of supplier markups. The manufacturer costs shown in Table 5-19 include additional markups to account for both manufacturer and dealer overhead and carrying costs. The application of overhead and carrying costs is consistent with the approach taken in the 2007 highway and NRT4 rulemakings. In those rules, we estimated the markup for catalyzed emission-control technologies based on input from catalyst manufacturers. Specifically, we were told that device manufacturers could not mark up the cost of the individual components within their products because those components consist of basic commodities (for example, precious metals used in the catalyst could not be arbitrarily marked up because of their commodity status). Instead, manufacturing entities could mark up costs only where they add a unique value to the product. In the case of catalyst systems, the underlying cost of precious metals, catalyst substrates, PM filter substrates, and canning materials were well known to both buyer and seller and no markup or profit recovery for those component costs could be realized by the catalyst manufacturer. In essence, these are components to which the supplier provides little value-added engineering.

The one component that is unique to each catalyst manufacturer (i.e., the component where they add a unique value) is the catalyst washcoat support materials. This mixture (which is effectively specialized clays) serves to hold the catalytic metals in place and to control the surface area of the catalytic metals available for emission control. Although the price for the materials used in the washcoat is almost negligible (i.e., perhaps one or two dollars), we have estimated a substantial cost for washcoating based on the engineering value added by the catalyst manufacturer in this step. This is reflected in the costs presented for SCR systems and DPF systems. This portion of the cost estimate – the washcoating – is where the catalyst manufacturer recovers the fixed cost for research and development as well as realizes a profit. To these manufacturer costs, we have added a four percent carrying cost to account for the capital cost of the extra inventory, and the incremental costs of insurance, handling, and storage. A dealer carrying cost is also included to cover the cost of capital tied up in extra inventory. Considering input received from industry, we have adopted this approach of estimating individually the manufacturer and dealer markups in an effort to better reflect the value each entity adds at various stages of the supply chain.[12] Also included is our estimate of warranty costs for the system.

Table 5-19 SCR System Costs (costs shown are costs per SCR system for the given engine power/displacement)

Typical Engine Power (kW)	7	25	57	187	375	746	3730
Typical Engine Displacement (Liter)	0.4	1.5	3.9	7.6	18.0	34.5	188.0
Material and component costs							
Catalyst Volume (Liter)	1.0	3.8	9.8	19.1	45.0	86.3	470.0
Substrate	$29	$113	$294	$573	$1,350	$2,588	$14,100
Washcoating and Canning	$423	$517	$721	$1,035	$1,910	$3,302	$16,258
Platinum	$0	$0	$0	$0	$0	$0	$0
Catalyst Can Housing	$12	$12	$13	$15	$20	$28	$100
Urea Dosing Unit (Injection Assembly w/ ECU)	$500	$527	$585	$674	$922	$1,318	$5,000
Urea Solution Tank & Brackets	$2	$8	$18	$60	$121	$240	$1,200
NO_x sensor (1 sensor/engine)	$200	$200	$200	$200	$200	$200	$200
DOC for cleanup	$233	$245	$271	$312	$425	$605	$2,280
Direct Labor Costs							
Estimated Labor hours	4	4	4	4	4	8	8
Labor Rate ($/hr)	$18	$18	$18	$18	$18	$18	$18
Labor Cost	$72	$72	$72	$72	$72	$145	$145
Labor Overhead @ 40%	$29	$29	$29	$29	$29	$58	$58
Total Direct Costs to Mfr.	$1,501	$1,723	$2,204	$2,971	$5,049	$8,484	$39,341
Warranty Cost (3% claim rate)	$111	$128	$164	$221	$377	$627	$2,941
Mfr. Carrying Cost - Near term	$60	$69	$88	$119	$202	$339	$1,574
Total Cost to Dealer - Near term	$1,672	$1,919	$2,456	$3,311	$5,628	$9,450	$43,856
Dealer Carrying Cost - Near term	$50	$58	$74	$99	$169	$283	$1,316
Baseline Cost to Buyer - Near term	$1,722	$1,977	$2,530	$3,410	$5,797	$9,733	$45,171
Loco/Marine Cost to Buyer (includes highway learning) - Near term	**$1,377**	**$1,581**	**$2,024**	**$2,728**	**$4,638**	**$7,787**	**$36,137**
Warranty Cost (1% claim rate)	$37	$43	$55	$74	$126	$209	$980
Mfr. Carrying Cost - Long term	$60	$69	$88	$119	$202	$339	$1,574
Total Cost to Dealer - Long term	$1,598	$1,834	$2,347	$3,163	$5,377	$9,032	$41,895
Dealer Carrying Cost - Long term	$48	$55	$70	$95	$161	$271	$1,257
Baseline Cost to Buyer - Long term	$1,646	$1,889	$2,418	$3,258	$5,538	$9,303	$43,152
Baseline Cost to Buyer (includes Highway Learning) - Long term	$1,317	$1,511	$1,934	$2,606	$4,431	$7,442	$34,521
Loco/Marine Cost to Buyer (includes Loco/Marine learning) - Long term	**$1,053**	**$1,209**	**$1,547**	**$2,085**	**$3,544**	**$5,954**	**$27,617**

We have estimated the cost of this system based on information from several reports.[13, 14, 15] The individual estimates and assumptions used to estimate the cost for the system are touched upon in the following paragraphs.

SCR Catalyst Volume

During development of this proposal, engine and aftertreatment device manufacturers have indicated that SCR catalyst volumes could be from one to three times engine displacement for locomotive and marine applications. As explained in Chapter 4 of this draft RIA, we have used a ratio of SCR volume to engine displacement equal to 2.5:1.

SCR Catalyst Substrate

The ceramic flow-through substrates used for the SCR catalyst were estimated to cost $30 per liter.

SCR Catalyst Washcoating and Canning

We have estimated a “value-added” engineering and material product, called washcoating and canning, based on feedback from members of the Manufacturers of Emission Control Association (MECA). By using a value-added component that accounts for fixed costs (including R&D), overhead, marketing and profits from likely suppliers of the technology, we can estimate this fraction of the cost for the technology apart from other components that are more widely available as commodities (e.g, precious metals and catalyst substrates). Based on conversations with MECA, we understand this element of the product to represent the catalyst manufacturer’s value added and, therefore, their opportunity for markup. As a result, the washcoating and canning costs shown in Table 5-19 represent costs with manufacturer markups included. The washcoating and canning costs can be expressed as $34(x) + $390, where x is the catalyst volume in liters. This washcoating cost is higher than our past rulemakings because of dual washcoating process we anticipate will be used to “zone coat” the diesel oxidation function onto a portion of the SCR catalyst (as discussed below).

SCR Catalyst Precious Metals

We expect that the SCR catalysts used in locomotive and marine applications will contain no precious metals (e.g., the platinum group metals platinum, palladium, and rhodium). As a result, we have estimated zero costs associated with these commodities.

SCR Can Housing

The material cost for the can housing is estimated based on the catalyst volume plus 20 percent for transition (inlet/outlet) cones, plus 20 percent for scrappage (material purchased but unused in the final product) and a price of $1 per pound for 18 gauge stainless steel as estimated in a contractor report to EPA and converted into $2005.[16]

Urea Dosing Unit

The costs for the urea dosing unit are based in part on our past contractor report that estimated the costs at $250 to $300 for units meant for 12 to 26 liter catalysts. Here, we have adjusted the numbers based on recent conversations with industry by estimating the costs for the smallest engines at $500 and the largest at $5,000. We then used a linear interpolation to arrive at the costs for engines in between.

Urea Solution Tank and Brackets

The estimated costs for the urea solution tank and brackets is based on industry input that fuel tank size is roughly one gallon per engine horsepower and urea dosing rate is roughly four percent of the fueling rate. We also estimated that a urea tank would cost $60 per 10 gallons of volume. Using these estimates, the needed urea tank size and associated cost can be estimated.

NO_x Sensor Cost

We believe that one sensor will be needed per catalyst and have used an estimated cost of $200 per sensor based on today's cost of $300 for use in retrofit applications (retrofit applications are typically considerably more costly than new). With increased NO_x sensor sales volumes in future locomotive, marine, highway, and nonroad markets, we believe that NO_x sensor costs may well be in the $50 to $100 range, if not lower. For this analysis, we have chosen to remain conservative by using the $200 per sensor estimate.

DOC for Cleanup

Included in the costs for the SCR system are costs for a diesel oxidation catalyst (DOC) for clean-up of possible excess ammonia emissions that might occur as a result of excessive urea usage. The methodology used to estimate DOC costs is consistent with the SCR system cost methodology and is presented below in Table 5-20. These cost estimates use a DOC to engine displacement ratio of 0.5:1 because the low emissions conversion demand placed on the DOC is not expected to require a larger device.

Table 5-20 Diesel Oxidation Costs (costs shown are costs per SCR system for the given engine power/displacement)

Typical Engine Power (kW)	7	25	57	187	375	746	3730
Typical Engine Displacement (Liter)	0.4	1.5	3.9	7.6	18.0	34.5	188.0
Material and component costs							
Catalyst Volume (liter)	0.2	0.8	2.0	3.8	9.0	17.3	94.0
	$0	$0	$0	$0	$0	$0	$0
Substrate	$187	$195	$212	$238	$310	$424	$1,491
Washcoating and Canning	$1	$4	$10	$19	$46	$88	$480
Platinum Catalyst Can Housing	$0	$0	$0	$0	$0	$0	$0
Direct Labor Costs							
	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Estimated Labor hours Labor Rate ($/hr)	$18	$18	$18	$18	$18	$18	$18
Labor Cost	$9	$9	$9	$9	$9	$9	$9
Labor Overhead @ 40%	$4	$4	$4	$4	$4	$4	$4
Total Direct Costs to Mfr.	$201	$212	$235	$270	$368	$525	$1,984
Warranty Cost - Near Term (3% claim rate)	$17	$18	$20	$22	$30	$41	$151
Mfr. Carrying Cost - Near Term	$8	$8	$9	$11	$15	$21	$79
Total Cost to Dealer - Near Term	$226	$238	$264	$303	$413	$588	$2,214
Dealer Carrying Cost - Near Term	$7	$7	$8	$9	$12	$18	$66
Loco/Marine Cost to Buyer	**$233**	**$245**	**$271**	**$312**	**$425**	**$605**	**$2,280**

Important to note here is that we expect the DOC function to be fulfilled within the confines of the SCR catalyst using a process known as “zone coating” by which the DOC washcoat is applied to the tail end of the SCR catalyst substrate. By doing this, a physically separate DOC is not necessary. We have remained conservative in our cost analysis by including costs associated with canning of the DOC.

Direct Labor Costs

The direct labor costs for the catalyst are estimated based on an estimate of the number of hours required for assembly and established labor rates. Additional overhead for labor was estimated as 40 percent of the labor costs.

SCR Warranty Costs

We have estimated both near-term and long-term warranty costs. Near-term warranty costs are based on a three percent claim rate and an estimate of parts and labor costs per incident, while long-term warranty costs are based on a one percent claim rate and an estimate of parts and labor costs per incident.[17] The labor rate is assumed to be $50 per hour with four hours required per claim, and parts costs are estimated to be 2.5 times the original manufacturing cost for the component. The calculation of near-term warranty costs for the 7 kW engine shown in Table 5-19 is as follows:

[($29+$423+$12+$500+$2+$200+$233)(2.5) + ($50)(4hours)](3%) = $111

Manufacturer and Dealer Carrying Costs

The manufacturer’s carrying cost was estimated at 4 percent of the direct costs. This reflects primarily the costs of capital tied up in extra inventory, and secondarily the incremental costs of insurance, handling and storage. The dealer’s carrying cost was estimated at 3 percent of the incremental cost, again reflecting primarily the cost of capital tied up in extra inventory.

SCR System Cost Estimation Function

Using the example SCR system costs shown in the table, we calculated a linear regression to determine the SCR system cost as a function of engine displacement. This way, the function can be applied to the wide array of engines in the locomotive line haul and marine fleets to determine the total or per engine costs for SCR hardware. The functions calculated for SCR system costs in line-haul locomotives and marine applications are shown in Table 5-21.

For locomotive switcher applications, we have used the costs developed for our NRT4 rulemaking because locomotive switchers tend to be powered by land based nonroad engines. For this reason, it seemed most appropriate to use the same costs developed for that rule. These costs are also shown in Table 5-21.

Table 5-21 SCR System Costs as a Function of Engine Displacement, x, in Liters

		Linear Regression	R^2
Line haul locomotive; marine	Near-term cost function	$185(x) + $1,323	0.999
	Long-term cost function	$142(x) + $1,012	0.999
Switcher locomotive	Near-term cost function	$103(x) + $183	0.999
	Long-term cost function	$83(x) + $160	0.999

Note: Near term costs include a 3 percent warranty claim rate while long term costs include a 1 percent warranty claim rate and the learning effect.

This table shows both a near-term and a long-term cost function for SCR system costs. The near-term function incorporates the near-term warranty costs determined using a three percent claim rate, while the long-term function incorporates the long-term warranty costs determined using a one percent claim rate. Additionally, the long-term function incorporates learning curve effects.

5.2.2.2 DPF System Costs

One means of meeting the proposed Tier 4 PM standard is to use a diesel particulate filter (DPF) system like that expected to be used for highway and NRT4 applications. However, as explained in Chapter 4 of this draft RIA, here we are projecting a DPF volume to engine displacement ratio of 1.7:1. In the highway and nonroad rules, we projected ratios of 1.5:1. For the DPF to function properly, a systems approach that includes precise control of engine air-fuel ratio is also necessary. Many of the new air handling and electronic fuel system technologies developed in order to meet the highway, nonroad, and past locomotive/marine standards can be applied to accomplish the DPF control functions as well.

We have used the same methodology to estimate costs associated with DPF systems as was used in our 2007 highway and NRT4 rulemakings. The basic components of the DPF are well known and include the following material elements:

- An oxidizing catalyst, typically platinum;
- a substrate upon which the catalyst washcoating is applied and upon which PM is trapped;

- a can to hold and support the substrate.

Examples of these material costs are summarized in Table 5-22 and represent costs to the engine manufacturers inclusive of supplier markups. The total direct cost to the manufacturer includes an estimate of warranty costs for the DPF system. Hardware costs are additionally marked up to account for both manufacturer and dealer overhead and carrying costs. The manufacturer's carrying cost was estimated to be four percent of the direct costs accounting for the capital cost of the extra inventory, and the incremental costs of insurance, handling, and storage. The dealer's carrying cost was marked up three percent reflecting the cost of capital tied up in inventory. We have adopted this approach of estimating individually the manufacturer and dealer markups in an effort to better reflect the value added at each stage of the supply chain based on industry input.[18]

Table 5-22 DPF System Costs (costs shown are costs per DPF system for the given engine power/displacement)

Typical Engine Power (kW)	7	25	57	187	375	746	3730
Typical Engine Displacement (Liter)	0.4	1.5	3.9	7.6	18.0	34.5	188.0
Material and component costs							
Filter Volume (Liter)	0.7	2.6	6.7	13.0	30.6	58.7	319.6
	$46	$176	$461	$898	$2,117	$4,057	$22,108
Filter Trap	$96	$111	$143	$192	$328	$546	$2,571
Washcoating and Canning	$41	$156	$408	$796	$1,874	$3,592	$19,575
Platinum Filter Can Housing	$9	$10	$11	$12	$16	$21	$74
Differential Pressure Sensor	$52	$52	$52	$52	$52	$52	$52
Direct Labor Costs							
	4	4	4	4	4	8	8
Estimated Labor hours Labor Rate ($/hr)	$18	$18	$18	$18	$18	$18	$18
Labor Cost	$72	$72	$72	$72	$72	$145	$145
Labor Overhead @ 40%	$29	$29	$29	$29	$29	$58	$58
Total Direct Costs to Mfr.	$345	$606	$1,175	$2,051	$4,488	$8,471	$44,583
Warranty Cost -- Near Term (3% claim rate)	$21	$41	$84	$149	$332	$623	$3,332
Mfr. Carrying Cost -- Near Term	$14	$24	$47	$82	$180	$339	$1,783
Total Cost to Dealer -- Near Term	$380	$671	$1,306	$2,282	$4,999	$9,433	$49,698
Dealer Carrying Cost -- Near Term	$11	$20	$39	$68	$150	$283	$1,491
Savings by removing silencer	($52)	($52)	($52)	($52)	($52)	($52)	($52)
Baseline Cost to Buyer -- Near Term	$340	$640	$1,293	$2,298	$5,098	$9,664	$51,137
Loco/Marine Cost to Buyer (includes highway learning) - Near term	**$272**	**$512**	**$1,035**	**$1,839**	**$4,078**	**$7,731**	**$40,910**
Warranty Cost -- Long Term (1% claim rate)	$7	$14	$28	$50	$111	$208	$1,111
Mfr. Carrying Cost -- Long Term	$14	$24	$47	$82	$180	$339	$1,783
Total Cost to Dealer -- Long Term	$366	$644	$1,250	$2,182	$4,778	$9,017	$47,477
Dealer Carrying Cost -- Long Term	$11	$19	$38	$65	$143	$271	$1,424
Savings by removing muffler	($52)	($52)	($52)	($52)	($52)	($52)	($52)
Baseline Cost to Buyer -- Long Term	$325	$611	$1,236	$2,196	$4,870	$9,236	$48,849
Baseline Cost to Buyer (includes Highway Learning) - Long term	$260	$489	$989	$1,757	$3,896	$7,389	$39,080
Loco/Marine Cost to Buyer (includes Loco/Marine learning) - Long term	**$208**	**$391**	**$791**	**$1,405**	**$3,117**	**$5,911**	**$31,264**

DPF Volume

During development of this proposal, engine manufacturers have suggested that DPF volumes could be up to three times engine displacement. The size of the DPF is based largely on the maximum allowable flow restriction for the engine. Generically, the filter size is inversely proportional to its resistance to flow (a larger filter is less restrictive than a similar smaller filter). In the 2007 highway and NRT4 rules, we estimated that the DPF would be sized to be 1.5 times the engine displacement based on the responses received from EMA and on-going research aimed at improving filter porosity control to give a better trade-off between flow restrictions and filtering efficiency. As explained in Chapter 4 of this draft RIA, here we have estimated a ratio of 1.7:1.

DPF Substrate

The DPF can be made from a wide range of filter materials including wire mesh, sintered metals, fibrous media, or ceramic extrusions. The most common material used for DPFs for heavy-duty diesel engines is cordierite. Here we have based our cost estimates on the use of silicon carbide (SiC) even though it is more expensive than other filter materials. In the 2007 highway rule, we estimated that DPFs would consist of a cordierite filter costing $30 per liter. To remain conservative in our cost estimates for nonroad applications, we assumed the use of silicon carbide filters costing double that amount, or $60 per liter, because silicon carbide filters are more durable. As discussed in Chapter 4 of this draft RIA, we believe that metal substrates may be choice for locomotive and marine DPFs, which would cost less than a silicon carbide substrate. Nonetheless, to be conservative in our cost estimates, we have assumed use of silicon carbide filters for locomotive and marine applications, so have based costs on the $60 per liter cost estimate. This cost is directly proportional to filter volume, which is proportional to engine displacement. We have converted the $60 value to $2005 using the Producer Price Index (PPI) for manufacturing industries; the end result being a cost of $62 per liter.[19]

DPF Washcoating and Canning

These costs are based on costs developed under contract for our 2007 highway rule.[20] We converted those costs to $2005 using the PPI for manufacturing industries. We then calculated a linear "best fit" to express the washcoating and canning costs as $8(x) + $91, where x is the DPF volume in liters.

DPF Precious Metals

The total precious metal content for DFPs is estimated to be 60 g/ft^3 with platinum as the only precious metal used in the filter. In our NRT4 rule, we used a price of $542 per troy ounce for platinum. Here we have used the 2005 average monthly price of $899 per troy ounce for platinum.[21]

DPF Can Housing

The material cost for the can housing is estimated based on the DPF volume plus 20 percent for transition (inlet/outlet) cones, plus 20 percent for scrappage (material purchased but unused in the final product) and a price of $1 per pound for 18 gauge stainless steel as estimated in a contractor report to EPA and converted into $2005.

DPF Differential Pressure Sensor

We believe that the DPF system will require the use of a differential pressure sensor to provide a diagnostic monitoring function of the filter. A contractor report to EPA estimated the cost for such a sensor at $45.[22] A PPI adjusted cost of $52 per sensor has been used in this analysis.

DPF Direct Labor

Consistent with the approach for SCR systems, the direct labor costs for the DPF are estimated based on an estimate of the number of hours required for assembly and established labor rates. Additional overhead for labor was estimated as 40 percent of the labor costs.

DPF Warranty

Consistent with the approach taken for SCR system costs, we have estimated both near-term and long-term warranty costs. Near-term warranty costs are based on a three percent claim rate and an estimate of parts and labor costs per incident, while long-term warranty costs are based on a one percent claim rate and an estimate of parts and labor costs per incident. The labor rate is estimated to be $50 per hour with two hours required per claim, and parts cost are estimated to be 2.5 times the original manufacturing cost for the component.

DPF Manufacturer and Dealer Carrying Costs

Consistent with the approach for SCR systems, the manufacturer’s carrying cost was estimated at four percent of the direct costs. This reflects primarily the costs of capital tied up in extra inventory, and secondarily the incremental costs of insurance, handling and storage. The dealer’s carrying cost was estimated at three percent of the incremental cost, again reflecting primarily the cost of capital tied up in extra inventory.

Savings Associated with Silencer Removal

DPF retrofits are often incorporated in, or are simply replacements for, the silencer (muffler) for diesel-powered vehicles and equipment. We believe that the DPF could be mounted in place of the silencer, although it may have slightly larger dimensions. We have estimated that applying a DPF allows for the removal of the silencer due to the noise attenuation characteristics of the DPF. We have accounted for this savings and have estimated a silencer costs at $52. The $52 estimate is an average for all engines; the actual savings will be higher for some and lower for others.

DPF System Cost Estimation Function

Using the example DPF costs shown in Table 5-22, we calculated a linear regression to determine the DPF system cost as a function of engine displacement. This way, the function can be applied to the wide array of engines in the locomotive line haul and/or marine fleets to determine the total or per engine costs for DPF system hardware. The functions calculated for DPF system costs for locomotive line-haul and marine applications are shown in Table 5-23.

For locomotive switcher applications, we have used the costs developed for our NRT4 rulemaking because locomotive switchers tend to be powered by land based nonroad engines making it appropriate to use the same costs developed for that rule. These costs are also shown in Table 5-23.

Table 5-23 DPF System Costs as a function of Engine Displacement, x, in Liters

		Linear Regression	R^2
Line-haul locomotive; marine	Near-term cost function	$217(x) + $199	0.999
	Long-term cost function	$166(x) + $153	0.999
Switcher locomotive	Near-term cost function	$146(x) + $75	0.999
	Long-term cost function	$112(x) + $57	0.999

Note: Near term costs include a 3 percent warranty claim rate while long term costs include a 1 percent warranty claim rate and the learning effect.

The near-term and long-term costs shown in Table 5-23 change due to the different warranty claim rates and the application of a 20 percent learning curve effect.

5.2.2.3 Aftertreatment Marinization Costs

For marine engines, the Tier 4 requirements will entail increased costs associated with marinizing the engines for the marine environment. Marine C1 and C2 engines are typically land based nonroad engines that are marinized for the marine environment. This marinization can take many forms, but is generally a matter of altering the cooling system to make use of sea or lake water rather than relying on ambient air since marine engines tend to be enclosed within vessels where ambient air radiators like those used in land based engines cannot operate efficiently. Such marinization efforts have been done for years and will continue but do not represent incremental costs associated with the new standards. Marinization costs associated with the new aftertreatment devices that would be added to comply with the Tier 4 standards—to control the surface temperatures in the typically tight space constraints onboard a vessel—do represent incremental costs associated with the proposed program and, thus, they must be considered.

Under contract to EPA, ICF International conducted a study that considered the costs associated with marinizing aftertreatment devices.[23] In their study, ICF looked at the costs associated with two methods of marinization: triple wall stainless steel; and, insulating blankets. Both methods could be used to control the surface temperature of the aftertreatment device such that accidental touching would not cause burns or otherwise compromise safety. The triple wall insulation method proved more cost efficient. Using this method, the device would, essentially, have three layers of stainless steel surrounding the substrate rather than the single layer normally used on land based engines. These layers would be separated by a few millimeters to provide an insulating air gap.

The ICF study looked at aftertreatment marinizing costs for a range of engine sizes in a manner similar to that discussed above for SCR and DPF systems. The details of these estimates are contained in the final report.[24] In the report, ICF calculated costs using a 1:1 or a 1.5:1 device volume to engine displacement ratio. However, as noted earlier, our analysis leads us to believe that a 2.5:1 ratio (SCR) and 1.7:1 ratio (DPF) are more applicable. As a result, we have adjusted the ICF results somewhat higher to reflect a larger sized device being insulated; these adjustments are reflected in Table 5-24 for marinization of SCR systems and in Table 5-25 for marinization of DPF systems. The resultant linear regression best fit curves for marinization costs as a function of engine displacement are shown in Table 5-26.

Table 5-24 SCR System Marinization Costs

Typical Engine Power (kW)	64	93	183	620	968	1425	1902	3805	5968
Typical Engine Displacement (L)	4.2	7	10.5	27	34.5	51.8	111	222	296
SCR Catalyst Marinization Hardware Cost	$23	$28	$29	$65	$77	$91	$173	$292	$350
Assembly	$0	$0	$0	$0	$0	$0	$0	$0	$0
Labor @ $28/hr	$3	$3	$3	$3	$3	$3	$3	$3	$3
Overhead @ 40%	$1	$1	$1	$1	$1	$1	$1	$1	$1
Total Assembly Cost	$4	$4	$4	$4	$4	$4	$4	$4	$4
Markup on Hardware and Assembly @ 29%	$8	$9	$9	$20	$24	$28	$51	$86	$103
Total SCR Catalyst Marinization Costs - Near term	$34	$42	$42	$90	$105	$123	$228	$382	$456
Total SCR Catalyst Marinization Costs - Long term	$27	$33	$34	$72	$84	$98	$182	$305	$365

Table 5-25 DPF System Marinization Costs

Typical Engine Power (kW)	64	93	183	620	968	1425	1902	3805	5968
Typical Engine Displacement (L)	4.2	7	10.5	27	34.5	51.8	111	222	296
DPF Marinization Hardware Cost	$15	$22	$29	$52	$61	$75	$112	$218	$262
Assembly	$0	$0	$0	$0	$0	$0	$0	$0	$0
Labor @ $28/hr	$3	$3	$3	$3	$3	$3	$3	$3	$3
Overhead @ 40%	$1	$1	$1	$1	$1	$1	$1	$1	$1
Total Assembly Cost	$4	$4	$4	$4	$4	$4	$4	$4	$4
Markup on Hardware and Assembly @ 29%	$6	$8	$9	$16	$19	$23	$34	$64	$77
Total DPF Marinization Costs - Near term	$25	$34	$42	$72	$84	$102	$150	$286	$343
Total DPF Marinization Costs - Long term	$20	$27	$34	$58	$67	$81	$120	$229	$274

Table 5-26 Marinization Costs as a function of Engine Displacement, x, in Liters

		Linear Regression	R^2
SCR System Marinization	Near-term cost function	$1(x) + $42	0.990
	Long-term cost function	$1(x) + $34	0.990
DPF System Marinization	Near-term cost function	$1(x) + $35	0.991
	Long-term cost function	$1(x) + $28	0.991

Note: Near term costs include a 3 percent warranty claim rate while long term costs include a 1 percent warranty claim rate and the learning effect.

5.2.2.4 Summary of Engine Variable Cost Equations

Engine variable costs are discussed in detail in sections 5.2.2.1 through 5.2.2.3. As described in those sections, we have generated cost estimation equations for SCR systems, DPF systems, and aftertreatment marinization as a function of engine displacement. These equations are summarized in Table 5-27. Note that not all equations were used for all engines and all market segments; equations were used in the manner shown in the table. We have calculated the aggregate engine variable costs and present them later in this chapter.

Table 5-27 Summary of Cost Equations for Engine Variable Costs (x represents the dependent variable)

Engine Technology	Time Frame	Cost Equation	Dependent Variable	How Used
SCR System Costs	Near term Long term	\$185(x) + \$1,323 \$142(x) + \$1,012	Engine Displacement (Liters)	Tier 4 Locomotive Line-haul and Marine Engines
SCR System Costs	Near term Long term	\$103(x) + \$183 \$83(x) + \$160	Engine Displacement (Liters)	Tier 4 Locomotive Switcher Engines
DPF System Costs	Near term Long term	\$217(x) + \$199 \$166(x) + \$153	Engine Displacement (Liters)	Tier 4 Locomotive Line-haul and Marine Engines
DPF System Costs	Near term Long term	\$146(x) + \$75 \$112(x) + \$57	Engine Displacement (Liters)	Tier 4 Locomotive Switcher Engines
SCR Marinization Costs	Near term Long term	\$1(x) + \$42 \$1(x) + \$34	Engine Displacement (Liters)	Tier 4 Marine Engines
DPF Marinization Costs	Near term Long term	\$1(x) + \$35 \$1(x) + \$28	Engine Displacement (Liters)	Tier 4 Marine Engines

Using these equations, we can calculate the variable costs associated with the Tier 4 standards for any engine provided we know its displacement, power, and intended application. We could do this for every compliant engine expected to be sold in the years following implementation of the new standards, total the results, and we would have the total annual variable costs associated with the rule. We can achieve essentially the same thing by calculating a sales weighted variable cost. This could be done for a single engine that could represent the entire fleet provided we sales weighted the critical characteristics of that engine. Doing this for one engine would not provide a particularly good look at the impact of the new standards on costs since the sizes of engines, their power, and use varies so much. Therefore, we have broken the fleet first into the market segments according to our regulatory definitions (i.e., marine C1, marine C2, locomotive, etc.). We have further broken each market segment into several power ranges, some of which are arbitrary and meant only to provide more stratification of the results, and some of which are chosen to align properly with the structure of the new standards (e.g., marine C1 has a power cutpoint at 600 kW since the Tier 4 standards apply to marine engines above 600 kW).

The necessary engine characteristics for sales weighting are engine displacement, power, and application. We have used the PSR database and sales figures from 2002. The resultant sales weighted engines within given market segments and power ranges are shown in Table 5-28.[i] For example, the sales weighted engine in the marine C1 segment, power range 800 to 2000 hp, has an engine displacement of 33.4 liters and is 1266 hp (944 kW). Empty cells in the table mean that there are no engines in that power range and market segment.

Table 5-28 Sales Weighted Engine Characteristics by Market Segment and Power Range

Power Range	Loco-LineHaul	Loco-Switcher	Marine C1	Marine C2	Marine Recreational	Small Marine
	Sales Weighted Displacement (Liters)					
0<hp<25						0.6
25<=hp<50						1.6
50<=hp<75		2.7	2.5		2.6	
75<=hp<200		5.8	5.5		5.0	
200<=hp<400		7.7	10.5		4.9	
400<=hp<800		18.9	17.6		8.8	
800<=hp<2000		51.8	33.4	93.0	28.9	
2000+	174.2	69.0	62.5	176.4	48.7	
	Sales Weighted Horsepower					
0<hp<25						15.8
25<=hp<50						36.0
50<=hp<75		67.0	58.2		61.1	
75<=hp<200		157.7	149.6		159.1	
200<=hp<400		227.3	301.1		269.7	
400<=hp<800		660.0	553.2		457.2	
800<=hp<2000		1500.0	1266.3	1508.6	1226.1	
2000+	4895.2	2000.0	2529.4	4014.5	2345.2	

Using these sales weighted engines shown in Table 5-28 and the variable cost equations shown in Table 5-27, we can calculate the individual piece costs for the various hardware elements expected to be added to engines to comply with the new standards. Those elements, as discussed above, being SCR systems, DPF systems, and costs associated with marinizing the SCR and the DPF systems (for marine engines only). The resultant piece costs are shown in Table 5-29. The table includes costs for engines in power ranges that are expected to add the new hardware or upgrade existing hardware. Empty cells reflect our belief that the technology will not be added as a result of our proposed rule. The rows containing data for “All engines” are costs for the sales weighted engine within each market segment. For Marine C1, we have also broken out the sales weighted costs for engines below and above 600 kW (805 hp). We use these values—those for “All engines” or, for the C1 marine

[i] Note that the Marine C1 entries in the table include recreational marine engines over 2000 kW.

segment, those for “<600 kW” or “>600 kW”—for our total cost calculations presented in section 5.6.

Table 5-29 Piece Costs for Engine Hardware by Market Segment and Power Range

Power Range	Line-Haul	Switchers	Marine C1	Marine C2
	SCR System Costs - Near term			
0<hp<25				
25<=hp<50				
50<=hp<75				
75<=hp<200		$778		
200<=hp<400		$979		
400<=hp<800		$2,140		
800<=hp<2000				$18,554
2000+	$33,591	$7,315	$12,904	$34,012
All engines	$33,591	$1,639		$30,502
<800 hp only		$852		
>800 hp only				
	SCR Marinization Costs - Near term			
0<hp<25				
25<=hp<50				
50<=hp<75				
75<=hp<200				
200<=hp<400				
400<=hp<800				
800<=hp<2000			$91	$178
2000+			$133	$300
All engines				$272
<800 hp only				
>800 hp only			$106	
	DPF System Costs - Near term			
0<hp<25				
25<=hp<50				
50<=hp<75		$467		
75<=hp<200		$918		
200<=hp<400		$1,203		
400<=hp<800				
800<=hp<2000		$7,650	$7,437	$20,344
2000+	$37,924	$10,175	$13,738	$38,416
All engines	$37,924	$2,137		$34,312
<800 hp only				
>800 hp only		$8,949	$9,679	
	DPF Marinization Costs - Near term			
0<hp<25				
25<=hp<50				
50<=hp<75				
75<=hp<200				
200<=hp<400				
400<=hp<800				
800<=hp<2000			$71	$135
2000+			$102	$225
All engines				$205
<800 hp only				
>800 hp only			$82	

Power Range	Line-Haul	Switchers	Marine C1	Marine C2
	SCR System Costs - Long term			
0<hp<25				
25<=hp<50				
50<=hp<75		$381		
75<=hp<200		$635		
200<=hp<400				
400<=hp<800		$1,723		
00<=hp<2000		$4,431	$5,743	$14,180
2000+	$25,672	$5,855	$9,862	$25,993
All engines				$23,311
<800 hp only		$695		
>800 hp only		$5,163	$7,209	
	SCR Marinization Costs - Long term			
0<hp<25				
25<=hp<50				
50<=hp<75				
75<=hp<200				
200<=hp<400				
400<=hp<800				
800<=hp<2000			$73	$143
2000+				$242
All engines				$219
<800 hp only				
>800 hp only			$85	
	DPF System Costs - Long term			
0<hp<25				
25<=hp<50				
50<=hp<75		$357		
75<=hp<200		$702		
200<=hp<400		$920		
400<=hp<800		$2,177		
800<=hp<2000		$5,850	$5,684	$15,547
2000+				$29,358
All engines	$28,982	$1,634		$26,222
<800 hp only		$782		
>800 hp only		$6,843	$7,397	
	DPF Marinization Costs - Long term			
0<hp<25				
25<=hp<50				
50<=hp<75				
75<=hp<200				
200<=hp<400				
400<=hp<800				
800<=hp<2000			$57	$108
2000+				$180
All engines				$163
<800 hp only				
>800 hp only			$66	

5.2.2.5 Annual Engine Variable Engineering Costs

Using the hardware piece costs shown in Table 5-29, we can calculate the annual costs for each market segment by multiplying piece costs by estimated future sales. Table 5-30 through Table 5-34 show these costs. These costs are associated with the Tier 4 standards since only Tier 4 engines are expected to incur new hardware costs. The PM/NO_x+NMHC cost allocations for engine variable costs used in this cost analysis are as follows: Urea SCR systems including marinization costs on marine applications are attributed 100% to NO_x+NMHC control; and DPF systems including marinization costs on marine applications are attributed 100% to PM control.

Table 5-30 Annual Locomotive Line-haul Engine Variable Costs; New Tier 4 Engines Only ($Millions)

Calendar Year	Sales	DPF	SCR	Total	PM	NO_X+ NMHC
2006		$ -	$ -	$ -	$ -	$ -
2007		$ -	$ -	$ -	$ -	$ -
2008		$ -	$ -	$ -	$ -	$ -
2009		$ -	$ -	$ -	$ -	$ -
2010		$ -	$ -	$ -	$ -	$ -
2011		$ -	$ -	$ -	$ -	$ -
2012	767	$ -	$ -	$ -	$ -	$ -
2013	765	$ -	$ -	$ -	$ -	$ -
2014	780	$ -	$ -	$ -	$ -	$ -
2015	816	$30.9	$ -	$30.9	$30.9	$ -
2016	854	$32.4	$ -	$32.4	$32.4	$ -
2017	877	$25.4	$29.4	$54.8	$25.4	$29.4
2018	894	$25.9	$30.0	$55.9	$25.9	$30.0
2019	917	$26.6	$23.6	$50.1	$26.6	$23.6
2020	948	$27.5	$24.3	$51.8	$27.5	$24.3
2021	979	$28.4	$25.1	$53.5	$28.4	$25.1
2022	1007	$29.2	$25.9	$55.0	$29.2	$25.9
2023	1034	$30.0	$26.6	$56.5	$30.0	$26.6
2024	1048	$30.4	$26.9	$57.3	$30.4	$26.9
2025	1078	$31.2	$27.7	$58.9	$31.2	$27.7
2026	1096	$31.8	$28.1	$59.9	$31.8	$28.1
2027	1119	$32.4	$28.7	$61.2	$32.4	$28.7
2028	1136	$32.9	$29.2	$62.1	$32.9	$29.2
2029	1150	$33.3	$29.5	$62.8	$33.3	$29.5
2030	1158	$33.6	$29.7	$63.3	$33.6	$29.7
2031	1173	$34.0	$30.1	$64.1	$34.0	$30.1
2032	1190	$34.5	$30.6	$65.0	$34.5	$30.6
2033	1209	$35.0	$31.0	$66.1	$35.0	$31.0
2034	1223	$35.5	$31.4	$66.9	$35.5	$31.4
2035	1231	$35.7	$31.6	$67.3	$35.7	$31.6
2036	1197	$34.7	$30.7	$65.4	$34.7	$30.7
2037	1172	$34.0	$30.1	$64.0	$34.0	$30.1
2038	1144	$33.2	$29.4	$62.5	$33.2	$29.4
2039	1112	$32.2	$28.6	$60.8	$32.2	$28.6
2040	1078	$31.2	$27.7	$58.9	$31.2	$27.7
NPV at 7%		$196.5	$152.5	$349.0	$196.5	$152.5
NPV at 3%		$426.6	$346.4	$773.0	$426.6	$346.4

Table 5-31 Annual Locomotive Switcher & Passenger Engine Variable Costs; New Tier 4 Engines Only ($Millions)

Calendar Year	Sales	DPF	SCR	Total	PM	NO_X+ NMHC
2006		$ -	$ -	$ -	$ -	$ -
2007		$ -	$ -	$ -	$ -	$ -
2008		$ -	$ -	$ -	$ -	$ -
2009		$ -	$ -	$ -	$ -	$ -
2010		$ -	$ -	$ -	$ -	$ -
2011		$ -	$ -	$ -	$ -	$ -
2012	92	$ -	$ -	$ -	$ -	$ -
2013	92	$ -	$ -	$ -	$ -	$ -
2014	93	$ -	$ -	$ -	$ -	$ -
2015	93	$0.9	$ -	$0.9	$0.9	$ -
2016	94	$1.0	$ -	$1.0	$1.0	$ -
2017	94	$0.7	$0.7	$1.4	$0.7	$0.7
2018	94	$0.7	$0.7	$1.4	$0.7	$0.7
2019	94	$0.7	$0.6	$1.3	$0.7	$0.6
2020	94	$0.7	$0.6	$1.3	$0.7	$0.6
2021	94	$0.7	$0.6	$1.3	$0.7	$0.6
2022	95	$0.7	$0.6	$1.3	$0.7	$0.6
2023	160	$1.2	$0.9	$2.2	$1.2	$0.9
2024	183	$1.4	$1.1	$2.5	$1.4	$1.1
2025	201	$1.6	$1.2	$2.7	$1.6	$1.2
2026	212	$1.6	$1.2	$2.9	$1.6	$1.2
2027	227	$1.8	$1.3	$3.1	$1.8	$1.3
2028	239	$1.9	$1.4	$3.3	$1.9	$1.4
2029	247	$1.9	$1.4	$3.4	$1.9	$1.4
2030	263	$2.0	$1.5	$3.6	$2.0	$1.5
2031	281	$2.2	$1.6	$3.8	$2.2	$1.6
2032	292	$2.3	$1.7	$4.0	$2.3	$1.7
2033	296	$2.3	$1.7	$4.0	$2.3	$1.7
2034	305	$2.4	$1.8	$4.2	$2.4	$1.8
2035	302	$2.3	$1.8	$4.1	$2.3	$1.8
2036	294	$2.3	$1.7	$4.0	$2.3	$1.7
2037	287	$2.2	$1.7	$3.9	$2.2	$1.7
2038	278	$2.2	$1.6	$3.8	$2.2	$1.6
2039	269	$2.1	$1.6	$3.7	$2.1	$1.6
2040	263	$2.0	$1.5	$3.6	$2.0	$1.5
NPV at 7%		$8.6	$5.9	$14.5	$8.6	$5.9
NPV at 3%		$20.4	$14.5	$35.0	$20.4	$14.5

Table 5-32 Annual C2 Marine Engine Variable Costs; New Tier 4 Engines Only ($Millions)

Calendar Year	Sales	DPF	SCR	Marinization	Total	PM	NO_X+ NMHC
2006		$ -	$ -	$ -	$ -	$ -	$ -
2007		$ -	$ -	$ -	$ -	$ -	$ -
2008		$ -	$ -	$ -	$ -	$ -	$ -
2009		$ -	$ -	$ -	$ -	$ -	$ -
2010		$ -	$ -	$ -	$ -	$ -	$ -
2011		$ -	$ -	$ -	$ -	$ -	$ -
2012	299	$ -	$ -	$ -	$ -	$ -	$ -
2013	301	$ -	$ -	$ -	$ -	$ -	$ -
2014	304	$ -	$ -	$ -	$ -	$ -	$ -
2015	307	$ -	$ -	$ -	$ -	$ -	$ -
2016	309	$10.6	$9.4	$0.1	$20.2	$10.7	$9.5
2017	312	$10.7	$9.5	$0.1	$20.4	$10.8	$9.6
2018	315	$8.3	$7.3	$0.1	$15.7	$8.3	$7.4
2019	318	$8.3	$7.4	$0.1	$15.9	$8.4	$7.5
2020	321	$8.4	$7.5	$0.1	$16.0	$8.5	$7.5
2021	324	$8.5	$7.5	$0.1	$16.2	$8.5	$7.6
2022	327	$8.6	$7.6	$0.1	$16.3	$8.6	$7.7
2023	330	$8.6	$7.7	$0.1	$16.4	$8.7	$7.7
2024	332	$8.7	$7.8	$0.1	$16.6	$8.8	$7.8
2025	335	$8.8	$7.8	$0.1	$16.7	$8.9	$7.9
2026	338	$8.9	$7.9	$0.1	$16.9	$8.9	$8.0
2027	342	$9.0	$8.0	$0.1	$17.0	$9.0	$8.0
2028	345	$9.0	$8.0	$0.1	$17.2	$9.1	$8.1
2029	348	$9.1	$8.1	$0.1	$17.4	$9.2	$8.2
2030	351	$9.2	$8.2	$0.1	$17.5	$9.3	$8.2
2031	354	$9.3	$8.3	$0.1	$17.7	$9.4	$8.3
2032	357	$9.4	$8.3	$0.1	$17.8	$9.4	$8.4
2033	360	$9.5	$8.4	$0.1	$18.0	$9.5	$8.5
2034	364	$9.5	$8.5	$0.1	$18.2	$9.6	$8.5
2035	367	$9.6	$8.6	$0.1	$18.3	$9.7	$8.6
2036	370	$9.7	$8.6	$0.1	$18.5	$9.8	$8.7
2037	374	$9.8	$8.7	$0.1	$18.6	$9.9	$8.8
2038	377	$9.9	$8.8	$0.1	$18.8	$10.0	$8.9
2039	380	$10.0	$8.9	$0.1	$19.0	$10.0	$8.9
2040	384	$10.1	$8.9	$0.1	$19.2	$10.1	$9.0
NPV at 7%		$54.4	$48.3	$0.8	$103.5	$54.7	$48.7
NPV at 3%		$119.3	$106.1	$1.7	$227.1	$120.2	$106.9

Table 5-33 Annual C1 Marine (>600 kW/805 hp) Engine Variable Costs including Recreational Marine >2000 kW; New Tier 4 Engines Only ($Millions)

Calendar Year	Sales	DPF	SCR	Marinization	Total	PM	NO_X+ NMHC
2006		$ -	$ -	$ -	$ -	$ -	$ -
2007		$ -	$ -	$ -	$ -	$ -	$ -
2008		$ -	$ -	$ -	$ -	$ -	$ -
2009		$ -	$ -	$ -	$ -	$ -	$ -
2010		$ -	$ -	$ -	$ -	$ -	$ -
2011		$ -	$ -	$ -	$ -	$ -	$ -
2012	1127	$ -	$ -	$ -	$ -	$ -	$ -
2013	1140	$ -	$ -	$ -	$ -	$ -	$ -
2014	1154	$ -	$ -	$ -	$ -	$ -	$ -
2015	1167	$ -	$ -	$ -	$ -	$ -	$ -
2016	1180	$11.4	$11.1	$0.2	$22.8	$11.5	$11.2
2017	1194	$11.6	$11.3	$0.2	$23.0	$11.7	$11.4
2018	1207	$8.9	$8.7	$0.2	$17.8	$9.0	$8.8
2019	1221	$9.0	$8.8	$0.2	$18.0	$9.1	$8.9
2020	1234	$9.1	$8.9	$0.2	$18.2	$9.2	$9.0
2021	1248	$9.2	$9.0	$0.2	$18.4	$9.3	$9.1
2022	1262	$9.3	$9.1	$0.2	$18.6	$9.4	$9.2
2023	1276	$9.4	$9.2	$0.2	$18.8	$9.5	$9.3
2024	1290	$9.5	$9.3	$0.2	$19.0	$9.6	$9.4
2025	1304	$9.6	$9.4	$0.2	$19.2	$9.7	$9.5
2026	1318	$9.7	$9.5	$0.2	$19.4	$9.8	$9.6
2027	1332	$9.9	$9.6	$0.2	$19.7	$10.0	$9.7
2028	1346	$10.0	$9.7	$0.2	$19.9	$10.1	$9.8
2029	1361	$10.1	$9.8	$0.2	$20.1	$10.2	$9.9
2030	1375	$10.2	$9.9	$0.2	$20.3	$10.3	$10.0
2031	1390	$10.3	$10.0	$0.2	$20.5	$10.4	$10.1
2032	1404	$10.4	$10.1	$0.2	$20.7	$10.5	$10.2
2033	1419	$10.5	$10.2	$0.2	$20.9	$10.6	$10.3
2034	1434	$10.6	$10.3	$0.2	$21.2	$10.7	$10.4
2035	1449	$10.7	$10.4	$0.2	$21.4	$10.8	$10.6
2036	1464	$10.8	$10.6	$0.2	$21.6	$10.9	$10.7
2037	1479	$10.9	$10.7	$0.2	$21.8	$11.1	$10.8
2038	1494	$11.1	$10.8	$0.2	$22.0	$11.2	$10.9
2039	1509	$11.2	$10.9	$0.2	$22.3	$11.3	$11.0
2040	1525	$11.3	$11.0	$0.2	$22.5	$11.4	$11.1
NPV at 7%		$59.5	$58.0	$1.2	$118.6	$60.1	$58.6
NPV at 3%		$131.0	$127.7	$2.7	$261.4	$132.3	$129.0

Table 5-34 Total Annual Engine Variable Costs; New Tier 4 Engines Only ($Millions)

Calendar Year	Locomotive	Marine C1	Marine C2	Recreational Marine	Small Marine	Total	PM	NO_X+ NMHC
2006	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2007	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2008	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2009	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2010	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2011	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2012	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2013	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2014	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2015	$31.9	$ -	$ -	$ -	$ -	$31.9	$31.9	$ -
2016	$33.3	$22.8	$20.2	$ -	$ -	$76.3	$55.6	$20.8
2017	$56.3	$23.0	$20.4	$ -	$ -	$99.7	$48.6	$51.1
2018	$57.4	$17.8	$15.7	$ -	$ -	$90.9	$44.0	$46.9
2019	$51.4	$18.0	$15.9	$ -	$ -	$85.3	$44.8	$40.5
2020	$53.1	$18.2	$16.0	$ -	$ -	$87.3	$45.9	$41.4
2021	$54.8	$18.4	$16.2	$ -	$ -	$89.4	$47.0	$42.4
2022	$56.3	$18.6	$16.3	$ -	$ -	$91.2	$48.0	$43.3
2023	$58.7	$18.8	$16.4	$ -	$ -	$94.0	$49.5	$44.5
2024	$59.8	$19.0	$16.6	$ -	$ -	$95.4	$50.2	$45.2
2025	$61.6	$19.2	$16.7	$ -	$ -	$97.6	$51.4	$46.2
2026	$62.8	$19.4	$16.9	$ -	$ -	$99.2	$52.2	$46.9
2027	$64.3	$19.7	$17.0	$ -	$ -	$101.0	$53.2	$47.8
2028	$65.3	$19.9	$17.2	$ -	$ -	$102.4	$53.9	$48.5
2029	$66.2	$20.1	$17.4	$ -	$ -	$103.6	$54.6	$49.0
2030	$66.9	$20.3	$17.5	$ -	$ -	$104.7	$55.2	$49.5
2031	$68.0	$20.5	$17.7	$ -	$ -	$106.1	$55.9	$50.2
2032	$69.0	$20.7	$17.8	$ -	$ -	$107.6	$56.7	$50.9
2033	$70.1	$20.9	$18.0	$ -	$ -	$109.0	$57.5	$51.6
2034	$71.0	$21.2	$18.2	$ -	$ -	$110.3	$58.2	$52.2
2035	$71.4	$21.4	$18.3	$ -	$ -	$111.1	$58.5	$52.5
2036	$69.4	$21.6	$18.5	$ -	$ -	$109.5	$57.7	$51.8
2037	$67.9	$21.8	$18.6	$ -	$ -	$108.4	$57.1	$51.3
2038	$66.3	$22.0	$18.8	$ -	$ -	$107.2	$56.4	$50.7
2039	$64.5	$22.3	$19.0	$ -	$ -	$105.7	$55.6	$50.1
2040	$62.5	$22.5	$19.2	$ -	$ -	$104.2	$54.8	$49.3
NPV at 7%	$363.5			-	$ -	$585.6	$319.9	$265.7
NPV at 3%	$808.0	$261.4	$227.1	$ -	$ -	$1,296.5	$699.6	$596.9

Note: Marine C1 costs include recreational marine >2000 kW.

Table 5-34 shows the net present value of the annual engine variable costs through 2040 as $1.3 billion at a three percent discount rate or $0.6 billion at a seven percent discount rate. These costs are fairly evenly split between NO_x+NMHC and PM with the primary difference between the two being the two year delay in Tier 4 NO_x standards for locomotive engines.

5.3 Equipment-Related Engineering Costs for New Pieces of Equipment

In this section, we present our estimated costs associated with the piece of equipment into which the new engines are placed—i.e., the locomotive itself or the marine vessel itself. In general, we refer generically to equipment rather than specifically to locomotives or vessels. Costs of control to equipment manufacturers include fixed costs (those costs for equipment redesign), and variable costs (for new hardware and increased equipment assembly time).

5.3.1 New Equipment Fixed Engineering Costs

5.3.1.1 New Equipment Redesign Costs

The projected modifications to equipment resulting from the new emission standards relate to the need to package emission control hardware that engine manufacturers will incorporate into their engines. As discussed above, the additional emission control hardware for equipment into which a Tier 4 engine is installed is proportional in size to engine displacement by roughly a 4:1 ratio (2.5x engine displacement for the SCR system and 1.7x engine displacement for the DPF system). We expect that equipment manufacturers will have to redesign their equipment to accommodate this new volume of hardware. As such, we would expect such costs for only those pieces of equipment that will be installing a Tier 4 engine since Tier 3 engines are expected to incorporate controls that will not result in a larger engine or otherwise require any more space within the piece of equipment.

To determine marine-related redesign costs, our first step was to determine the number of vessels sold each year. Unfortunately, we do not have good data regarding vessel sales. We do have good data regarding engine sales using the PSR database for 2002. To estimate vessel sales, we looked first at the number of engines being sold as marine engines. Since only C2 engines and C1 engines >600 kW (805 hp), including those recreational marine engines >2000 kW, would be complying with the Tier 4 standards, we limited ourselves to those engines. Further, we eliminated those engines sold as auxiliary engines since we know that there exists a direct correlation between vessel sales and propulsion engine sales because every new vessel will have at least one propulsion engine while having anywhere from zero to many auxiliary engines. In the year 2015—one year before vessels would be adding engines equipped with aftertreatment devices and, hence, being redesigned—this leaves us with 993 marine C1 propulsion engines >600 kw and 147 marine C2 propulsion engines.

We know that most vessels in the larger C1 and the C2 categories are fitted with more than one engine. To remain conservative, we estimated that, on average, each new vessel is fitted with 1.5 new propulsion engines. This results in an estimated 660 marine C1 and 100 marine C2 vessels sold.

We believe that not every vessel will require a full redesign. Instead, we believe that, while some vessels truly are a one-design/one-vessel effort, many vessels are a one-design/five-vessel or even ten or more-vessel effort. To be conservative, we have estimated that a redesign effort will accommodate two new vessels. That is, on average, a fleet of 100 new C2 vessels would require 50 redesign efforts. We have estimated the costs per redesign at $50,000 for C1 vessel redesigns and $100,000 for C2 vessel redesigns. These estimates are summarized in Table 5-35.

Table 5-35 Estimated Vessel Redesigns in Year One and Costs per Redesign

	Hp Range	Propulsion Engines in 2015	Engines / Vessel	Vessels	Vessels / Redesign	Redesigns	$/Redesign
Marine-C1 propulsion	>800hp						$50,000
Marine-C2 propulsion	All	147	1.5	100	2	50	$100,000
Total		1140		760		380	

Using these estimates, we can estimate the annual total costs associated with vessel redesigns. But first it is important to note that we do not believe that the C1 and C2 fleets will require these redesign efforts every year. Nor will the need to redesign vessels cease once the Tier 4 standards are implemented. Instead, in the second year of implementation we would expect vessel sales to be similar but in many ways different than in year one. Such is the nature of the marine fleet in contrast to say, the automotive fleet where a new vehicle design is typically carried-over for four to six years with no significant redesign. Nonetheless, a first year redesign effort will no doubt make a second year redesign effort less costly given what was learned by redesign and construction firms during the first year. To estimate this effect, we considered year two to require half the effort of year one, year three half again, and year four half again. We then carried this effort forward until we had accumulated at least 1,000 redesigns which, we believe, is sufficient to have fully redesigned the applicable fleet. The number of marine redesign efforts and the annual total costs are shown in Table 5-36.

Table 5-36 Estimated Total Number of Vessel Redesigns and the Associated Annual Costs; New Tier 4 Equipment only (monetary entries are in $Millions)

Calendar Year	C1 Redesigns	C2 Redesigns	Annual Total Redesigns	Cumulative Redesigns	C1 Redesign Costs	C2 Redesign Costs	Annual Total Costs	PM	NO_X+NMHC
2006	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2007	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2008	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2009	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2010	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2011	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2012	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2013	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2014	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2015	330	50	380	380	$16.5	$5.0	$21.5	$10.8	$10.8
2016	170	30	200	580	$8.5	$3.0	$11.5	$5.8	$5.8
2017	90	20	110	690	$4.5	$2.0	$6.5	$3.3	$3.3
2018	50	10	60	750	$2.5	$1.0	$3.5	$1.8	$1.8
2019	50	10	60	810	$2.5	$1.0	$3.5	$1.8	$1.8
2020	50	10	60	870	$2.5	$1.0	$3.5	$1.8	$1.8
2021	50	10	60	930	$2.5	$1.0	$3.5	$1.8	$1.8
2022	50	10	60	990	$2.5	$1.0	$3.5	$1.8	$1.8
2023	50	10	60	1050	$2.5	$1.0	$3.5	$1.8	$1.8
2024	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2025	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2026	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2027	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2028	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2029	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2030	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2031	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2032	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2033	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2034	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2035	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2036	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2037	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2038	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2039	-	-	-	-	$ -	$ -	$ -	$ -	$ -
2040	-	-	-	-	$ -	$ -	$ -	$ -	$ -
Total						$16.0	$60.5	$30.3	$30.3
NPV at 7%						$7.0	$26.7	$13.3	$13.3
NPV at 3%						$11.1	$42.2	$21.1	$21.1

$44.5
$19.7
$31.1

For locomotive redesign efforts, we believe that the cost per redesign should be roughly equivalent to that for a C2 marine vessel, or $100,000 dollars per redesign, since the engine sizes and corresponding aftertreatment sizes should be roughly the same. Unlike the marine industry, the locomotive industry generally sells many of units of the same design. In fact, we estimate that there are only seven locomotive models—two line haul and five switcher—that comprise the hundreds of locomotives sold each year. Therefore, we have estimated that one redesign effort per model will suffice. The number of locomotive redesign efforts and the annual total costs are shown in

Table 5-37 Estimated Total Number of Locomotive Redesigns and the Associated Annual Costs; New Tier 4 Equipment only (monetary entries are in $Millions)

Calendar Year	Line haul Redesigns	Switcher Redesigns	Line haul Redesign Costs	Switcher Redesign Costs	Annual Total Costs	PM	NO_X+ NMHC
2006	-	-	$ -	$ -	$ -	$ -	$ -
2007	-	-	$ -	$ -	$ -	$ -	$ -
2008	-	-	$ -	$ -	$ -	$ -	$ -
2009	-	-	$ -	$ -	$ -	$ -	$ -
2010	-	-	$ -	$ -	$ -	$ -	$ -
2011	-	-	$ -	$ -	$ -	$ -	$ -
2012	-	-	$ -	$ -	$ -	$ -	$ -
2013	-	-	$ -	$ -	$ -	$ -	$ -
2014	2	5	$0.2	$0.5	$0.7	$0.4	$0.4
2015	-	-	$ -	$ -	$ -	$ -	$ -
2016	-	-	$ -	$ -	$ -	$ -	$ -
2017	-	-	$ -	$ -	$ -	$ -	$ -
2018	-	-	$ -	$ -	$ -	$ -	$ -
2019	-	-	$ -	$ -	$ -	$ -	$ -
2020	-	-	$ -	$ -	$ -	$ -	$ -
2021	-	-	$ -	$ -	$ -	$ -	$ -
2022	-	-	$ -	$ -	$ -	$ -	$ -
2023	-	-	$ -	$ -	$ -	$ -	$ -
2024	-	-	$ -	$ -	$ -	$ -	$ -
2025	-	-	$ -	$ -	$ -	$ -	$ -
2026	-	-	$ -	$ -	$ -	$ -	$ -
2027	-	-	$ -	$ -	$ -	$ -	$ -
2028	-	-	$ -	$ -	$ -	$ -	$ -
2029	-	-	$ -	$ -	$ -	$ -	$ -
2030	-	-	$ -	$ -	$ -	$ -	$ -
2031	-	-	$ -	$ -	$ -	$ -	$ -
2032	-	-	$ -	$ -	$ -	$ -	$ -
2033	-	-	$ -	$ -	$ -	$ -	$ -
2034	-	-	$ -	$ -	$ -	$ -	$ -
2035	-	-	$ -	$ -	$ -	$ -	$ -
2036	-	-	$ -	$ -	$ -	$ -	$ -
2037	-	-	$ -	$ -	$ -	$ -	$ -
2038	-	-	$ -	$ -	$ -	$ -	$ -
2039	-	-	$ -	$ -	$ -	$ -	$ -
2040	-	-	$ -	$ -	$ -	$ -	$ -
Total			$0.2	$0.5	$0.7	$0.4	$0.4
NPV at 7%			$0.1	$0.3	$0.4	$0.2	$0.2
NPV at 3%			$0.2	$0.4	$0.5	$0.3	$0.3

The net present value of the vessel redesign costs are estimated at $42 million using a three percent discount rate and at $27 million using a seven percent discount rate. The net present value of the locomotive redesign costs are estimated at $0.5 million using a three percent discount rate and at $0.4 million using a seven percent discount rate. In total, the net present value of the equipment redesign costs are estimated at $43 million using a three percent discount rate and at $27 million using a seven percent discount rate. These equipment redesign costs are arbitrarily split evenly between NO_x+NMHC and PM control.

5.3.2 New Equipment Variable Engineering Costs

As discussed above, we are projecting that SCR systems and DPFs will be the most likely technologies used to comply with the Tier 4 standards. Upon installation in a new locomotive or a new marine vessel, these devices would require some new equipment related hardware in the form of brackets and/or new sheet metal. Based on engineering judgement, we estimated this cost as shown in Table 5-38. Since the equipment variable costs are linked closely with the size of aftertreatment devices being installed (i.e., the large the diesel engine being installed in the piece of equipment, the larger the aftertreatment devices and, therefore, the larger the necessary brackets and/or greater the necessary sheet metal), it makes sense to scale the equipment hardware costs accordingly. Note that these costs would be incurred by only those pieces of equipment required to comply with the Tier 4 standards.

Table 5-38 Estimated Variable Costs per Piece of New Equipment

	$/new equipment
Locomotive Line-haul	$4,000
Locomotive Switcher	$4,000
Marine C1 (600-1492 kW; 805-2000 hp)	$2,000
Marine C1 (>2000 kW)	$4,000
Marine C1 (sales weighted)	$2,700
Marine C2 (600-1492 kW; 805-2000 hp)	$2,000
Marine C2 (>2000 kW)	$4,000
Marine C2 (sales weighted)	$3,500

Using these costs and estimated future sales of locomotives and vessels, we can estimate the annual costs for the fleet. These costs are shown in Table 5-39, in which we have used the sales weighted costs shown in Table 5-38 for marine vessels. As shown, we estimate the net present value of annual equipment variable costs at $99 million using a three percent discount rate and $44 million using a seven percent discount rate. These costs are arbitrarily split evenly between NO_x+NMHC and PM control.

Table 5-39 Annual Equipment Variable Costs; New Tier 4 Equipment Only ($Millions)

Calendar Year	Line Haul		Switchers		Locomotive Subtotal	Marine C1		Marine C2		Marine Subtotal	Total	PM	NO_X+ NMHC
	Sales					Vessels	Costs	Vessels	Costs				
2006		$ -		$ -	$ -		$ -		$ -	$ -	$ -	$ -	$ -
2007		$ -		$ -	$ -		$ -		$ -	$ -	$ -	$ -	$ -
2008		$ -		$ -	$ -		$ -		$ -	$ -	$ -	$ -	$ -
2009		$ -		$ -	$ -		$ -		$ -	$ -	$ -	$ -	$ -
2010		$ -		$ -	$ -		$ -		$ -	$ -	$ -	$ -	$ -
2011		$ -		$ -	$ -		$ -		$ -	$ -	$ -	$ -	$ -
2012	767	$ -	92	$ -	$ -		$ -		$ -	$ -	$ -	$ -	$ -
2013	765	$ -	92	$ -	$ -		$ -		$ -	$ -	$ -	$ -	$ -
2014	780	$ -	93	$ -	$ -		$ -		$ -	$ -	$ -	$ -	$ -
2015	816	$3.3	93	$0.4	$3.6		$ -		$ -	$ -	$3.6	$1.8	$1.8
2016	854	$3.4	94	$0.4	$3.8	666	$1.8	101	$0.4	$2.2	$6.0	$3.0	$3.0
2017	877	$3.5	94	$0.4	$3.9	672	$1.8	102	$0.4	$2.2	$6.1	$3.0	$3.0
2018	894	$3.6	94	$0.4	$4.0	678	$1.8	103	$0.4	$2.2	$6.2	$3.1	$3.1
2019	917	$3.7	94	$0.4	$4.0	684	$1.9	104	$0.4	$2.2	$6.3	$3.1	$3.1
2020	948	$3.8	94	$0.4	$4.2	690	$1.9	105	$0.4	$2.2	$6.4	$3.2	$3.2
2021	979	$3.9	94	$0.4	$4.3	696	$1.9	106	$0.4	$2.3	$6.6	$3.3	$3.3
2022	1007	$4.0	95	$0.4	$4.4	703	$1.9	106	$0.4	$2.3	$6.7	$3.3	$3.3
2023	1034	$4.1	160	$0.6	$4.8	709	$1.9	107	$0.4	$2.3	$7.1	$3.5	$3.5
2024	1048	$4.2	183	$0.7	$4.9	715	$1.9	108	$0.4	$2.3	$7.2	$3.6	$3.6
2025	1078	$4.3	201	$0.8	$5.1	722	$2.0	109	$0.4	$2.3	$7.5	$3.7	$3.7
2026	1096	$4.4	212	$0.8	$5.2	728	$2.0	110	$0.4	$2.4	$7.6	$3.8	$3.8
2027	1119	$4.5	227	$0.9	$5.4	735	$2.0	111	$0.4	$2.4	$7.8	$3.9	$3.9
2028	1136	$4.5	239	$1.0	$5.5	742	$2.0	112	$0.4	$2.4	$7.9	$4.0	$4.0
2029	1150	$4.6	247	$1.0	$5.6	748	$2.0	113	$0.4	$2.4	$8.0	$4.0	$4.0
2030	1158	$4.6	263	$1.1	$5.7	755	$2.0	114	$0.4	$2.5	$8.1	$4.1	$4.1
2031	1173	$4.7	281	$1.1	$5.8	762	$2.1	115	$0.4	$2.5	$8.3	$4.1	$4.1
2032	1190	$4.8	292	$1.2	$5.9	769	$2.1	116	$0.4	$2.5	$8.4	$4.2	$4.2
2033	1209	$4.8	296	$1.2	$6.0	776	$2.1	118	$0.4	$2.5	$8.5	$4.3	$4.3
2034	1223	$4.9	305	$1.2	$6.1	782	$2.1	119	$0.4	$2.5	$8.7	$4.3	$4.3
2035	1231	$4.9	302	$1.2	$6.1	790	$2.1	120	$0.4	$2.6	$8.7	$4.3	$4.3
2036	1197	$4.8	294	$1.2	$6.0	797	$2.2	121	$0.4	$2.6	$8.5	$4.3	$4.3
2037	1172	$4.7	287	$1.1	$5.8	804	$2.2	122	$0.4	$2.6	$8.4	$4.2	$4.2
2038	1144	$4.6	278	$1.1	$5.7	811	$2.2	123	$0.4	$2.6	$8.3	$4.2	$4.2
2039	1112	$4.4	269	$1.1	$5.5	818	$2.2	124	$0.4	$2.7	$8.2	$4.1	$4.1
2040	1078	$4.3	263	$1.1	$5.4	826	$2.2	125	$0.4	$2.7	$8.0	$4.0	$4.0
NPV at 7%		$26.1		$4.3	$30.4		$11.6		$2.3	$13.9	$44.3	$22.1	$22.1
NPV at 3%		$57.4		$10.3	$67.7		$25.8		$5.1	$30.9	$98.6	$49.3	$49.3

5.4 Operating Costs for New and Remanufactured Engines

We anticipate an increase in costs associated with operating locomotives and marine vessels. We anticipate three sources of increased operating costs: urea use; DPF maintenance; and a fuel consumption impact. Increased operating costs associated with urea use would occur only in those locomotives/vessels equipped with a urea SCR engine. Maintenance costs associated with the DPF (for periodic cleaning of accumulated ash resulting from unburned material that accumulates in the DPF) would occur in those locomotives/vessels that are equipped with a DPF engine. The fuel consumption impact is anticipated to occur more broadly—we expect that a one percent fuel consumption increase would occur for all new Tier 4 locomotive and marine engines due to higher exhaust backpressure resulting from aftertreatment devices. We also expect a one percent fuel consumption increase would occur for remanufactured Tier 0 locomotives due to our expectation that the tighter NO_x standard may in part be met using retarded fuel injection timing.

5.4.1 Increased Operating Costs Associated with Urea Use

New Tier 4 engines are expected to be equipped with urea SCR systems. The costs associated with the urea SCR system, including the urea tank and urea dosing system, are discussed in section 5.2.2.1 of this chapter. To estimate the costs associated with urea use, we first considered the urea dosage rate. For this analysis, we have used a urea dosing rate of four percent urea to every gallon of fuel burned. Using our marine and locomotive emissions analysis work (see Chapter 3 of this draft RIA), we can determine the gallons of fuel burned every year by SCR equipped pieces of equipment. The amount of urea used each year is then four percent of those gallons.

The cost per gallon of urea would be dependent on the volume of urea dispensed at each facility, with smaller refueling sites experiencing higher costs. The type of urea storage/dispensing equipment, and the ultimate cost-per-gallon, for railroad and marine industries will depend on the volume of fuel and urea dispensed at each site. High-volume fixed sites may choose to mix emissions-grade dry urea (or urea liquor) and de-mineralized water on-site, whereas others may choose bulk or container delivery of a pre-mixed 32.5 percent urea-water solution. In 2015, one source suggests that urea cost is expected to be ~$0.75/gallon for retail facilities dispensing 200,000 - 1,000,000 gallons/month, and ~$1.00/gallon for those dispensing 80,000 - 200,000 gallons/month.[25] With the implementation of SCR for the on-highway truck fleet in 2010, the economic factors for each urea supply option will be well-known prior to implementation of the 2016 and 2017 NO_x standards for marine engines and locomotives, respectively. To remain conservative, for this analysis we have used a urea cost of $1.00/gallon. This cost should cover the costs associated with distributing urea to the necessary point of transfer to locomotive and/or vessel (i.e., the necessary infrastructure). The resultant increased operating costs associated with urea use are presented in section 5.4.4. The costs associated with urea use are attributed solely to NO_x+NMHC control.

5.4.2 Increased Operating Costs Associated with DPF Maintenance

The maintenance demands associated with the addition of DPF hardware are discussed in Chapter 4 of this draft RIA. For this analysis, we have estimated a maintenance interval of 200,000 gallons of fuel burned between DPF ash maintenance events. For a typical locomotive engine having ~4000 hp this equates to roughly 7000 hours of operation between maintenance events. By comparison, our NRT4 rule estimated a maintenance interval of 3,000 hours for engines under 175 hp and 4,500 hours for engines over 750 hp. We believe that the estimate of nearly 7,000 hours for the size engines used in applicable marine vessels and locomotives is appropriate, especially given potential use of “pass-through” DPF technologies as discussed in Chapter 4 of this draft RIA. We have also estimated the ash maintenance event to take four hours per event at $50 per hour for labor, or $200 per event.

By using only those gallons burned in DPF equipped engines, we are then able to calculate the maintenance costs associated with DPF maintenance. These costs are presented in section 5.4.4. The costs associated with DPF maintenance are attributed solely to PM control.

5.4.3 Increased Operating Costs Associated with Fuel Consumption Impacts

The high efficiency emission-control technologies expected to be used to meet the proposed Tier 4 standards involve wholly new system components integrated into engine designs and calibrations and, as such, would be expected to change the fuel consumption characteristics of the overall engine design. After reviewing the likely technology options available to the engine manufacturers, we believe the integration of the engine and exhaust emission-control systems into a single synergistic emission-control system will lead to locomotive and marine engines that can meet demanding emission-control targets with only a small impact on fuel consumption. Technology improvements have historically eliminated these marginal impacts in the past and it is our expectation that this kind of continuing improvement will eliminate the modest impact estimated here. However, because we cannot project the time frame for when this improvement would be realized, we have included this impact in our cost estimates for the full period of the program to avoid underestimating costs.

Diesel particulate filters are anticipated to provide a step-wise decrease in PM emissions by trapping and oxidizing the PM. The trapping of the very fine diesel PM is accomplished by forcing the exhaust through a porous filtering media with extremely small openings and long path lengths. This approach, called a wall flow filter, results in filtering efficiencies for diesel PM greater than 90 percent but requires additional pumping work to force the exhaust through these small openings. The impact of this additional pumping work on fuel consumption is dependent on engine operating conditions. At low exhaust flow conditions (i.e., low engine load, low turbocharger boost levels), the impact is so small that it typically cannot be measured, while at very high load conditions, with high exhaust flow conditions, the fuel economy impact can be as large as one to two percent. In our NRT4 rule, for wall flow filters, we estimated that the average impact of this increased pumping work was equivalent to an increased fuel consumption of approximately one percent. To be conservative in this analysis, we have used this one percent impact regardless of DPF technology even though the pass through technology that may be used is expected to have a lower impact on fuel consumption because it results in less pumping work to force the exhaust through the device.

As for the urea SCR system, we do not expect a fuel consumption increase associated with this device. Urea SCR catalysts are flow through devices and while they do indeed represent a slight increase in backpressure (i.e., increased pumping work to force exhaust through the device), we expect that impact to be easily offset through engine control changes that take advantage of the high NO_x conversion afforded by the SCR system. Therefore, in total, we expect a one percent fuel consumption increase for all new Tier 4 engines.

We have also estimated an incremental operating cost associated with the locomotive remanufacturing program (see section 5.5 of this chapter for our analysis of other costs associated with the locomotive remanufacturing program). We expect a fuel consumption impact would occur for those engines remanufactured to a more stringent NO_x standard than the NO_x standard to which they were designed originally. We would expect this because those engines are expected to employ engine control changes—retarded injection timing—to help control NO_x emissions. The result of such a change is slightly higher fuel consumption on the order of one percent. Only Tier 0 locomotives would be remanufactured to a more stringent NO_x standard than that for which they were originally designed. Therefore, we have estimated a one percent fuel consumption increase for remanufactured Tier 0 locomotives.

Using the gallons burned in new DPF equipped engines and, for line-haul and passenger locomotives, the gallons burned in remanufactured Tier 0 engines, along with an estimated diesel fuel price less taxes of $1.28/gallon, the costs associated with a fuel consumption impact can be calculated.[j] These costs are presented in section

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[j] To estimate the diesel fuel price, we started with the annual average nationwide price for 2004 for high sulfur diesel fuel (excluding taxes) sold to commercial consumers from Table 41 of the Energy Information Administration (EIA) Petroleum Marketing Annual 2004. We adjusted this 2004 price of $1.24/gallon to a 2012 price using the ratio of projected consumer purchased diesel fuel price in 2012 to the consumer purchased diesel fuel price in 2004 as reported in Table 12 of the Annual Energy Outlook (AEO) 2006. Note that the Petroleum Marketing Annual 2005 shows a corresponding

5.4.4 of this chapter. The costs associated with the fuel consumption impact are split evenly between NO_x and PM control.

5.4.4 Total Increased Operating Costs

The increased annual operating costs for each applicable market segment—locomotive line haul; switcher/passenger; non-recreational marine C1>600 kW; marine C2—are presented in Table 5-40, Table 5-41, Table 5-42, and Table 5-43, respectively. These costs are summarized to give the total increased operating costs in Table 5-44. Table 5-45 shows the increased operating costs by cost element—urea, DPF maintenance, and fuel consumption impact.

Note that operating costs are attributed as follows: costs associated with urea use are attributed solely to NO_x+NMHC control; costs associated with DPF maintenance are attributed solely to PM control; and, costs associated with the fuel consumption impact are split evenly between NO_x+NMHC and PM control.

nationwide average price for 2005 of $1.80/gallon versus $1.24/gallon. However, the AEO 2007 was not released in time to update our estimated 2012 price using on the $1.80/gallon number. Were we to simply use the $1.80/gallon number, it would increase our 2030 costs from $605 million to $646 million, or roughly seven percent. For the final rule, we will update the fuel price to ensure that we are using the most recent data available.

Table 5-40 Estimated Increased Operating Costs for Line Haul Locomotives; New Tier 4 and Remanufactured Tier 0 and Tier 4 Engines

Calendar Year	SCR Equipped Fuel Usage (MM gal)	Urea Usage (MM gal)	Annual Urea Cost ($MM)	DPF Equipped Fuel Usage (MM gal)		Annual DPF Maintenance Cost ($MM)	Reman Tier 0 Fuel Usage (MM gal)	New Tier 4 Fuel Usage (MM gal)	Increased Fuel Consumption at 1 percent (MM gal)	Annual Cost of Fuel Consumption Impact ($MM)	Annual Increased Operating Costs ($MM)
2006	0	0	$0.0	0	0	$0.0	0			$0.0	$0.0
2007	0	0	$0.0	0	0	$0.0	0	0	0	$0.0	$0.0
2008	0	0	$0.0	0	0	$0.0	147	0	1	$1.9	$1.9
2009	0	0	$0.0	0	0	$0.0	145	0	1	$1.9	$1.9
2010	0	0	$0.0	0	0	$0.0	375	0	4	$4.8	$4.8
2011	0	0	$0.0	0	0	$0.0	778	0	8	$10.0	$10.0
2012	0	0	$0.0	0	0	$0.0	945	0	9	$12.1	$12.1
2013	0	0	$0.0	0	0	$0.0	1174	0	12	$15.0	$15.0
2014	0	0	$0.0	0	0	$0.0	1227	0	12	$15.7	$15.7
2015	0	0	$0.0	202	1009	$0.2	1232	202	14	$18.4	$18.6
2016	0	0	$0.0	413	2065	$0.4	1400	413	18	$23.2	$23.6
2017	217	9	$8.7	630	3149	$0.6	1553	630	22	$27.9	$37.2
2018	438	18	$17.5	851	4255	$0.9	1511	851	24	$30.2	$48.6
2019	665	27	$26.6	1078	5389	$1.1	1444	1078	25	$32.3	$59.9
2020	899	36	$36.0	1312	6561	$1.3	1335	1312	26	$33.9	$71.2
2021	1141	46	$45.7	1554	7771	$1.6	1219	1554	28	$35.5	$82.7
2022	1390	56	$55.6	1803	9017	$1.8	1108	1803	29	$37.3	$94.7
2023	1853	74	$74.1	2059	10296	$2.1	1002	2059	31	$39.2	$115.3
2024	2314	93	$92.6	2314	11572	$2.3	901	2314	32	$41.2	$136.0
2025	2573	103	$102.9	2573	12866	$2.6	804	2573	34	$43.2	$148.7
2026	2832	113	$113.3	2832	14162	$2.8	710	2832	35	$45.3	$161.5
2027	3093	124	$123.7	3093	15467	$3.1	622	3093	37	$47.6	$174.4
2028	3354	134	$134.2	3354	16770	$3.4	539	3354	39	$49.8	$187.3
2029	3614	145	$144.6	3614	18069	$3.6	462	3614	41	$52.2	$200.3
2030	3871	155	$154.8	3871	19355	$3.9	393	3871	43	$54.6	$213.3
2031	4127	165	$165.1	4127	20637	$4.1	330	4127	45	$57.1	$226.3
2032	4383	175	$175.3	4383	21916	$4.4	273	4383	47	$59.6	$239.3
2033	4639	186	$185.5	4639	23193	$4.6	221	4639	49	$62.2	$252.4
2034	4893	196	$195.7	4893	24464	$4.9	168	4893	51	$64.8	$265.4
2035	5144	206	$205.7	5144	25718	$5.1	124	5144	53	$67.4	$278.3
2036	5383	215	$215.3	5383	26917	$5.4	88	5383	55	$70.0	$290.7
2037	5614	225	$224.6	5614	28072	$5.6	58	5614	57	$72.6	$302.8
2038	5837	233	$233.5	5837	29184	$5.8	33	5837	59	$75.1	$314.5
2039	6050	242	$242.0	6050	30250	$6.0	16	6050	61	$77.6	$325.7
2040	6253	250	$250.1	6253	31267	$6.3	5	6253	63	$80.1	$336.5
NPV at 7%			$546.3			$15.0				$305.5	$866.7
NPV at 3%			$1,455.8			$38.6				$681.7	$2,176.2

Table 5-41Estimated Increased Operating Costs for New Tier 4 Switcher & Passenger Locomotives and Remanufactured Tier 0 and Tier 4 Passenger Locomotives

Calendar Year	SCR Equipped Fuel Usage (MM gal)	Urea Usage (MM gal)	Annual Urea Cost ($MM)	DPF Equipped Fuel Usage (MM gal)		Annual DPF Maintenance Cost ($MM)	Reman Tier 0 Passenger Fuel Usage (MM gal)	New Tier 4 Passenger Fuel Usage (MM gal)	Increased Passenger Fuel Consumption at 1 percent (MM gal)	Annual Cost of Fuel Consumption Impact ($MM)	Annual Increased Operating Costs ($MM)
2006	0	0	$0.0	0	0	$0.0	0	0	0	$0.0	$0.0
2007	0	0	$0.0	0	0	$0.0	0	0	0	$0.0	$0.0
2008	0	0	$0.0	0	0	$0.0	5	0	0	$0.1	$0.1
2009	0	0	$0.0	0	0	$0.0	17	0	0	$0.2	$0.2
2010	0	0	$0.0	0	0	$0.0	29	0	0	$0.4	$0.4
2011	0	0	$0.0	0	0	$0.0	40	0	0	$0.5	$0.5
2012	0	0	$0.0	0	0	$0.0	44	0	0	$0.6	$0.6
2013	0	0	$0.0	0	0	$0.0	48	0	0	$0.6	$0.6
2014	0	0	$0.0	0	0	$0.0	51	0	1	$0.7	$0.7
2015	0	0	$0.0	10	51	$0.0	47	7	1	$0.7	$0.7
2016	0	0	$0.0	21	104	$0.0	49	14	1	$0.8	$0.8
2017	17	1	$0.7	31	156	$0.0	49	22	1	$0.9	$1.6
2018	27	1	$1.1	42	209	$0.0	44	29	1	$0.9	$2.1
2019	38	2	$1.5	53	263	$0.1	38	36	1	$1.0	$2.5
2020	49	2	$2.0	63	317	$0.1	33	44	1	$1.0	$3.0
2021	60	2	$2.4	74	371	$0.1	28	51	1	$1.0	$3.5
2022	78	3	$3.1	85	426	$0.1	22	58	1	$1.0	$4.2
2023	101	4	$4.0	101	505	$0.1	17	66	1	$1.1	$5.2
2024	119	5	$4.8	119	594	$0.1	14	73	1	$1.1	$6.0
2025	138	6	$5.5	138	691	$0.1	10	80	1	$1.2	$6.8
2026	159	6	$6.3	159	793	$0.2	7	88	1	$1.2	$7.7
2027	180	7	$7.2	180	902	$0.2	4	95	1	$1.3	$8.7
2028	203	8	$8.1	203	1016	$0.2	3	102	1	$1.3	$9.7
2029	227	9	$9.1	227	1137	$0.2	1	109	1	$1.4	$10.7
2030	253	10	$10.1	253	1265	$0.3	0	116	1	$1.5	$11.9
2031	281	11	$11.2	281	1404	$0.3	0	123	1	$1.6	$13.1
2032	310	12	$12.4	310	1549	$0.3	0	131	1	$1.7	$14.4
2033	340	14	$13.6	340	1699	$0.3	0	138	1	$1.8	$15.7
2034	371	15	$14.8	371	1856	$0.4	0	146	1	$1.9	$17.1
2035	403	16	$16.1	403	2014	$0.4	0	154	2	$2.0	$18.5
2036	434	17	$17.4	434	2170	$0.4	0	161	2	$2.1	$19.9
2037	464	19	$18.6	464	2322	$0.5	0	168	2	$2.1	$21.2
2038	494	20	$19.8	494	2472	$0.5	0	173	2	$2.2	$22.5
2039	524	21	$20.9	524	2619	$0.5	0	178	2	$2.3	$23.8
2040	553	22	$22.1	553	2764	$0.6	0	183	2	$2.3	$25.0
NPV at 7%			$37.1			$1.0				$9.6	$47.7
NPV at 3%			$102.4			$2.6				$20.6	$125.7

Table 5-42 Estimated Increased Operating Costs for Marine C1 Engines >600 kW, including Recreational Marine >2000 kW; New Tier 4 Engines

Calendar Year	SCR Equipped Fuel Usage (MM gal)	Urea Usage (MM gal)	Annual Urea Cost ($MM)	DPF Equipped Fuel Usage (MM gal)		Annual DPF Maintenance Cost ($MM)	New Tier 4 Fuel Usage (MM gal)	Increased Fuel Consumption at 1 percent (MM gal)	Annual Cost of Fuel Consumption Impact ($MM)	Annual Increased Operating Cost ($MM)
2006	0	0	$0.0	0	0	$0.0	0	0	$0.0	$0.0
2007	0	0	$0.0	0	0	$0.0	0	0	$0.0	$0.0
2008	0	0	$0.0	0	0	$0.0	0	0	$0.0	$0.0
2009	0	0	$0.0	0	0	$0.0	0	0	$0.0	$0.0
2010	0	0	$0.0	0	0	$0.0	0	0	$0.0	$0.0
2011	0	0	$0.0	0	0	$0.0	0	0	$0.0	$0.0
2012	0	0	$0.0	0	0	$0.0	0	0	$0.0	$0.0
2013	0	0	$0.0	0	0	$0.0	0	0	$0.0	$0.0
2014	0	0	$0.0	0	0	$0.0	0	0	$0.0	$0.0
2015	0	0	$0.0	0	0	$0.0	0	0	$0.0	$0.0
2016	55	2	$2.2	55	275	$0.1	55	1	$0.7	$3.0
2017	150	6	$6.0	150	752	$0.2	150	2	$1.9	$8.1
2018	283	11	$11.3	283	1413	$0.3	283	3	$3.6	$15.2
2019	414	17	$16.6	414	2072	$0.4	414	4	$5.3	$22.3
2020	545	22	$21.8	545	2727	$0.5	545	5	$7.0	$29.3
2021	676	27	$27.0	676	3378	$0.7	676	7	$8.6	$36.3
2022	805	32	$32.2	805	4024	$0.8	805	8	$10.3	$43.3
2023	933	37	$37.3	933	4664	$0.9	933	9	$11.9	$50.2
2024	1059	42	$42.4	1059	5295	$1.1	1059	11	$13.6	$57.0
2025	1183	47	$47.3	1183	5917	$1.2	1183	12	$15.1	$63.7
2026	1305	52	$52.2	1305	6527	$1.3	1305	13	$16.7	$70.2
2027	1424	57	$57.0	1424	7121	$1.4	1424	14	$18.2	$76.6
2028	1539	62	$61.5	1539	7693	$1.5	1539	15	$19.7	$82.8
2029	1639	66	$65.6	1639	8196	$1.6	1639	16	$21.0	$88.2
2030	1719	69	$68.8	1719	8597	$1.7	1719	17	$22.0	$92.5
2031	1782	71	$71.3	1782	8912	$1.8	1782	18	$22.8	$95.9
2032	1835	73	$73.4	1835	9174	$1.8	1835	18	$23.5	$98.7
2033	1882	75	$75.3	1882	9412	$1.9	1882	19	$24.1	$101.3
2034	1925	77	$77.0	1925	9627	$1.9	1925	19	$24.6	$103.6
2035	1964	79	$78.6	1964	9819	$2.0	1964	20	$25.1	$105.7
2036	1999	80	$79.9	1999	9993	$2.0	1999	20	$25.6	$107.5
2037	2030	81	$81.2	2030	10152	$2.0	2030	20	$26.0	$109.2
2038	2060	82	$82.4	2060	10300	$2.1	2060	21	$26.4	$110.8
2039	2087	83	$83.5	2087	10437	$2.1	2087	21	$26.7	$112.3
2040	2113	85	$84.5	2113	10566	$2.1	2113	21	$27.0	$113.7
NPV at 7%			$241.9			$6.0			$77.4	$325.4
NPV at 3%			$620.4			$15.5			$198.5	$834.4

Table 5-43 Estimated Increased Operating Costs for Marine C2 Engines; New Tier 4 Engines

Calendar Year	SCR Equipped Fuel Usage (MM gal)	Urea Usage (MM gal)	Annual Urea Cost ($MM)	DPF Equipped Fuel Usage (MM gal)	# of DPF Maintenance Events/Year	Annual DPF Maintenance Cost ($MM)	New Tier 4 Fuel Usage (MM gal)	Increased Fuel Consumption at 1 percent (MM gal)	Annual Cost of Fuel Consumption Impact ($MM)	Annual Increased Operating Cost ($MM)
2006	0	0	$0.0	0	0	$0.0	0	0	$0.0	$0.0
2007	0	0	$0.0	0	0	$0.0	0	0	$0.0	$0.0
2008	0	0	$0.0	0	0	$0.0	0	0	$0.0	$0.0
2009	0	0	$0.0	0	0	$0.0	0	0	$0.0	$0.0
2010	0	0	$0.0	0	0	$0.0	0	0	$0.0	$0.0
2011	0	0	$0.0	0	0	$0.0	0	0	$0.0	$0.0
2012	0	0	$0.0	0	0	$0.0	0	0	$0.0	$0.0
2013	0	0	$0.0	0	0	$0.0	0	0	$0.0	$0.0
2014	55	2	$2.2	55	276	$0.1	55	1	$0.7	$3.0
2015	110	4	$4.4	110	552	$0.1	110	1	$1.4	$5.9
2016	213	9	$8.5	213	1063	$0.2	213	2	$2.7	$11.4
2017	317	13	$12.7	317	1585	$0.3	317	3	$4.1	$17.0
2018	422	17	$16.9	422	2108	$0.4	422	4	$5.4	$22.7
2019	526	21	$21.1	526	2632	$0.5	526	5	$6.7	$28.3
2020	631	25	$25.2	631	3155	$0.6	631	6	$8.1	$33.9
2021	735	29	$29.4	735	3677	$0.7	735	7	$9.4	$39.6
2022	840	34	$33.6	840	4199	$0.8	840	8	$10.7	$45.2
2023	944	38	$37.8	944	4719	$0.9	944	9	$12.1	$50.8
2024	1048	42	$41.9	1048	5238	$1.0	1048	10	$13.4	$56.4
2025	1151	46	$46.0	1151	5756	$1.2	1151	12	$14.7	$61.9
2026	1255	50	$50.2	1255	6274	$1.3	1255	13	$16.1	$67.5
2027	1358	54	$54.3	1358	6791	$1.4	1358	14	$17.4	$73.1
2028	1461	58	$58.5	1461	7307	$1.5	1461	15	$18.7	$78.6
2029	1564	63	$62.6	1564	7820	$1.6	1564	16	$20.0	$84.1
2030	1666	67	$66.6	1666	8331	$1.7	1666	17	$21.3	$89.6
2031	1767	71	$70.7	1767	8836	$1.8	1767	18	$22.6	$95.1
2032	1868	75	$74.7	1868	9339	$1.9	1868	19	$23.9	$100.5
2033	1967	79	$78.7	1967	9833	$2.0	1967	20	$25.2	$105.8
2034	2064	83	$82.6	2064	10321	$2.1	2064	21	$26.4	$111.1
2035	2160	86	$86.4	2160	10800	$2.2	2160	22	$27.6	$116.2
2036	2253	90	$90.1	2253	11263	$2.3	2253	23	$28.8	$121.2
2037	2335	93	$93.4	2335	11675	$2.3	2335	23	$29.9	$125.6
2038	2407	96	$96.3	2407	12033	$2.4	2407	24	$30.8	$129.5
2039	2468	99	$98.7	2468	12339	$2.5	2468	25	$31.6	$132.8
2040	2520	101	$100.8	2520	12598	$2.5	2520	25	$32.3	$135.6
NPV at 7%			$264.4			$6.6			$84.6	$355.7
NPV at 3%			$671.4			$16.8			$214.8	$903.0

Table 5-44 Estimated Increased Operating Costs by Market Segment Associated with the Proposal ($Millions)

Calendar Year	Locomotive Line-haul	Locomotive Switcher & Passenger	Marine C1 >600kW	Marine C2	Total	PM	NO_X+ NMHC
2006	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2007	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2008	$1.9	$0.1	$0.0	$0.0	$1.9	$1.0	$1.0
2009	$1.9	$0.2	$0.0	$0.0	$2.1	$1.0	$1.0
2010	$4.8	$0.4	$0.0	$0.0	$5.2	$2.6	$2.6
2011	$10.0	$0.5	$0.0	$0.0	$10.5	$5.2	$5.2
2012	$12.1	$0.6	$0.0	$0.0	$12.7	$6.3	$6.3
2013	$15.0	$0.6	$0.0	$0.0	$15.6	$7.8	$7.8
2014	$15.7	$0.7	$0.0	$3.0	$19.3	$8.6	$10.7
2015	$18.6	$0.7	$0.0	$5.9	$25.2	$10.6	$14.6
2016	$23.6	$0.8	$3.0	$11.4	$38.9	$14.4	$24.4
2017	$37.2	$1.6	$8.1	$17.0	$64.0	$18.5	$45.4
2018	$48.6	$2.1	$15.2	$22.7	$88.6	$21.7	$66.9
2019	$59.9	$2.5	$22.3	$28.3	$113.1	$24.7	$88.4
2020	$71.2	$3.0	$29.3	$33.9	$137.4	$27.5	$109.9
2021	$82.7	$3.5	$36.3	$39.6	$162.1	$30.3	$131.8
2022	$94.7	$4.2	$43.3	$45.2	$187.4	$33.2	$154.2
2023	$115.3	$5.2	$50.2	$50.8	$221.5	$36.2	$185.3
2024	$136.0	$6.0	$57.0	$56.4	$255.4	$39.2	$216.2
2025	$148.7	$6.8	$63.7	$61.9	$281.1	$42.2	$239.0
2026	$161.5	$7.7	$70.2	$67.5	$306.9	$45.2	$261.7
2027	$174.4	$8.7	$76.6	$73.1	$332.7	$48.3	$284.5
2028	$187.3	$9.7	$82.8	$78.6	$358.4	$51.3	$307.1
2029	$200.3	$10.7	$88.2	$84.1	$383.4	$54.3	$329.1
2030	$213.3	$11.9	$92.5	$89.6	$407.3	$57.2	$350.1
2031	$226.3	$13.1	$95.9	$95.1	$430.3	$60.0	$370.4
2032	$239.3	$14.4	$98.7	$100.5	$452.9	$62.7	$390.2
2033	$252.4	$15.7	$101.3	$105.8	$475.2	$65.4	$409.7
2034	$265.4	$17.1	$103.6	$111.1	$497.1	$68.1	$429.0
2035	$278.3	$18.5	$105.7	$116.2	$518.7	$70.8	$447.9
2036	$290.7	$19.9	$107.5	$121.2	$539.3	$73.3	$466.0
2037	$302.8	$21.2	$109.2	$125.6	$558.8	$75.8	$483.1
2038	$314.5	$22.5	$110.8	$129.5	$577.2	$78.1	$499.2
2039	$325.7	$23.8	$112.3	$132.8	$594.5	$80.2	$514.3
2040	$336.5	$25.0	$113.7	$135.6	$610.7	$82.3	$528.4
NPV at 7%	$866.7	$47.7	$325.4	$355.7	$1,595.4	$267.2	$1,328.3
NPV at 3%	$2,176.2	$125.7	$834.4	$903.0	$4,039.3	$631.4	$3,407.9

Table 5-45 Estimated Increased Operating Costs by Cost Element Associated with the Proposal ($Millions)

Calendar Year	Urea Use	DPF Maintenance	Fuel Impact	Total	PM	NO_x+ NMHC
2006	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2007	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2008	$0.0	$0.0	$1.9	$1.9	$1.0	$1.0
2009	$0.0	$0.0	$2.1	$2.1	$1.0	$1.0
2010	$0.0	$0.0	$5.2	$5.2	$2.6	$2.6
2011	$0.0	$0.0	$10.5	$10.5	$5.2	$5.2
2012	$0.0	$0.0	$12.7	$12.7	$6.3	$6.3
2013	$0.0	$0.0	$15.6	$15.6	$7.8	$7.8
2014	$2.2	$0.1	$17.1	$19.3	$8.6	$10.7
2015	$4.4	$0.3	$20.5	$25.2	$10.6	$14.6
2016	$10.7	$0.7	$27.4	$38.9	$14.4	$24.4
2017	$28.0	$1.1	$34.8	$64.0	$18.5	$45.4
2018	$46.8	$1.6	$40.2	$88.6	$21.7	$66.9
2019	$65.7	$2.1	$45.3	$113.1	$24.7	$88.4
2020	$85.0	$2.6	$49.9	$137.4	$27.5	$109.9
2021	$104.5	$3.0	$54.6	$162.1	$30.3	$131.8
2022	$124.5	$3.5	$59.4	$187.4	$33.2	$154.2
2023	$153.2	$4.0	$64.3	$221.5	$36.2	$185.3
2024	$181.6	$4.5	$69.2	$255.4	$39.2	$216.2
2025	$201.8	$5.0	$74.3	$281.1	$42.2	$239.0
2026	$222.0	$5.6	$79.3	$306.9	$45.2	$261.7
2027	$242.2	$6.1	$84.4	$332.7	$48.3	$284.5
2028	$262.3	$6.6	$89.6	$358.4	$51.3	$307.1
2029	$281.8	$7.0	$94.6	$383.4	$54.3	$329.1
2030	$300.4	$7.5	$99.4	$407.3	$57.2	$350.1
2031	$318.3	$8.0	$104.1	$430.3	$60.0	$370.4
2032	$335.8	$8.4	$108.7	$452.9	$62.7	$390.2
2033	$353.1	$8.8	$113.2	$475.2	$65.4	$409.7
2034	$370.1	$9.3	$117.7	$497.1	$68.1	$429.0
2035	$386.8	$9.7	$122.2	$518.7	$70.8	$447.9
2036	$402.7	$10.1	$126.5	$539.3	$73.3	$466.0
2037	$417.8	$10.4	$130.6	$558.8	$75.8	$483.1
2038	$431.9	$10.8	$134.5	$577.2	$78.1	$499.2
2039	$445.2	$11.1	$138.2	$594.5	$80.2	$514.3
2040	$457.6	$11.4	$141.7	$610.7	$82.3	$528.4
NPV at 7%	$1,089.7	$28.6	$477.1	$1,595.4	$267.2	$1,328.3
NPV at 3%	$2,850.0	$73.5	$1,115.7	$4,039.3	$631.4	$3,407.9

As shown in Table 5-45, the net present value of the annual operating costs is estimated at $4 billion at a three percent discount rate or $1.6 billion at a seven percent discount rate. The primary increased operating cost is associated with urea use which accounts for nearly three quarters of the estimated costs. Since urea use is meant for NO_x+NMHC control, most of the increased operating costs are attributed to NO_x+NMHC control. Of note in these operating cost tables is the annual reduction of gallons consumed by remanufactured Tier 0 locomotives. This is a result of older Tier 0 locomotives slowly being retired from duty and being replaced by new Tier 4 locomotives. This also explains the corresponding increase in gallons consumed by new Tier 4 locomotives. Not shown in the locomotive operating cost tables are gallons consumed by remanufactured Tier 1, 2 and 3 locomotives because we expect no increased operating cost for those locomotives as a result of this proposal (no new aftertreatment devices so no urea nor DPF maintenance costs and no fuel consumption impact). Also, in Table 5-41 where fuel consumption impacts are calculated, we have considered gallons burned by remanufactured and new Tier 4 passenger locomotives but have not included switchers. We have not included switchers because those locomotives are expected to be powered by nonroad Tier 4 engines having better fuel economy than the switcher engines they replace.

5.5 Engineering Hardware Costs Associated with the Locomotive Remanufacturing Program

Our proposal also contains requirements that remanufactured locomotives meet more stringent standards than those to which they were designed originally. Because the standards for those engines are more stringent, they cannot necessarily be remanufactured to their original configuration but must, instead, include some new technology and/or engine controls to ensure compliance with the more stringent standards. The incremental costs associated with those new technologies must be considered as part of this proposal. The remanufacturing process is not a low cost endeavor. However, it is much less costly than purchasing a perfectly new engine. The costs we have estimated for the remanufacturing program are meant to capture the incremental costs associated with remanufacturing as a result of the proposed program.

To summarize the proposed requirements, the existing fleet of locomotives that are currently subject to Tier 0 standards would need to comply with a new Tier 0 PM standard and a new Tier 0 NO_x line-haul standard, except that Tier 0 locomotives that were newly built before 1994 would remain subject to the existing Tier 0 NO_x standards. In general, these new Tier 0 standards would apply when the locomotive is remanufactured as early as January 1, 2008. For locomotives currently subject to Tier 1 and Tier 2 standards, more stringent PM standards would apply at the point of next remanufacture as early as January 1, 2008, but not later than 2010.

To meet the proposed locomotive remanufactured engine standards, we project that engine manufacturers will utilize incremental improvements to existing engine components. In many cases, similar improvements have already been implemented on new locomotives to meet our current new locomotive standards. To meet the lower NO_x standard proposed for Tier 0 locomotives, we expect possible improvements in the fuel system, the turbo charger, and the engine calibration. Such changes are expected to impact fuel consumption as was discussed in section 5.4.3 of this draft RIA. We have estimated the incremental costs associated with the remanufacture of a Tier 0 locomotive to be $33,800 for the first remanufacture and $22,300 for the second one. The lower cost for the second remanufacture is because not all of the new technology would have to be remanufactured during the second effort. We have estimated that first remanufacture would occur through 2016 with the second one occurring after 2016.

To meet the proposed PM standards for the Tier 1 remanufacturing program, we expect that lubricating oil consumption controls will be implemented, along with the ultra low sulfur diesel fuel requirement for locomotive engines (which was previously finalized in our nonroad clean diesel rulemaking). Because of the significant fraction of lubricating oil present in PM from today's locomotives, we believe that existing low-oil-consumption piston ring-pack designs, when used in conjunction with improvements to closed crankcase ventilation systems, will provide significant, near-term PM reductions. We have estimated these costs to be roughly equivalent to the costs associated with the Tier 0 remanufacturing. We have also estimated the first remanufacture would occur through 2016 with the second one occurring after 2016.

To meet the more stringent proposed PM standards for the Tier 2 remanufacturing program, we expect use of improved fuel systems. Based on work previously done for our NRT4 rule, we have estimated the incremental cost of a new fuel system on a line haul locomotive at $11,750 and on a switcher at $8,700. This cost differential exists because the line haul locomotives have larger engines and, hence, larger fuel rails and pumps, etc. We have not estimated an incremental cost associated with a second remanufacture for Tier 2 locomotives because we would not expect the fuel system would need a second remanufacture. We have estimated that the first remanufacture would occur prior to 2020.

We have not estimated any incremental costs for Tier 3 remanufacturing because these locomotives would not meet a remanufactured standard more stringent than their original design. Therefore, while costs would be incurred to remanufacture these engines, those costs would not be different from current remanufacturing kits.

In the case of our proposed locomotive standards, it is worthwhile to note the difference in how we have handled variable costs for the remanufactured Tier 2 engines versus the new Tier 3 standards. In some cases, we believe manufacturers may choose to introduce more modern common rail fuel systems for both their new Tier 3 products and for application to their existing Tier 2 products at the time of remanufacturing. In the case of the new Tier 3 engine, we are projecting no increase in engine variable cost because, for example, we expect the common rail fuel system to be no more expensive (and perhaps cheaper) than the fuel system that would have been used absent our proposed standards. However, we have accounted for these higher costs for the remanufactured Tier 2 engines reflecting the fact that the new fuel system is an incremental cost for the rebuild that would not have occurred absent our proposed standard (because the existing fuel system could be reused at remanufacture absent the new standard).

For Tier 4 remanufacturing, we have estimated that locomotive engines would need a new set of aftertreatment devices and a remanufactured fuel system. We have estimated the aftertreatment device costs at slightly lower than the original equipment costs because we would expect that precious metals would be recycled from the device being removed and replaced. This results in remanufactured DPF and SCR system costs of 60 percent and 94 percent, respectively, relative to the original cost. The 60/94 differential occurs because of the larger amount of precious metals contained in the DPF versus the SCR catalyst which contains only a small amount of precious metal for the DOC function. For the remanufactured fuel system, we have included the costs already mentioned above associated with costs for Tier 2 remanufacturing (i.e., $11,750 or $8,700).

These estimated incremental remanufacturing costs are summarized in Table 5-46.

Table 5-46 Estimated Incremental Costs Associated with the Locomotive Remanufacturing Program ($/remanufacture)

Segment	Tier	1st Remanufacture	2nd Remanufacture
Locomotive Line-haul	Tier 0	$33,800	$22,300
	Tier 1	$33,800	$22,300
	Tier 2	$11,750	$0
	Tier 3	$0	$0
	Tier 4	$66,000	$66,000
Locomotive Switcher/Passenger	Tier 0	$33,800	$22,300
	Tier 1	$33,800	$22,300
	Tier 2	$8,700	$0
	Tier 3	$0	$0
	Tier 4	$21,700	$21,700

Using these per remanufacture costs, we can calculate the total costs associated with the proposed remanufacturing program. These costs are presented in Table 5-47 for line haul and Table 5-48 for switchers and passenger locomotives. See Chapter 3 of this draft RIA for how we determined the rate at which locomotives are remanufactured. The number remanufactured and the calendar years in which they occur are also shown in the tables. As shown, the net present value of the annual remanufacturing costs is estimated at $1.2 billion and $0.6 billion for line haul locomotives at a three percent and seven percent discount rate, respectively. For switchers and passenger locomotives, we have estimated the net present value of the annual costs at $150 million and $85 million at a three and seven percent discount rate, respectively. In total, the proposed remanufacturing program would have a net present value cost of $1.4 billion at a three percent discount rate and $0.7 billion at a seven percent discount rate. Note that, while not shown in Table 5-47 and Table 5-48, the costs associated with the proposed locomotive remanufacturing program are arbitrarily split evenly between NO_x+NMHC and PM control. This split is shown in Table 5-54.

Table 5-47 Estimated Annual Costs Associated with the Remanufacturing Program for Line Haul Locomotives

Calendar Year	Tier 0			Tier 1			Tier 2			Tier 3			Tier 4			Total ($MM)
	Remans	$/reman	Subtotal ($MM)	Remans	$/reman	Subtotal ($MM)	Remans	$/reman	Subtotal ($MM)	Remans		Subtotal ($MM)	Remans	$/reman	Subtotal ($MM)	
2006	-		$0.0	-		$0.0	-		$0.0	-		$0	-		$0.0	$0.0
2007	-		$0.0	-		$0.0	-		$0.0	-		$0	-		$0.0	$0.0
2008	661	$33,800	$22.3	-		$0.0	-		$0.0	-		$0	-		$0.0	$22.3
2009	-	$33,800	$0.0	803	$33,800	$27.1	-		$0.0	-		$0	-		$0.0	$27.1
2010	1220	$33,800	$41.2	-	$33,800	$0.0	-		$0.0	-		$0	-		$0.0	$41.2
2011	2078	$33,800	$70.2	489	$33,800	$16.5	-		$0.0	-		$0	-		$0.0	$86.8
2012	972	$33,800	$32.8	931	$33,800	$31.5	-		$0.0	-		$0	-		$0.0	$64.3
2013	1310	$33,800	$44.3	-	$33,800	$0.0	719	$11,749	$8.4	-		$0	-		$0.0	$52.7
2014	618	$33,800	$20.9	-	$33,800	$0.0	826	$11,749	$9.7	-		$0	-		$0.0	$30.6
2015	390	$33,800	$13.2	-	$33,800	$0.0	646	$11,749	$7.6	-		$0	-		$0.0	$20.8
2016	1174	$33,800	$39.7	-	$33,800	$0.0	666	$11,749	$7.8	-		$0	-		$0.0	$47.5
2017	1164	$22,300	$26.0	-	$22,300	$0.0	693	$11,749	$8.1	-		$0	-		$0.0	$34.1
2018	1271	$22,300	$28.4	-	$22,300	$0.0	729	$11,749	$8.6	-		$0	-		$0.0	$36.9
2019	231	$22,300	$5.2	803	$22,300	$17.9	751	$11,749	$8.8	-		$0	-		$0.0	$31.9
2020	370	$22,300	$8.2	-	$22,300	$0.0	-	$0	$0.0	767	$0	$0	-		$0.0	$8.2
2021	-	$22,300	$0.0	489	$22,300	$10.9	-	$0	$0.0	765	$0	$0	-		$0.0	$10.9
2022	579	$22,300	$12.9	931	$22,300	$20.8	-	$0	$0.0	780	$0	$0	-		$0.0	$33.7
2023	1103	$22,300	$24.6	-	$22,300	$0.0	719	$0	$0.0	-	$0	$0	816	$66,021	$53.9	$78.5
2024	501	$22,300	$11.2	-	$22,300	$0.0	826	$0	$0.0	-	$0	$0	854	$66,021	$56.4	$67.5
2025	646	$22,300	$14.4	-	$22,300	$0.0	646	$0	$0.0	-	$0	$0	877	$66,021	$57.9	$72.3
2026	-	$22,300	$0.0	-	$22,300	$0.0	666	$0	$0.0	-	$0	$0	894	$66,021	$59.0	$59.0
2027	-	$22,300	$0.0	-	$22,300	$0.0	693	$0	$0.0	-	$0	$0	917	$66,021	$60.6	$60.6
2028	622	$22,300	$13.9	-	$22,300	$0.0	729	$0	$0.0	-	$0	$0	948	$66,021	$62.6	$76.5
2029	610	$22,300	$13.6	-	$22,300	$0.0	751	$0	$0.0	-	$0	$0	979	$66,021	$64.6	$78.2
2030	505	$22,300	$11.3	-	$22,300	$0.0	-	$0	$0.0	767	$0	$0	1007	$66,021	$66.5	$77.8
2031	-	$22,300	$0.0	442	$22,300	$9.8	-	$0	$0.0	765	$0	$0	1034	$66,021	$68.3	$78.1
2032	-	$22,300	$0.0	-	$22,300	$0.0	-	$0	$0.0	780	$0	$0	1048	$66,021	$69.2	$69.2
2033	-	$22,300	$0.0	-	$22,300	$0.0	-	$0	$0.0	-	$0	$0	1894	$66,021	$125.0	$125.0
2034	-	$22,300	$0.0	220	$22,300	$4.9	-	$0	$0.0	-	$0	$0	1950	$66,021	$128.8	$133.7
2035	-	$22,300	$0.0	419	$22,300	$9.3	-	$0	$0.0	-	$0	$0	1996	$66,021	$131.8	$141.1
2036	-	$22,300	$0.0	-	$22,300	$0.0	324	$0	$0.0	-	$0	$0	2030	$66,021	$134.0	$134.0
2037	-	$22,300	$0.0	-	$22,300	$0.0	372	$0	$0.0	-	$0	$0	2067	$66,021	$136.5	$136.5
2038	-	$22,300	$0.0	-	$22,300	$0.0	291	$0	$0.0	-	$0	$0	2106	$66,021	$139.1	$139.1
2039	-	$22,300	$0.0	-	$22,300	$0.0	300	$0	$0.0	-	$0	$0	2152	$66,021	$142.1	$142.1
2040	-	$22,300	$0.0	-	$22,300	$0.0	312	$0	$0.0	-	$0	$0	2197	$66,021	$145.1	$145.1
NPV at 7%			$231.7			$72.1			$28.4			$0			$264.6	$596.8
NPV at 3%			$332.9			$105.2			$42.8			$0			$743.4	$1,224.3

Table 5-48 Estimated Annual Costs Associated with the Remanufacturing Program for Switcher and Passenger Locomotives

Calendar Year	Tier 0/1			Tier 2			Tier 3			Tier 4			Total ($MM)
	Remans	$/reman	Subtotal ($MM)	Remans	$/reman	Subtotal ($MM)	Remans	$/reman	Subtotal ($MM)	Remans	$/reman	Subtotal ($MM)	
2006	-		$0.0	-		$0.0	-		$0	-		$0.0	$0.0
2007	-		$0.0	-		$0.0	-		$0	-		$0.0	$0.0
2008		$33,800	$1.1	-		$0.0	-		$0	-		$0.0	$1.1
2009		$33,800	$2.6	-		$0.0	-		$0	-		$0.0	$2.6
2010	31	$33,800	$10.6	-		$0.0	-		$0	-		$0.0	$10.6
2011	78	$33,800	$10.5	-		$0.0	-		$0	-		$0.0	$10.5
2012	314	$33,800	$10.5	-		$0.0	-		$0	-		$0.0	$10.5
2013	312	$33,800	$10.4	-		$0.0	-		$0	-		$0.0	$10.4
2014	309	$33,800	$10.4	-		$0.0	-		$0	-		$0.0	$10.4
2015	307	$33,800	$9.1		$8,728	$1.0	-		$0	-		$0.0	$10.1
2016	307	$33,800	$9.2		$8,728	$1.3	-		$0	-		$0.0	$10.5
2017	269	$22,300	$6.1	112	$8,728	$0.8	-		$0	-		$0.0	$6.8
2018	271	$22,300	$6.1	154	$8,728	$0.8	-		$0	-		$0.0	$6.9
2019	273	$22,300	$6.2	88	$8,728	$0.8	-		$0	-		$0.0	$6.9
2020	274	$22,300	$6.2	89	$8,728	$0.8	-		$0	-		$0.0	$7.0
2021	276	$22,300	$6.2	90	$0	$0.0		$0	$0	-		$0.0	$6.2
2022	278	$22,300	$6.3	91	$0	$0.0		$0	$0	-		$0.0	$6.3
2023	279	$22,300	$7.1	-	$0	$0.0	46	$0	$0	-		$0.0	$7.1
2024	281	$22,300	$7.0	-	$0	$0.0	46	$0	$0	-		$0.0	$7.0
2025	318	$22,300	$6.9		$0	$0.0	92	$0	$0		$21,695	$1.0	$7.9
2026	315	$22,300	$5.9		$0	$0.0	92	$0	$0		$21,695	$2.0	$8.0
2027	311	$22,300	$5.8	57	$0	$0.0	46	$0	$0	47	$21,695	$2.0	$7.8
2028	266	$22,300	$5.6	169	$0	$0.0	-	$0	$0	93	$21,695	$2.0	$7.7
2029	260	$22,300	$5.5	86	$0	$0.0	-	$0	$0	94	$21,695	$2.0	$7.5
2030	253	$22,300	$5.3	88	$0	$0.0	-	$0	$0	94	$21,695	$2.0	$7.3
2031	245	$22,300	$5.0	89	$0	$0.0		$0	$0	94	$21,695	$2.0	$7.1
2032	236	$22,300	$4.2	90	$0	$0.0		$0	$0	94	$21,695	$2.0	$6.3
2033	226	$22,300	$4.0	45	$0	$0.0	46	$0	$0	94	$21,695	$3.5	$7.4
2034	190	$22,300	$3.7	-	$0	$0.0	46	$0	$0	94	$21,695	$4.0	$7.7
2035	179	$22,300	$3.4		$0	$0.0	92	$0	$0	160	$21,695	$4.4	$7.8
2036	166	$22,300	$3.2		$0	$0.0	92	$0	$0	183	$21,695	$4.6	$7.8
2037	154	$22,300	$2.9	57	$0	$0.0	46	$0	$0	201	$21,695	$5.0	$7.9
2038	142	$22,300	$2.7	114	$0	$0.0	-	$0	$0	212	$21,695	$5.2	$7.9
2039	132	$22,300	$2.5	46	$0	$0.0	-	$0	$0	230	$21,695	$5.3	$7.9
2040	123	$22,300	$2.3	46	$0	$0.0	-	$0	$0	238	$21,695	$5.7	$8.0
NPV at 7%	114		$75.0	46		$2.4			$0	246		$7.5	$84.9
NPV at 3%	105		$123.9	46		$3.8			$0	263		$22.3	$150.0

5.6 Summary of Proposed Program Engineering Costs

Details of our engine and equipment cost estimates were presented in Sections 5.2 and 5.3. Here we summarize the cost estimates. Section 5.6.1 summarizes the engine-related costs associated with the proposed program. Section 5.6.2 summarizes the equipment-related costs associated with the proposed program. Section 5.6.3 summarizes the operating costs associated with the proposed program for both new and remanufactured engines. Section 5.6.4 summarizes the hardware costs associated with the locomotive remanufacturing program. Section 5.6.5 summarizes all these costs and presents the total estimated costs for the proposed program. Note that all present value costs presented here are 2006 through 2040 numbers (the net present values in 2006 of the stream of costs occurring from 2006 through 2040, expressed in $2005).

5.6.1 New Engine Engineering Costs

5.6.1.1 New Engine Fixed Engineering Costs

Engine fixed costs include costs for engine R&D, tooling, and certification. These costs are discussed in detail in Section 5.2.1. The total estimated engine fixed costs are summarized in Table 5-49. The table also includes net present values using both a three percent and a seven percent discount rate.

Table 5-49 Summary of Engine-Related Fixed Costs for the Proposed Program ($Millions)

	Costs Incurred	2006-2040 NPV at 3%	2006-2040 NPV at 7%
Engine and Emission Control Research	$ 415	$ 341	$ 267
Engine Tooling	$ 41	$ 33	$ 24
Engine Certification	$ 9	$ 7	$ 6
Total Engine Fixed Costs	$ 466	$ 381	$ 297
Total Allocated to PM	$ 162	$ 133	$ 104
Total Allocated to NO_x+NMHC	$ 303	$ 248	$ 193

Note: As explained in the text, we have attributed engine fixed costs to NO_x+NMHC and PM control as follows: engine research costs are split two-thirds to NO_x+NMHC control and one-third to PM control; engine tooling costs are split equally; engine certification costs are split equally except where new standards are implemented in different years (e.g., for Tier 4 locomotive standards).

5.6.1.2 New Engine Variable Engineering Costs

Engine variable, or hardware, costs are discussed in detail in Section 5.2.2. For engine variable costs, we have generated cost estimation equations as a function of engine displacement (see Table 5-27). Using these equations, we have calculated the hardware costs for new engines meeting the proposed standards for each year through 2040. We present those annual engine variable costs in Section 5.2.2. Table 5-50 shows the net present value of those annual costs using a three percent discount rate and a seven percent discount rate.

Table 5-50 Summary of Engine-Related Variable Costs for the Proposed Program ($Millions)

	2006-2040 NPV at 3%	2006-2040 NPV at 7%
Locomotive	$ 808	$ 364
C1 Marine & Recreational Marine >2000 kW	$ 261	$ 119
C2 Marine	$ 227	$ 104
Recreational Marine <2000 kW	$ 0	$ 0
Small Marine	$ 0	$ 0
Total Engine Variable Costs	$ 1,297	$ 586
Total Allocated to PM	$ 700	$ 320
Total Allocated to NO_X+NMHC	$ 597	$ 266

Note: The PM/NO_X+NMHC cost allocations for engine variable costs are as follows: Urea SCR systems including marinization costs on marine applications are attributed 100% to NO_X+NMHC control; and, DPF systems including marinization costs on marine applications are attributed 100% to PM control.

5.6.2 New Equipment Engineering Costs

5.6.2.1 New Equipment Fixed Engineering Costs

Equipment fixed costs are discussed in detail in Section 5.3.1. Table 5-51 shows the estimated equipment fixed costs—for redesign efforts—associated with the proposed program. The table also includes net present values of the annual costs using both a three percent and a seven percent discount rate.

Table 5-51 Summary of Equipment-Related Fixed Costs for the Proposed Program ($Millions)

	Costs Incurred	2006-2040 NPV at 3%	2006-2040 NPV at 7%
Locomotive	$ 0.7	$ 0.5	$ 0.4
C1 Marine & Recreational Marine >2000 kW	$ 45	$ 31	$ 20
C2 Marine	$ 16	$ 11	$ 7
Recreational Marine <2000 kW	$ 0	$ 0	$ 0
Small Marine	$ 0	$ 0	$ 0
Total Equipment Fixed Costs	$ 61	$ 43	$ 27
Total Allocated to PM	$ 31	$ 21	$ 14
Total Allocated to NO_X+NMHC	$ 31	$ 21	$ 14

Note: Equipment fixed costs are arbitrarily split evenly between NO_X+NMHC and PM control.

5.6.2.2 New Equipment Variable Engineering Costs

Equipment variable costs are discussed in detail in Section 5.3.2. Using the costs presented there we have calculated the hardware costs for new pieces of equipment—locomotives and vessels—meeting the proposed standards for each year through 2040. We present those annual equipment variable costs in Section 5.3.2. Table 5-52 shows the net present value of those annual costs using a three percent and a seven percent discount rate.

Table 5-52 Summary of Equipment-Related Variable Costs for the Proposed Program ($Millions)

	2006-2040 NPV at 3%	2006-2040 NPV at 7%
Locomotive	$ 68	$ 30
C1 Marine & Recreational Marine >2000 kW	$ 26	$ 12
C2 Marine	$ 5	$ 2
Recreational Marine <2000 kW	$ 0	$ 0
Small Marine	$ 0	$ 0
Total Equipment Variable Costs	$ 99	$ 44
Total Allocated to PM	$ 50	$ 22
Total Allocated to NO_X+NMHC	$ 50	$ 22

Note: Equipment variable costs are arbitrarily split evenly between NO_X+NMHC and PM control.

5.6.3 Operating Costs for New and Remanufactured Engines

Operating costs are discussed in detail in Section 5.4 where we present the operating costs for each year through 2040. Operating costs consist of costs associated with urea use, DPF maintenance, and a fuel consumption impact on some engines. Table 5-53 shows the net present value of those annual operating costs using a three percent and a seven percent discount rate.

Table 5-53 Summary of Operating Costs for the Proposed Program ($Millions)

	2006-2040 NPV at 3%				2006-2040 NPV at 7%			
	Urea	DPF Maint.	Fuel	Total	Urea	DPF Maint.	Fuel	Total
Locomotive	$1,558	$41	$702	$2,302	$583	$16	$315	$914
C1 Marine	$620	$16	$199	$834	$242	$6	$77	$325
C2 Marine	$671	$17	$215	$903	$264	$7	$85	$356
Recreational Marine	$ 0	$0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0
Small Marine	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0
Total Operating	$2,850	$74	$1,116	$4,039	$1,090	$29	$477	$1,595

Costs								
Total Allocated to PM	$ 0	$74	$558	$631	$ 0	$29	$239	$267
Total Allocated to NO_X+NMHC	$2,850	$ 0	$558	$3,408	$1,090	$ 0	$239	$1,328

Note: Operating costs are attributed as follows: costs associated with urea use are attributed solely to NO_X+NMHC control; costs associated with DPF maintenance are attributed solely to PM control; and, costs associated with the fuel consumption impact are split evenly between NO_X+NMHC and PM control.

5.6.4 Remanufacturing Program Engineering Hardware Costs

Costs associated with the locomotive remanufacturing program are discussed in detail in Section 5.5 where we present the costs for each year through 2040. These costs include the hardware costs that are incremental to current remanufacturing practices. Table 5-54 shows the net present value of those annual remanufacturing costs using a three percent and a seven percent discount rate.

Table 5-54 Summary of Locomotive Remanufacturing Program Hardware Costs ($Millions)

	2006-2040 NPV at 3%	2006-2040 NPV at 7%
Line Haul	$ 1,224	$ 597
Switcher & Passenger	$ 150	$ 85
Total Remanufacturing Costs	$ 1,374	$ 682
Total Allocated to PM	$ 687	$ 341
Total Allocated to NO_X+NMHC	$ 687	$ 341

Note: Costs associated with the proposed locomotive remanufacturing program are arbitrarily split evenly between NO_X+NMHC and PM control.

5.6.5 Total Engineering Costs Associated with the Proposed Program

Table 5-55 shows the total annual costs for each market segment—locomotive line haul, C2 marine, etc—for the proposed program. Table 5-56 shows the total annual costs for each cost element—engine, equipment, operating, etc.—on an annual basis for the proposed program. As shown, the net present value of the annual costs is estimated at $7.2 billion at a three percent discount rate and $3.2 billion at a seven percent discount rate. In the year 2030, the annual costs are estimated at $605 million.

Note that costs throughout this analysis have been allocated as follows: engine research costs are split two-thirds to NO_x+NMHC control and one-third to PM control; engine tooling costs are split equally; engine certification costs are split equally except where new standards are implemented in different years (e.g., for Tier 4 locomotive standards); urea SCR systems including marinization costs on marine applications are attributed 100% to NO_x+NMHC control; DPF systems including marinization costs on marine applications are attributed 100% to PM control; equipment fixed and variable costs are arbitrarily split evenly between NO_x+NMHC and PM control; costs associated with urea use are attributed solely to NO_x+NMHC control; costs associated with DPF maintenance are attributed solely to PM control; costs associated with the fuel consumption impact are split evenly between NO_x+NMHC and PM control; and, costs associated with the locomotive remanufacturing program are arbitrarily split evenly between NO_x+NMHC and PM control.

Table 5-55 Estimated Annual Engineering Costs by Market Segment for the Proposed Program ($Millions)

Calendar Year	Locomotive		Marine					Total
	Line Haul	Switcher & Passenger	C2 Marine	C1 Marine >600kW	C1 Marine <600kW	Recreational Marine	Small Marine	
2006	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2007	$0.6	$2.6	$4.2	$2.3	$10.9	$5.8	$1.7	$28.2
2008	$24.9	$3.7	$4.2	$2.3	$10.9	$5.8	$1.7	$53.5
2009	$29.6	$5.4	$4.2	$2.3	$10.9	$5.8	$1.7	$60.0
2010	$48.4	$15.9	$4.2	$2.3	$10.9	$5.8	$1.7	$89.3
2011	$100.6	$18.0	$27.7	$29.4	$16.2	$10.9	$3.7	$206.5
2012	$81.5	$18.2	$20.7	$21.8	$0.0	$0.0	$0.0	$142.2
2013	$72.9	$18.2	$20.7	$21.8	$0.0	$0.0	$0.0	$133.5
2014	$53.7	$21.2	$23.7	$21.8	$0.0	$0.0	$0.0	$120.4
2015	$77.0	$16.9	$40.8	$46.5	$0.0	$0.0	$0.0	$181.2
2016	$112.5	$20.0	$35.0	$36.0	$0.0	$0.0	$0.0	$203.5
2017	$129.7	$10.2	$39.8	$37.4	$0.0	$0.0	$0.0	$217.2
2018	$145.0	$10.8	$39.8	$37.4	$0.0	$0.0	$0.0	$232.9
2019	$145.7	$11.1	$45.6	$44.7	$0.0	$0.0	$0.0	$247.0
2020	$135.0	$11.6	$51.3	$51.9	$0.0	$0.0	$0.0	$249.9
2021	$151.0	$11.4	$57.1	$59.2	$0.0	$0.0	$0.0	$278.6
2022	$187.4	$12.2	$62.9	$66.3	$0.0	$0.0	$0.0	$328.8
2023	$254.5	$15.1	$68.6	$73.4	$0.0	$0.0	$0.0	$411.6
2024	$265.0	$16.2	$73.3	$77.9	$0.0	$0.0	$0.0	$432.6
2025	$284.2	$18.3	$79.1	$84.9	$0.0	$0.0	$0.0	$466.4
2026	$284.8	$19.4	$84.8	$91.6	$0.0	$0.0	$0.0	$480.7
2027	$300.6	$20.5	$90.5	$98.3	$0.0	$0.0	$0.0	$509.9
2028	$330.4	$21.6	$96.2	$104.7	$0.0	$0.0	$0.0	$552.9
2029	$346.0	$22.6	$101.9	$110.3	$0.0	$0.0	$0.0	$580.8
2030	$359.0	$23.8	$107.6	$114.8	$0.0	$0.0	$0.0	$605.2
2031	$373.2	$25.1	$113.2	$118.5	$0.0	$0.0	$0.0	$630.0
2032	$378.3	$25.8	$118.7	$121.5	$0.0	$0.0	$0.0	$644.3
2033	$448.3	$28.4	$124.2	$124.3	$0.0	$0.0	$0.0	$725.2
2034	$470.8	$30.1	$129.6	$126.9	$0.0	$0.0	$0.0	$757.5
2035	$491.6	$31.6	$134.9	$129.2	$0.0	$0.0	$0.0	$787.3
2036	$495.0	$32.8	$140.1	$131.3	$0.0	$0.0	$0.0	$799.1
2037	$508.0	$34.2	$144.7	$133.2	$0.0	$0.0	$0.0	$820.1
2038	$520.6	$35.3	$148.7	$135.1	$0.0	$0.0	$0.0	$839.7
2039	$533.0	$36.4	$152.2	$136.8	$0.0	$0.0	$0.0	$858.4
2040	$544.8	$37.7	$155.2	$138.4	$0.0	$0.0	$0.0	$876.0
NPV at 7%	$1,859.0	$186.0	$551.4	$555.6	$45.3	$25.7	$8.0	$3,231.1
NPV at 3%	$4,258.3	$366.4	$1,255.8	$1,259.5	$52.9	$30.2	$9.4	$7,232.5

Table 5-56 Estimated Annual Engineering Costs by Cost Element for the Proposed Program ($Millions)

Calendar Year	Engine Costs	Equipment Costs	Loco Reman Costs	Operating Costs	Total	PM	NO_X+NMHC
2006	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2007	$28.2	$0.0	$0.0	$0.0	$28.2	$9.3	$18.9
2008	$28.2	$0.0	$23.4	$1.9	$53.5	$22.0	$31.5
2009	$28.2	$0.0	$29.8	$2.1	$60.0	$25.2	$34.8
2010	$32.2	$0.0	$51.8	$5.2	$89.3	$41.9	$47.4
2011	$98.8	$0.0	$97.3	$10.5	$206.5	$93.3	$113.2
2012	$54.8	$0.0	$74.8	$12.7	$142.2	$61.8	$80.4
2013	$54.8	$0.0	$63.1	$15.6	$133.5	$57.5	$76.1
2014	$59.4	$0.7	$41.0	$19.3	$120.4	$52.1	$68.3
2015	$100.0	$25.1	$30.8	$25.2	$181.2	$93.2	$88.1
2016	$89.2	$17.5	$58.0	$38.9	$203.5	$107.7	$95.8
2017	$99.7	$12.6	$40.9	$64.0	$217.2	$93.9	$123.3
2018	$90.9	$9.7	$43.8	$88.6	$232.9	$92.4	$140.5
2019	$85.3	$9.8	$38.8	$113.1	$247.0	$93.9	$153.2
2020	$87.3	$9.9	$15.2	$137.4	$249.9	$86.0	$163.9
2021	$89.4	$10.1	$17.1	$162.1	$278.6	$90.9	$187.7
2022	$91.2	$10.2	$39.9	$187.4	$328.8	$106.2	$222.5
2023	$94.0	$10.6	$85.6	$221.5	$411.6	$133.7	$277.9
2024	$95.4	$7.2	$74.6	$255.4	$432.6	$130.3	$302.3
2025	$97.6	$7.5	$80.2	$281.1	$466.4	$137.4	$329.0
2026	$99.2	$7.6	$67.0	$306.9	$480.7	$134.7	$345.9
2027	$101.0	$7.8	$68.4	$332.7	$509.9	$139.5	$370.3
2028	$102.4	$7.9	$84.1	$358.4	$552.9	$151.3	$401.6
2029	$103.6	$8.0	$85.7	$383.4	$580.8	$155.8	$425.0
2030	$104.7	$8.1	$85.1	$407.3	$605.2	$159.0	$446.2
2031	$106.1	$8.3	$85.2	$430.3	$630.0	$162.7	$467.3
2032	$107.6	$8.4	$75.5	$452.9	$644.3	$161.4	$483.0
2033	$109.0	$8.5	$132.5	$475.2	$725.2	$193.4	$531.8
2034	$110.3	$8.7	$141.3	$497.1	$757.5	$201.3	$556.2
2035	$111.1	$8.7	$148.9	$518.7	$787.3	$208.1	$579.2
2036	$109.5	$8.5	$141.8	$539.3	$799.1	$206.2	$593.0
2037	$108.4	$8.4	$144.4	$558.8	$820.1	$209.3	$610.8
2038	$107.2	$8.3	$147.0	$577.2	$839.7	$212.2	$627.6
2039	$105.7	$8.2	$150.0	$594.5	$858.4	$215.0	$643.4
2040	$104.2	$8.0	$153.1	$610.7	$876.0	$217.7	$658.3
NPV at 7%	$882.6			$1,595.4	$3,231.1	$1,067.9	$2,163.2
NPV at 3%	$1,677.7	$141.3	$1,374.4	$4,039.3	$7,232.5	$2,222.1	$5,010.5

5.7 Engineering Costs Associated with a Possible Marine Remanufacturing Program

We are requesting comment on the possibility of requiring a remanufacturing program for commercial marine propulsion engines over 600 kW (805 hp), including those recreational marine engines over 2000 kW. While such a program is not being proposed, we believe it is important to estimate costs associated with such a program so as to better inform commenters. We have estimated these costs in a manner similar to those generated for the proposed locomotive remanufacture program. We have estimated the number of remanufactured engines as being equal to our estimate of sales of marine propulsion engines >600 kW, but shifted by nine years to represent the time passage between original sale and remanufacture. We then multiplied those estimated remanufactured engines by the same Tier 0/1 and Tier 2 costs per remanufacture estimated for locomotives since we would expect a similar or identical remanufacturing kit to be used on marine as locomotive engines.

The estimated annual costs of a possible marine remanufacturing program are presented in Table 5-57. As shown, we have estimated the net present value of the annual costs at $413 million and $275 million at a three percent and seven percent discount rate, respectively. Including a marine remanufacturing program would increase the net present value of the annual costs associated with the proposal from $7.2 billion to $7.6 billion using a three percent discount rate and from $3.2 billion to $3.5 billion using a seven percent discount rate. On an annual basis, including a marine remanufacturing program would increase the costs of the proposed program in 2030 from $605 million to $618 million.

Table 5-57 Estimated Annual Costs Associated with a Possible Remanufacturing Program for Marine Engines >600 kW

Calendar Year	Tier 0/1			Tier 2			Total ($MM)
	Remans	$/reman	Subtotal ($MM)	Remans	$/reman	Subtotal ($MM)	
2006	-		$0.0	-		$0.0	$0.0
2007	-		$0.0	-		$0.0	$0.0
2008	866	$33,800	$29.3	-		$0.0	$29.3
2009	902	$33,800	$30.5	-		$0.0	$30.5
2010	939	$33,800	$31.7	-		$0.0	$31.7
2011	976	$33,800	$33.0	-		$0.0	$33.0
2012	1013	$33,800	$34.2	-		$0.0	$34.2
2013	1025	$33,800	$34.7	-		$0.0	$34.7
2014	1038	$33,800	$35.1	-		$0.0	$35.1
2015	1050	$33,800	$35.5	-		$0.0	$35.5
2016	-	$33,800	$0.0	1063	$11,749	$12.5	$12.5
2017	829	$22,300	$18.5	1076	$11,749	$12.6	$31.1
2018	866	$22,300	$19.3	1088	$11,749	$12.8	$32.1
2019	902	$22,300	$20.1	1101	$11,749	$12.9	$33.1
2020	939	$22,300	$20.9	1114	$11,749	$13.1	$34.0
2021	976	$22,300	$21.8	-	$11,749	$0.0	$21.8
2022	1013	$22,300	$22.6	-	$11,749	$0.0	$22.6
2023	1025	$22,300	$22.9	-	$11,749	$0.0	$22.9
2024	1038	$22,300	$23.1	-	$11,749	$0.0	$23.1
2025	1050	$22,300	$23.4	-	$11,749	$0.0	$23.4
2026	-	$0	$0.0	1063	$11,749	$12.5	$12.5
2027	-	$0	$0.0	1076	$11,749	$12.6	$12.6
2028	-	$0	$0.0	1088	$11,749	$12.8	$12.8
2029	-	$0	$0.0	1101	$11,749	$12.9	$12.9
2030	-	$0	$0.0	1114	$11,749	$13.1	$13.1
2031	-	$0	$0.0	-	$11,749	$0.0	$0.0
2032	-	$0	$0.0	-	$11,749	$0.0	$0.0
2033	-	$0	$0.0	-	$11,749	$0.0	$0.0
2034	-	$0	$0.0	-	$11,749	$0.0	$0.0
2035	-	$0	$0.0	-	$11,749	$0.0	$0.0
2036	-	$0	$0.0	-	$11,749	$0.0	$0.0
2037	-	$0	$0.0	-	$11,749	$0.0	$0.0
2038	-	$0	$0.0	-	$11,749	$0.0	$0.0
2039	-	$0	$0.0	-	$11,749	$0.0	$0.0
2040	-	$0	$0.0	-	$11,749	$0.0	$0.0
NPV at 7%			$235.7			$40.1	$275.9
NPV at 3%			$337.0			$75.9	$413.0

5.8 Engineering Costs and Savings Associated with Idle Reduction Technology

Locomotives idle for many reasons, not all of which can be avoided. The primary reason they idle is to protect their engines. Locomotives use water, not antifreeze to cool their engines because water is much more efficient at removing heat, and therefore, one of the primary reasons they idle is to keep the water from freezing and damaging the engine block. Engineers may also idle a locomotive to maintain critical system parameters: the batteries must maintain a certain charge in order to be able to restart the engine, the air brake system must be kept pressurized, and in some cases the locomotive is left to idle in order to properly cool down after heavy use. It may also be necessary to idle a locomotive to provide and maintain cab comfort for the crew, including heat and air conditioning. Idling locomotives can be found both inside and outside of the switchyard, for example, line-hauls may idle while waiting on sidings for other trains to pass, during crew changes, or while moving (when some locomotives in a consist are not needed to provide power).

There are several technologies currently available to reduce unnecessary locomotive idling or idling emissions. First, shore power systems allow for the locomotive engine to be plugged into a stationary power source to keep the batteries charged, and heat and circulate the water and oil. They range in price from $4,000 - $14,000 depending on the options installed.[k] These systems are most widely used on passenger trains that return to the same location at night, but are not practical for switchers that idle in different locations throughout a switchyard, or for line-hauls that generally stop in many locations outside a switchyard. Second, Low Emission Idle Systems (LEI) made by Energy Conversions Inc. work by alternating the banks of cylinders that fire during idle. LEI runs the engine on half of its cylinders at idle which increases the load on the firing cylinders and causes them to burn fuel more efficiently, however, while this system may reduce some idling emissions it does not eliminate idling. An electronic timer controls the switching, and no operator intervention is required. The cost of the system is approximately $4000, and it can be installed in just two hours.[l] Third, an Auxiliary Power Unit (APU) is an idle reduction technology that reduces unnecessary idling by using a small diesel engine (less than 50 hp) to provide power to run cab accessories, heat and circulate water and oil, and charge the locomotive batteries instead of this work being done by the much larger (2,000-4,000 hp) locomotive engine. There are two main manufacturers of APUs, EcoTrans which makes the K9 APU and Kim Hotstart which makes the Diesel Driven Heating System (DDHS). APUs can provide substantial fuel savings depending primarily on the region in which the locomotive it is installed on operates. The cost of an APU is approximately $25,000 - $35,000.[m] Fourth, a more complex solution is being demonstrated in the Advanced Locomotive Emissions Control Systems (ALECS). It uses emission reduction technology developed for stationary sources to capture the emissions from both stationary and slow moving trains in a railyard. Its cost can be upwards of one million dollars.[n] Fifth, locomotive engines can be replaced with two or three smaller on-highway engines. The on-highway

[k] Linda Gaines, “Reduction of Impacts from Locomotive Idling”, Center for Transportation Research, Argonne National Laboratory

[l] www.energyconversions.com/lei1.htm

[m] Case Study: Chicago Locomotive Idle Reduction Project, EPA420-R-04-003

[n] Tom Christofk, "Statewide Railyard Agreement" Presentation given at Second Public Meeting 7/13/06 for Placer County Air Pollution Control District
htttp://www.placer.ca.gov/upload/apc/documents/up/up_arb_public_meeting_7_13_06.pdf

engines are referred to as gensets[o] which allow one smaller engine to idle while the others are used when more power is needed. Sixth, a hybrid-electric system has been designed for switch yard purposes only (known as the GreenGoat.)[p]

Finally, one of the most cost effective onboard solutions that can provide idle reduction benefits to both line-haul and switcher locomotives nearly everywhere they operate is an automatic engine stop/start system (AESS). AESS is an electronic control system that reduces idling by shutting down a locomotive engine when it is idling unnecessarily. AESS is a microprocessor technology that operates by continually monitoring certain operating parameters such as: reverser and throttle position, engine coolant and ambient air temperature, battery charge, brake system pressure, and time spent idling. The AESS will shutdown the locomotive engine after a prescribed period of time spent idling, usually fifteen to thirty minutes, if conditions meet a preprogrammed set of values (for example the ambient temperature must be greater than 32ºF, and the water temperature must be greater than 100ºF), and will restart the engine if one of the aforementioned parameters is out of its specified range in order to both protect the locomotive engine and keep it in a ready-to-use state.

AESS is limited in its ability to provide idle reduction in cold weather as it can only monitor the conditions under which the locomotive engine is operating and the condition of the engine itself. An APU can provide further reductions for those locomotives operating in colder climates by actually maintaining the necessary engine parameters, and are part of some Tier 0 certified kits. In fact, EPA demonstrated an APU/AESS combined systems approach in one of its grant projects using a Kim Hotstart DDHS.[q] An AESS alone can provide some fuel savings during the cold winter, but when combined with an APU will achieve considerable fuel savings. Under the proposed program, AESS systems will be required on all newly-built Tier 3 and Tier 4 locomotives, and on all existing locomotives when they are first remanufactured under the revised remanufacturing program (see section III.C.(1)(c) of the Preamble for more details on the idle reduction program).

If installed at the time of remanufacture, the AESS installation costs vary depending on the age and characteristics of the locomotive. On average, the cost of a basic system is approximately $10,000, and in some cases volume discounts may be available.[k,r] This cost estimate includes not only labor costs for installation, but also

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[o] www.northeastdiesel.org, "Multi-Engine GenSet Ultra Low Emissions Road-Switcher Locomotive" presentation by National Railway Equipment Co., Jan, 2006.

[p] www.railpower.com

[q] See "Case Study: Chicago Locomotive Idle Reduction Project" (EPA420-R-04-003) (March, 2004), available at http://www.epa.gov/smartway/documents/420r04003.pdf

[r] Jessica Montañez and Matthew Mahler, "Reducing Idling Locomotives Emissions", North Carolina Department of Environment and Natural Resources, DAQ http://daq.state.nc.us/planning/locoindex.shtml

the hardware costs for a basic AESS microprocessor system and monitoring equipment (systems including GPS or satellite uplink optional features are more expensive). The cost may also vary depending on whether the locomotive is already equipped with the necessary sensors, and whether the AESS would require a stand alone electronic control unit as may be the case for older locomotives that are completely mechanical and do not have electronic controls. If installed on a new locomotive, costs should be much lower since the equipment could be installed at the factory and integrated with the original design of the locomotive.

Idle reduction technology (e.g., AESS systems) can provide substantial emission reductions as well as cost savings by reducing fuel consumption. We estimated these cost savings for both a line-haul and switcher locomotive using 4,350 annual hours of operation for a line-haul or 36,500 hours over one useful life, and 4,450 annual hours for a switcher or 101,000 hours over one useful life (see section 3.3.2 of this RIA for more details). The regulatory duty cycle (see 40CFR 92.132 for more details) indicates that a line-haul idles for 38% of its operating time, and that a switcher locomotive idles for 59.8% of its operating time. Using these values, we can estimate that a line-haul locomotive idles approximately 1,650 hours annually or nearly 14,000 hours over one useful life, and a switcher locomotive idles approximately 2,660 hours annually or slightly over 60,000 hours over one useful life.

These duty cycles include two types of idling: normal idle and low idle. Low idle indicates that there is no accessory load on the engine where normal idle indicates a load on the engine (for example, an accessory load occurs when the locomotive engine is charging a battery). As a conservative estimate, we are calculating a 50% reduction in low idling, although additional reductions in both low and normal idling may be possible. Using this reduction value, we have estimated that an AESS will reduce unnecessary idling by over 410 hours a year on a line-haul, and approximately 660 hours a year on a switcher. This means that over the useful life a line-haul locomotive, we expect at least 2,900 hours of idling at a 3% net present value (2,500 at 7% net present value) to have been eliminated, and at least 11,000 hours of idling at a 3% net present value (7,400 hours at 7% net present value) over the course of one useful life for a switcher locomotive. Using a fuel consumption value of three gallons per hour from Tier 2 Certification data, and a price of $1.28 for one gallon of diesel fuel and the yearly amount of idle hours avoided, we can estimate that this technology will pay for itself in just under four years on a switcher locomotive, and over one useful life on a line-haul locomotive will return all but $500.00 of the initial investment. It is important to note that locomotives typically operate for more than one useful life, and this technology does not have to be replaced upon remanufacturing the locomotive and therefore, it should continue to provide savings throughout the additional useful lives of the locomotives. It is also important to note that our estimates are conservative when compared to estimates by other groups, and when compared to data from locomotives equipped with AESS in the field. For comparative purposes, Table 5-58 shows the different payback times associated with the different savings estimates. Data from locomotives in the field indicate that payback time may be just slightly over one year, and that figure comes from an average of both line-haul and switcher locomotives that have been collected over many years of operation in many different geographical regions of the country.

Table 5-58 Estimates of Typical AESS Payback Time by other Sources

Source of Estimate	Hours of Idle per switcher locomotive per year	AESS reduced hours of idle	Fuel Usage during idle (gal/hour)	Gallons Saved per Year	Cost of Fuel[b]	Fuel Savings ($)	Payback time of AESS[c]
EPA - Ann Arbor	2,650	665	3[d]	2,000	$1.28	$2,600	3.8 years
DOE	5,300	2,650	4.5	12,000	$1.28	$15,400	8 months
EPA - NE	4,000	1,000	3-11	5,700	$1.28	$7,300	1.4 years
SmartStart Reports	3,840[a]	2,050	4.5	9,200	$1.28	$11,800	10 months

[a] This average value comes from data accumulated over at least three years on both line-haul and switcher locomotives

[b] The $1.28 cost of a gallon of diesel is calculated in Chapter 5 of this RIA

[c] Payback time of AESS is based on average price of $10,000 which includes installation costs

[d] 3 gal/hr is based on Tier 2 Certification Data

For simplicity we are presenting savings and emission reductions for a single useful life, even though locomotives are typically remanufactured at least three times before being scrapped. The AESS hardware would generally be expected to last for the remainder of a locomotive's service life, which could be as little as one useful life for a very old locomotive being remanufactured for the last time to more than four useful lives for a newly manufactured locomotive. Thus actual cost savings will be significantly higher than the single useful life values presented here, even when discounted.

It is also important to note that while we present annual and per-useful life emission reductions here, these reductions are considered as part of the emission reductions from the proposed standards. Under the current and proposed regulations, locomotives are tested and emissions are calculated to reflect the emission reductions associated with idle reduction technologies. AESS systems are currently being used by some manufacturers and remanufacturers as part of their certified locomotive emission controls. From both a regulatory and inventory perspective, the use of AESS is considered the same as installing aftertreatment or recalibrating the engine. The emission reductions are presented here merely to show the environmental significance of AESS.

AESS targets ‘low idle’ operation which occurs when the locomotive is not:

- Maintaining critical system parameters (such as air brake cylinder pressure)
- Propelling the locomotive

- Protecting the engine from freezing
- Providing cabin comfort to its crew.

The AESS is designed to eliminate unnecessary idling which is primarily composed of low idle, and it is estimated that at least half of this low idle can be eliminated using an AESS.[s,t,u] This conservative estimate shows that on a per-locomotive basis, idling of a line-haul locomotive can be reduced by over 400 hours annually or at least 3,500 hours over its useful life using an AESS. For switchers, which spend considerably more time idling because of their function, AESS could reduce idling by over 660 hours annually or by at least 15,000 hours over the useful life of the locomotive.

This reduced idling time means less fuel consumed. Tier 2 certification data indicates that modern locomotives typically burn 3 gallons of fuel an hour during low-idle. We calculated the cost savings of using an AESS based on an estimated diesel fuel price less taxes of $1.28/gallon (see 5.4.3 for more details). For a line-haul locomotive, use of an AESS is estimated to provide fuel cost savings of almost $1,600 annually. Over the useful life, this would mean a net present value savings of nearly $11,000 at a three percent discount rate ($9,500 at a seven percent discount rate). For a switcher locomotive, an AESS could provide fuel savings of nearly $2,500 annually or, over its useful life, a net present value savings of approximately $41,000 at a three percent discount rate ($28,000 at a seven percent discount rate).

Idle reduction would also result in emissions reductions. Tier 2 certification data suggests that locomotives emit an average of 10g/hr of PM and 600g/hr of NO_x during low idle. This means that a line-haul locomotive's emissions could be reduced by over 0.005 tons of PM and 0.27 tons of NO_x annually. Over the useful life, the net present value of PM reductions could be 0.032 tons at a three percent discount rate (0.027 tons at a seven percent discount rate). Likewise, the net present value of NO_x reductions could be 1.9 tons at a three percent discount rate (1.5 tons at a seven percent discount rate). A switcher locomotive's emissions can be reduced by over 0.007 tons of PM and 0.44 tons NO_x annually. Over the useful life of the switcher, the net present value of PM reductions could be 0.12 tons at a three percent discount rate (0.08 tons at a seven percent discount rate) and, for NO_x reductions, 7.0 tons at a three percent discount rate (4.9 tons at a seven percent discount rate), older switchers would be expected to emit more pollutants than the Tier 2 estimates given here.

Table 5-59 shows the annual fuel savings, the associated cost savings, and the emissions reductions we estimate would result from the proposed AESS

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[s] David E. Brann, "Locomotive Idling Reduction" http://www1.eere.energy.gov/vehiclesandfuels/pdfs/idling_2004/brann.pdf

[t] http://www.arb.ca.gov/railyard/ryagreement/aess_electromotive.pdf

[u] Draft Maryland Locomotive Idle Reduction Program Demonstration Project – DE-FG36-02GO12022 http://www.osti.gov/bridge/servlets/purl/838872-D6MxUD/838872.PDF

requirements. These values would be expected to be consistent for newer locomotives, although older locomotives may provide greater savings as they may consume more fuel at idle. Table -5-60 shows this information on a useful life basis along with net present value information and a net cost. The idle emission reductions are particularly important considering that we do not expect aftertreatment technologies to reduce NO_x emissions at idle, and further, we expect PM control to be reduced due to poor oxidation efficiency at idle. The ability of aftertreatment technologies to control emissions during idle operation is discussed in more detail in Chapter 4 of this draft RIA. Because of the limitations of the aftertreatment technology at idle, idle reduction via an AESS system is the best method to ensure control of emissions at idle.

Table 5-59 Annual Effects of Using AESS on Line-Haul and Switcher Locomotives

Annual Estimates for a Typical Tier 2 Locomotive						
Type of Locomotive	Time Spent Idling[a] (hrs)	Idling Reduced Using AESS[b] (hrs)	Fuel Savings[c] (gals)	Fuel Savings[d] ($)	PM Emission Reductions[e] (tons)	NO_x Emission Reductions[f] (tons)
Line-Haul	1,650	413	1,238	1,584	0.005	0.27
Switcher	2,650	663	1,988	2,544	0.007	0.44

a Using 38% idling time for line-hauls and 59.8% for switchers from Duty-Cycle (see 40CFR 92.132)
b Assuming 50% of low-idle is reduced by AESS
c Using 3 gallons of fuel burned per hour at low-idle (estimated from Tier 2 Certification Data)
d Using diesel fuel price less taxes of $1.28/gallon (see section 5.4.3)
e Using PM estimate of 10g/hr emitted during low idle (estimated from Tier 2 Certification Data)
f Using NO_x estimate of 600g/hr emitted during low idle (estimated from Tier 2 Certification Data)

Table -5-60 NPV 3% & 7% Effects of Using AESS Over the First Useful Life on Line-Haul and Switcher Locomotives

Estimates Over the First[a] Useful Life of a Typical Tier 2 Locomotive									
Type of Locomotive	NPV Factor	Time Spent Idling[b] (hrs)	Idling Reduced Using AESS[c] (hrs)	Fuel Savings[d] (gals)	Fuel Savings[e] ($)	Average Installation Cost of AESS($)	Net Savings ($)	PM Emission Reductions[f] (tons)	NO_x Emission Reductions[g] (tons)
Line-Haul	NPV 3%	12,000	2,900	8,700	11,000	10,000	1,000	0.032	1.9
	NPV 7%	9,900	2,500	7,400	9,500	10,000	-500	0.027	1.6
Switcher	NPV 3%	42,000	11,000	32,000	41,000	10,000	29,000	0.12	7.0
	NPV 7%	29,000	7,400	22,000	28,000	10,000	16,000	0.08	4.9

a Additional savings not accounted for in this analysis include: reduced wear on engine components, reduced oil consumption, and fuel savings over subsequent useful lives of a locomotive's full lifetime.
b Using 38% idling time for line-hauls and 59.8% for switchers from Duty-Cycle (see 40CFR 92.132)
c Assuming 50% of low-idle is reduced by AESS

d Using 3 gallons of fuel burned per hour at low-idle (estimated from Tier 2 Certification Data)
e Using diesel fuel price less taxes of $1.28/gallon (see section 5.4.3)
f Using PM estimate of 10g/hr emitted during low idle (estimated from Tier 2 Certification Data)
g Using NO_X estimate of 600g/hr emitted during low idle (estimated from Tier 2 Certification Data)

Note that we have not included the costs and savings associated with AESS systems in the overall cost analysis of the program summarized in Section 5.6. The primary reason for this is the expectation that these systems would be in widespread use absent a requirement from EPA, even in retrofit applications on existing locomotives. We did not believe it would be appropriate to assume no one would employ these systems absent a requirement, nor did we want to assume that everyone would absent a requirement. Further, as shown in Table -5-60, a net savings is likely which would, in effect, reduce the overall cost of our proposed program were we to include the costs and savings associated with AESS systems. Because of the difficulty and uncertainty involved in estimating their use absent a requirement, and their net effect of providing savings to users, we decided to present the costs and savings separately from the overall program.

5.9 Analysis of Energy Effects

Under E.O. 13211, a “significant energy action” is any regulatory action that might have a significant adverse effect on the supply, distribution, or use of energy. A significant adverse effect is, along with several other factors, any outcome that could reduce crude oil supply in excess of 10,000 barrels per day, reduce fuel production in excess of 4,000 barrels per day, or increase energy usage in excess of either of those thresholds. The proposed locomotive and marine program is projected to have an impact on fuel usage in excess of one of these thresholds.

Section 5.4.3 of this draft RIA presents our analysis of the increased costs associated with fuel consumption impacts that would result from both the addition of diesel particulate filters to some locomotive and marine engines, and the remanufacture of Tier 0 locomotive engines. Table 5-40 through Table 5-43 show the increased number of gallons we have estimated would be consumed as a result of the proposed program. Using the metrics of 42 gallons of fuel per barrel of crude oil and 365 days in a year, the projected number of barrels of oil per day can be calculated as shown in Table 5-61. As shown, in the year 2026, our proposed program is projected to result in excess of 4,000 barrels of oil per day in increased energy usage. Note that the fuel consumption estimates shown in Table 5-61 do not reflect the potential fuel savings associated with automatic engine stop/start (AESS) systems or other idle reduction technologies. As discussed in section 5.8, such technologies can provide significant fuel savings which could offset the increased fuel consumption estimates shown in Table 5-61.

Table 5-61 Estimated Increase in Fuel Consumed in Million Gallons per Year and Average Barrels per Day

Calendar Year	Increase in Fuel Consumed (Million gallons per year)			Barrels/day
	Locomotive	Marine	Total	
2006	0	0	0	0
2007	0	0	0	0
2008	2	0	2	99
2009	2	0	2	106
2010	4	0	4	264
2011	8	0	8	534
2012	10	0	10	646
2013	12	0	12	797
2014	13	1	13	870
2015	15	1	16	1043
2016	19	3	21	1399
2017	23	5	27	1775
2018	24	7	31	2047
2019	26	9	35	2307
2020	27	12	39	2544
2021	29	14	43	2781
2022	30	16	46	3025
2023	31	19	50	3275
2024	33	21	54	3528
2025	35	23	58	3785
2026	36	26	62	4043
2027	38	28	66	4303
2028	40	30	70	4564
2029	42	32	74	4820
2030	44	34	78	5066
2031	46	35	81	5304
2032	48	37	85	5538
2033	50	38	88	5771
2034	52	40	92	5999
2035	54	41	95	6227
2036	56	43	99	6447
2037	58	44	102	6657
2038	60	45	105	6856
2039	62	46	108	7044
2040	64	46	111	7224

5.10 Cost Effectiveness

One tool that can be used to assess the value of the proposed program is the costs incurred per ton of emissions reduced. This analysis involves a comparison of our proposed program to other measures that have been or could be implemented. We have calculated the cost per ton of our proposed program based on the net present value of all costs incurred and all emission reductions generated from the current year 2006 through the year 2040. This approach captures all of the costs and emissions reductions from our proposed program including those costs incurred and emissions reductions generated by the locomotive remanufacturing program. The baseline case for this evaluation is the existing set of engine standards for locomotive and marine diesel engines and the existing locomotive remanufacturing requirements. The analysis timeframe is meant to capture both the early period of the program when very few new engines that meet the proposed standards would be in the fleet, and the later period when essentially all engines would meet the new standards.

Table 5-62 shows the emissions reductions associated with the proposed locomotive and marine program. These reductions are discussed in more detail in Chapter 3 of this draft RIA.

Table 5-62 Estimated Emissions Reductions Associated with the Proposed Locomotive and Marine Standards (Short tons)

Year	$PM_{2.5}$	PM_{10} [a]	NO_x	NMHC
2015	7,000	7,000	84,000	14,000
2020	15,000	15,000	293,000	25,000
2030	28,000	29,000	765,000	39,000
2040	38,000	40,000	1,123,000	50,000
NPV at 3%	315,000	325,000	7,869,000	480,000
NPV at 7%	136,000	140,000	3,188,000	216,000

a Note that, $PM_{2.5}$ is estimated to be 97 percent of the more inclusive PM_{10} emission inventory. In Chapter 3 we generate and present $PM_{2.5}$ inventories since recent research has determined that these are of greater health concern. Traditionally, we have used PM_{10} in our cost effectiveness calculations. Since cost effectiveness is a means of comparing control measures to one another, we use PM_{10} in our cost effectiveness calculations for comparisons to past control measures.

Using the costs associated with PM and NO_x control shown in Table 5-56 and the emission reductions shown in Table 5-62, we can calculate the $/ton associated with the proposed program. These are shown in Table 5-63. The resultant cost per ton numbers depend on how the costs are allocated to each pollutant. We have allocated costs as closely as possible to the pollutants for which they are incurred. These allocations are also discussed in detail in Section 5.6 of this draft RIA.

Table 5-63 Proposed Program Aggregate Cost per Ton and Long-Term Annual Cost per Ton

Pollutant	2006 Thru 2040 Discounted Lifetime Cost Per Ton At 3%	2006 Thru 2040 Discounted Lifetime Cost Per Ton At 7%	Long-Term Cost Per Ton In 2030
NO_x+NMHC	$600	$630	$550
PM	$6,840	$7,640	$5,560

The costs per ton shown in Table 5-63 for 2006 through 2040 use the net present value of the annualized costs and emissions reductions associated with the program for the years 2006 through 2040. We have also calculated the costs per ton of emissions reduced in the year 2030 using the annual costs and emissions reductions in that year alone. These numbers are also shown in Table 5-63 and represent the long-term annual costs per ton of emissions reduced.[v] All of the costs per ton include costs and emission reductions that will occur from the locomotive remanufacturing program.

We can also look at the costs, emissions reductions, and cost per ton associated with each of the proposed program elements: the locomotive remanufacturing program; the Tier 3 program; and, the Tier 4 program. We have done this simply by breaking out the costs we have allocated to each of these program elements and the emissions reductions we have allocated to each of these program elements. In other words, we have not done a true incremental analysis that would look at the costs and emissions reductions of, say, the Tier 3 program were it to go on forever, or the Tier 4 program were it done absent of the Tier 3 program. We have looked at program alternatives that would approximate such an analysis and have summarized our findings in Chapter 8 of this draft RIA. There, we look at alternatives that consist of a Tier 3 program that lasts forever but also includes a locomotive remanufacturing program. We have also looked at a Tier 4 program absent any Tier 3 standards but, again, that alternative includes a locomotive remanufacturing program and a different Tier 4 start year. Here, we look simply at the costs and emissions reductions we have allocated to each of our program elements within the context of the entire program. The results are shown in Table 5-64. The table shows costs, reductions, and costs per ton in the year 2030 and as net present values using a three percent discount rate. The results show that the Tier 3 program is the most cost efficient of the program elements, and that all three elements are very cost efficient.

[v] "Long-term" cost here refers to the ongoing cost of the program where only operating and variable costs remain (no more fixed costs). We have chosen 2030 to represent those costs here.

Table 5-64 Costs, Emissions Reductions, and Cost per Ton Associated with the Proposed Program Elements

Costs ($Millions)	Present Values @ 3%							2030						
	Locomotive		Marine		Loco & Marine		Total	Locomotive		Marine		Loco & Marine		Total
Program Element	PM	NO_X	PM	NO_X	PM	NO_X		PM	NO_X	PM	NO_X	PM	NO_X	
Reman Program (T0,T1,T2)	$401						$802	$11	$11	n/a	n/a	$11	$11	$22
Tier 3	$6	$11	$45	$83	$51	$94	$145	$0	$0	$0	$0	$0	$0	$0
Tier 4	$1,180	$2,626	$590	$1,890	$1,770	$4,515	$6,285	$102	$259	$46	$177	$148	$435	$584
Total Cost of Proposal	$1,587	$3,038	$635	$1,973	$2,222	$5,010	$7,233	$113	$270	$46	$177	$159	$446	$605

Reductions (Tons)	Present Values @ 3%						2030					
	Locomotive		Marine		Loco & Marine		Locomotive		Marine		Loco & Marine	
Program Element	PM2.5	NO_X	PM2.5	NO_X	PM2.5	NO_X	PM2.5	NO_X	PM2.5	NO_X	PM2.5	NO_X
Reman Program (T0,T1,T2)			n/a	n/a			3,010					24,440
Tier 3	64,020	694,410			64,020	694,410 2,213,580	5,860			205,510	13,820	212,620
Tier 4	62,420					4,969,730	5,730	7,110 369,030	7,960	159,690	10,900	528,720
Total Reductions from Proposal	57,200 183,630	4,252,990	131,350	3,624,720	314,980	7,877,710	14,600	400,580	5,170 13,120	365,200	27,720	765,780

Cost Effectiveness ($/ton)	Present Values @ 3%						2030					
	Locomotive		Marine		Loco & Marine		Locomotive		Marine		Loco & Marine	
Program Element	PM10	NO_X	PM10	NO_X	PM10	NO_X	PM10	NO_X	PM10	NO_X	PM10	NO_X
Reman Program (T0,T1,T2)	$6,080	$580	n/a	n/a	$6,080	$580	$3,480					$440
Tier 3	$90					$40	$0	$0	$0	$0	$0	$0
Tier 4	$20,010					$910	$17,340	$700	$8,600	$1,110	$13,200	$820
$/ton of Proposal	$8,380	$714	$4,690	$540	$6,840	$640	$7,520	$670	$3,390	$480	$5,560	$580

Note: Table 5-63 shows $/ton NO_X; there is a slight difference compared to tables showing $/ton NO_X+NMHC.

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[18] "Economic Analysis of Diesel Aftertreatment System Changes Made Possible by Reduction of Diesel Fuel Sulfur Content," Engine, Fuel, and Emissions Engineering, Incorporated, December 15, 1999, Public Docket No. A-2001-28, Docket Item II-A-76.
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