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 8
Regulatory Alternatives

Assessment and Standards Division
Office of Transportation and Air Quality
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CHAPTER 8: Regulatory Alternatives

Our proposal consists of a broad and comprehensive program to reduce emissions from locomotive and marine diesel engines. As we have developed this proposal, we have evaluated a number of alternatives with regard to the scope and timing of the proposed standards. We also examined an alternative that would require emission reductions from a significant fraction of the existing marine diesel engine fleet. This section presents a summary of our analysis of these alternative control scenarios. We believe our proposal to be superior to the alternatives considered here given the feasibility, cost, and environmental impact of each. In this chapter we present and discuss the alternative program options that we evaluated in order to make this determination.

8.1 Alternatives Considered

Our proposed emission control program consists of a two-step program to reduce NO_x and PM engine standards. The two steps consist of: (1) near-term emission standards that reflect the application of engine-based controls to new diesel marine engines and locomotives, and (2) long-term emission standards that reflect the application of high efficiency catalytic aftertreatment technology which will be enabled by the availability of clean diesel fuel with sulfur content capped at 15 parts per million. It also includes a locomotive remanufacturing program that sets new more stringent standards for Tier 0,1, and 2 applications. We have developed emission inventory impacts, cost estimates and benefit estimates for two types of alternatives. The first type looks at the impacts of varying the timing and scope of our proposed standards. The second considers a programmatic alternative that would set emission standards for existing marine diesel engines.

Table 8-1 Summary of Alternatives and Standards

Proposal	• Locomotive Remanufacturing • Tier 3 Near-term program • Tier 4 Long-term standards
Alternative 1: Exclusion of Locomotive Remanufacturing	• Tier 3 Near-term program • Tier 4 Long-term standards
Alternative 2: Tier 4 Advanced One Year	• Locomotive Remanufacturing • Tier 3 Near-term program • Tier 4 Long-term standards *moved ahead one year*
Alternative 3: Tier 4 Exclusively in 2013	• Tier 4 Long-term standards *moved ahead to 2013*
Alternative 4: Elimination of Tier 4	• Locomotive Remanufacturing • Tier 3 Near-term program
Alternative 5: Inclusion of Marine Remanufacturing	• Locomotive Remanufacturing • Tier 3 Near-term program • Tier 4 Long-term standards • Marine Remanufacturing

8.1.1 Alternative 1: Exclusion of Locomotive Remanufacturing

Alternative 1 examines the potential impacts of the locomotive remanufacturing program by excluding it from the analysis (see section III.C.(1)(a)(*i*) for more details of the locomotive remanufacturing program). It is identical to the proposal with the exception of the removal of the locomotive remanufacturing standards as the timing and scope of Tier 3 and Tier 4 standards remain unchanged in this alternative. These results can be compared with the results of the primary program to estimate the benefits that would be lost if we did not finalize the proposed locomotive remanufacturing program.

8.1.2 Alternative 2: Tier 4 Advanced One Year

Alternative 2 is the most stringent of our alternatives, and considers the possibility of pulling ahead the Tier 4 standards by one year for both the locomotive and marine programs, while leaving the rest of the proposed program the same. The timing and scope of both Tier 3 and the locomotive remanufacturing program would remain unchanged. These results can be compared with the results of the primary program to estimate the additional benefits that could occur if compliant engines were introduced one year earlier for both tiers of standards.

8.1.3 Alternative 3: Tier 4 Exclusively in 2013

Alternative 3 most closely reflects the program we described in our Advanced Notice of Proposed Rulemaking, whereby we would set new aftertreatment based emission standards as soon as possible. In this case, we believe the earliest that such standards could logical be started is in 2013 (3 months after the introduction of 15 ppm ULSD in this sector). This alternative would eliminate the Tier 3 standards and locomotive remanufacturing standards, while pulling the Tier 4 standards ahead to 2013 for all portions of the Tier 4 program. These results can be compared with the results of the primary program to estimate the benefits that would be lost if engine manufacturers were not required to develop emission control packages for near-term standards but, instead, could focus their efforts on the long-term standards.

8.1.4 Alternative 4: Elimination of Tier 4

Alternative 4 would eliminate the Tier 4 standards, retaining the Tier 3 and locomotive remanufacturing requirements. The timing and scope of both Tier 3 and the locomotive remanufacturing program would remain unchanged. These results can be compared with the results of the primary program to estimate the benefits that would be foregone if the more technology-forcing standards are not adopted at this time.

8.1.5 Alternative 5: Inclusion of Marine Remanufacturing

We are considering a fifth programmatic alternative which would impose a requirement on existing marine diesel engines similar to the existing remanufacture

program for locomotives (see Section VI.A.2 of the preamble for further details). The standards would apply to engines above 800 hp and would consist of a two-part program. In the first part, which could begin as early as 2008, vessel owners and rebuilders (also called remanufacturers) would be required to use a certified kit when the engine is rebuilt (or remanufactured) if such a kit is available. Initially, these kits would be expected to be locomotive kits and therefore applicable only to those engines derived from similar locomotive engines. Eventually, however, it is expected that the large engine manufacturers would also provide kits for their engines. In the second part of this program, which could begin in 2013, the remanufacturer/owner of a marine diesel engine identified by the EPA as a high-sales volume engine model would have to meet specified emission requirements when the engine is remanufactured. Specifically, the remanufacturer or owner would be required to use a certified system to meet the standard; if no certified system is available, he or she would need to either retrofit an emission reduction technology for the engine that demonstrates at least a 25 percent reduction and does not exceed 0.22 g/kW-hr PM (equivalent to the new Tier 0/1 PM limit) or repower (replace the engine with a new one).

8.2 Emission Inventory Impacts

8.2.1 Methodology

8.2.1.1 Inventory Impacts

Based on our primary case, we estimated inventory impacts using a methodology based on engine population, hours of use, average engine loads, and in-use emissions factors for each alternative. (Refer to Chapter 3 of this Draft RIA for a more complete discussion of how the primary control inventories were generated). The results are shown in Table 8-1.

8.2.1.2 Costs

We have estimated the costs associated with each alternative using the same methods employed for the proposal. The cost estimates for the locomotive remanufacturing program include adjustments for costs associated with hardware requirements. The cost estimates for the marine remanufacturing program were generated in a similar manner as those generated for the proposed locomotive remanufacturing program. We have estimated the cost per remanufactured engine as equal to that for a remanufactured locomotive engine because we would expect a similar or identical remanufacture kit to be used. At this time, for alternatives 2 & 3 we are unable to make an accurate estimate of the cost for pulling ahead Tier 4 technologies, since we do not believe it to be feasible at this time. However, we have reported cost in the summary table reflecting the same cost estimation we have used for our primary case and have denoted unestimated additional costs as ‘C’. These additional unestimated costs would include costs for additional engine test cells, engineering staff, and engineering facilities necessary to accelerate the development

of Tier 4. The details of our estimated remanufacturing program costs can be found in Chapter 5 of this draft RIA.

8.2.1.3 Benefits

To estimate the PM-related monetized benefits for each of the alternative scenarios, we used a benefits transfer approach to scale the PM benefits from the proposed Locomotive and Marine Engine control scenario. The PM benefits scaling approach is similar to the scaling approach conducted for the Clean Air Nonroad Diesel (CAND) Rule (see Chapter 9 of the CAND RIA). For the estimate of benefits generated for the proposal, we ran a sophisticated photochemical air quality model, the Community Multiscale Air Quality model (CMAQ), to estimate baseline and post-control ambient concentrations of PM for 2030. Benefits for the final proposed standards were then generated using the inputs and methods described in Chapter 6 of the draft RIA for this rule. We then scaled these PM benefits to reflect the magnitude of the PM2.5 precursor emissions changes estimated to occur as a result of the alternative control scenarios.

8.2.2 Analysis

Table 8-2 includes the expected yearly emission reductions associated with each alternative, including: the estimated PM and NO_x reductions for years 2006-2040 expressed as a net present value (NPV) using discounting rates of 3% and 7%. The yearly estimated costs are also expressed in this table at both 3% and 7% NPV. The benefit analysis from 2020 and 2030 is also included on this table. For further analysis, Table 8-3 and Table 8-4 summarize the PM and NO_x emission reductions and costs for each alternative; and Table 8-5 and Table 8-6 summarize the emission reductions, costs and benefits for the year 2020 and the year 2030. Figure 8.2-1 and Figure 8.2-2 illustrate the inventory impacts of each alternative from 2006-2040 for comparison.

Table 8-2 Inventory, Cost, and Benefits year from 2006-2040

	Primary Case				Alternative 1			
Calendar Year	$PM_{2.5}$ Emissions Reductions (tons)	NO_X Emissions Reductions (tons)	Total Costs (Millions)	Benefits[a,b] (Billions) $PM_{2.5}$ only 2030 3% (7%)	$PM_{2.5}$ Emissions Reductions (tons)	NO_X Emissions Reductions (tons)	Total Costs (Millions)	Benefits[a,b] (Billions) $PM_{2.5}$ only 2030 3% (7%)
2006	0	0	$0	---	0	0	$0	---
2007	0	0	$30	---	0	0	$30	---
2008	200	4,500	$50	---	0	0	$30	---
2009	600	4,700	$60	---	3	0	$30	---
2010	1,100	15,000	$90	---	6	0	$30	---
2011	2,200	33,000	$210	---	12	140	$100	---
2012	3,500	43,000	$140	---	350	1,800	$50	---
2013	4,500	56,000	$130	---	840	5,600	$50	---
2014	5,600	71,000	$120	---	1,600	18,000	$60	---
2015	6,800	84,000	$180	---	2,500	31,000	$130	---
2016	8,600	110,000	$200	---	3,700	51,000	$130	---
2017	10,000	160,000	$220	---	5,000	94,000	$160	---
2018	12,000	210,000	$230	---	6,400	140,000	$170	---
2019	13,000	250,000	$250	---	7,800	190,000	$190	---
2020	15,000	290,000	$250	$4.4-$9.2 ($4.0-$8.3)	9,300	230,000	$220	$3.2-$6.7 ($2.9-$6.0)
2021	16,000	340,000	$280	---	11,000	280,000	$250	---
2022	17,000	380,000	$330	---	12,000	330,000	$270	---
2023	19,000	440,000	$410	---	14,000	390,000	$370	---
2024	20,000	510,000	$430	---	15,000	460,000	$400	---
2025	21,000	550,000	$470	---	17,000	510,000	$430	---
2026	23,000	600,000	$480	---	19,000	560,000	$470	---
2027	24,000	640,000	$510	---	20,000	600,000	$500	---
2028	25,000	680,000	$550	---	22,000	650,000	$530	---
2029	27,000	720,000	$580	---	23,000	700,000	$560	---
2030	28,000	770,000	$610	$12-$25 ($11-$23)	25,000	740,000	$580	8.8-$19 ($8.0-$17)
2031	29,000	810,000	$630	---	26,000	780,000	$610	---
2032	30,000	850,000	$640	---	28,000	830,000	$640	---
2033	31,000	880,000	$730	---	29,000	870,000	$720	---
2034	32,000	920,000	$760	---	30,000	910,000	$750	---
2035	34,000	960,000	$790	---	32,000	950,000	$770	---
2036	35,000	1,000,000	$800	---	33,000	990,000	$790	---
2037	36,000	1,030,000	$820	---	34,000	1,000,000	$820	---
2038	37,000	1,060,000	$840	---	35,000	1,100,000	$840	---
2039	38,000	1,090,000	$860	---	37,000	1,100,000	$860	---
2040	38,000	1,120,000	$880	---	37,000	1,100,000	$870	---
2040 NPV 3%	315,000	7,870,000	$7,230	---	250,000	7,180,000	$6,430	---
2040 NPV 7%	135,000	3,180,000	$3,230	---	100,000	2,780,000	$2,700	---

	Alternative 2				Alternative 3			
Calendar Year	$PM_{2.5}$ Emissions Reductions (tons)	NO_X Emissions Reductions (tons)	Total Costs (Millions)[a]	Benefits[b,c] (Billions) $PM_{2.5}$ only 2030 3% (7%)	$PM_{2.5}$ Emissions Reductions (tons)	NO_X Emissions Reductions (tons)	Total Costs (Millions)	Benefits[a,b] (Billions) $PM_{2.5}$ only 2030 3% (7%)
2006	0	0	$0	---	0	0	$0	---
2007	0	0	$30	---	0	0	$0	---
2008	200	4,500	$50	---	0	0	$50	---
2009	600	4,700	$80	---	0	0	$50	---
2010	1,100	15,000	$130	---	-8	0	$50	---
2011	2,200	33,000	$210	---	-16	0	$50	---
2012	3,500	43,000	$140	---	-27	0	$100	---
2013	4,700	62,000	$160	---	1,900	40,000	$130	---
2014	6,100	78,000	$180	---	2,700	81,000	$150	---
2015	7,300	100,000	$170	---	3,600	120,000	$150	---
2016	9,300	150,000	$220	---	4,900	160,000	$180	---
2017	11,000	200,000	$230	---	6,200	210,000	$200	---
2018	13,000	240,000	$250	---	7,500	250,000	$230	---
2019	14,000	290,000	$270	---	8,800	290,000	$260	---
2020	16,000	330,000	$270	$4.6-$9.7 ($4.2-$8.7)	10,000	340,000	$340	$3.6-$7.4 ($3.2-$6.7)
2021	17,000	370,000	$300	---	12,000	380,000	$370	---
2022	18,000	420,000	$360	---	13,000	430,000	$400	---
2023	19,000	500,000	$440	---	14,000	470,000	$430	---
2024	21,000	540,000	$460	---	16,000	520,000	$460	---
2025	22,000	580,000	$490	---	17,000	560,000	$490	---
2026	23,000	630,000	$500	---	19,000	600,000	$520	---
2027	25,000	670,000	$530	---	20,000	650,000	$550	---
2028	26,000	710,000	$570	---	22,000	690,000	$580	---
2029	27,000	750,000	$600	---	23,000	730,000	$600	---
2030	28,000	790,000	$620	$12-$25 ($11-$23)	25,000	770,000	$630	$11-$24 ($10-$21)
2031	30,000	830,000	$650	---	26,000	810,000	$650	---
2032	31,000	870,000	$660	---	27,000	850,000	$730	---
2033	32,000	910,000	$740	---	29,000	880,000	$760	---
2034	33,000	950,000	$770	---	30,000	920,000	$790	---
2035	34,000	980,000	$800	---	31,000	960,000	$810	---
2036	35,000	1,000,000	$810	---	32,000	990,000	$830	---
2037	36,000	1,000,000	$830	---	33,000	1,000,000	$850	---
2038	37,000	1,100,000	$850	---	34,000	1,100,000	$870	---
2039	38,000	1,100,000	$860	---	35,000	1,100,000	$890	---
2040	39,000	1,100,000	$880	---	36,000	1,100,000	$910	---
2040 NPV 3%	324,000	8,290,000	$7590 +C	---	255,000	8,050,000	$7410 +C	---
2040 NPV 7%	140,000	3,390,000	$3440 +C	---	104,000	3,280,000	$3220 +C	---

	Alternative 4				Alternative 5			
Calendar Year	$PM_{2.5}$ Emissions Reductions (tons)	NO_X Emissions Reductions (tons)	Total Costs (Millions)	Benefits[a,b] (Billions) $PM_{2.5}$ only 2030 3% (7%)	$PM_{2.5}$ Emissions Reductions (tons)	NO_X Emissions Reductions (tons)	Total Costs (Millions)	Benefits[a,b] (Billions) $PM_{2.5}$ only 2030 3% (7%)
2006	0	0	$0	---	0	0	$0	---
2007	0	0	$28	---	0	0	$30	---
2008	200	4,500	$53	---	560	13,000	$80	---
2009	600	4,700	$60	---	1,300	20,000	$90	---
2010	1,100	15,000	$85	---	2,200	36,000	$120	---
2011	2,200	33,000	$160	---	3,700	58,000	$240	---
2012	3,500	43,000	$87	---	5,200	70,000	$180	---
2013	4,500	56,000	$79	---	6,700	87,000	$170	---
2014	5,600	71,000	$57	---	8,000	110,000	$160	---
2015	6,500	84,000	$47	---	9,000	120,000	$220	---
2016	7,800	110,000	$77	---	11,000	140,000	$220	---
2017	9,000	130,000	$61	---	13,000	190,000	$250	---
2018	9,900	140,000	$64	---	14,000	230,000	$270	---
2019	10,800	150,000	$58	---	16,000	270,000	$280	---
2020	11,000	160,000	$33	$3.2-$6.7 ($2.9-$6.0)	17,000	310,000	$280	$5.0-$10 ($4.5-$9.4)
2021	12,000	160,000	$33	---	18,000	350,000	$300	---
2022	13,000	170,000	$54	---	19,000	390,000	$350	---
2023	13,000	180,000	$45	---	20,000	450,000	$430	---
2024	14,000	190,000	$30	---	22,000	520,000	$460	---
2025	14,000	200,000	$32	---	23,000	560,000	$490	---
2026	15,000	210,000	$15	---	24,000	600,000	$490	---
2027	15,000	210,000	$14	---	25,000	650,000	$520	---
2028	16,000	220,000	$26	---	26,000	690,000	$570	---
2029	16,000	230,000	$25	---	28,000	730,000	$590	---
2030	17,000	240,000	$22	$6.2-$13 ($5.7-$12)	29,000	770,000	$620	$12-$26 ($11-$23)
2031	17,000	240,000	$19	---	30,000	810,000	$630	---
2032	18,000	250,000	$8	---	31,000	850,000	$640	---
2033	18,000	260,000	$7	---	32,000	890,000	$730	---
2034	19,000	270,000	$11	---	33,000	930,000	$760	---
2035	19,000	270,000	$14	---	34,000	960,000	$790	---
2036	19,000	280,000	$4	---	35,000	1,000,000	$800	---
2037	20,000	290,000	$4	---	36,000	1,000,000	$820	---
2038	20,000	290,000	$3	---	37,000	1,100,000	$840	---
2039	20,000	300,000	$3	---	38,000	1,100,000	$860	---
2040	21,000	300,000	$2	---	39,000	1,100,000	$880	---
2040 NPV 3%	207,000	2,910,000	$950	---	342,000	8,190,000	$7,650	---
2040 NPV 7%	94,000	1,310,000	$650	---	151,000	3,400,000	$3,510	---

Table 8-3 Summary of Total Inventory and Costs Through 2040 NPV 3%

Program	$PM_{2.5}$ Emissions Reductions (tons) NPV 3%	NO_x Emissions Reductions (tons) NPV 3%	Total Costs (Millions) NPV 3%[a]
Primary Case	315,000	7,870,000	$7,230
Alternative 1: Exclusion of Locomotive Remanufacturing	250,000	7,180,000	$6,430
Alternative 2: Tier 4 Advanced One Year	324,000	8,290,000	$7,590+C
Alternative 3: Tier 4 Exclusively in 2013	255,000	8,050,000	$7,410+C
Alternative 4: Elimination of Tier 4	207,000	2,910,000	$950
Alternative 5: Inclusion of Marine Remanufacturing	342,000	8,190,000	$7,650

[a] 'C' represents additional costs necessary to accelerate the introduction of Tier 4 technologies that we are unable to estimate at this time.

Table 8-4 Summary of Total Inventory and Costs Through 2040 NPV 7%

Program	$PM_{2.5}$ Emissions Reductions (tons) NPV 7%	NO_x Emissions Reductions (tons) NPV 7%	Total Costs (Millions) NPV 7%[a]
Primary Case	135,000	3,180,000	$3,230
Alternative 1: Exclusion of Locomotive Remanufacturing	100,000	2,780,000	$2,700
Alternative 2: Tier 4 Advanced One Year	140,000	3,390,000	$3,440+C
Alternative 3: Tier 4 Exclusively in 2013	104,000	3,280,000	$3,220+C
Alternative 4: Elimination of Tier 4	94,000	1,310,000	$650
Alternative 5: Inclusion of Marine Remanufacturing	151,000	3,400,000	$3,510

[a] 'C' represents additional costs necessary to accelerate the introduction of Tier 4 technologies that we are unable to estimate at this time.

Table 8-5 Summary of Inventory, Costs, and Benefits for 2020

	2020 $PM_{2.5}$ Emissions Reductions (tons)	2020 NO_x Emissions Reductions (tons)	2020 Total Costs (Millions)	2020 Benefits (Billions) $PM_{2.5}$ only 3% (7%)
Primary Case	15,000	290,000	$250	$4.4-$9.2 ($4.0$8.3)
Alternative 1	9,300	230,000	$220	$3.2-$6.7 ($2.9-$6.0)
Alternative 2	16,000	330,000	$270	$4.6-$9.7 ($4.2-$8.7)
Alternative 3	10,000	340,000	$340	$3.6-$7.4 ($3.2-$6.7)
Alternative 4	11,000	160,000	$33	$3.2-$6.7 ($2.9-$6.0)
Alternative 5	17,000	310,000	$280	$5.0-$10 ($4.5-$9.4)

Table 8-6 Summary of Inventory, Costs, and Benefits for 2030

	2030 $PM_{2.5}$ Emissions Reductions (tons)	2030 NO_x Emissions Reductions (tons)	2030 Total Costs (Millions)	2030 Benefits[a,b] (Billions) $PM_{2.5}$ only 3% (7%)
Primary Case	28,000	770,000	$610	$12-$25 ($11-$23)
Alternative 1: Exclusion of Locomotive Remanufacturing	25,000	740,000	$580	$8.8-$19 ($8.0-$17)
Alternative 2: Tier 4 Advanced One Year	28,000	790,000	$620	$12-$25 ($11-$23)
Alternative 3: Tier 4 Exclusively in 2013	25,000	770,000	$630	$11-$24 ($10-$21)
Alternative 4: Elimination of Tier 4	17,000	240,000	$22	$6.2-$13 ($5.7-$12)
Alternative 5: Inclusion of Marine Remanufacturing	29,000	770,000	$620	$12-$26 ($11-$23)

Figure 8.2-1 $PM_{2.5}$ Inventories for 2006-2040

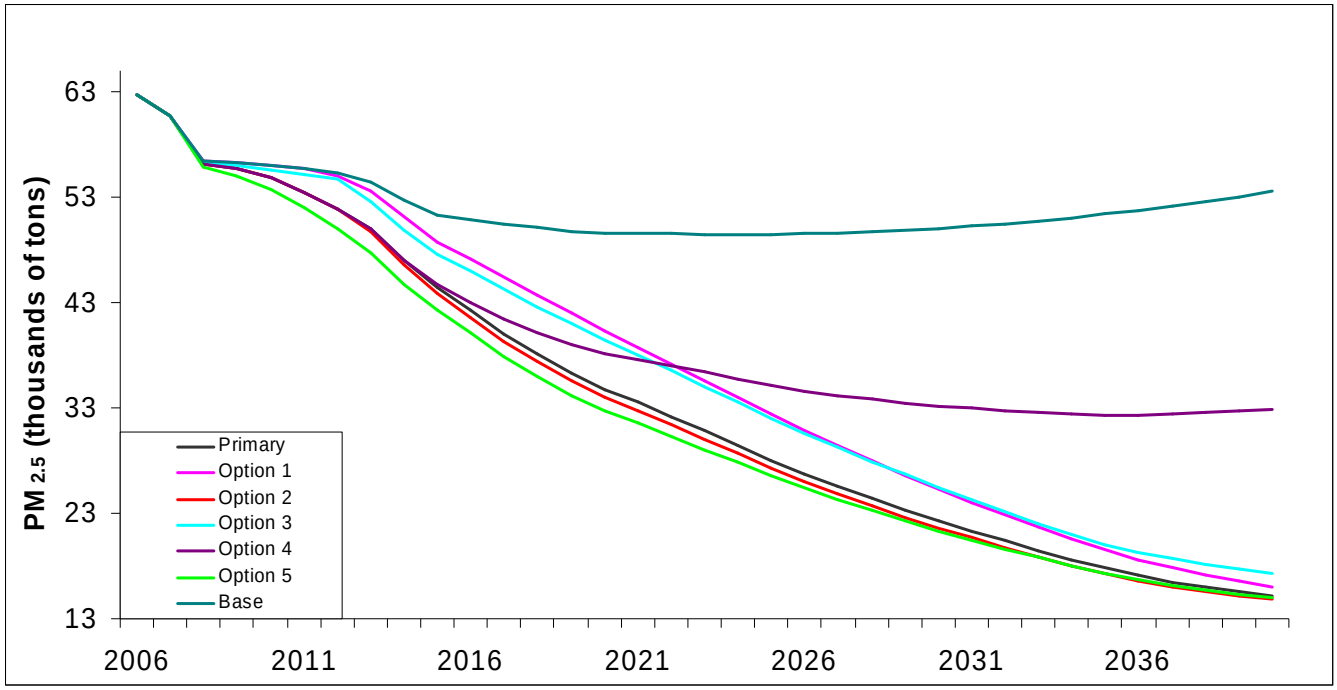
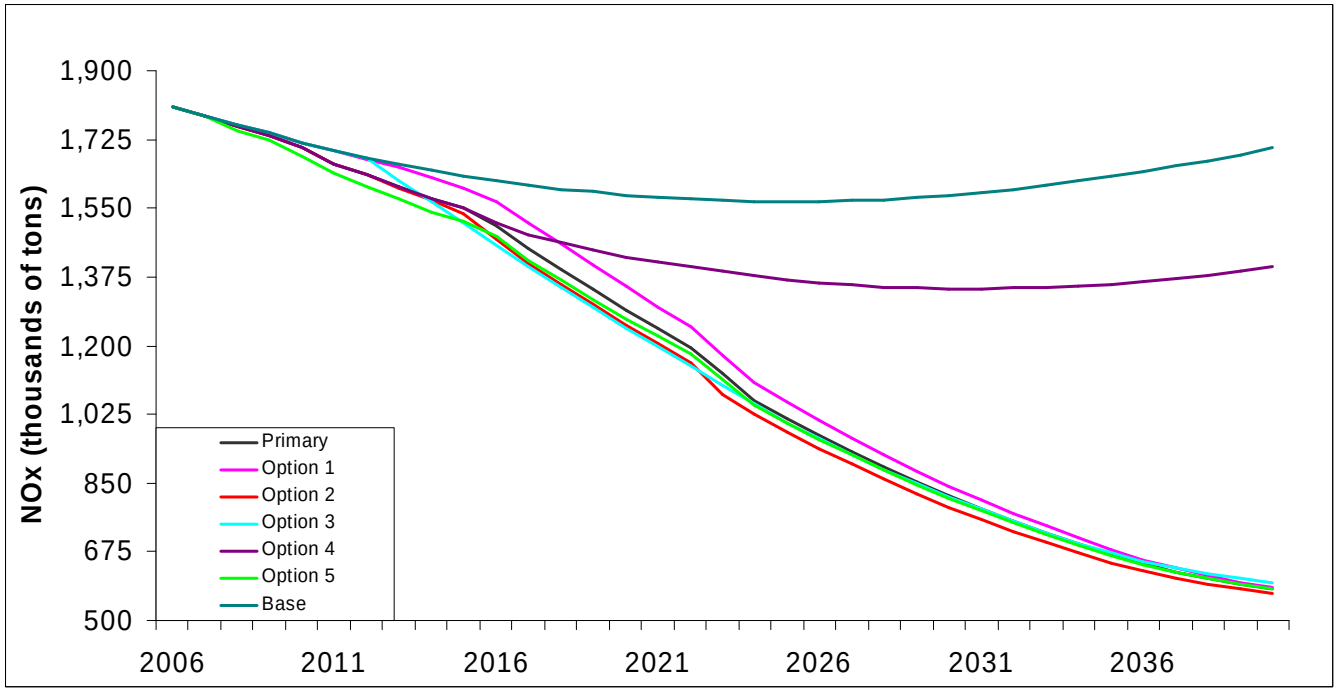


Figure 8.2-2 NO_x Inventories for 2006-2040



8.3 Summary of Results

8.3.1 Alternative 1: Exclusion of Locomotive Remanufacturing

Table 8-2 shows that the locomotive remanufacturing program provides substantial inventory impacts and benefits for a marginal increase in costs. This alternative shows that through 2040 the locomotive remanufacturing program would reduce $PM_{2.5}$ emissions by 65,000 tons NPV 3% (35,000 tons NPV 7%) and NO_x emissions by nearly 690,000 tons NPV 3% (400,000 tons at NPV 7%) at a cost of $870 million (NPV 3%). The monetized health and welfare benefits of the locomotive remanufacturing program in 2030 are $2.9-6.3 billion at a 3% discount rate (DR) or $2.7-$5.7 at a 7% DR. While this alternative could have the advantage of enabling industry to focus its resources on Tier 3 and Tier 4 technology development, given its substantial benefits, we have decided to retain the locomotive remanufacturing program in our proposal.

8.3.2 Alternative 2: Tier 4 Advanced One Year

This alternative is the most environmentally protective alternative we have given consideration to. However, our review of the technical challenges to introduce the Tier 4 program, especially in the context of the locomotive remanufacturing program and the Tier 3 standards which go before it, leads us to conclude that introducing Tier 4 a year earlier is not feasible. Our analysis suggests that introducing Tier 4 one year earlier than our proposal could reduce $PM_{2.5}$ emissions by 9,000 tons NPV 3% (5,000 tons NPV 7%) and NO_x emissions by 420,000 tons NPV 3% (210,000 tons NPV 7%). We are unable to make an accurate estimate of the cost for such an approach since we do not believe it to be feasible at this time. However, we have reported a cost in the summary table reflecting the same cost estimation method we have used for our primary case and have denoted unestimated additional costs as 'C'. These additional unestimated costs would include costs for additional engine test cells, engineering staff, and engineering facilities necessary to introduce Tier 4 one year earlier.

8.3.3 Alternative 3: Tier 4 Exclusively in 2013

Alternative 3 most closely reflects the program we described in our Advanced Notice of Proposed Rulemaking, whereby we would set new aftertreatment based emission standards as soon as possible. In this case, we believe the earliest that such standards could logically be started in is 2013 (3 months after the introduction of 15 ppm ULSD in this sector). Alternative 3 eliminates our proposed Tier 3 standards and the locomotive remanufacturing standards, while pulling the Tier 4 standards ahead to 2013 for all portions of the Tier 4 program. As with alternative 2, we are concerned that it may not be feasible to introduce Tier 4 technologies on locomotive

and marine diesel engines earlier than the proposal specifies. However, eliminating the technical work necessary to develop the Tier 3 and locomotive remanufacturing programs would certainly go a long way towards making such an approach possible. This alternative would actually result in substantially higher PM emissions than our primary case while reducing NO_x emissions. Through 2040 this alternative loses more than 60,000 tons NPV 3% (31,000 tons NPV 7%) of $PM_{2.5}$ reductions while only adding approximately 180,000 tons NPV 3% (100,000 tons NPV 7%) of NO_x reductions. As a result in 2030 alone, this alternative realizes approximately $0.6-$1.3 billion less at a 3% DR ($0.5-$1.2 billion less at a 7% DR) in public health and welfare benefits than does our proposal. As was the case with alternative 2, we have used the same cost estimation approach for this alternative as that of our proposal, and have denoted the unestimated costs that are necessary to accelerate the development of Tier 4 technologies with a 'C' in the summary tables. While alternative 3 could have been considered the Agency's leading option going into this rulemaking process, our review of the technical challenges necessary to introduce Tier 4 technologies and the substantial additional benefits that a more comprehensive solution can provide has lead us to drop this approach in favor of the comprehensive proposal we have laid out today.

8.3.4 Alternative 4: Elimination of Tier 4

Alternative 4 would eliminate the Tier 4 standards and retain the Tier 3 and locomotive remanufacturing requirements. This alternative allows us to consider the value of combining the Tier 3 and locomotive remanufacturing standards together as one program, and conversely, allows us to see the additional benefits gained when combining them with the Tier 4 standards. As a stand alone alternative, the combined Tier 3 and locomotive remanufacturing program is very attractive, resulting in large emission reductions of 207,000 tons NPV 3% (94,000 tons NPV 7%) of $PM_{2.5}$ and 2,910,000 tons NPV 3% (1,310,000 tons NPV 7%) of NOx through 2040 at an estimated cost of $950 million NPV 3% ($650 million at NPV 7%) through the same time period. In 2030 alone, such a program is projected to realize health and welfare benefits of $5.5-$12 billion at a 3% DR ($5.0-$11 billion at a 7% DR). Yet, this alternative falls well short of the total benefits that our comprehensive program is expected to realize, and also would not take advantage of new aftertreatment technologies which have been developed and used on both nonroad and on-highway applications. Elimination of Tier 4 would result in the loss of 108,000 tons NPV 3% (41,000 tons NPV 7%) of $PM_{2.5}$ and almost 4,960,000 tons NPV 3% (1,870,000 tons NPV 7%) of NO_x through 2040. Through the addition of the Tier 4 standards, the estimated health and welfare benefits are nearly doubled in 2030. As these alternatives show, each element of our comprehensive program: the locomotive remanufacturing program, the Tier 3 emission standards, or the Tier 4 emission standards, represents a valuable emission control program on its own, while the collective program results in the greatest emission reductions we believe to be possible giving consideration to all of the elements described in today's proposal.

8.3.5 Alternative 5: Inclusion of Marine Remanufacturing

This alternative would provide additional PM and NO_x benefits as shown in Figure 8.2-1 and Figure 8.2-2. With regard to benefits, the application of locomotive remanufacture kits to similar marine diesel engines would be expected to result in similar reductions in PM and NO_x emissions. In some cases, this could be as much as 60 percent reduction for PM and 25 percent reduction for NOx. However, because many marine diesel engines start at a cleaner baseline, we would not expect to accomplish the same reductions from all engines that would be subject to the program. Based on a minimal control case of a 25 percent PM reduction from existing marine diesel engines above 800 hp, we estimate about an additional 27,000 tons NPV 3% (16,000 tons NPV 7%) of $PM_{2.5}$ reductions, and an additional 320,000 tons NPV 3% (220,000 tons NPV 7%) of NO_x reductions through 2040. In general, we estimate that the compliance costs associated with this program to be about $10 million per year in additional costs in 2030. Using the benefits transfer approach from the primary control scenario to estimate the benefits of these inventory reductions, the additional monetized benefits would be expected to be about $0.3-$0.7 billion at a 3% DR ($0.3-$0.6 at a 7% DR) in 2030.