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

Executive Summary

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EPA United States Environmental Protection Agency

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Executive Summary

The Environmental Protection Agency (EPA) is proposing a comprehensive three-part program to reduce emissions of particulate matter (PM) and oxides of nitrogen (NO_x) from locomotives and marine diesel engines below 30 liters per cylinder displacement. Locomotives and marine diesel engines designed to these proposed standards would achieve PM reductions of 90 percent and NO_x reductions of 80 percent, compared to engines meeting the current Tier 2 standards. The proposed standards would also yield sizeable reductions in emissions of nonmethane hydrocarbons (NMHC), carbon monoxide (CO), and hazardous compounds known as air toxics.

This proposal is part of EPA's ongoing National Clean Diesel Campaign (NCDC) to reduce harmful emissions from diesel engines of all types. The anticipated emission reductions will significantly reduce exposure to harmful pollutants and also provide assistance to states and regions facing ozone and particulate air quality problems that are causing a range of adverse health effects, especially in terms of respiratory impairment and related illnesses.

This Regulatory Impact Analysis provides technical, economic, and environmental analyses of the proposed emission standards. Chapter 1 provides industry characterization for both the locomotive and marine industry. Chapter 2 presents air quality modeling results and describes the health and welfare effects associated with particulate matter (PM), ozone, and air toxics. Chapter 3 provides our estimates of the current emission inventories and the reductions that can be expected from the proposed standards. Chapter 4 contains our technical feasibility justification for the emission limits, and Chapter 5 contains the estimated costs of complying with those standards. Chapter 6 presents the estimated societal benefits of the proposed rulemaking. Chapter 7 contains our estimates of the market impacts of the proposed standards and the distribution of costs among stakeholders. Finally, Chapter 8 contains our analysis of several alternative control scenarios we considered during the development of this proposal.

1. Proposed Emission Standards

The proposed program addresses emissions from all types of diesel locomotives, including line-haul, switch, and passenger rail, and all types of marine diesel engines below 30 liters per cylinder displacement (collectively called "marine diesel engines.").[A] These include marine propulsion engines used on vessels from recreational and small fishing boats to super-yachts, tugs and Great Lakes freighters, and marine auxiliary engines ranging from small gensets to large generators on ocean-going vessels. Each of these markets is described in Chapter 1.

We are proposing a comprehensive three-part emission control program for locomotives and for marine diesel engines that will dramatically reduce the emissions from these sources. The standards and our technical feasibility justification are contained in Chapter 4.

The first part consists of near-term engine-out emission standards, referred to as Tier 3 standards, for newly-built locomotives and marine diesel engines. These standards reflect the application of engine-out PM and NO_x reduction technologies and begin to phase in starting in 2009. The second part consists of longer-term standards, referred to as Tier 4 standards, for newly-built locomotives and marine diesel engines. These standards phase in over time, beginning in 2014. For most engines, these standards are similar in stringency to the final standards included in the 2007 highway diesel and Clean Air Nonroad Diesel programs and are expected to require the use of high-efficiency aftertreatment systems to ensure compliance. These standards will be enabled by the availability of ultra-low sulfur diesel fuel (ULSD. Third, we are proposing to tighten emission standards for existing locomotives when they are remanufactured. Also included in our proposal are provisions to eliminate emissions from unnecessary locomotive idling, and we are requesting comment on applying standards to certain existing marine diesel engines when they are manufactured.

Locomotive Standards

The proposed standards for newly-built line-haul, passenger, and switch locomotives and for existing 1973 and later Tier 0, Tier 1, and Tier 2 locomotives are set out in Tables 1 and 2. With some exceptions, these standards would apply to all locomotives that operate extensively within the United States. Exceptions include historic steam-powered locomotives and locomotives powered solely by an external source of electricity. The regulations also generally do not apply to existing locomotives owned by railroads that are classified as small businesses. In addition, engines used in locomotive-type vehicles with less than 750 kW (1006 hp) total power (used primarily for railway maintenance), engines used only for hotel power (for passenger railcar equipment), and engines that are used in self-propelled passenger-carrying railcars, are excluded from these regulations. The engines used in

[A] In this RIA, "marine diesel engine" refers to compression-ignition marine engines below 30 liters per cylinder displacement unless otherwise indicated. Engines at or above 30 liters per cylinder are being addressed in separate EPA actions.

these smaller locomotive-type vehicles are generally subject to our nonroad engine requirements (40 CFR Parts 89 and 1039).

Table ES-1 – Proposed Standards for New and Existing Line-Haul and Passenger Locomotives (g/bhp-hr)

STANDARDS APPLY TO:	DATE	PM	NO_x	HC
Remanufactured Tier 0 & 1	2008 as available, 2010 required	0.22	7.4 [a]	0.55 [a]
Remanufactured Tier 2	2008 as available, 2013 required	0.10	5.5	0.30
New Tier 3	2012	0.10	5.5	0.30
New Tier 4	PM and HC 2015 NOx 2017	0.03	1.3	0.14

(a) For Tier 0 locomotives originally manufactured without a separate loop intake air cooling system, these standards are 8.0 and 1.00 for NO_X and HC, respectively.

Table ES-2 – Proposed Standards for New and Existing Switch Locomotives (g/bhp-hr)

SWITCH LOCOMOTIVE STANDARDS APPLY TO:	DATE	PM	NO_x	HC
Remanufactured Tier 0	2008 as available, 2010 required	0.26	11.8	2.10
Remanufactured Tier 1	2008 as available, 2010 required	0.26	11.0	1.20
Remanufactured Tier 2	2008 as available, 2013 required	0.13	8.1	0.60
New Tier 3	2011	0.10	5.0	0.60
New Tier 4	2015	0.03	1.3	0.14

Marine Standards

The proposed standards for newly-built marine diesel engines are set out in Tables 3, 4, 5, and 6. The Tier 3 standards would apply to all marine diesel engines with per cylinder displacement up to 30 liters. The Tier 4 standards would apply only to commercial marine diesel engines above 600 kW and recreational marine diesel engines above 2,000 kW.

For the purposes of this emission control program, Category 1 marine diesel engines are those with per cylinder displacement up to 7 liters. Category 2 marine diesel engines are those with per cylinder displacement from 7 to 30 liters. High power density engines are those with a power density above 35 kW/liter).

Table ES-3 – Proposed Tier 3 Standards for Marine Diesel C1

RATED KW	L/CYLINDER	PM G/BHP-HR	NO_x+HC G/BHP-HR	MODEL YEAR
<19 kW	<0.9	0.30	5.6	2009
19 - <75 kW	<0.9 [a]	0.22	5.6	2009
		0.22 [b]	3.5 [b]	2014
75 - 3700 kW	<0.9	0.10	4.0	2012
	0.9- <1.2	0.09	4.0	2013
	1.2- <2.5	0.08 [c]	4.2	2014
	2.5- <3.5	0.08 [c]	4.2	2013
	3.5- <7.0	0.08 [c]	4.3	2012

(a) <75 kW engines at or above 0.9 L/cylinder are subject to the corresponding 75-3700 kW standards.
(b) Option: 0.15 PM / 4.3 NO_X in 2014.
(c) This standard level drops to 0.07 in 2018 for <600 kW engines.

Table ES-4 – Proposed Tier 3 Standards for Marine Diesel C1 Recreational and Commercial High Power Density

RATED KW	L/CYLINDER	PM G/BHP-HR	NO_x+HC G/BHP-HR	MODEL YEAR
<19 kW	<0.9	0.30	5.6	2009
19 - <75 kW	<0.9 [a]	0.22	5.6	2009
		0.22 [b]	3.5 [b]	2014
75 - 3700 kW	<0.9	0.11	4.3	2012
	0.9- <1.2	0.10	4.3	2013
	1.2- <2.5	0.09	4.3	2014
	2.5- <3.5	0.09	4.3	2013
	3.5- <7.0	0.09	4.0	2012

(a) <75 kW engines at or above 0.9 L/cylinder are subject to the corresponding 75-3700 kW standards.
(b) Option: 0.15 PM / 4.3 NO_X+HC in 2014.

Table ES-5 – Proposed Tier 3 Standards for Marine Diesel C2

RATED KW	L/CYLINDER	PM G/BHP-HR	NO_x+HC G/BHP-HR	MODEL YEAR
=<3700 kW	7- <15	0.10	4.6	2013
	15- <20	0.20 [a]	6.5 a	2014
	20- <25	0.20	7.3	2014
	25- <30	0.20	8.2	2014

(a) For engines at or below 3300 kW in this group, the PM / NO_X+HC Tier 3 standards are 0.25 / 5.2.

Table ES-6 – Proposed Tier 4 Standards for Marine Diesel C1 and C2

RATED KW	PM G/BHP-HR	NO_x G/BHP-HR	HC G/BHP-HR	MODEL YEAR
>3700 kW	0.09 [a]	1.3	0.14	2014
	0.04	1.3	0.14	2016 [b]
1400 - 3700 kW	0.03	1.3	0.14	2016 [c]
600 - <1400 kW	0.03	1.3	0.14	2017 [b]

(a) This standard is 0.19 for engines with 15-30 liter/cylinder displacement.
(b) Optional compliance start dates are proposed within these model years; see discussion below.
(c) Option for engines with 7-15 liter/cylinder displacement: Tier 4 PM and HC in 2015 and Tier 4 NO_X in 2017.

2. Projected Inventory and Cost Impacts

Our analysis of the projected impacts of the proposed standards can be found in Chapter 2 (air quality impacts), Chapter 3 (inventory impacts) and Chapter 6 (benefits).

Inventory Reductions

A discussion of the estimated current and projected inventories for several key air pollutants are contained in Chapter 3. Nationally, in 2007 these engines account for about 20 percent of mobile source NO_x emissions and 25 percent of mobile source diesel $PM_{2.5}$ emissions. Absent new emissions standards, we expect overall emissions from these engines to remain relatively flat over the next 10 to 15 years due to existing regulations such as lower fuel sulfur requirements and the phase-in of locomotive and marine diesel Tier 1 and Tier 2 engine standards but starting in about 2025 emissions from these engines would begin to grow. Without new controls, by

2030, these engines would become a large portion of the total mobile source emissions inventory constituting 35 percent of mobile source NO_x emissions and 65 percent of diesel PM emissions.

We estimate that the proposed standards would reduce annual NO_x emissions by about 765,000 tons and $PM_{2.5}$ and 28,000 tons in 2030. Table 7 shows the emissions reductions associated with today's proposal for selected years, and the cumulative reductions through 2040 discounted at 3 and 7 percent. These reductions in PM and NO_x levels would produce nationwide air quality improvements.

Table ES-7 – 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 Section II 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.

Engineering Costs

The engineering cost analysis for the proposed standards can be found in Chapter 5. The total engineering costs associated with today's proposal are the summation of the engine and equipment compliance costs, both fixed and variable, the operating costs, and the costs associated with the locomotive remanufacturing program. These costs are summarized in Table 8.

Table ES-8 – Total Engineering Costs of the Proposal ($Millions)

YEAR	ENGINE COSTS	EQUIPMENT COSTS	OPERATING COSTS	COSTS OF REMANUFACTURING PROGRAM	TOTAL COSTS
2011	$99	$0	$11	$97	$207
2012	$55	$0	$13	$75	$142
2015	$100	$25	$25	$31	$181
2020	$87	$10	$187	$15	$250
2030	$105	$8	$407	$85	$605
2040	$104	$8	$611	$153	$876
NPV at 3%	$1,678	$141	$4,039	$1,374	$7,233
NPV at 7%	$883	$71	$1,596	$682	$3,231

These engineering costs are allocated to NO_x and PM reductions in Table 9. About half of the costs of complying with the program are operating costs, with the bulk of those being urea-related costs associated with SCR technology. Since SCR is a technique for reduce NO_x emissions, this means that most of the operating costs and, therefore, the majority of the total engineering costs of the program are associated with NO_x control.

Table ES-9 – Total Engineering Costs, Allocated by Pollutant ($Millions)

YEAR	PM COSTS	NO_x COSTS
2011	$93	$113
2012	$62	$80
2015	$93	$88
2020	$836	$164
2030	$159	$446
2040	$218	$658
NPV at 3%	$2,222	$5,011
NPV at 7%	$1,068	$2,163

Cost per Ton of Reduced Emissions

Using the inventory and engineering cost information, we can estimate the cost per ton of pollutant reduced as a result of the proposed standards. Table 10 contains the estimated cost per ton of pollutant reduced based on the net present value of the engineering costs and inventory reductions from 2006 through 2040. This estimate captures all of the engineering costs and emissions reductions including those associated with the locomotive remanufacturing program. Table 10 also presents the estimated cost per ton of pollutant reduced for 2030 using the annual costs and emissions reductions in that year alone. That estimates includes engineering costs and emission reductions that will occur from the new engine standards and locomotive remanufacturing program in that year.

Table ES-10 – Proposed Program Cost per Ton Estimates

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

3. Estimated Benefits and Economic Impacts

Estimated Benefits

We estimate that the requirements in this proposal will result in substantial benefits to public health and welfare and the environment, as described in Chapter 6. The benefits analysis performed for this proposal uses sophisticated air quality and benefit modeling tools and is based on peer-reviewed studies of air quality and health and welfare effects associated with improvements in air quality and peer-reviewed studies of the dollar values of those public health and welfare effects.

EPA typically quantifies PM- and ozone-related benefits in its regulatory impact analyses (RIAs) when possible. In the analysis of past air quality regulations, ozone-related benefits have included morbidity endpoints and welfare effects such as damage to commercial crops. EPA has not recently included a separate and additive mortality effect for ozone, independent of the effect associated with fine particulate matter. For a number of reasons, including 1) advice from the Science Advisory Board (SAB) Health and Ecological Effects Subcommittee (HEES) that EPA consider the plausibility and viability of including an estimate of premature mortality associated with short-term ozone exposure in its benefits analyses and 2) conclusions regarding the scientific support for such relationships in EPA's 2006 Air Quality Criteria for Ozone and Related Photochemical Oxidants (the CD), EPA is in the process of determining how to appropriately characterize ozone-related mortality benefits within the context of benefits analyses for air quality regulations. As part of this process, we are seeking advice from the National Academy of Sciences (NAS) regarding how the ozone-mortality literature should be used to quantify the reduction in premature mortality due to diminished exposure to ozone, the amount of life expectancy to be added and the monetary value of this increased life expectancy in the context of health benefits analyses associated with regulatory assessments. In addition, the Agency has sought advice on characterizing and communicating the uncertainty associated with each of these aspects in health benefit analyses.

Since the NAS effort is not expected to conclude until 2008, the agency is currently deliberating how best to characterize ozone-related mortality benefits in its rulemaking analyses in the interim. For the analysis of the proposed locomotive and marine standards, we do not quantify an ozone mortality benefit. So that we do not provide an incomplete picture of all of the benefits associated with reductions in emissions of ozone precursors, we have chosen not to include an estimate of total ozone benefits in the proposed RIA. By omitting ozone benefits in this proposal, we acknowledge that this analysis underestimates the benefits associated with the proposed standards. Our analysis, however, indicates that the rule's monetized $PM_{2.5}$ benefits alone substantially exceed our estimate of the costs.

The range of benefits associated with the proposed program are estimated based on the risk of several sources of PM-related mortality effect estimates, along with all other PM non-mortality related benefits information. These benefits are presented in Table ES-11. The benefits reflect two different sources of information about the impact of reductions in PM on reduction in the risk of premature death, including both the American Cancer Society (ACS) cohort study and an expert elicitation study conducted by EPA in 2006. In order to provide an indication of the sensitivity of the benefits estimates to alternative assumptions, in Chapter 6 of the RIA we present a variety of benefits estimates based on two epidemiological studies (including the ACS Study and the Six Cities Study) and the expert elicitation. EPA intends to ask the Science Advisory Board to provide additional advice as to which scientific studies should be used in future RIAs to estimate the benefits of reductions in PM. These estimates are in year 2005 dollars.

Table ES-11– Estimated Monetized PM-Related Health Benefits of the Proposed Locomotive and Marine Engine Standards

	TOTAL BENEFITS[A,B,C,D] (BILLIONS 2005$)	
	2020	2030
PM mortality derived from the ACS cohort study; Morbidity functions from epidemiology literature		
Using a 3% discount rate	$4.4+B	$12+B
Confidence Intervals (5th - 95th %ile)	($1.0 - $10)	($2.1 - $27)
Using a 7% discount rate	$4.0+B	$11+B
Confidence Intervals (5th - 95th %ile)	($1.0 - $9.2)	($1.8 - $25)
PM mortality derived from lower bound and upper bound expert-based result;[e] Morbidity functions from epidemiology literature		
Using a 3% discount rate	$1.7+B - $12+B	$4.6+B - $33+B
Confidence Intervals (5th - 95th %ile)	($0.2 - $8.5) – ($2.0 - $27)	($1.0 - $23) – ($5.4 - $72)
Using a 7% discount rate	$1.6+B - $11+B	$4.3+B - $30+B
Confidence Intervals (5th - 95th %ile)	($0.2 - $7.8) – ($1.8 - $24)	($1.0 - $21) – ($4.9 - $65)

[a] Benefits include avoided cases of mortality, chronic illness, and other morbidity health endpoints.
[b] PM-related mortality benefits estimated using an assumed PM threshold of 10 μg/m3. There is uncertainty about which threshold to use and this may impact the magnitude of the total benefits estimate. For a more detailed discussion of this issue, please refer to Section 6.6.1.3 of the RIA.
[c] For notational purposes, unquantified benefits are indicated with a "B" to represent the sum of additional monetary benefits and disbenefits. A detailed listing of unquantified health and welfare effects is provided in Chapter 6 of the RIA.
[d] Results reflect the use of two different discount rates: 3 and 7 percent, which are recommended by EPA's Guidelines for Preparing Economic Analyses and OMB Circular A-4. Results are rounded to two significant digits for ease of presentation and computation.
[e] The effect estimates of nine of the twelve experts included in the elicitation panel fall within the empirically-derived range provided by the ACS and Six-Cities studies. One of the experts fall below this range and two of the experts are above this range. Although the overall range across experts is summarized in this table, the full uncertainty in the estimates is reflected by the results for the full set of 12 experts. The twelve experts' judgments as to the likely mean effect estimate are not evenly distributed across the range illustrated by arraying the highest and lowest expert means. Likewise the 5th and 95th percentiles for these highest and lowest judgments of the effect estimate do not imply any particular distribution within those bounds. The distribution of benefits estimates associated with each of the twelve expert responses can be found in Tables 6.4-3 and 6.4-4 in the RIA.

We estimate that the annual emission reductions associated with the proposed standards would annually prevent 1,500 premature deaths (based on the ACS cohort study), 170,000 work days lost, and 1,000,000 minor restricted-activity days. Using the ACS-based estimate of PM-related premature mortality incidence, we estimate that the monetized benefits of this rule in 2030 would be approximately $12 billion, assuming a 3 percent discount rate (or $11 billion assuming a 7 percent discount rate). Using the range of results derived from the expert elicitation, we estimate that the monetized benefits in 2030 would range from approximately $4.6 billion to $33 billion, assuming a 3 percent discount rate (or $4.3 to $30 billion assuming a 7 percent discount rate). These estimates would be increased substantially if we were to adopt the remanufactured marine engine program concept. The annual cost of the program in 2030 would be significantly less, at approximately $600 million.

Economic Impact

We also performed an economic impact analysis to estimate the market and social welfare impacts of the proposed standards. This analysis can be found in Chapter 7. According to this analysis, the average price of a locomotive in 2030 is expected to increase by less than three percent as a result of the proposed standards. The average price of a commercial marine diesel engine in 2030 is expected to increase by about 8.5 percent for Category 1 engines above 800 hp and about 19 percent for Category 2 engines above 800 hp.[B] The average price of a marine vessel using those engines is expected increase by about 1 percent for vessels using Category 1 engines above 800 hp (about $16,000) and about 3.6 percent for vessels using Category 2 engines above 800 hp (about $142,000). Increases in engine and vessel prices for commercial engines below 800 hp and recreational engines are expected to be negligible.

Overall, producers and consumers of rail and marine transportation services are expected to bear the majority of the social costs of the program, in large part because they bear the operating (urea) and remanufacturing costs that make up most of the compliance costs of the proposal. Providers of those transportation services are expected to bear about 42 percent of the social costs of the rule, and users are expected to bear about 50 percent. However, the price of rail and transportation services is expected to increase by less than 1 percent. Locomotive, marine diesel engine, and marine vessel manufacturers will bear the remainder of the social costs.

4. Alternative Program Options

In the course of designing our proposed program, we investigated several alternative approaches to both the engine and fuel programs. Chapter 8 contains a description of these alternatives and an analysis of their potential costs and benefits.

[B] Marine diesel engines are divided into three categories for the purposes of EPA's standards. Category 1 are engines above 50 hp and up to 5 liters per cylinder displacement. Category 2 are engines from 5 to 30 liters per cylinder. Category 3 are engines at or above 30 liters per cylinder. See 40 CFR 94.2. Note that we are proposing to change the definition of Category 1 and Category 2 engines to reflect a 7 liter per cylinder cut-off.