CHAPTER 3: Emission Inventory

This chapter presents our analysis of the emission impact of the final rule for the four categories of nonroad diesel engines affected: land-based diesel engines, commercial marine diesel vessels, locomotives, and recreational marine diesel engines. New engine controls are being adopted for the land-based diesel engine category. For the other three nonroad diesel categories, the final rule includes no new engine controls; however, the diesel fuel sulfur requirements will decrease emissions of particulate matter smaller than 2.5 microns ($PM_{2.5}$) and sulfur dioxide (SO_2) for these categories.

Section 3.1 presents an overview of the methodology used to generate the baseline inventories. The baseline inventories represent current and future emissions with only the existing standards. Sections 3.2 and 3.3 then describe the contribution of nonroad diesel engines to national and selected local baseline inventories, respectively. Section 3.4 describes the development of the controlled inventories, specifically the changes made to the baseline inputs to incorporate the new standards and fuel sulfur requirements. Section 3.5 follows with the projected emission reductions resulting from the final rule. Section 3.6 concludes the chapter by describing the changes in the inputs and resulting emission inventories between the preliminary baseline and control scenarios used for the air quality modeling and the updated baseline and control scenarios in this final rule.

The controlled inventory estimates do not include the potential uses of the averaging, banking, and trading (ABT) program or the transition provisions for engine manufacturers, since these are flexibilities that would be difficult to predict and model. More information regarding these provisions can be found in Section III of the preamble.

The estimates of baseline emissions and emission reductions for nonroad land-based, recreational marine, locomotive, and commercial marine vessel diesel engines are reported for both 48-state and 50-state inventories. The 48-state inventories are used for the air quality modeling that EPA uses to analyze regional ozone and PM air quality, of which Alaska and Hawaii are not a part. In addition, 50-state emission estimates for other sources (such as stationary and area sources) are not available. As a result, in cases where nonroad diesel sources are compared with other emission sources, the 48-state emission inventory estimates are used.

Inventories are presented for the following pollutants: $PM_{2.5}$, PM_{10}, oxides of nitrogen (NO_x), SO_2, volatile organic compounds (VOC), carbon monoxide (CO), and air toxics. The specific air toxics are benzene, formaldeyde, acetaldehyde, 1,3-butadiene, and acrolein. The PM inventories include directly emitted PM only, although secondary sulfates are taken into account in the air quality modeling.

3.1 Nonroad Diesel Baseline Emission Inventory Development

This section describes how the baseline emission inventories were developed for the four categories of nonroad diesel engines affected by this final rule: land-based diesel engines, commercial marine diesel vessels, locomotives, and recreational marine diesel engines. For land-based diesel engines, there is a section that discusses inventory development for $PM_{2.5}$, NO_x, SO_2, VOC, and CO, followed by a section for air toxics.

3.1.1 Land-Based Nonroad Diesel Engines—$PM_{2.5}$, NO_x, SO_2, VOC, and CO Emissions

The baseline emission inventories for land-based diesel engines were generated using the draft NONROAD2004 model. The baseline inventories account for the effect of existing federal emission standards that establish three tiers of emission standards (Tier 1 through Tier 3). Section 3.1.1.1 provides an overview of the draft NONROAD2004 model and a description of the methodology used in the model to estimate emissions. Details of the baseline modeling inputs (e.g., populations, activity, and emission factors) for land-based diesel engines can be found in the technical reports documenting the model. The single scenario option variable that affects diesel emissions is the in-use fuel sulfur level. The in-use diesel fuel sulfur level inputs used for the baseline scenarios are given in Section 3.1.1.2.3.

For the proposed rule, the draft NONROAD2002 model was used. Section 3.1.1.8 describes the changes made to the model for the final rule.

3.1.1.1 Overview

The draft NONROAD2004 model estimates emission inventories of important air emissions from diverse nonroad equipment. The model's scope includes all nonroad sources with the exception of locomotives, aircraft and commercial marine vessels. Users can construct inventories for criteria pollutants including carbon monoxide (CO), oxides of nitrogen (NO_x), oxides of sulfur (SO_2), and particulate matter (PM), as well as other emissions including total hydrocarbon (THC) and carbon dioxide (CO_2). As a related feature, the model estimates fuel consumption. The model can distinguish emissions on the basis of equipment type, size and technology group. A central feature of the model is projection of future or past emissions between 1970 and 2050.

The draft NONROAD2004 model contains three major components: (1) the core model, a FORTRAN program that performs model calculations, (2) the reporting utility, a Microsoft Access application that compiles and presents results, and (3) the graphic user interface (GUI), a Visual-Basic application that allows users to easily construct scenarios for submission to the core model. The following discussion will describe processes performed by the core model in the calculation of emission inventories.

This section describes how the draft NONROAD2004 model estimates emissions particularly relevant to this analysis, including particulate matter (PM), oxides of nitrogen (NO_x), oxides of sulfur (SO_2), carbon monoxide (CO) and volatile organic compounds (VOC). As appropriate, we will focus on estimation of emissions of these pollutants by diesel engines. The model estimates emissions from approximately 80 types of diesel equipment. As with other engine classes, the model defines engine or equipment "size" in terms of the rated power (horsepower) of the engine. For diesel engines, the regulations also classify engines on the basis of rated power.

The first four chemical species are exhaust emissions, i.e., pollutants emitted directly as exhaust from combustion of diesel fuel in the engine. However, the last emission, VOC, includes both exhaust and evaporative components. The exhaust component represents hydrocarbons emitted as products of combustion; the evaporative component includes compounds emitted from unburned fuel during operation, i.e., "crankcase emissions." For VOC, we will first describe estimation of total hydrocarbon exhaust emissions, in conjunction with the description for the other exhaust emissions. We discuss subsequent estimation of associated VOC emissions in Section 3.1.1.4.

3.1.1.2 NONROAD's Major Inputs

The draft NONROAD2004 model uses three major sets of inputs in estimation of exhaust emission inventories: (1) emission calculation variables, (2) projection variables, and (3) scenario option variables.

3.1.1.2.1 Emission Calculation Variables

The draft NONROAD2004 model estimates exhaust emissions using the equation

$$I_{exh} = E_{exh} \cdot A \cdot L \cdot P \cdot N$$

where each term is defined as follows:

I_{exh} = the exhaust emission inventory (gram/year, gram/day),
E_{exh} = exhaust emission factor (gram/hp-hr),
A = equipment activity (operating hours/year),
L = Load factor (average proportion of rated power used during operation (percent)),
P = average rated power (hp)
N = Equipment population (units).

Emissions are then converted and reported as tons/year or tons/day.

For diesel engines, each of the inputs applies to sub-populations of equipment, as classified by type (dozer, tractor, backhoe, etc.), rated power class (50-100 hp, 100-300 hp, etc.) and regulatory tier (tier 1, tier 2, etc.).

Exhaust Emission Factor. The emission factor in a given simulation year consists of three components, a "zero-hour" emission level (ZHL) , a transient adjustment factor (TAF) and a deterioration factor (DF). The ZHL represents the emission rate for recently manufactured engines, i.e., engines with few operating hours, and is typically derived directly from laboratory measurements on new or nearly new engines on several commonly used duty cycles, hence the term "zero-hour."

Because most emission data have been collected under steady-state conditions (constant engine speed and load), and because most real-world operation involves transient conditions (variable speed and load), we attempt to adjust for the difference between laboratory measurements and real-world operation through the use of transient adjustment factors (TAFs). The TAF is a ratio representing the difference in the emission rate between transient and steady-state operation. The TAFs are estimated by collecting emission measurements on specific engines using both transient and steady-state cycles, and calculating the ratio

$$\mathrm{TAF} = \frac{\mathrm{EF}_{\mathrm{transient}}}{\mathrm{EF}_{\mathrm{steady-state}}}$$

where $\mathrm{EF}_{\mathrm{transient}}$ is the measurement for a given engine on a specific transient cycle, and $\mathrm{EF}_{\mathrm{steady\text{-}state}}$ is the corresponding measurement for the same engine on a selected steady-state cycle. Data from seven transient cycles were used to develop seven TAFs for each of the four pollutants. The seven cycle TAFs were then binned into two categories, based on the cycle load factors. TAFs were then assigned to each equipment type represented in the model on the basis of engineering judgment. If steady-state operation was typical of an equipment type, no adjustment was made (i.e., TAF = 1.0).

Emission factors in the model input file represent the product (ZHL·TAF) for each combination of equipment type, size class and regulatory tier represented by the model. We refer to this product as the "baseline emission factor." For more detail on the derivation and application of EFs and TAFs, refer to the model documentation on diesel emission factors.[1]

During a model run, the model applies emission deterioration to the baseline emission factor, based on the age distribution of the equipment type in the year simulated. Deterioration expresses an assumption that emissions increase with equipment age and is expressed as a multiplicative deterioration factor (DF). Thus, the final emission factor applied in the simulation year is the product ZHL·TAF·DF. Deterioration factors vary from year to year; we describe their calculation in more detail in Section 3.1.1.2.2 below.

The model estimates fuel consumption by substituting brake-specific fuel consumption (BSFC, lb/hp-hr) for the emission factor in the equation above. We apply a TAF to the BSFC but assume that BSFC does not deteriorate with equipment age.

In estimation of PM emissions, we apply an additional adjustment to the emission factor to account for the in-use sulfur level of diesel fuel.[1] Based on user-specified diesel sulfur levels for a given scenario, NONROAD adjusts the PM emission factor by the margin S_{PMadj} (g/hp-hr) calculated as

$$S_{PMadj} = BSFC \cdot m_{SO4,S} \cdot m_{PM,S} \cdot 0.01 \cdot (S_{base} - S_{in-use})$$

where: BSFC = brake-specific fuel consumption (g fuel/hp-hr),
$m_{SO4,S}$ = a constant, representing the sulfate fraction of total particulate sulfur, equal to 7.0 g PM SO_4/g PM S,
$m_{PM,S}$ = a constant, representing the fraction of fuel sulfur converted to particulate sulfur, equal to 0.02247 g PM S/g fuel S,
0.01 = conversion factor from wt% to wt fraction
S_{base} = base sulfur level in NONROAD (0.33 wt%, 3300 ppm for pre-control and Tier 1 engines; 0.20 wt%, 2000 ppm for Tier 2-3 engines),
S_{in-use} = in-use diesel sulfur level as specified by user (wt%).

Equipment Activity. Activity represents the usage of equipment, expressed in operating hours per year. Activity estimates are specific to equipment types and remain constant in any given simulation year. Activity estimates for diesel equipment have been adopted from the *Partslink* model, a commercial source developed and maintained by Power Systems Research/Compass International, Inc. For discussion of activity estimates for specific equipment types, refer to the technical documentation for the model.[2]

Load Factor. This parameter represents the average fraction of rated power that equipment uses during operation. Load factors are assigned by equipment type, and remain constant in any simulation year. For use in draft NONROAD2004, we derived load factors from the results of a project designed to develop transient engine test cycles. During the course of the project, seven cycles were developed, designed to represent the operation of specific common equipment types.

Specific load factors for the cycles fell into two broad groups, which we designated as “high” and “low.” We calculated an average for each group, with the high group containing four cycles and the low group three; resulting load factors were 0.59 for the high group and 0.21 for the low group. Then, we assigned one of these two factors to each equipment type for which we believed engineering judgment was sufficient to make an assignment. For remaining equipment types, for which we considered engineering judgment insufficient to make an assignment, we assigned a ‘steady-state’ load factor, calculated as the average of load factors for all seven transient cycles (0.43). Of NONROAD’s 90 diesel applications, half were assigned ‘high’ or ‘low’ load factors, with the remainder assigned ‘steady-state’ load factors. For more detail on the derivation of load factors and assignment to specific equipment types, refer to the appropriate technical report[2].

Rated Power. This parameter represents the average rated power for equipment, as assigned to each combination of equipment type and rated-power class represented by the model. Values assigned to a given type/power combination represents the sales-weighted average of engines for that equipment type in that rated-power class.[3] Rated-power assignments remain constant in any given simulation year. For use in draft NONROAD2004, we obtained estimates from the *Partslink* database, maintained by Power Systems Research/Compass International, Inc. The product of load factor and rated power (*LP*) represents actual power output during equipment operation.

Equipment Population. As the name implies, this model input represents populations of equipment pieces. For diesel engines, the model generates separate sub-populations for individual combinations of equipment type and rated-power class. However, unlike activity and load factor, populations do not remain constant from year to year. Projection of future or past populations is the means through which the draft NONROAD2004 model projects future or past emissions. As a reference point, the input file contains populations in the model's base year 2000 (updated from 1998 in draft NONROAD2002). We generated populations in the base year using a simple attrition model that calculated base-year populations as a function of equipment sales, scrappage, activity and load factor. Equipment sales by model year were obtained from the commercially available *Partslink* database, developed and maintained by Power Systems Research/Compass International, Inc. (PSR). This database contains sales estimates for nonroad equipment for model years 1973 through 2000. Base-year population development is discussed in the technical documentation.[3]

3.1.1.2.2 Projection Variables

The model uses three variables to project emissions over time: the annual population growth rate, the equipment median life, and the relative deterioration rate. Collectively, these variables represent population growth, changes in the equipment age distribution, and emission deterioration.

Annual Population Growth Rate (percent/year). The population growth rate represents the percentage increase in the equipment population for a given equipment type over successive years. The growth rate is linear for diesel equipment, and is applied to the entire population, including all rated-power classes and tiers.[4] Diesel growth rates vary by sector (e.g., agricultural, construction).

Equipment Median Life (hours @ full load). This variable represents the period of time over which 50 percent of the engines in a given "model-year cohort" are scrapped. A "model-year cohort" represents a sub-population of engines represented as entering the population in a given year. The input value assumes that (1) engines are run at full load until failure, and (2) equipment scrappage follows the model's scrappage curve. During a simulation, the model uses the "annualized median life," which represents the actual service life of equipment in years, depending on how much and how hard the equipment is used. Annualized median life is calculated as median life in hours (l_h), divided by the product of activity and load factor ($l_y = l_h/AL$). Engines persist in the equipment population over two median lives ($2l_y$); during the first median life, 50 percent of the engines are scrapped, and over the second, the remaining 50 percent are scrapped. For a more detailed description of median life, see the model documentation.[2]

Relative Deterioration Rate (percent increase in emission factor/percent median life expended). This variable plays a key role in calculation of the deterioration factor. Values of the relative deterioration rate are assigned based on pollutant, rated-power class, and tier. Using the relative deterioration rate (d), the annualized median life (l_y) and the equipment age, draft NONROAD2004 calculates the deterioration factor as

$$\mathrm{DF}_{\mathrm{pollutant,tier,year}} = 1 + d_{\mathrm{pollutant,tier}}\left(\frac{\mathrm{age}_{\mathrm{year}}}{l_y}\right)$$

where:

$\mathrm{DF}_{\mathrm{pollutant,year}}$ = the deterioration factor for a given pollutant for a model-year cohort in the simulation year

d = the relative deterioration rate for a given pollutant (percent increase in emission factor /percent useful life expended) and regulatory tier

age = the age of a specific model-year group of engines in the simulation year

l_y = the annualized median life of the given model-year cohort (years)

The deterioration factor adjusts the exhaust emission factor for engines in a given model-year cohort in relation to the proportion of median life expended. The model calculates the deterioration linearly over one median life for a given model-year cohort (represented as a fraction of the entire population). Following the first median life, the deteriorated emission factor is held constant over the remaining life for engines in the cohort. The model's deterioration calculations are discussed in greater detail in the technical documentation.[1]

3.1.1.2.3 Scenario Option Variables

These inputs apply to entire model runs or scenarios, rather than to equipment. Scenario options describe fuel characteristics and ambient weather conditions. The option that applies to inventories for diesel equipment is the in-use diesel sulfur level (wt%).

The in-use diesel fuel sulfur level inputs used for land-based diesel engines for the baseline scenarios are provided in Table 3.1-1. The fuel sulfur levels account for spillover use of highway fuel and are discussed in more detail in Chapter 7. The in-use sulfur levels in Table 3.1-1 used for modeling differ slightly from those presented in Chapter 7, since minor revisions were made subsequent to the modeling.

Table 3.1-1
Modeled Baseline In-Use Diesel Fuel Sulfur Content
for Land-Based Nonroad Diesel Engines

Calendar Year	48-State Fuel Sulfur (ppm)	50-State Fuel Sulfur (ppm)
through 2005	2283	2284
2006	2249	2242
2007-2009	2224	2212
2010	2167	2155
2011+	2126	2114

3.1.1.3 Emission Estimation Process

To project emissions in a given year, the draft NONROAD2004 model performs a series of steps (not necessarily in the order described).

Equipment Population. The model projects the equipment population for the user-specified simulation year. The current year's population (N_{year}) is projected as a function of the base-year population (N_{base}) as

$$N_{\text{year}} = N_{\text{base}}(1 + ng)$$

where g is the annual growth rate and n is the number of years between the simulation year and the base year. For diesel equipment, population projection follows a linear trend as in the equation above. Diesel growth rates in the model vary only by sector (e.g., agricultural, construction). The sector-specific growth rates are applied to all equipment types and hp categories within each sector.

Equipment Age Distribution. The model assigns an age distribution for each sub-population calculated in the previous step. This calculation divides the total population into a series of model-year cohorts of decreasing size, with the number of cohorts equal to twice the annualized median life for the rated-power class under consideration ($2l_y$). Each model-year cohort is estimated as a fraction of the total population, using fractions derived from NONROAD's scrappage curve, scaled to the useful life of the given rated-power class, also equal to $2l_y$.[5]

Emission and Deterioration Factors. Because the previous steps were performed for engines of a given rated-power class, the model assigns emission factors to different model year cohorts simply by relating equipment age to regulatory tier. Similarly, the model calculates deterioration factors for each cohort. The algorithm identifies the appropriate relative deterioration rate in relation to tier and rated-power class, calculates the age of the cohort, and supplies these inputs to the deterioration factor equation.

Activity and Load Factor. The model obtains the appropriate activity, load factor and rated power estimates. Activity and load factor are defined on the basis of equipment type alone; they are constant for all model-year cohorts, and rated power is determined on the basis of equipment type and rated power class.

Emission Calculation. For a given pollutant, the calculations described above are performed and the resulting inputs multiplied in the exhaust emission equation. The steps are repeated for each rated-power class within an equipment type to obtain total emissions for that type. The resulting subtotals for equipment types are then summed to obtain total emissions from all equipment types included in the simulation. These processes are repeated for each pollutant requested for the simulation. Using summation notation, the process may be summarized as

$$I_{\text{exh,poll}} = \overbrace{\sum \left[\overbrace{\sum \left(\overbrace{\sum \left(E_{\text{exh,poll}} \cdot A \cdot L \cdot P \cdot N \right)}^{\substack{\text{sum over all model-year cohorts} \\ \text{within a rated-power class}}} \right)}^{\substack{\text{sum over all rated-power classes} \\ \text{within an equipment type}}} \right]}^{\text{sum over all equipment types}}$$

3.1.1.4 Estimation of VOC Emissions

Volatile organic compounds are a class of hydrocarbons considered to be of regulatory interest. For purposes of inventory modeling, we define VOC as total hydrocarbon (THC) plus reactive oxygenated species, represented by aldehydes (RCHO) and alcohols (RCOH), less nonreactive species represented by methane and ethane (CH_4 and CH_3CH_3), as follows:

$$\text{VOC} = \text{THC} + (\text{RCHO} + \text{RCOH}) - (\text{CH}_4 + \text{CH}_3\text{CH}_3)$$

The NONROAD model estimates VOC in relation to THC, where THC is defined as those hydrocarbons measured by a flame ionization detector (FID) calibrated to propane. Total hydrocarbon has exhaust and evaporative components, where the evaporative THC represents 'crankcase emissions.' Crankcase emissions are hydrocarbons that escape from the cylinder through the piston rings into the crankcase. The draft NONROAD2004 model assumes that all diesel engines have open crankcases, allowing that gases in the crankcase to escape to the atmosphere.

For diesel engines, the emission factor for crankcase emissions (EF_{crank}) is estimated as a fraction of the exhaust emission factor (EF_{exh}), as

$$\text{EF}_{\text{crank,HC,year}} = 0.02 \cdot \text{EF}_{\text{exh,HC,year}}$$

Note that the model adjusts crankcase emissions for deterioration. In a given simulation year, the crankcase emission factor is calculated from the deteriorated exhaust emission factor for that year, i.e., $EF_{exh,year} = ZHL \cdot TAF \cdot DF_{year}$.

The model estimates exhaust and crankcase VOC as a fraction of exhaust and crankcase THC, respectively.

$$VOC_{exh} = 1.053 \cdot THC_{exh}, \quad VOC_{crank} = 1.053 \cdot THC_{crank}$$

Note the fraction is greater than one, reflecting the addition of oxygenated species to THC. For additional discussion of the model's estimation of crankcase and VOC emissions, refer to the model documentation.[1, 6]

3.1.1.5 Estimation of SO_2 Emissions

To estimate SO_2 emissions, the draft NONROAD2004 model does not use an explicit emission factor. Rather, the model estimates a SO_2 emission factor EF_{SO2} on the basis of brake-specific fuel consumption, the user-defined diesel sulfur level, and the emission factor for THC.

$$EF_{SO_2} = \left[BSFC \cdot (1 - m_{PM,S}) - EF_{THC}\right] \cdot S_{in-use} \cdot m_{SO_2,S}$$

where:

- BSFC = brake-specific fuel consumption (g/hp-hr),
- $m_{PM,S}$ = a constant, representing the fraction of fuel sulfur converted to particulate sulfur, equal to 0.02247 g PM S/g fuel S,
- EF_{THC} = the in-use adjusted THC emission factor (g/hp-hr),
- S_{in-use} = the user-specified scenario-specific sulfur content of diesel fuel (weight fraction), and
- $m_{SO2,S}$ = a constant, representing fraction of fuel sulfur converted to SO_2, equal to 2.0 g SO_2/g S.

This equation includes corrections for the fraction of sulfur that is converted to PM ($m_{PM,S}$) and for the sulfur remaining in the unburned fuel (EF_{THC}). The correction for unburned fuel, as indicated by THC emissions, is more significant for gasoline emissions, but insubstantial for diesel emissions.

Having estimated EF_{SO2}, the model estimates SO_2 emissions as it does other exhaust emissions.

3.1.1.6 Estimation of $PM_{2.5}$ Emissions

The model estimates emissions of diesel $PM_{2.5}$ as a multiple of PM_{10} emissions. $PM_{2.5}$ is estimated to compose 97 percent of PM_{10} emissions. This is an updated estimate, based on an analysis of size distribution data for diesel engines.[7]

3.1.1.7 Estimation of Fuel Consumption

The draft NONROAD2004 model estimates fuel consumption using the equation

$$F = \frac{BSFC \cdot A \cdot L \cdot P \cdot N}{D}$$

where:

F = fuel consumption (gallons/year)
BSFC = brake-specific fuel consumption (lb/hp-hr)
A = equipment activity (operating hours/year)
L = load factor (average proportion of rated power used during operation (percent))
P = average rated power (hp)
N = equipment population (units)
D = fuel density (lb/gal); diesel fuel density = 7.1 lb/gal

The fuel consumption estimates for land-based diesel and recreational marine diesel engines are given in Section 3.1.5.

3.1.1.8 Changes from Draft NONROAD2002 to Draft NONROAD2004

For the final rule, we have updated the model to incorporate the following changes:

1) Draft NONROAD2004 contains more horsepower bins in order to model the final standards. Specifically, the 50-100 hp bin was split into 50-75 hp and 75-100 hp bins. Also, the 1000-1500 hp bin was split into 1000-1200 hp and 1200-1500 hp bins.

2) Draft NONROAD2004 eliminates the Tier 3 NOx and PM transient adjustment factors (TAFs) for steady-state applications, which were mistakenly included in draft NONROAD2002.

3) The base year populations in draft NONROAD2004 were updated from 1998 to 2000, based on newer sales data.

4) The $PM_{2.5}$ fraction of PM_{10} was revised from 0.92 to 0.97, based on an updated analysis of size distribution data for diesel engines.

5) The recreational marine populations, median life, and deterioration factors for HC and NO_x were revised to match what was used in the 2002 final rulemaking that covers large spark ignition engines (>25 hp), recreational equipment, and recreational marine diesel engines (>50 hp).[8] The exhaust emission factors for these three categories were also revised in draft NONROAD2004 to reflect the final standards.

6) The output label was changed from 'SO_x' to 'SO_2' to avoid confusion, since SO_2 emissions are calculated by the model.

For land-based diesel nonroad engines, the net effect of these changes is generally within 3 percent, with the direction and variation of the change dependent on the calendar year and pollutant of interest.

3.1.1.9 Baseline Inventory

Tables 3.1-2a and 3.1-2b present the PM_{10}, $PM_{2.5}$, NO_x, SO_2, VOC, and CO baseline emissions for land-based nonroad engines in 1996 and 2000-2040, for the 48-state and 50-state inventories, respectively.

Table 3.1-2a
Baseline (48-State) Emissions for Land-Based Nonroad Diesel Engines (short tons)

Year	PM_{10}	$PM_{2.5}$	NO_x	SO_2	VOC	CO
1996	192,275	186,507	1,564,904	143,572	220,971	1,004,586
2000	176,056	170,774	1,550,355	161,977	199,887	916,507
2001	170,451	165,338	1,537,890	166,644	191,472	880,129
2002	165,017	160,067	1,526,119	171,309	183,525	845,435
2003	159,268	154,490	1,505,435	175,971	176,383	813,886
2004	153,932	149,314	1,486,335	180,630	169,873	787,559
2005	148,720	144,259	1,467,547	185,287	163,663	763,062
2006	143,840	139,525	1,435,181	187,085	156,952	741,436
2007	139,990	135,791	1,399,787	189,511	150,357	724,449
2008	137,366	133,245	1,359,661	194,019	143,306	710,202
2009	135,097	131,044	1,317,995	198,526	136,426	697,893
2010	132,712	128,730	1,278,038	197,829	129,711	687,234
2011	130,964	127,035	1,242,159	198,415	123,573	678,980
2012	130,091	126,189	1,211,982	202,740	118,363	674,285
2013	129,779	125,885	1,188,162	207,062	114,022	672,732
2014	129,700	125,809	1,168,310	211,382	110,284	672,819
2015	129,831	125,936	1,152,199	215,699	107,084	674,296
2016	130,128	126,224	1,139,969	219,971	104,426	677,095
2017	130,606	126,688	1,130,663	224,241	102,252	681,156
2018	131,211	127,275	1,124,057	228,510	100,383	685,866
2019	131,993	128,034	1,120,529	232,777	98,766	691,194
2020	133,049	129,058	1,119,481	237,044	97,513	697,630
2021	134,251	130,223	1,120,802	241,309	96,566	704,932
2022	135,491	131,426	1,124,159	245,573	95,837	712,591
2023	136,799	132,695	1,129,090	249,836	95,344	720,565
2024	138,136	133,992	1,135,338	254,099	95,061	729,001
2025	139,555	135,369	1,142,889	258,360	94,975	737,967
2026	141,007	136,777	1,151,480	262,591	95,043	747,219
2027	142,429	138,156	1,160,868	266,822	95,234	756,611
2028	143,901	139,584	1,170,868	271,052	95,529	766,274
2029	145,385	141,023	1,181,457	275,282	95,906	776,141
2030	146,891	142,484	1,192,833	279,511	96,374	786,181
2031	148,452	143,999	1,205,007	283,740	96,942	796,408
2032	150,035	145,534	1,217,535	287,969	97,568	806,761
2033	151,640	147,091	1,230,337	292,198	98,241	817,199
2034	153,253	148,655	1,243,467	296,426	98,967	827,712
2035	154,851	150,205	1,256,924	300,654	99,747	838,224
2036	156,499	151,804	1,270,722	304,882	100,591	848,884
2037	158,171	153,426	1,284,718	309,110	101,473	859,588
2038	160,204	155,398	1,299,415	313,337	102,472	870,258
2039	162,240	157,373	1,314,296	317,564	103,495	880,968
2040	164,275	159,346	1,329,330	321,792	104,543	891,684

Table 3.1-2b
Baseline (50-State) Emissions for Land-Based Nonroad Diesel Engines (short tons)

Year	PM_{10}	$PM_{2.5}$	NO_x	SO_2	VOC	CO
1996	193,166	187,371	1,573,083	144,409	222,084	1,009,804
2000	176,881	171,575	1,558,392	162,920	200,903	921,226
2001	171,256	166,118	1,545,852	167,615	192,447	884,645
2002	165,801	160,827	1,534,007	172,307	184,462	849,756
2003	160,030	155,229	1,513,203	176,996	177,287	818,037
2004	154,670	150,030	1,493,989	181,683	170,744	791,568
2005	149,434	144,951	1,475,092	186,368	164,505	766,944
2006	144,479	140,145	1,442,534	187,508	157,762	745,216
2007	140,579	136,362	1,406,936	189,505	151,134	728,159
2008	137,945	133,807	1,366,584	194,013	144,049	713,862
2009	135,668	131,598	1,324,685	198,521	137,135	701,516
2010	133,274	129,276	1,284,510	197,795	130,388	690,829
2011	131,521	127,576	1,248,440	198,360	124,220	682,563
2012	130,648	126,729	1,218,098	202,685	118,984	677,865
2013	130,337	126,426	1,194,153	207,006	114,621	676,320
2014	130,260	126,352	1,174,204	211,325	110,863	676,420
2015	130,394	126,482	1,158,023	215,641	107,647	677,918
2016	130,695	126,774	1,145,751	219,912	104,977	680,746
2017	131,178	127,243	1,136,425	224,181	102,793	684,843
2018	131,788	127,835	1,129,817	228,449	100,917	689,593
2019	132,575	128,598	1,126,301	232,716	99,294	694,964
2020	133,637	129,628	1,125,276	236,982	98,037	701,445
2021	134,844	130,799	1,126,633	241,246	97,086	708,795
2022	136,091	132,008	1,130,034	245,509	96,355	716,502
2023	137,406	133,284	1,135,015	249,772	95,860	724,528
2024	138,750	134,587	1,141,319	254,033	95,575	733,017
2025	140,177	135,972	1,148,929	258,294	95,490	742,039
2026	141,637	137,388	1,157,584	262,525	95,558	751,348
2027	143,067	138,775	1,167,040	266,754	95,752	760,798
2028	144,547	140,211	1,177,111	270,984	96,049	770,520
2029	146,038	141,657	1,187,773	275,213	96,429	780,446
2030	147,552	143,126	1,199,225	279,442	96,900	790,547
2031	149,123	144,649	1,211,478	283,670	97,472	800,835
2032	150,715	146,193	1,224,086	287,898	98,102	811,250
2033	152,329	147,759	1,236,969	292,126	98,779	821,751
2034	153,950	149,332	1,250,181	296,354	99,511	832,326
2035	155,557	150,891	1,263,722	300,581	100,296	842,901
2036	157,214	152,498	1,277,605	304,808	101,146	853,624
2037	158,896	154,129	1,291,688	309,035	102,033	864,392
2038	160,938	156,110	1,306,473	313,262	103,038	875,126
2039	162,984	158,095	1,321,443	317,489	104,068	885,901
2040	165,028	160,077	1,336,566	321,715	105,122	896,682

3.1.2 Land-Based Nonroad Diesel Engines—Air Toxics Emissions

EPA focused on five major air toxics pollutants for this rule: benzene, formaldehyde, acetaldehyde, 1,3-butadiene, and acrolein. These pollutants are VOCs and are included in the total land-based nonroad diesel VOC emission estimate. EPA developed the baseline inventory estimates for these pollutants by multiplying the baseline VOC emissions from the draft NONROAD2004 model for a given year by the constant fractional amount that each air toxic pollutant contributes to VOC emissions. Table 3.1-3 shows the fractions that EPA used for each air toxics pollutant. EPA developed these nonroad air toxics pollutant fractions for the National Emission Inventory.[9]

Table 3.1-3
Air Toxics Fractions of VOC

Benzene	Formaldehyde	Acetaldehyde	1,3-Butadiene	Acrolein
0.020	0.118	0.053	0.002	0.003

Tables 3.1-4a and 3.1-4b show our 48-state and 50-state estimates of national baseline emissions for five selected major air toxic pollutants (benzene, formaldehyde, acetaldehyde, 1,3-butadiene, and acrolein) for 1996, as well as for selected years from 2005 to 2030, modeled with the existing Tier 1-3 standards. Toxics emissions decrease over time until 2025 as engines meeting the Tier 1-3 standards are introduced into the fleet. Beyond 2025, the growth in population overtakes the effect of the existing emission standards. Chapter 2 discusses the health effects of these pollutants.

Table 3.1-4a
Baseline (48-State) Air Toxics Emissions
for Land-Based Nonroad Diesel Engines (short tons)

Year	Benzene	Formaldehyde	Acetaldehyde	1,3-Butadiene	Acrolein
1996	4,419	26,075	11,711	442	663
2000	3,998	23,587	10,594	400	600
2005	3,273	19,312	8,674	327	491
2007	3,007	17,742	7,969	301	451
2010	2,594	15,306	6,875	259	389
2015	2,142	12,636	5,675	214	321
2020	1,950	11,507	5,168	195	293
2025	1,900	11,207	5,034	190	285
2030	1,927	11,372	5,108	193	289

Table 3.1-4b
Baseline (50-State) Air Toxics Emissions
for Land-Based Nonroad Diesel Engines (short tons)

Year	Benzene	Formaldehyde	Acetaldehyde	1,3-Butadiene	Acrolein
1996	4,442	26,206	11,770	444	666
2000	4,018	23,707	10,648	402	603
2005	3,290	19,412	8,719	329	494
2007	3,023	17,834	8,010	302	453
2010	2,608	15,386	6,911	261	391
2015	2,153	12,702	5,705	215	323
2020	1,961	11,568	5,196	196	294
2025	1,910	11,268	5,061	191	286
2030	1,938	11,434	5,136	194	291

3.1.3 Commercial Marine Vessels and Locomotives

Though no new engine controls are being proposed for diesel commercial marine and locomotive engines, these engines use diesel fuel and the effects of the fuel changes in the final rule need to be modeled. This section addresses the modeling of the baseline case for these engines, which includes effects of certain other rules such as (a) the April 1998 final rule for locomotives, (b) the December 1999 final rule for Category 1 and 2 commercial marine diesel engines, (c) the January 2003 final rule for Category 3 commercial marine residual engines, and (c) the January 2001 heavy duty highway diesel fuel rule that takes effect in June 2006.

Since the draft NONROAD2004 model does not generate emission estimates for these applications, the emission inventories were calculated using the following methodology. VOC, CO, and NO_x emissions for 1996, 2020, and 2030 (the years chosen for air quality modeling) for commercial marine diesel engines were taken from the rulemaking documentation. For locomotives, the fuel-specific emission factors from the rulemaking documentation were multiplied by the updated fuel consumption annual estimates described in Chapter 7 to obtain the emission estimates. The VOC, CO, and NOx emission estimates for commercial marine diesel engines and locomotives are presented in Table 3.1-5. VOC emissions were calculated by multiplying THC emissions by a factor of 1.053, which is also the factor used for land-based diesel engines.

Table 3.1-5
Baseline (48-State) NO_x, VOC, and CO Emissions
for Locomotives and Commercial Marine Diesel Vessels (short tons)

Year	NO_x		VOC		CO	
	Locomotives	CMV	Locomotives	CMV	Locomotives	CMV
1996	934,070	639,630	38,035	21,540	92,496	93,638
2020	508,084	587,115	30,125	24,005	99,227	114,397
2030	481,077	602,967	28,580	26,169	107,780	123,436

Tables 3.1-6a and 3.1-6b provide the 48-state and 50-state baseline fuel volumes, fuel sulfur levels, PM sulfate, $PM_{2.5}$, and SO_2 emissions. The fuel sulfur levels account for "spillover" of low-sulfur highway diesel fuel into use by nonroad applications. The slight decrease in average sulfur level in 2006 is due to the introduction of highway diesel fuel meeting the 2007 15 ppm standard, and the "spillover" of this highway fuel into the nonroad fuel pool. The derivation of the fuel volumes and sulfur levels is discussed in more detail in Chapter 7. The marine fuel volumes reported in Chapter 7 include both commercial and recreational marine usage. The fuel consumption specific to commercial marine in Tables 3.1-6a and 3.1-6b was calculated by subtracting the recreational marine fuel consumption as generated by the draft NONROAD2004 model.

Table 3.1-6a
Baseline (48-State) Fuel Sulfur Levels, SO_2, Sulfate PM, and $PM_{2.5}$ Emissions for Locomotives and Commercial Marine Diesel Vessels

Year	Locomotive Usage (10^9 gal/yr)	Commercial Marine Usage (10^9 gal/yr)	Base Sulfur Level (ppm)	Base					
				SO_2		Sulfate PM		Total $PM_{2.5}$	
				Loco (tons/yr)	CMV (tons/yr)	Loco (tons/yr)	CMV (tons/yr)	Loco (tons/yr)	CMV (tons/yr)
1996	3.065	1.644	2641	56,193	30,136	4,521	2,424	22,266	17,782
2000	2.687	1.556	2641	49,268	28,523	3,964	2,295	19,522	18,542
2001	2.772	1.533	2637	50,737	28,065	4,082	2,258	20,137	18,723
2002	2.692	1.493	2638	49,291	27,339	3,966	2,199	19,554	18,905
2003	2.722	1.507	2638	49,843	27,598	4,010	2,220	19,772	19,090
2004	2.741	1.518	2639	50,205	27,793	4,039	2,236	19,913	19,019
2005	2.762	1.522	2639	50,583	27,867	4,070	2,242	19,474	18,915
2006	2.818	1.556	2616	51,170	28,252	4,117	2,273	19,270	18,808
2007	2.868	1.575	2599	51,736	28,416	4,162	2,286	18,998	18,671
2008	2.900	1.594	2599	52,317	28,749	4,209	2,313	18,588	18,533
2009	2.939	1.609	2599	53,021	29,019	4,266	2,335	18,526	18,394
2010	2.986	1.625	2444	50,658	27,565	4,076	2,218	18,183	18,259
2011	3.043	1.646	2334	49,278	26,655	3,965	2,144	18,527	18,125
2012	3.073	1.663	2334	49,779	26,947	4,005	2,168	18,384	17,996
2013	3.097	1.674	2334	50,176	27,118	4,037	2,182	18,198	17,871
2014	3.121	1.691	2335	50,581	27,395	4,069	2,204	18,007	17,752
2015	3.148	1.706	2335	51,011	27,645	4,104	2,224	17,821	17,640
2016	3.181	1.718	2335	51,551	27,837	4,147	2,240	17,671	17,575
2017	3.210	1.733	2335	52,028	28,093	4,186	2,260	17,490	17,541
2018	3.234	1.757	2336	52,437	28,495	4,219	2,292	17,619	17,538
2019	3.266	1.786	2337	52,973	28,972	4,262	2,331	17,444	17,588
2020	3.288	1.804	2338	53,352	29,268	4,292	2,355	17,213	17,665
2021	3.305	1.823	2339	53,646	29,593	4,316	2,381	16,947	17,765
2022	3.335	1.852	2340	54,148	30,072	4,356	2,419	16,743	17,890
2023	3.364	1.870	2340	54,635	30,364	4,396	2,443	16,891	18,032
2024	3.393	1.893	2341	55,123	30,745	4,435	2,473	16,675	18,188
2025	3.426	1.912	2341	55,659	31,062	4,478	2,499	16,469	18,356
2026	3.455	1.935	2341	56,140	31,440	4,517	2,529	16,238	18,533
2027	3.483	1.958	2342	56,624	31,825	4,556	2,560	16,374	18,720
2028	3.513	1.981	2343	57,113	32,216	4,595	2,592	16,136	18,906
2029	3.542	2.005	2343	57,606	32,615	4,635	2,624	15,892	19,098
2030	3.572	2.030	2344	58,103	33,020	4,675	2,657	16,025	19,294
2031	3.602	2.055	2345	58,605	33,433	4,715	2,690	15,775	19,497
2032	3.632	2.080	2345	59,111	33,852	4,756	2,723	15,519	19,701
2033	3.662	2.106	2346	59,621	34,279	4,797	2,758	15,649	19,903
2034	3.693	2.132	2346	60,136	34,713	4,838	2,793	15,385	20,108
2035	3.724	2.158	2347	60,655	35,154	4,880	2,828	15,514	20,315
2036	3.755	2.185	2348	61,179	35,603	4,922	2,864	15,644	20,523
2037	3.786	2.213	2348	61,707	36,059	4,964	2,901	15,370	20,733
2038	3.818	2.240	2349	62,240	36,523	5,007	2,938	15,499	20,945
2039	3.850	2.269	2349	62,777	36,995	5,051	2,976	15,218	21,158
2040	3.882	2.298	2350	63,319	37,475	5,094	3,015	15,345	21,372

Table 3.1-6b
Baseline (50-State) Fuel Sulfur Levels, SO_2, Sulfate PM, and $PM_{2.5}$ Emissions for Locomotives and Commercial Marine Diesel Vessels

Year	Locomotive Usage (10^9 gal/yr)	Commercial Marine Usage (10^9 gal/yr)	Base Sulfur Level (ppm)	Base					
				SO_2		Sulfate PM		Total $PM_{2.5}$	
				Loco (tons/yr)	CMV (tons/yr)	Loco (tons/yr)	CMV (tons/yr)	Loco (tons/yr)	CMV (tons/yr)
1996	3.072	1.724	2640	56,287	31,587	4,528	2,541	22,319	18,717
2000	2.691	1.634	2640	49,305	29,926	3,967	2,408	19,551	19,518
2001	2.776	1.610	2635	50,778	29,454	4,085	2,370	20,167	19,708
2002	2.696	1.569	2637	49,330	28,702	3,969	2,309	19,583	19,900
2003	2.726	1.584	2637	49,882	28,978	4,013	2,331	19,801	20,095
2004	2.745	1.595	2637	50,244	29,186	4,042	2,348	19,943	20,020
2005	2.766	1.599	2637	50,622	29,269	4,073	2,355	19,502	19,911
2006	2.823	1.636	2588	50,693	29,374	4,078	2,363	19,298	19,798
2007	2.873	1.656	2552	50,877	29,330	4,093	2,360	19,026	19,653
2008	2.904	1.675	2552	51,447	29,676	4,139	2,388	18,616	19,508
2009	2.944	1.691	2552	52,140	29,958	4,195	2,410	18,553	19,363
2010	2.990	1.708	2400	49,822	28,464	4,008	2,290	18,210	19,220
2011	3.047	1.731	2292	48,471	27,529	3,900	2,215	18,554	19,079
2012	3.077	1.749	2292	48,962	27,832	3,939	2,239	18,411	18,943
2013	3.102	1.761	2292	49,351	28,012	3,970	2,254	18,225	18,811
2014	3.126	1.778	2293	49,748	28,299	4,002	2,277	18,034	18,686
2015	3.152	1.794	2293	50,169	28,559	4,036	2,298	17,847	18,568
2016	3.186	1.807	2293	50,701	28,761	4,079	2,314	17,697	18,500
2017	3.215	1.824	2293	51,170	29,028	4,117	2,335	17,516	18,464
2018	3.239	1.849	2294	51,567	29,442	4,149	2,369	17,645	18,461
2019	3.271	1.879	2295	52,091	29,934	4,191	2,408	17,469	18,514
2020	3.293	1.898	2295	52,462	30,240	4,221	2,433	17,238	18,595
2021	3.310	1.919	2296	52,747	30,576	4,244	2,460	16,972	18,700
2022	3.339	1.949	2297	53,236	31,069	4,283	2,500	16,767	18,831
2023	3.369	1.968	2297	53,714	31,372	4,321	2,524	16,916	18,981
2024	3.398	1.992	2298	54,191	31,766	4,360	2,556	16,699	19,146
2025	3.431	2.012	2298	54,717	32,095	4,402	2,582	16,493	19,322
2026	3.460	2.037	2298	55,187	32,486	4,440	2,614	16,262	19,509
2027	3.489	2.061	2299	55,661	32,884	4,478	2,646	16,398	19,705
2028	3.518	2.086	2299	56,139	33,288	4,517	2,678	16,159	19,901
2029	3.547	2.111	2300	56,621	33,699	4,555	2,711	15,916	20,104
2030	3.577	2.137	2300	57,107	34,118	4,594	2,745	16,049	20,309
2031	3.607	2.163	2301	57,597	34,543	4,634	2,779	15,798	20,523
2032	3.637	2.190	2301	58,092	34,976	4,674	2,814	15,542	20,738
2033	3.668	2.217	2302	58,591	35,416	4,714	2,849	15,672	20,951
2034	3.698	2.244	2302	59,094	35,864	4,754	2,885	15,408	21,166
2035	3.729	2.272	2303	59,601	36,319	4,795	2,922	15,537	21,384
2036	3.760	2.301	2303	60,113	36,782	4,836	2,959	15,667	21,603
2037	3.792	2.330	2304	60,629	37,252	4,878	2,997	15,393	21,825
2038	3.824	2.359	2304	61,150	37,731	4,920	3,036	15,522	22,047
2039	3.856	2.389	2305	61,675	38,217	4,962	3,075	15,240	22,271
2040	3.888	2.420	2305	62,205	38,711	5,005	3,114	15,368	22,497

Annual SO_2 emission estimates for locomotives and commercial marine vessels were calculated by multiplying the gallons of fuel use by the fuel density, the fuel sulfur content, and the molecular weight ratio of SO_2 to sulfur. This is then reduced by the fraction of fuel sulfur that is converted to sulfate PM (2.247 percent on average for engines without aftertreatment).[1] Following is an example of the calculation for the case when fuel sulfur content is 2300 ppm.

SO_2 tons = gallons × 7.1 lb/gallon × 0.0023 S wt. Fraction × (1-0.02247 S fraction converted to SO_2) × 64/32 SO_2 to S M.W. ratio / 2000 lb/ton

Unlike the equation used in the draft NONROAD2004 model for land-based diesel and recreational marine diesel engines (described in Section 3.1.1.5), this equation does not include a correction for the sulfur remaining in the unburned fuel. The correction for unburned fuel, as indicated by THC emissions is insubstantial for diesel emissions.

Annual sulfate PM emission estimates for locomotives and commercial marine vessels were calculated by multiplying the gallons of fuel use by the fuel density, the fuel sulfur content, the molecular weight ratio of hydrated sulfate to sulfur, and the fraction of fuel sulfur converted to sulfate on average. Following is an example of the calculation for the case when fuel sulfur content is 2300 ppm.

Sulfate tons = gallons × 7.1 lb/gallon × 0.0023 S wt. Fraction × 0.02247 fraction of S converted to sulfate × 224/32 sulfate to S M.W. ratio / 2000 lb/ton

The baseline sulfate PM estimates are not used to generate baseline PM_{10} emission estimates, but are needed in order to calculate the PM benefits of reductions in fuel sulfur levels with the final rule.

Annual total PM_{10} emission estimates for locomotives were calculated by multiplying the gallons of fuel use by the gram per gallon PM emission factor from the 1998 locomotive final rule Regulatory Support Document. Following is an example calculation:

PM_{10} tons = gallons × g/gal EF / 454g/lb / 2000 lbs/ton

Annual PM_{10} emission estimates for commercial marine vessels were derived from the rulemaking documentation.

PM_{10} is assumed to be equivalent to total PM, and $PM_{2.5}$ is estimated by multiplying PM_{10} emissions by a factor of 0.97. This is the factor used for all nonroad diesel engines; the basis is described in Section 3.1.1.6.

3.1.4 Recreational Marine Engines

Diesel recreational marine engines consist mainly of inboard engines used in larger power boats and sailboats, but there are also a small number of outboard diesel engines in use. Emission estimates for this category were generated using the draft NONROAD2004 model. Details of the modeling inputs (e.g., populations, activity, and emission factors) for these engines can be found in the technical reports documenting the draft NONROAD2004 model. The emission inventory numbers presented here assume that recreational marine applications will use diesel fuel with the same sulfur content and sulfur-to-sulfate conversion rate as locomotives and commercial marine vessels.

It should be noted that, unlike the previous version of the NONROAD model, these inventory values generated with the draft NONROAD2004 model now account for the newest standards promulgated in September 2002, which take effect in 2006-2009, for diesel recreational marine engines greater than 37 kw (50 hp). Although those standards provide substantial benefits for the affected engines (e.g., 25 to 37 percent reductions of PM, NO_x, and HC in 2030), the impact of this on the total nonroad diesel inventory is quite small, representing less than 1 percent of the baseline nonroad diesel inventory (without locomotives or commercial marine) for PM, NO_x, and HC in 2030.

Tables 3.1-7a and 3.1-7b present the PM_{10}, $PM_{2.5}$, NO_x, SO_2, VOC, and CO emissions for recreational marine engines in 1996 and 2000-2040 for the 48-state and 50-state inventories, respectively.

Table 3.1-7a
Baseline (48-State) Emissions for Recreational Marine Diesel Engines (short tons)

Year	PM_{10}	$PM_{2.5}$	NO_x	SO_2	VOC	CO
1996	951	923	33,679	4,286	1,297	5,424
2000	1,070	1,038	37,943	4,831	1,455	6,098
2001	1,099	1,066	39,071	4,968	1,494	6,271
2002	1,130	1,096	40,198	5,114	1,533	6,444
2003	1,160	1,125	41,325	5,259	1,571	6,615
2004	1,190	1,154	42,452	5,406	1,609	6,787
2005	1,220	1,183	43,578	5,551	1,647	6,958
2006	1,233	1,196	44,105	5,647	1,657	7,128
2007	1,247	1,210	44,602	5,754	1,664	7,298
2008	1,262	1,225	45,066	5,897	1,670	7,467
2009	1,275	1,237	45,415	6,041	1,670	7,636
2010	1,257	1,219	45,729	5,816	1,668	7,804
2011	1,245	1,208	46,022	5,682	1,665	7,971
2012	1,254	1,216	46,282	5,811	1,660	8,137
2013	1,261	1,223	46,528	5,939	1,655	8,303
2014	1,269	1,230	46,765	6,070	1,649	8,469
2015	1,275	1,236	46,969	6,198	1,642	8,635
2016	1,280	1,242	47,168	6,327	1,634	8,802
2017	1,285	1,247	47,362	6,455	1,627	8,969
2018	1,290	1,251	47,525	6,587	1,618	9,137
2019	1,295	1,256	47,687	6,718	1,611	9,308
2020	1,300	1,261	47,847	6,850	1,604	9,482
2021	1,304	1,265	48,003	6,982	1,597	9,655
2022	1,309	1,270	48,182	7,114	1,592	9,829
2023	1,314	1,275	48,363	7,243	1,586	10,004
2024	1,320	1,281	48,593	7,375	1,583	10,178
2025	1,330	1,290	48,961	7,504	1,587	10,354
2026	1,344	1,303	49,501	7,633	1,599	10,529
2027	1,359	1,319	50,092	7,765	1,614	10,704
2028	1,376	1,335	50,716	7,897	1,630	10,880
2029	1,394	1,352	51,392	8,026	1,649	11,056
2030	1,413	1,371	52,085	8,158	1,669	11,232
2031	1,432	1,389	52,790	8,290	1,689	11,409
2032	1,451	1,408	53,510	8,419	1,710	11,585
2033	1,471	1,427	54,228	8,552	1,731	11,762
2034	1,491	1,446	54,959	8,681	1,753	11,938
2035	1,511	1,466	55,702	8,814	1,775	12,115
2036	1,531	1,485	56,444	8,946	1,798	12,292
2037	1,552	1,505	57,197	9,075	1,820	12,469
2038	1,573	1,526	57,963	9,208	1,844	12,646
2039	1,593	1,546	58,729	9,338	1,868	12,823
2040	1,615	1,566	59,506	9,471	1,892	13,001

Table 3.1-7b
Baseline (50-State) Emissions for Recreational Marine Diesel Engines (short tons)

Year	PM_{10}	$PM_{2.5}$	NO_x	SO_2	VOC	CO
1996	957	929	33,891	4,312	1,305	5,458
2000	1,076	1,044	38,182	4,859	1,464	6,137
2001	1,106	1,073	39,317	4,995	1,503	6,311
2002	1,137	1,103	40,452	5,145	1,542	6,484
2003	1,167	1,132	41,586	5,290	1,581	6,657
2004	1,197	1,161	42,719	5,436	1,619	6,829
2005	1,227	1,190	43,852	5,582	1,658	7,001
2006	1,236	1,199	44,383	5,622	1,667	7,173
2007	1,246	1,209	44,883	5,685	1,674	7,344
2008	1,262	1,224	45,350	5,827	1,680	7,514
2009	1,274	1,236	45,701	5,969	1,680	7,684
2010	1,256	1,219	46,018	5,747	1,678	7,853
2011	1,245	1,208	46,312	5,615	1,675	8,021
2012	1,253	1,215	46,573	5,742	1,671	8,189
2013	1,261	1,223	46,821	5,869	1,665	8,356
2014	1,268	1,230	47,060	5,998	1,660	8,523
2015	1,273	1,235	47,265	6,125	1,652	8,690
2016	1,279	1,241	47,465	6,252	1,645	8,857
2017	1,284	1,245	47,660	6,379	1,637	9,025
2018	1,288	1,250	47,825	6,509	1,629	9,195
2019	1,293	1,254	47,987	6,639	1,621	9,367
2020	1,298	1,259	48,148	6,766	1,614	9,541
2021	1,302	1,263	48,305	6,897	1,607	9,716
2022	1,307	1,268	48,485	7,027	1,602	9,891
2023	1,312	1,272	48,667	7,155	1,596	10,067
2024	1,317	1,278	48,899	7,285	1,593	10,243
2025	1,327	1,287	49,269	7,412	1,597	10,419
2026	1,341	1,301	49,813	7,540	1,609	10,595
2027	1,357	1,316	50,408	7,670	1,624	10,772
2028	1,373	1,332	51,036	7,797	1,640	10,949
2029	1,391	1,349	51,716	7,928	1,659	11,126
2030	1,410	1,367	52,413	8,055	1,679	11,303
2031	1,429	1,386	53,123	8,186	1,700	11,481
2032	1,448	1,404	53,847	8,313	1,721	11,658
2033	1,467	1,423	54,570	8,444	1,742	11,836
2034	1,487	1,442	55,305	8,572	1,764	12,013
2035	1,507	1,462	56,053	8,703	1,786	12,191
2036	1,527	1,481	56,799	8,830	1,809	12,369
2037	1,548	1,501	57,558	8,961	1,832	12,547
2038	1,568	1,521	58,329	9,089	1,856	12,726
2039	1,589	1,542	59,099	9,220	1,879	12,904
2040	1,610	1,562	59,881	9,348	1,904	13,082

3.1.5 Fuel Consumption for Nonroad Diesel Engines

Table 3.1-8 presents the fuel consumption estimates for the land-based, recreational marine, locomotive, and commercial marine nonroad diesel categories. Fuel consumption estimates are provided for 1996 and 2000-2040 for the 48-state and 50-state inventories.

The fuel consumption estimates for land-based diesel and recreational marine diesel engines were obtained using the draft NONROAD2004 model. The methodology is described in Section 3.1.1.7. The derivation of the fuel consumption estimates for locomotives and commercial marine vessels is described in Section 3.1.3.

For the final rule, the draft NONROAD2004 estimates for fuel consumption are the basis for both inventory generation and for the cost analyses. The land-based diesel fuel estimates in Chapter 7 differ from those presented in Table 3.1-8 by less than 1 percent, due to simple rounding error.

Although the locomotive diesel demand volumes in this chapter are identical to those described in Chapter 7, the marine diesel volumes are slightly different. In Chapter 7, the marine end-use category is a combination of both commercial and recreational marine end uses. In this chapter, recreational marine demand is estimated separately with the draft NONROAD2004 model for each calendar year, and subtracted from the respective combined marine end use volume to produce the commercial marine estimate.

Table 3.1-8
Fuel Consumption for Nonroad Diesel Engines

Year	Fuel Consumption (10^6 gal/year)							
	Land-Based Diesel		Recreational Marine		Locomotives		Commercial Marine	
	48-State	50-State	48-State	50-State	48-State	50-State	48-State	50-State
1996	9,120	9,169	234	236	3,065	3,072	1,644	1,724
2000	10,276	10,331	264	266	2,687	2,691	1,556	1,634
2001	10,568	10,625	272	274	2,772	2,776	1,533	1,610
2002	10,861	10,919	280	282	2,692	2,696	1,493	1,569
2003	11,153	11,213	288	289	2,722	2,726	1,507	1,584
2004	11,445	11,507	296	297	2,741	2,745	1,518	1,595
2005	11,737	11,801	303	305	2,762	2,766	1,522	1,599
2006	12,028	12,092	311	313	2,818	2,823	1,556	1,636
2007	12,318	12,384	319	321	2,868	2,873	1,575	1,656
2008	12,608	12,676	327	329	2,900	2,904	1,594	1,675
2009	12,898	12,968	335	337	2,939	2,944	1,609	1,691
2010	13,188	13,259	343	345	2,986	2,990	1,625	1,708
2011	13,480	13,553	351	353	3,043	3,047	1,646	1,731
2012	13,772	13,846	359	361	3,073	3,077	1,663	1,749
2013	14,063	14,139	367	369	3,097	3,102	1,674	1,761
2014	14,355	14,433	375	377	3,121	3,126	1,691	1,778
2015	14,647	14,726	383	385	3,148	3,152	1,706	1,794
2016	14,936	15,016	391	393	3,181	3,186	1,718	1,807
2017	15,224	15,307	399	401	3,210	3,215	1,733	1,824
2018	15,513	15,597	407	409	3,234	3,239	1,757	1,849
2019	15,802	15,887	415	417	3,266	3,271	1,786	1,879
2020	16,091	16,178	423	425	3,288	3,293	1,804	1,898
2021	16,380	16,468	431	433	3,305	3,310	1,823	1,919
2022	16,668	16,759	438	441	3,335	3,339	1,852	1,949
2023	16,957	17,049	446	449	3,364	3,369	1,870	1,968
2024	17,246	17,339	454	457	3,393	3,398	1,893	1,992
2025	17,535	17,630	462	465	3,426	3,431	1,912	2,012
2026	17,821	17,918	470	473	3,455	3,460	1,935	2,037
2027	18,108	18,206	478	481	3,483	3,489	1,958	2,061
2028	18,395	18,495	486	489	3,513	3,518	1,981	2,086
2029	18,682	18,783	494	497	3,542	3,547	2,005	2,111
2030	18,968	19,071	502	505	3,572	3,577	2,030	2,137
2031	19,255	19,360	510	513	3,602	3,607	2,055	2,163
2032	19,542	19,648	518	521	3,632	3,637	2,080	2,190
2033	19,829	19,936	526	529	3,662	3,668	2,106	2,217
2034	20,116	20,225	534	537	3,693	3,698	2,132	2,244
2035	20,402	20,513	542	545	3,724	3,729	2,158	2,272
2036	20,689	20,801	549	553	3,755	3,760	2,185	2,301
2037	20,976	21,090	557	561	3,786	3,792	2,213	2,330
2038	21,263	21,378	565	569	3,818	3,824	2,240	2,359
2039	21,549	21,666	573	577	3,850	3,856	2,269	2,389
2040	21,836	21,955	581	585	3,882	3,888	2,298	2,420

3.2 Contribution of Nonroad Diesel Engines to National Emission Inventories

This section provides the contribution of nonroad diesel engines to national baseline emission inventories in 1996, 2020, and 2030. The emission inventories are based on 48-state inventories that exclude Alaska and Hawaii to be consistent with the air quality modeling region. The baseline cases represent current and future emissions only with the existing standards. For the final rule, these baseline inventories now incorporate recent standards that cover large spark-ignition engines (>25 hp), recreational equipment, and recreational marine diesel engines (>50 hp).[10]

The calendar years correspond to those chosen for the air quality modeling. Pollutants discussed include $PM_{2.5}$, NO_x, SO_2, VOC, and CO. VOC includes both exhaust and evaporative emissions.

Of interest are the contributions of emissions from nonroad diesel sources affected by the final rule. For $PM_{2.5}$ and SO_2, this includes emissions from all nonroad diesel sources. For NO_x, VOC, and CO, this includes emissions from land-based nonroad diesel engines. Contributions to both total mobile source emissions and total emissions from all sources are presented. For $PM_{2.5}$, contributions of nonroad diesel engines to both total diesel $PM_{2.5}$ and total manmade $PM_{2.5}$ are also presented.

The development of the 1996, 2020, and 2030 baseline emission inventories for the nonroad sector and for the sectors not affected by this rule are briefly described, followed by discussions for each pollutant of the contribution of nonroad diesel engines to national baseline inventories.

3.2.1 Baseline Emission Inventory Development

For 1996, 2020, and 2030, county-level emission estimates were developed by Pechan under contract to EPA. These were used as input for the air quality modeling. These inventories account for county-level differences in parameters such as fuel characteristics and temperature. The draft NONROAD2002 model was used to generate the county-level emission estimates for all nonroad sources, with the exception of commercial marine engines, locomotives, and aircraft. The methodology has been documented elsewhere.[11]

The highway estimates are based on the MOBILE5b model, but with some further adjustments to reflect MOBILE6 emission factors. The highway inventories are similar to those prepared for HD2007 rulemaking, with the exception of adjustments to NO_x and VOC for California counties, based on county-level estimates from the California Air Resources Board.[12]

The stationary point and area source estimates are also based on the HD2007 rulemaking, with the exception of adjustments to NO_x and VOC for California counties, based on county-level estimates from the California Air Resources Board. There were also some stack parameter corrections made to the point source estimates.

The inventories developed by Pechan were used in this section for the following categories: recreational marine spark-ignition engines, commercial marine vessels fueled with gasoline and coal, aircraft, and stationary point and area sources. For the remaining categories, updated national estimates were substituted that reflect recent rulemakings and/or updated model inputs, fuel parameters and usage. The basis for the updated estimates for the remaining categories is described below.

The model inputs for the nonroad diesel sources have been described in detail in Section 3.1. The emission estimates for the land-based diesel and recreational marine diesel categories were based on national level runs with the draft NONROAD2004 model. This was done for two reasons. First, the baseline inventories for 2020 and 2030 were revised since the county-level estimates were developed (specifically, $PM_{2.5}$ and SO_2 emissions were changed to reflect revised diesel fuel sulfur inputs, standards affecting recreational marine diesel engines were promulgated, and model inputs such as base year populations were updated). It was not possible to develop revised county-level estimates for these categories due to resource and time constraints. Second, county-level estimates were developed only for 2020 and 2030. Estimates for interim years are also needed to fully evaluate the anticipated emission benefits of the final rule. Interim year estimates are generated using national level model runs. To be consistent with other sections of the Final RIA in which interim year estimates from 1996 to 2030 are presented, the inventory estimates presented here for the land-based diesel and recreational marine diesel categories are based on national level model runs. Model results for national level runs are similar to those based on an aggregation of county-level runs.

For nonroad spark-ignition engines, the emission estimates were based on national level runs with the draft NONROAD2004 model, in order to account for the recent rulemaking that affects large spark-ignition engines. The draft NONROAD2004 model accounts for the exhaust provisions of the rule. Additional adjustments were made to the VOC model output to account for the evaporative provisions of the rule, since the draft NONROAD2004 model does not yet incorporate the evaporative provisions of the rulemaking.

The commercial marine category has been divided into three subcategories: commercial marine diesel, commercial marine residual, and commercial marine other. The commercial marine diesel category includes compression-ignition engines using diesel fuel (generally includes Category 1 and 2 engines). The commercial marine residual category includes compression-ignition engines using residual fuel (includes Category 3 engines). The commercial marine other category includes commercial marine engines using gasoline or coal. The emission estimates for the commercial marine diesel and residual categories were updated to reflect the 1999 and 2003 rulemakings affecting commercial marine compression-ignition engines. In addition, the SO2 estimates for commercial marine diesel vessels are based on the updated fuel sulfur levels and fuel consumption estimates provided in Section 3.1.

Emission estimates for the locomotive category were revised to reflect the updated fuel sulfur levels and fuel consumption estimates provided in Section 3.1. Finally, the motorcycle portions of the highway estimates were revised to incorporate updated estimates contained in the recent rulemaking affecting motorcycles.

3.2.2 $PM_{2.5}$ Emissions

Table 3.2-1 provides the contribution of land-based diesel engines and other source categories to total diesel $PM_{2.5}$ emissions.

$PM_{2.5}$ emissions from land-based nonroad diesel engines are 46 percent of the total diesel $PM_{2.5}$ emissions in 1996, and this percentage increases to 72 percent by 2030. Emissions from land-based nonroad diesel engines actually decrease from 186,507 tons in 1996 to 129,058 tons in 2020 due to the existing emission standards. From 2020 to 2030, however, emissions increase to 142,484 tons, as growth in this sector offsets the effect of the existing emission standards.

$PM_{2.5}$ emissions from recreational marine diesel engines, commercial marine diesel engines, and locomotives will also be affected by this rule due to the fuel sulfur requirements. For all nonroad diesel sources affected by this rule, the contribution to total diesel $PM_{2.5}$ emissions increases from 56 percent in 1996 to 91 percent in 2030.

Table 3.2-2 provides the contribution of land-based diesel engines and other source categories to total manmade $PM_{2.5}$ emissions. $PM_{2.5}$ emissions from land-based nonroad diesel engines are 8 percent of the total manmade $PM_{2.5}$ emissions in 1996, and this percentage drops slightly to 6 percent in 2020 and 2030. The contribution of land-based diesel engines to total mobile source $PM_{2.5}$ emissions is 33 percent in 1996, rising slightly to 35 percent by 2030. For all nonroad diesel sources, the contribution to total manmade $PM_{2.5}$ emissions is 10 percent in 1996, and this percentage drops slightly to 8 percent in 2020 and 2030.

3.2.3 NO_x Emissions

Table 3.2-3 provides the contribution of land-based diesel engines and other source categories to total NO_x emissions.

NO_x emissions from land-based nonroad diesel engines are 6 percent of the total emissions in 1996, and this percentage increases to 8 percent by 2030. The contribution of land-based diesel engines to total mobile source NO_x emissions is 12 percent in 1996, rising to 24 percent by 2030. Emissions from land-based nonroad diesel engines actually decrease from 1,564,904 tons in 1996 to 1,119,481 tons in 2020 due to the existing emission standards. From 2020 to 2030, however, emissions increase to 1,192,833 tons, as growth in this sector offsets the effect of the existing emission standards.

NO_x emissions from recreational marine diesel engines, commercial marine diesel engines, and locomotives will not be affected by this rule. For these categories combined, the contribution to total NO_x emissions remains stable at 7-8 percent from 1996 to 2030.

3.2.4 SO_2 Emissions

Table 3.2-4 provides the contribution of land-based diesel engines and other source categories to total SO_2 emissions.

SO_2 emissions from land-based nonroad diesel engines are 1 percent of the total emissions in 1996, and this percentage increases to 2 percent by 2030. The contribution of land-based diesel engines to total mobile source SO_2 emissions is 20 percent in 1996, rising to 33 percent by 2030, due to continued growth in this sector.

SO_2 emissions from recreational marine diesel engines, commercial marine diesel engines, and locomotives will also be affected by this rule due to the fuel sulfur requirements. For all nonroad diesel sources affected by this rule, the contribution to total SO_2 emissions remains relatively stable at 1 percent.

3.2.5 VOC Emissions

Table 3.2-5 provides the contribution of land-based diesel engines and other source categories to total VOC emissions. VOC includes both exhaust and evaporative emissions. VOC is an ozone precursor; therefore, VOC inventories are required for air quality modeling.

VOC emissions from land-based nonroad diesel engines are 1 percent of the total emissions in 1996, and this percentage increases to 2 percent by 2030. The contribution of land-based diesel engines to total mobile source VOC emissions is 3 percent in 1996, decreasing slightly to 2 percent by 2030. Emissions from land-based nonroad diesel engines actually decrease from 220,971 tons in 1996 to 97,513 tons in 2020 due to the existing emission standards. From 2020 to 2030, however, emissions increase to 96,374 tons, as growth in this sector offsets the effect of the existing emission standards.

VOC emissions from recreational marine diesel engines, commercial marine diesel engines, and locomotives will not be affected by this rule. For these categories combined, the contribution to total VOC emissions is less than 1 percent.

3.2.6 CO Emissions

Table 3.2-6 provides the contribution of land-based diesel engines and other source categories to total CO emissions.

CO emissions from land-based nonroad diesel engines are 1 percent of the total emissions in 1996, and this percentage remains stable at 1 percent by 2030. The contribution of land-based diesel engines to total mobile source CO emissions is also 1 percent in 1996, remaining at 1 percent by 2030. Emissions from land-based nonroad diesel engines actually decrease from 1,004,586 tons in 1996 to 697,630 tons in 2020 due to the existing emission standards. From 2020 to 2030, however, emissions increase to 786,181 tons, as growth in this sector offsets the effect of the existing emission standards.

CO emissions from recreational marine diesel engines, commercial marine diesel engines, and locomotives will not be affected by this rule. For these categories combined, the contribution to total CO emissions is less than 1 percent in 1996 and 2030.

Table 3.2-1
Annual Diesel $PM_{2.5}$ Baseline Emission Levels for Mobile and Other Source Categories[a]

Category	1996			2020			2030		
	short tons	% of mobile source	% of total	short tons	% of mobile source	% of total	short tons	% of mobile source	% of total
Land-Based Nonroad Diesel	186,507	47.2%	45.8%	129,058	70.3%	68.8%	142,484	73.8%	72.2%
Recreational Marine Diesel ≤50 hp	56	0.0%	0.0%	46	0.0%	0.0%	50	0.0%	0.0%
Recreational Marine Diesel >50 hp	867	0.2%	0.2%	1,214	0.7%	0.6%	1,321	0.7%	0.7%
Commercial Marine Diesel [b]	17,782	4.5%	4.4%	17,665	9.6%	9.4%	19,294	10.0%	9.8%
Locomotive	22,266	5.6%	5.5%	17,213	9.4%	9.2%	16,025	8.3%	8.1%
Total Nonroad Diesel	227,478	58%	56%	165,196	90%	88%	179,173	93%	91%
Total Highway Diesel	167,384	42%	41%	18,426	10%	10%	13,948	7%	7%
Total Mobile Source Diesel	394,862	100%	97%	183,622	100%	98%	193,121	100%	98%
Stationary Point and Area Source Diesel [c]	12,199	—	3%	4,010	—	2%	4,231	—	2%
Total Man-Made Diesel Sources	407,061	—		187,632	—		197,352	—	
Mobile Source Percent of Total	97%	—		98%	—		98%	—	

[a] These are 48-state inventories. They do not include Alaska and Hawaii.
[b] This category includes compression-ignition (CI) vessels using diesel fuel. It does not include CI vessels using residual fuel.
[c] This category includes point sources burning either diesel, distillate oil (diesel), or diesel/kerosene fuel.

Table 3.2-2
Annual $PM_{2.5}$ Baseline Emission Levels for Mobile and Other Source Categories [a,b]

Category	1996			2020			2030		
	short tons	% of mobile source	% of total	short tons	% of mobile source	% of total	short tons	% of mobile source	% of total
Land-Based Nonroad Diesel	186,507	32.6%	8.4%	129,058	34.7%	6.2%	142,484	34.6%	6.4%
Recreational Marine Diesel ≤50 hp	56	0.0%	0.0%	46	0.0%	0.0%	50	0.0%	0.0%
Recreational Marine Diesel >50 hp	867	0.2%	0.0%	1,214	0.3%	0.1%	1,321	0.3%	0.1%
Recreational Marine SI	35,147	6.1%	1.6%	26,110	7.0%	1.3%	27,223	6.6%	1.2%
Nonroad SI ≤25 hp	24,309	4.2%	1.1%	30,151	8.1%	1.4%	34,598	8.4%	1.5%
Nonroad SI >25hp	1,374	0.2%	0.1%	2,302	0.6%	0.1%	2,692	0.7%	0.1%
Recreational SI	7,968	1.4%	0.4%	9,963	2.7%	0.5%	9,460	2.3%	0.4%
Commercial Marine Diesel [c]	17,782	3.1%	0.8%	17,665	4.7%	0.8%	19,294	4.7%	0.9%
Commercial Marine Residual [c]	16,126	2.8%	0.7%	34,532	9.3%	1.7%	51,026	12.4%	2.3%
Commercial Marine Other [c]	1,370	0.2%	0.1%	1,326	0.4%	0.1%	1,427	0.3%	0.1%
Locomotive	22,266	3.9%	1.0%	17,213	4.6%	0.8%	16,025	3.9%	0.7%
Aircraft	27,891	4.9%	1.3%	30,024	8.1%	1.4%	30,606	7.4%	1.4%
Total Nonroad	341,663	60%	15%	299,603	81%	14%	336,206	82%	15%
Total Highway	230,684	40%	10%	72,377	19%	4%	75,825	18%	3%
Total Mobile Sources	572,346	100%	26%	371,980	100%	18%	412,030	100%	18%
Stationary Point and Area Sources	1,653,392	—	74%	1,712,004	—	82%	1,824,609	—	82%
Total Man-Made Sources	2,225,738	—		2,083,984	—		2,236,639	—	
Mobile Source Percent of Total	26%	—		18%	—		18%	—	

[a] These are 48-state inventories. They do not include Alaska and Hawaii.
[b] Excludes natural and miscellaneous sources.

[c] Commercial marine diesel includes Category 1 and 2 compression-ignition (CI) engines using diesel fuel. The residual category includes Category 3 CI engines using residual fuel. The other category includes engines using gasoline and steamships fueled with coal.

Table 3.2-3
Annual NO_x Baseline Emission Levels for Mobile and Other Source Categories [a]

Category	1996			2020			2030		
	short tons	% of mobile source	% of total	short tons	% of mobile source	% of total	short tons	% of mobile source	% of total
Land-Based Nonroad Diesel	1,564,904	12.1%	6.4%	1,119,481	22.2%	7.4%	1,192,833	24.3%	7.8%
Recreational Marine Diesel ≤50 hp	438	0.0%	0.0%	491	0.0%	0.0%	554	0.0%	0.0%
Recreational Marine Diesel >50 hp	33,241	0.3%	0.1%	47,356	0.9%	0.3%	51,531	1.0%	0.3%
Recreational Marine SI	33,304	0.3%	0.1%	61,749	1.2%	0.4%	67,893	1.4%	0.4%
Nonroad SI ≤25 hp	63,120	0.5%	0.3%	98,584	2.0%	0.7%	114,447	2.3%	0.8%
Nonroad SI >25hp	273,082	2.1%	1.1%	43,315	0.9%	0.3%	43,527	0.9%	0.3%
Recreational SI	4,297	0.0%	0.0%	17,129	0.3%	0.1%	19,389	0.4%	0.1%
Commercial Marine Diesel [b]	639,630	4.9%	2.6%	587,115	11.6%	3.9%	602,967	12.3%	4.0%
Commercial Marine Residual [b]	184,275	1.4%	0.8%	356,445	7.1%	2.4%	514,881	10.5%	3.4%
Commercial Marine Other [b]	5,979	0.0%	0.0%	4,207	0.1%	0.0%	4,020	0.1%	0.0%
Locomotive	934,070	7.2%	3.8%	508,084	10.1%	3.4%	481,077	9.8%	3.2%
Aircraft	165,018	1.3%	0.7%	228,851	4.5%	1.5%	258,102	5.2%	1.7%
Total Nonroad	3,901,357	30%	16%	3,072,808	61%	20%	3,351,220	68%	22%
Total Highway	9,060,923	70%	37%	1,975,312	39%	13%	1,566,902	32%	10%
Total Mobile Sources	12,962,279	100%	53%	5,048,120	100%	33%	4,918,123	100%	32%
Stationary Point and Area Sources [c]	11,449,752	—	47%	10,050,213	—	67%	10,320,361	—	68%
Total Man-Made Sources	24,412,031	—		15,098,333	—		15,238,484	—	
Mobile Source Percent of Total	53%	—		33%	—		32%	—	

[a] These are 48-state inventories. They do not include Alaska and Hawaii.

[b] Commercial marine diesel includes Category 1 and 2 compression-ignition (CI) engines using diesel fuel. The residual category includes Category 3 CI engines using residual fuel. The other category includes engines using gasoline and steamships fueled with coal.

[c] Does not include effects of the proposed Rule to Reduce Interstate Transport of Fine Particulate Matter and Ozone (Interstate Air Quality Rule). 69 FR 4566 (January 30, 2004). See http://www.epa.gov/interstateairquality/rule.html.

Table 3.2-4
Annual SO_2 Baseline Emission Levels for Mobile and Other Source Categories [a]

Category	1996			2020			2030		
	short tons	% of mobile source	% of total	short tons	% of mobile source	% of total	short tons	% of mobile source	% of total
Land-Based Nonroad Diesel	143,572	19.9%	0.8%	237,044	35.7%	1.6%	279,511	32.8%	1.8%
Recreational Marine Diesel ≤50 hp	53	0.0%	0.0%	85	0.0%	0.0%	101	0.0%	0.0%
Recreational Marine Diesel >50 hp	4,234	0.6%	0.0%	6,766	1.0%	0.0%	8,057	0.9%	0.1%
Recreational Marine SI	2,170	0.3%	0.0%	2,522	0.4%	0.0%	2,698	0.3%	0.0%
Nonroad SI ≤25 hp	6,803	0.9%	0.0%	8,623	1.3%	0.1%	10,007	1.2%	0.1%
Nonroad SI >25hp	890	0.1%	0.0%	879	0.1%	0.0%	998	0.1%	0.0%
Recreational SI	949	0.1%	0.0%	2,561	0.4%	0.0%	2,691	0.3%	0.0%
Commercial Marine Diesel [b]	30,136	4.2%	0.2%	29,268	4.4%	0.2%	33,020	3.9%	0.2%
Commercial Marine Residual [b]	151,559	21.0%	0.8%	263,076	39.6%	1.7%	387,754	45.6%	2.5%
Commercial Marine Other [b]	9,266	1.3%	0.1%	9,677	1.5%	0.1%	10,366	1.2%	0.1%
Locomotive	56,193	7.8%	0.3%	53,352	8.0%	0.4%	58,103	6.8%	0.4%
Aircraft	11,305	1.6%	0.1%	15,267	2.3%	0.1%	16,813	2.0%	0.1%
Total Nonroad	417,128	58%	2%	629,118	95%	4%	810,119	95%	5%
Total Highway	302,938	42%	2%	35,311	5%	0%	40,788	5%	0%
Total Mobile Sources	720,066	100%	4%	664,429	100%	4%	850,907	100%	5%
Stationary Point and Area Sources [c]	17,636,602	—	96%	14,510,426	—	96%	14,782,220	—	95%
Total Man-Made Sources	18,356,668	—		15,174,855	—		15,633,127	—	
Mobile Source Percent of Total	4%	—		4%	—		5%	—	

[a] These are 48-state inventories. They do not include Alaska and Hawaii.

[b] Commercial marine diesel includes Category 1 and 2 compression-ignition (CI) engines using diesel fuel. The residual category includes Category 3 CI engines using residual fuel. The other category includes engines using gasoline and steamships fueled with coal.
[c] Does not include effects of the proposed Rule to Reduce Interstate Transport of Fine Particulate Matter and Ozone (Interstate Air Quality Rule). 69 FR 4566 (January 30, 2004). See http://www.epa.gov/interstateairquality/rule.html.

Table 3.2-5
Annual VOC Baseline Emission Levels for Mobile and Other Source Categories [a]

Category	1996			2020			2030		
	short tons	% of mobile source	% of total	short tons	% of mobile source	% of total	short tons	% of mobile source	% of total
Land-Based Nonroad Diesel	220,971	2.7%	1.2%	97,513	2.5%	0.7%	96,374	2.3%	0.6%
Recreational Marine Diesel ≤50 hp	106	0.0%	0.0%	52	0.0%	0.0%	50	0.0%	0.0%
Recreational Marine Diesel >50 hp	1,191	0.0%	0.0%	1,552	0.0%	0.0%	1,619	0.0%	0.0%
Recreational Marine SI	804,488	9.7%	4.3%	380,891	9.8%	2.8%	372,970	8.8%	2.5%
Nonroad SI ≤25 hp	1,332,392	16.0%	7.2%	656,845	16.9%	4.9%	758,512	17.9%	5.1%
Nonroad SI >25hp	88,526	1.1%	0.5%	10,629	0.3%	0.1%	9,664	0.2%	0.1%
Recreational SI	322,766	3.9%	1.7%	345,649	8.9%	2.6%	327,403	7.7%	2.2%
Commercial Marine Diesel [b]	21,540	0.3%	0.1%	24,005	0.6%	0.2%	26,169	0.6%	0.2%
Commercial Marine Residual [b]	7,446	0.1%	0.0%	17,584	0.5%	0.1%	26,711	0.6%	0.2%
Commercial Marine Other [b]	892	0.0%	0.0%	925	0.0%	0.0%	1,001	0.0%	0.0%
Locomotive	38,035	0.5%	0.2%	30,125	0.8%	0.2%	28,580	0.7%	0.2%
Aircraft	176,394	2.1%	1.0%	239,654	6.2%	1.8%	265,561	6.3%	1.8%
Total Nonroad	3,014,747	36%	16%	1,805,424	47%	13%	1,914,614	45%	13%
Total Highway	5,291,388	64%	29%	2,071,456	53%	15%	2,312,561	55%	15%
Total Mobile Sources	8,306,135	100%	45%	3,876,880	100%	29%	4,227,175	100%	28%
Stationary Point and Area Sources	10,249,136	—	55%	9,648,376	—	71%	10,751,134	—	72%
Total Man-Made Sources	18,555,271	—		13,525,256	—		14,978,309	—	
Mobile Source Percent of Total	45%	—		29%	—		28%	—	

[a] These are 48-state inventories. They do not include Alaska and Hawaii.
[b] Commercial marine diesel includes Category 1 and 2 compression-ignition (CI) engines using diesel fuel. The residual category includes Category 3 CI engines using residual fuel. The other category includes engines using gasoline and steamships fueled with coal.

Table 3.2-6
Annual CO Baseline Emission Levels for Mobile and Other Source Categories [a]

Category	1996			2020			2030		
	short tons	% of mobile source	% of total	short tons	% of mobile sources	% of total	short tons	% of mobile source	% of total
Land-Based Nonroad Diesel	1,004,586	1.3%	1.1%	697,630	0.9%	0.7%	786,181	0.8%	0.7%
Recreational Marine Diesel ≤50 hp	304	0.0%	0.0%	243	0.0%	0.0%	259	0.0%	0.0%
Recreational Marine Diesel >50 hp	5,120	0.0%	0.0%	9,239	0.0%	0.0%	10,973	0.0%	0.0%
Recreational Marine SI	1,995,907	2.5%	2.1%	1,977,403	2.4%	2.0%	2,075,666	2.2%	1.9%
Nonroad SI ≤25 hp	18,013,533	23.0%	19.0%	26,372,980	32.4%	27.2%	30,611,599	32.8%	27.9%
Nonroad SI >25hp	1,614,394	2.1%	1.7%	275,647	0.3%	0.3%	264,047	0.3%	0.2%
Recreational SI	921,345	1.2%	1.0%	1,820,865	2.2%	1.9%	1,836,350	2.0%	1.7%
Commercial Marine Diesel [b]	93,638	0.1%	0.1%	114,397	0.1%	0.1%	123,436	0.1%	0.1%
Commercial Marine Residual [b]	15,245	0.0%	0.0%	36,165	0.0%	0.0%	54,924	0.1%	0.1%
Commercial Marine Other [b]	5,869	0.0%	0.0%	6,542	0.0%	0.0%	7,058	0.0%	0.0%
Locomotive	92,496	0.1%	0.1%	99,227	0.1%	0.1%	107,780	0.1%	0.1%
Aircraft	949,313	1.2%	1.0%	1,387,178	1.7%	1.4%	1,502,265	1.6%	1.4%
Total Nonroad	24,711,750	32%	26%	32,797,515	40%	34%	37,380,538	40%	34%
Total Highway	53,685,026	68%	57%	48,529,203	60%	50%	55,847,203	60%	51%
Total Mobile Sources	78,396,776	100%	83%	81,326,718	100%	84%	93,227,742	100%	85%
Stationary Point and Area Sources	16,318,451	—	17%	15,648,555	—	16%	16,325,306	—	15%
Total Man-Made Sources	94,715,227	—		96,975,273	—		109,553,048	—	
Mobile Source Percent of Total	83%	—		84%	—		85%	—	

[a] These are 48-state inventories. They do not include Alaska and Hawaii.

[b] Commercial marine diesel includes Category 1 and 2 compression-ignition (CI) engines using diesel fuel. The residual category includes Category 3 CI engines using residual fuel. The other category includes engines using gasoline and steamships fueled with coal.

3.3 Contribution of Nonroad Diesel Engines to Selected Local Emission Inventories

The contribution of land-based nonroad compression-ignition (CI) engines to $PM_{2.5}$ and NO_x emission inventories in many U.S. cities can be significantly greater than that reflected by national average values.[A] This is not surprising given the high density of these engines one would expect to be operating in urban areas. EPA selected a collection of typical cities spread across the United States to compare projected urban inventories with national average ones for 1996, 2020, and 2030. The results of this analysis are shown below.

3.3.1 $PM_{2.5}$ Emissions

As illustrated in Tables 3.3-1, 3.3-2, and 3.3-3, EPA's city-specific analysis of selected metropolitan areas for 1996, 2020, and 2030 show that land-based nonroad diesel engine engines are a significant contributor to total $PM_{2.5}$ emissions from all man-made sources.

[A] Construction, industrial, and commercial nonroad diesel equipment comprise most of the land-based nonroad emission inventory. These types of equipment are more concentrated in urban areas where construction projects, manufacturing, and commercial operations are prevalent.

Table 3.3-1
Land-Based Nonroad Percent Contribution
to $PM_{2.5}$ Inventories in Selected Urban Areas in 1996[a,b]

MSA, CMSA / State	Land-Based Diesel (short tons)	Mobile Sources (short tons)	Total Man-Made Sources (short tons)	Land-Based Diesel as % of Total	Land-Based Diesel as % of Mobile Sources
Atlanta, GA	1,650	7,308	22,190	7%	23%
Boston, MA	4,265	9,539	23,254	18%	45%
Chicago, IL	3,374	10,106	40,339	8%	33%
Dallas-Fort Worth, TX	1,826	5,606	13,667	13%	33%
Indianapolis, IN	1,040	3,126	7,083	15%	33%
Minneapolis, MN	1,484	4,238	15,499	10%	35%
New York, NY	2,991	6,757	23,380	13%	44%
Orlando, FL	764	2,559	5,436	14%	30%
Sacramento, CA	529	2,140	7,103	7%	25%
San Diego, CA	879	3,715	9,631	9%	24%
Denver, CO	1,125	3,199	10,107	11%	35%
El Paso, TX	252	822	1,637	15%	31%
Las Vegas, NV-AZ	1,155	2,700	7,511	15%	43%
Phoenix-Mesa, AZ	1,549	4,994	10,100	15%	31%
Seattle, WA	1,119	4,259	15,187	7%	26%

[a] Includes only direct exhaust emissions; see Chapter 2 for a discussion of secondary fine PM levels.
[b] Based on inventories developed for the proposed rule.

Table 3.3-2
Annual Land-Based Nonroad Diesel Contributions
to $PM_{2.5}$ Inventories in Selected Urban Areas in 2020[a,b]

MSA, CMSA / State	Land-Based Diesel (short tons)	Mobile Sources (short tons)	Total Man-Made Sources (short tons)	Land-Based Diesel as % of Total	Land-Based Diesel as % of Mobile Sources
Atlanta, GA	1,429	4,506	22,846	6%	32%
Boston, MA	3,580	6,720	20,365	18%	53%
Chicago, IL	2,824	6,984	42,211	7%	40%
Dallas-Fort Worth, TX	1,499	3,544	15,202	10%	42%
Indianapolis, IN	794	1,779	6,238	13%	45%
Minneapolis, MN	1,188	2,509	15,096	8%	47%
New York, NY	2,573	4,549	21,566	12%	57%
Orlando, FL	652	1,743	5,627	12%	37%
Sacramento, CA	391	1,301	5,505	7%	30%
San Diego, CA	678	2,478	9,135	7%	27%
Denver, CO	923	2,149	10,954	8%	43%
El Paso, TX	212	478	1,140	19%	44%
Las Vegas, NV-AZ	961	2,080	7,804	12%	46%
Phoenix-Mesa, AZ	1,299	3,512	10,768	12%	37%
Seattle, WA	946	3,043	13,094	7%	31%

[a] Includes only direct exhaust emissions; see Chapter 2 for a discussion of secondary fine PM levels.
[b] Based on inventories developed for the proposed rule.

Table 3.3-3
Land-Based Nonroad Percent Contribution
to $PM_{2.5}$ Inventories in Selected Urban Areas in 2030[a,b]

MSA, CMSA / State	Land-Based Diesel (short tons)	Mobile Sources (short tons)	Total Man-Made Sources (short tons)	Land-Based Diesel as % of Total	Land-Based Diesel as % of Mobile Sources
Atlanta, GA	1,647	4,937	24,880	7%	33%
Boston, MA	4,132	7,529	21,846	19%	55%
Chicago, IL	3,236	7,735	45,975	7%	42%
Dallas-Fort Worth, TX	1,721	3,919	16,622	10%	44%
Indianapolis, IN	902	1,934	6,753	13%	47%
Minneapolis, MN	1,354	2,769	16,586	8%	49%
New York, NY	2,953	5,064	22,891	13%	58%
Orlando, FL	752	1,957	6,084	12%	38%
Sacramento, CA	447	1,445	5,890	8%	31%
San Diego, CA	777	2,770	10,096	8%	28%
Denver, CO	1,060	2,379	12,117	9%	45%
El Paso, TX	244	524	1,243	20%	47%
Las Vegas, NV-AZ	1,113	2,307	8,512	13%	48%
Phoenix-Mesa, AZ	1,499	3,870	11,989	13%	39%
Seattle, WA	1,084	3,357	14,148	8%	32%

[a] Includes only direct exhaust emissions; see Chapter 2 for a discussion of secondary fine PM levels.
[b] Based on inventories developed for the proposed rule.

3.3.2 NO_x Emissions

As presented in Tables 3.3-4, 3.3-5, and 3.3-6, EPA's city-specific analysis of selected metropolitan areas for 1996, 2020, and 2030 show that land-based nonroad diesel engine engines are a significant contributor to total NO_x emissions from all man-made sources.

Table 3.3-4
Land-Based Nonroad Percent Contribution
to NO_x Inventories in Selected Urban Areas in 1996[a]

MSA, CMSA / State	Land-Based Diesel (short tons)	Mobile Sources (short tons)	Total Man-Made Sources (short tons)	Land-Based Diesel as % of Total	Land-Based Diesel as % of Mobile Sources
Atlanta, GA	16,238	205,465	298,361	5%	8%
Boston, MA	43,362	232,444	311,045	14%	19%
Chicago, IL	32,276	296,710	509,853	6%	11%
Dallas-Fort Worth, TX	17,852	152,878	186.824	10%	12%
Indianapolis, IN	9,487	89,291	113,300	8%	11%
Minneapolis, MN	13,843	124,437	224,817	6%	11%
New York, NY	29,543	184,384	262,021	11%	16%
Orlando, FL	7,493	61,667	75,714	10%	12%
Sacramento, CA	5,666	55,144	58,757	10%	10%
San Diego, CA	9,460	99,325	107,024	9%	10%
Denver, CO	11,080	86,329	146,807	8%	13%
El Paso, TX	2,498	24,382	30,160	8%	10%
Las Vegas, NV-AZ	11,788	50,724	108,875	11%	23%
Phoenix-Mesa, AZ	15,145	115,544	161,606	9%	13%
Seattle, WA	11,227	115,264	133,840	8%	10%

[a] Based on inventories developed for the proposed rule.

Table 3.3-5
Annual Land-Based Nonroad Diesel Contributions
to NO_x Inventories in Selected Urban Areas in 2020[a]

MSA, CMSA / State	Land-Based Diesel (short tons)	Mobile Sources (short tons)	Total Man-Made Sources (short tons)	Land-Based Diesel as % of Total	Land-Based Diesel as % of Mobile Sources
Atlanta, GA	12,650	69,816	193,456	7%	18%
Boston, MA	31,282	93,308	167,572	19%	34%
Chicago, IL	24,732	123,823	333,945	7%	20%
Dallas-Fort Worth, TX	13,334	60,745	101,453	13%	22%
Indianapolis, IN	6,982	36,283	60,059	12%	19%
Minneapolis, MN	10,376	47,375	165,775	6%	22%
New York, NY	22,456	67,083	112,960	20%	33%
Orlando, FL	5,837	28,653	45,362	13%	20%
Sacramento, CA	4,297	18,870	23,111	19%	23%
San Diego, CA	7,464	46,005	51,909	14%	16%
Denver, CO	8,251	38,435	103,533	8%	21%
El Paso, TX	1,847	10,105	12,452	15%	18%
Las Vegas, NV-AZ	8,501	26,840	72,829	12%	32%
Phoenix-Mesa, AZ	11,560	48,348	105,185	11%	24%
Seattle, WA	8,283	51,252	76,161	11%	16%

[a] Based on inventories developed for the proposed rule.

Table 3.3-6
Land-Based Nonroad Percent Contribution
to NO_x Inventories in Selected Urban Areas in 2030[a]

MSA, CMSA / State	Land-Based Diesel (short tons)	Mobile Sources (short tons)	Total Man-Made Sources (short tons)	Land-Based Diesel as % of Total	Land-Based Diesel as % of Mobile Sources
Atlanta, GA	14,190	65,746	191,932	7%	22%
Boston, MA	35,039	92,537	168,422	21%	38%
Chicago, IL	27,525	120,694	334,334	8%	23%
Dallas-Fort Worth, TX	14,839	56,907	100,721	15%	26%
Indianapolis, IN	7,641	34,442	58,793	13%	22%
Minneapolis, MN	11,444	45,326	167,154	7%	25%
New York, NY	25,064	67,163	108,215	23%	37%
Orlando, FL	6,551	28,365	45,267	14%	23%
Sacramento, CA	4,806	17,498	21,952	22%	27%
San Diego, CA	8,401	43,930	50,296	17%	19%
Denver, CO	9,185	37,105	104,217	9%	25%
El Paso, TX	2,062	9,422	11,905	17%	22%
Las Vegas, NV-AZ	9,544	26,349	72,926	13%	36%
Phoenix-Mesa, AZ	12,952	46,280	106,061	12%	28%
Seattle, WA	9,247	49,258	77,133	12%	19%

[a] Based on inventories developed for the proposed rule.

3.4 Nonroad Diesel Controlled Emission Inventory Development

This section describes how the controlled emission inventories were developed for the four categories of nonroad diesel engines affected by this rule: land-based diesel engines, commercial marine diesel vessels, locomotives, and recreational marine diesel engines. For land-based diesel engines, there are separate sections for criteria (i.e., $PM_{2.5}$, NO_x, SO_2, VOC, and CO) and air toxics emission development.

3.4.1 Land-Based Diesel Engines—$PM_{2.5}$, NO_x, SO_2, VOC, and CO Emissions

The emission inventory estimates used in this rule were generated using the draft NONROAD2004 model with certain input modifications to account for the in-use diesel fuel sulfur reductions and the engine controls associated with the new emission standards. This section will describe only these modifications to the model inputs, since the other aspects of the model, including inputs for earlier engines, are covered in detail in the technical reports that document the draft NONROAD2004 model.

3.4.1.1 Standards and Zero-Hour Emission Factors

The new emission standards are summarized in Table 3.4-1. The modeled emission factors corresponding to the new emission standards are shown in Table 3.4-2. These emission factors are derived from the standards by applying an assumed 8 percent compliance margin to the standard. This compliance margin was derived from data for highway diesel vehicles and used in the HD2007 rulemaking.

Besides exhaust emissions, the final rule includes changes in crankcase hydrocarbon emissions. Crankcase losses before Tier 4 have been modeled as 2.0 percent of exhaust HC, and any crankcase emissions of other pollutants have been considered negligible. For all Tier 4 engines, including those using transitional controls without particulate traps, our modeling now assumes zero crankcase emissions.

3.4.1.2 Transient Adjustment Factors

The supplemental nonroad transient test will apply to a nonroad diesel engine when that engine must first show compliance with the Tier 4 PM and NO_x+NMHC emissions standards which are based on the performance of the advanced post-combustion emissions control systems (e.g., catalyzed-diesel particulate filters and NO_x adsorbers). This is 2011 for engines at or above 175 hp, 2012 for 75-175 hp engines, and 2013 for engines under 75 hp. Details regarding the transient testing requirements and manufacturer options are provided in Section III of the preamble. More broadly though, transient emissions control is expected to be an integral part of all Tier 4 engine design considerations, including engines under 75 hp meeting either the 0.22 g/hp-hr or 0.30 g/hp-hr Tier 4 PM standards in 2008. Thus, there was no Transient Adjustment Factor (TAF) applied to the emission factors for Tier 4 engines (i.e., the model applies a TAF of 1.0); the zero-hour emission factor was modeled simply as the value of the standard minus an assumed 8 percent compliance margin.

Table 3.4-1
Tier 4 Emission Standards Modeled

Engine Power	Emission Standard (g/hp-hr)					Model Year(s)
	transitional or final	PM	NO_x[a]	NMHC [a]	CO [d]	
kW < 19 (hp <25)	final	0.30	5.6 [b,c]		6.0/4.9 [c]	2008
19 ≤ kW < 56 (25 ≤ hp < 75)	transitional	0.22	5.6/3.5 [b,c]		4.1/3.7 [c]	2008-2012
	final	0.02	3.5 [b]		4.1/3.7 [c]	2013
56 ≤ kW < 130 (75 ≤ hp < 175)	transitional	0.01	0.30 (50%)	0.14 (50%)	3.7 [c]	2012-2013
	final	0.01	0.30	0.14	3.7 [c]	2014
130 ≤ kW < 560 (175 ≤ hp < 750)	transitional	0.01	0.30 (50%)	0.14 (50%)	2.6 [c]	2011-2013
	final	0.01	0.30	0.14	2.6 [c]	2014
kW ≥ 560 (hp ≥ 750) except Generator sets	transitional	0.075	2.6	0.30	2.6 [c]	2011-2014
	final	0.03	2.6	0.14	2.6 [c]	2015
Generator sets 560 ≤ kW ≤ 895 (750 ≤ hp ≤ 1200)	transitional	0.075	2.6	0.30	2.6 [c]	2011-2014
	final	0.02	0.50	0.14	2.6 [c]	2015
Generator sets kW > 895 (hp > 1200)	transitional	0.075	0.50	0.30	2.6 [c]	2011-2014
	final	0.02	0.50	0.14	2.6 [c]	2015

[a] Percentages are model year sales fractions required to comply with the indicated NO_x and NMHC standards, for model years where less than 100 percent is required. For a complete description of manufacturer options and alternative standards, refer to Section II of the preamble.
[b] This is a combined NMHC + NO_x standard.
[c] This emission standard level is unchanged from the level that applies in the previous model year. For 25-75 hp engines, the transitional NMHC + NO_x standard is 5.6 g/hp-hr for engines below 50 hp and 3.5 g/hp-hr for engines at or above 50 hp. For engines under 75 hp, the CO standard is 6.0 g/hp-hr for engines below 11 hp, 4.9 g/hp-hr for engines 11 to under 25 hp, 4.1 g/hp-hr for engines 25 to below 50 hp and 3.7 g/hp-hr for engines at or above 50 hp.
[d] There are no Tier 4 CO standards. The CO emission standard level is unchanged from the level that applies in the previous model year.

Table 3.4-2
NONROAD Model EF Inputs for Tier 4 Engines

Engine Power	Emission Factor Modeling Inputs, g/hp-hr [a]					Model Year(s)
	Type of standard	PM	NO_x [b,c]	THC [c,d]	CO [e]	
hp ≤ 11	final	0.28	4.30	0.55	4.11	2008
11 < hp ≤ 25	final	0.28	4.44	0.44	2.16	2008
25 < hp ≤ 50	transitional	0.20	4.73	0.28	1.53	2008
	final	0.018	3.0	0.13	0.15	2013
50 < hp ≤ 75	transitional	0.20	3.0	0.18	2.4	2008
	final	0.018	3.0	0.13	0.24	2013
75 < hp ≤ 100	transitional	0.01	3.0 (50%) 0.28 (50%)	0.13	0.24	2012-2013
	final	0.01	0.28	0.13	0.24	2014
100 < hp ≤ 175	transitional	0.01	2.5 (75%) 0.28 (25%)	0.13	0.087	2012-2014
	final	0.01	0.28	0.13	0.087	2015
175 < hp ≤ 300	transitional	0.01	2.5 (50%) 0.28 (50%)	0.13	0.075	2011-2013
	final	0.01	0.28	0.13	0.075	2014
300 < hp ≤ 600	transitional	0.01	2.5 (50%) 0.28 (50%)	0.13	0.084	2011-2013
	final	0.01	0.28	0.13	0.084	2014
600 < hp ≤ 750	transitional	0.01	2.5 (50%) 0.28 (50%)	0.13	0.13	2011-2013
	final	0.01	0.28	0.13	0.13	2014
hp > 750 except Generator sets	transitional	0.069	2.39	0.28	0.076	2011-2014
	final	0.028	2.39	0.13	0.076	2015
Generator sets 750 ≤ hp ≤ 1200	transitional	0.069	2.39	0.28	0.076	2011-2014
	final	0.018	0.46	0.13	0.076	2015
Generator sets hp > 1200	transitional	0.069	0.46	0.28	0.076	2011-2014
	final	0.018	0.46	0.13	0.076	2015

[a] Transient emission control is assumed for Tier 4 engines, so Transient Adjustment Factors are not applied to the emission factors shown here.
[b] Percentages are model-year sales fractions required to comply with the indicated standard.
[c] NMHC + NO_x is a combined standard, so for modeling purposes the NO_x and HC are separated using a NO_x/HC ratio that approximates the results found in prior test programs, as described in technical report NR-009b.
[d] HC Standards are in terms of NMHC, but the model expects inputs as THC, so a conversion factor of 1.02 is applied to the NMHC value to get the THC model input.

[e] CO emissions from Tier 4 engines are assumed to decrease by 90% from its prior levels in any cases where particulate traps are expected for PM control.

3.4.1.3 Deterioration Rates

The deterioration rates (*d*) used for the modeling of Tier 4 engines are the same as used for Tier 3 engines for all affected pollutants (PM, NO_x, HC, and CO). These are listed in Table 3.4-3 below and are fully documented in technical report NR-009b.[1]

Table 3.4-3
Deterioration Rates for Nonroad Diesel Engines

Pollutant	Relative Deterioration Rate (percent increase per percent useful life expended)[a]				
	Base/Tier 0	Tier 1	Tier 2	Tier 3	Tier 4
HC	0.047	0.036	0.034	0.027	0.027
CO	0.185	0.101	0.101	0.151	0.151
NO_x	0.024	0.024	0.009	0.008	0.008
PM	0.473	0.473	0.473	0.473	0.473

[a] At the median life point, the Deterioration Factor = 1 + relative deterioration rate.

3.4.1.4 In-Use Sulfur Levels, Certification Sulfur Levels, and Sulfur Conversion Factors

Tables 3.4-4 and 3.4-5 show the certification and in-use fuel sulfur levels by calendar year and engine power range that were assumed for modeling the engines regulated under this rule. The certification sulfur levels are the default fuel sulfur levels used to calculate the zero mile PM and SO_2 emission factors in the model (referred to as S_{base} in Section 3.1.1.2.1). The in-use fuel sulfur level is the episodic fuel sulfur level (referred to as $S_{in\text{-}use}$ in Section 3.1.1.2.1). Adjustments to PM and SO_2 for in-use fuel sulfur levels are made relative to the certification sulfur levels in the model. As described above for the baseline inventory development, the in-use fuel sulfur content, fuel consumption, sulfate conversion factor, and exhaust HC emission factor (unburned fuel) determine the SO_2 emissions, and a fraction of the fuel sulfur is also converted to sulfate PM. The changes for modeling of the control case are (a) lower sulfur content for in-use and certification fuel per this rule, and (b) the use of a higher sulfur-to-sulfate conversion factor for engines that are expected to use a particulate trap/filter to achieve the PM standards of 0.01 or 0.02 g/hp-hr (30 percent conversion instead of 2.247 percent that is used for all earlier nontrap-equipped engines).

The in-use sulfur levels account for the 500 ppm standard beginning in 2007, the 15 ppm standard for land-based engines beginning in 2010, and the 15 ppm standard for marine engines and locomotives beginning in 2012. The derivation of the annual fuel sulfur levels is described in detail in Chapter 7. The in-use sulfur levels in Table 3.4-5 used for modeling differ slightly from those presented in Chapter 7, since minor revisions were made subsequent to the modeling.

Table 3.4-4
Modeled Certification Diesel Fuel Sulfur Content

Engine Power	Standards	Modeled Certification Fuel Sulfur Content, PPM	Model Year(s)
kW < 56 (hp <75)	Tier 2	2000	through 2007
	transitional	500	2008-2012
	final	15	2013
56 ≤ kW < 75 (75 ≤ hp < 100)	Tier 3 transitional [a]	500	2008-2011
	final	15	2012
75 ≤ kW < 130 (100 ≤ hp < 175)	Tier 3	2000	2007-2011
	final	15	2012
130 ≤ kW < 560 (175 ≤ hp < 750)	Tier 3	2000	2006-2010
	final	15	2011
kW ≥ 560 (hp ≥ 750)	Tier 2	2000	2006-2010
	final	15	2011

[a] The emission standard here is still Tier 3 as in the Baseline case, but since the Tier 3 standard begins in 2008 for 50-100 hp engines it is assumed that this new technology introduction will allow manufacturers to take advantage of the availability of 500 ppm fuel that year.

Table 3.4-5
Modeled 48-State & 50-State In-Use Diesel Fuel Sulfur Content for Controlled Inventories

Applications	Calendar Year(s)	Modeled In-Use Fuel Sulfur Content, ppm	
		48-State	50-State
Land-based, all power ranges	through 2005	2283	2284
	2006	2249	2242
	2007	1140	1139
	2008-2009	348	351
	2010	163	165
	2011-2013	31	32
	2014	19	20
	2015+	11	11
Recreational Marine, Commercial Marine, and Locomotives	through 2000	2641	2640
	2001	2637	2635
	2002-2003	2638	2637
	2004-2005	2639	2637
	2006	2616	2588
	2007	1328	1332
	2008-2009	408	435
	2010	307	319
	2011	234	236
	2012	123	124
	2013	43	44
	2014	51	52
	2015-2017	56	56
	2018-2038	56	55
	2039-2040	55	55

3.4.1.5 Controlled Inventory

Tables 3.4-6a and 3.4-6b present the PM_{10}, $PM_{2.5}$, NO_x, SO_2, VOC, and CO controlled emissions for land-based nonroad diesel engines in 1996 and 2000-2040, for the 48-state and 50-state inventories, respectively.

Table 3.4-6a
Controlled (48-State) Emissions for Land-Based Nonroad Diesel Engines (short tons)

Year	PM_{10}	$PM_{2.5}$	NO_x	SO_2	VOC	CO
1996	192,275	186,507	1,564,904	143,572	220,971	1,004,586
2000	176,056	170,774	1,550,355	161,977	199,887	916,507
2001	170,451	165,338	1,537,890	166,644	191,472	880,129
2002	165,017	160,067	1,526,119	171,309	183,525	845,435
2003	159,268	154,490	1,505,435	175,971	176,383	813,886
2004	153,932	149,314	1,486,335	180,630	169,873	787,559
2005	148,720	144,259	1,467,547	185,287	163,663	763,062
2006	143,840	139,525	1,435,181	187,085	156,952	741,436
2007	132,534	128,558	1,399,787	97,142	150,357	724,449
2008	123,646	119,936	1,359,631	30,359	143,138	707,098
2009	120,512	116,896	1,317,925	31,064	136,085	691,627
2010	116,263	112,775	1,277,888	14,881	129,186	677,599
2011	110,940	107,612	1,224,329	2,853	122,434	650,276
2012	104,319	101,189	1,165,155	2,850	115,877	609,685
2013	97,187	94,271	1,108,560	2,832	109,726	563,695
2014	89,522	86,837	1,031,680	1,724	104,160	518,729
2015	81,780	79,326	958,769	992	98,766	475,349
2016	74,718	72,476	890,935	987	93,976	435,137
2017	68,079	66,036	828,178	984	89,760	398,578
2018	61,986	60,127	772,291	983	85,896	365,813
2019	56,496	54,801	722,094	984	82,398	336,094
2020	51,613	50,065	677,420	986	79,372	309,593
2021	47,285	45,866	639,156	991	76,813	286,679
2022	43,376	42,074	606,068	996	74,680	266,071
2023	39,837	38,642	576,872	1,003	72,854	247,738
2024	36,548	35,452	551,570	1,011	71,291	231,324
2025	33,508	32,503	529,260	1,019	69,973	216,510
2026	30,735	29,813	510,126	1,028	68,878	203,435
2027	28,234	27,387	493,869	1,039	68,008	192,100
2028	26,125	25,341	479,930	1,050	67,319	182,716
2029	24,177	23,452	467,852	1,062	66,761	174,448
2030	22,369	21,698	458,649	1,074	66,344	167,014
2031	20,873	20,247	451,478	1,087	66,118	161,116
2032	19,492	18,907	445,218	1,100	65,979	155,882
2033	18,188	17,643	439,984	1,113	65,904	151,053
2034	16,970	16,461	435,620	1,126	65,909	146,747
2035	15,877	15,401	432,306	1,140	66,004	143,229
2036	14,930	14,482	429,867	1,155	66,186	140,378
2037	14,053	13,631	428,058	1,169	66,418	137,840
2038	13,577	13,169	427,438	1,183	66,781	135,517
2039	13,194	12,798	427,591	1,198	67,195	133,748
2040	12,852	12,467	428,084	1,213	67,645	132,256

Table 3.4-6b
Controlled (50-State) Emissions for Land-Based Nonroad Diesel Engines (short tons)

Year	PM_{10}	$PM_{2.5}$	NO_x	SO_2	VOC	CO
1996	193,166	187,371	1,573,083	144,409	222,084	1,009,804
2000	176,881	171,575	1,558,392	162,920	200,903	921,226
2001	171,256	166,118	1,545,852	167,615	192,447	884,645
2002	165,801	160,827	1,534,007	172,307	184,462	849,756
2003	160,030	155,229	1,513,203	176,996	177,287	818,037
2004	154,670	150,030	1,493,989	181,683	170,744	791,568
2005	149,434	144,951	1,475,092	186,368	164,505	766,944
2006	144,479	140,145	1,442,534	187,508	157,762	745,216
2007	133,159	129,165	1,406,936	97,580	151,134	728,159
2008	124,257	120,529	1,366,553	30,786	143,880	710,743
2009	121,113	117,479	1,324,613	31,501	136,792	695,221
2010	116,841	113,336	1,284,357	15,145	129,859	681,150
2011	111,492	108,147	1,230,489	2,961	123,074	653,692
2012	104,846	101,700	1,170,969	2,957	116,483	612,882
2013	97,687	94,757	1,114,051	2,939	110,299	566,639
2014	89,993	87,293	1,036,731	1,825	104,704	521,423
2015	82,171	79,706	963,408	997	99,281	477,800
2016	75,070	72,818	895,198	992	94,464	437,357
2017	68,395	66,343	832,101	989	90,227	400,587
2018	62,269	60,401	775,920	988	86,343	367,637
2019	56,750	55,047	725,464	989	82,828	337,757
2020	51,840	50,285	680,563	991	79,786	311,112
2021	47,489	46,064	642,114	996	77,214	288,075
2022	43,560	42,254	608,874	1,001	75,070	267,360
2023	40,006	38,806	579,551	1,008	73,234	248,939
2024	36,703	35,602	554,147	1,016	71,662	232,449
2025	33,651	32,641	531,753	1,024	70,338	217,569
2026	30,866	29,940	512,553	1,034	69,237	204,437
2027	28,355	27,504	496,243	1,044	68,363	193,052
2028	26,237	25,450	482,261	1,056	67,671	183,622
2029	24,280	23,552	470,147	1,068	67,110	175,312
2030	22,464	21,790	460,918	1,080	66,690	167,841
2031	20,963	20,334	453,730	1,093	66,464	161,916
2032	19,577	18,990	447,458	1,106	66,324	156,659
2033	18,269	17,721	442,218	1,119	66,250	151,810
2034	17,047	16,536	437,851	1,133	66,256	147,486
2035	15,951	15,472	434,539	1,147	66,352	143,953
2036	15,000	14,550	432,104	1,161	66,535	141,089
2037	14,120	13,696	430,302	1,175	66,769	138,541
2038	13,642	13,233	429,692	1,190	67,135	136,210
2039	13,257	12,859	429,857	1,204	67,551	134,435
2040	12,915	12,527	430,365	1,219	68,004	132,940

3.4.2 Land-Based Diesel Engines—Air Toxics Emissions

Since air toxics emissions are part of the VOC emission inventory, NMHC standards in this rule will also affect air toxics emissions. Tables 3.4-7a and 3.4-7b show 48-state and 50-state estimated emissions for five major air toxics, benzene, formaldehyde, acetaldehyde, 1,3-butadiene, and acrolein, resulting from the final rule. EPA uses the same fractions used to calculate the base air toxic emissions without the final rule (see Section 3.1.2), along with the estimated VOC emissions resulting from the final rule, to calculate the air toxics emissions resulting from the final rule.

Table 3.4-7a
Controlled (48-State) Air Toxic Emissions for Land-Based Nonroad Diesel Engines (short tons)

Year	Benzene	Formaldehyde	Acetaldehyde	1,3-butadiene	Acrolein
2000	3,998	23,587	10,594	400	600
2005	3,273	19,312	8,674	327	491
2007	3,007	17,742	7,969	301	451
2010	2,584	15,244	6,847	258	388
2015	1,975	11,654	5,235	198	296
2020	1,587	9,366	4,207	159	238
2025	1,399	8,257	3,709	140	210
2030	1,327	7,829	3,516	133	199

Table 3.4-7b
Controlled (50-State) Air Toxic Emissions for Land-Based Nonroad Diesel Engines (short tons)

Year	Benzene	Formaldehyde	Acetaldehyde	1,3-butadiene	Acrolein
2000	4,018	23,707	10,648	402	603
2005	3,290	19,412	8,719	329	494
2007	3,023	17,834	8,010	302	453
2010	2,597	15,323	6,883	260	390
2015	1,986	11,715	5,262	199	298
2020	1,596	9,415	4,229	160	239
2025	1,407	8,300	3,728	141	211
2030	1,334	7,869	3,535	133	200

3.4.3 Commercial Marine Vessels and Locomotives

The control case locomotive and commercial marine inventories for VOC, CO, and NO_x are identical to the base case inventories, since no new controls apply for these engines. However, due to the new requirements to reduce sulfur levels in diesel fuel, decreases are expected in PM and SO_2 inventories for these engines.

The method used for estimating PM and SO_2 emissions in the control case is nearly almost identical to that described in Section 3.1.3 for the base case, but the fuel sulfur levels in the equations are changed to reflect the control case sulfur. The control case PM and SO_2 emission inventory estimates presented here assume that locomotive and commercial marine applications will use diesel fuel meeting a 500 ppm sulfur standard beginning in June 2007 and a 15 ppm sulfur standard beginning in June 2012. Additional sulfur adjustments were made to account for the "spillover" of low-sulfur highway fuel meeting a 15 ppm standard in the applicable years before the start of the 15 ppm nonroad fuel standard.

As in the base case, the same sulfur-to-sulfate conversion rate was used as for land-based diesel applications before they started using aftertreatment technologies (2.247 percent). The slight decrease in average sulfur level in 2006 is due to the introduction of highway diesel fuel meeting the 2007 15 ppm standard, and the "spillover" of this highway fuel into the nonroad fuel pool. Note that there are transition years in which the control sulfur level begins in June, in which case the annual average sulfur level shown reflects an interpolation of five months at the higher sulfur level of the prior year plus seven months at the new lower sulfur level. The derivation of these sulfur levels are described in more detail in Chapter 7.

The control case locomotive and commercial marine PM inventories were calculated by subtracting the sulfate PM benefits (from decreased fuel sulfur content) described above from the base case locomotive and commercial marine PM inventories. The 48-state and 50-state control case locomotive and commercial marine $PM_{2.5}$ and SO_2 inventories are given in Tables 3.4-8a and 3.4-8b, respectively.

Table 3.4-8a
Controlled (48-State) Fuel Sulfur Levels, SO_2,
Sulfate PM, and $PM_{2.5}$ Emissions for Locomotives and Commercial Marine Vessels

Year	Control Sulfur Level (ppm)	Control					
		SO_2		Sulfate PM		Total $PM_{2.5}$	
		Loco (tons/yr)	CMV (tons/yr)	Loco (tons/yr)	CMV (tons/yr)	Loco (tons/yr)	CMV (tons/yr)
2007	1,328	26,430	14,517	2,126	1,168	17,023	17,586
2008	408	8,210	4,512	661	363	15,146	16,641
2009	408	8,321	4,554	669	366	15,038	16,485
2010	307	6,352	3,457	511	278	14,725	16,377
2011	234	4,944	2,675	398	215	15,067	16,254
2012	123	2,614	1,415	210	114	14,703	16,003
2013	43	921	498	74	40	14,354	15,793
2014	51	1,099	595	88	48	14,146	15,660
2015	56	1,231	667	99	54	13,936	15,534
2016	56	1,244	672	100	54	13,745	15,455
2017	56	1,255	678	101	55	13,527	15,402
2018	56	1,263	687	102	55	13,626	15,367
2019	56	1,274	697	103	56	13,409	15,382
2020	56	1,282	703	103	57	13,149	15,436
2021	56	1,288	710	104	57	12,861	15,511
2022	56	1,298	721	104	58	12,618	15,599
2023	56	1,309	727	105	59	12,729	15,719
2024	56	1,319	736	106	59	12,476	15,846
2025	56	1,332	743	107	60	12,229	15,990
2026	56	1,342	751	108	60	11,962	16,138
2027	56	1,352	760	109	61	12,060	16,295
2028	56	1,363	769	110	62	11,785	16,452
2029	56	1,373	777	110	63	11,504	16,614
2030	56	1,384	786	111	63	11,599	16,778
2031	56	1,394	795	112	64	11,310	16,950
2032	56	1,405	805	113	65	11,016	17,122
2033	56	1,416	814	114	65	11,107	17,292
2034	56	1,427	824	115	66	10,804	17,463
2035	56	1,438	833	116	67	10,893	17,636
2036	56	1,449	843	117	68	10,983	17,811
2037	56	1,460	853	117	69	10,669	17,986
2038	56	1,471	863	118	69	10,757	18,162
2039	55	1,482	874	119	70	10,434	18,339
2040	55	1,494	884	120	71	10,520	18,517

Table 3.4-8b
Controlled (50-State) Fuel Sulfur Levels, SO_2,
Sulfate PM, and $PM_{2.5}$ Emissions for Locomotives and Commercial Marine Vessels

Year	Control Sulfur Level (ppm)	Control					
		SO_2		Sulfate PM		Total $PM_{2.5}$	
		Loco (tons/yr)	CMV (tons/yr)	Loco (tons/yr)	CMV (tons/yr)	Loco (tons/yr)	CMV (tons/yr)
2007	1,332	26,548	15,305	2,136	1,231	17,127	18,559
2008	435	8,764	5,055	705	407	15,285	17,587
2009	435	8,881	5,103	715	411	15,177	17,423
2010	319	6,615	3,779	532	304	14,838	17,293
2011	236	4,990	2,834	401	228	15,161	17,152
2012	124	2,646	1,504	213	121	14,796	16,888
2013	44	943	535	76	43	14,447	16,667
2014	52	1,133	645	91	52	14,240	16,528
2015	56	1,215	692	98	56	14,027	16,393
2016	56	1,228	697	99	56	13,836	16,310
2017	56	1,239	703	100	57	13,619	16,254
2018	55	1,247	712	100	57	13,719	16,219
2019	55	1,258	723	101	58	13,502	16,234
2020	55	1,266	729	102	59	13,243	16,292
2021	55	1,271	737	102	59	12,955	16,372
2022	55	1,281	747	103	60	12,713	16,465
2023	55	1,291	754	104	61	12,825	16,591
2024	55	1,302	763	105	61	12,572	16,726
2025	55	1,314	771	106	62	12,326	16,878
2026	55	1,324	779	107	63	12,058	17,034
2027	55	1,334	788	107	63	12,158	17,200
2028	55	1,344	797	108	64	11,883	17,366
2029	55	1,355	806	109	65	11,603	17,537
2030	55	1,365	815	110	66	11,699	17,710
2031	55	1,375	825	111	66	11,411	17,892
2032	55	1,386	834	112	67	11,116	18,073
2033	55	1,397	844	112	68	11,208	18,253
2034	55	1,407	854	113	69	10,906	18,434
2035	55	1,418	864	114	70	10,996	18,617
2036	55	1,429	874	115	70	11,087	18,801
2037	55	1,440	885	116	71	10,774	18,987
2038	55	1,451	895	117	72	10,863	19,173
2039	55	1,462	906	118	73	10,541	19,359
2040	55	1,473	917	119	74	10,628	19,548

3.4.4 Recreational Marine Engines

Even though this final rule does not include any emission standards for marine engines, there are PM and SO_2 benefits associated with these engines due to the fuel sulfur standards. The emission inventory estimates presented in Tables 3.4-9a and 3.4-9b assume that recreational marine applications will use diesel fuel meeting the same standards as locomotive and commercial marine diesel fuel, as shown in Table 3.4-5.

Table 3.4-9a
Controlled (48-State) Emissions for Recreational Marine Diesel Engines (short tons)

Year	PM_{10}	$PM_{2.5}$	NO_x	SO_2	VOC	CO
1996	951	923	33,679	4,286	1,297	5,424
2000	1,070	1,038	37,943	4,831	1,455	6,098
2001	1,099	1,066	39,071	4,968	1,494	6,271
2002	1,130	1,096	40,198	5,114	1,533	6,444
2003	1,160	1,125	41,325	5,259	1,571	6,615
2004	1,190	1,154	42,452	5,406	1,609	6,787
2005	1,220	1,183	43,578	5,551	1,647	6,958
2006	1,233	1,196	44,105	5,647	1,657	7,128
2007	1,020	990	44,602	2,940	1,664	7,298
2008	862	836	45,066	926	1,670	7,467
2009	865	839	45,415	948	1,670	7,636
2010	847	822	45,729	731	1,668	7,804
2011	833	808	46,022	570	1,665	7,971
2012	810	786	46,282	306	1,660	8,137
2013	792	768	46,528	109	1,655	8,303
2014	790	767	46,765	133	1,649	8,469
2015	787	764	46,969	149	1,642	8,635
2016	783	759	47,168	152	1,634	8,802
2017	778	755	47,362	155	1,627	8,969
2018	772	749	47,525	158	1,618	9,137
2019	767	744	47,687	161	1,611	9,308
2020	761	738	47,847	164	1,604	9,482
2021	756	733	48,003	167	1,597	9,655
2022	750	728	48,182	170	1,592	9,829
2023	745	722	48,363	173	1,586	10,004
2024	740	718	48,593	176	1,583	10,178
2025	740	717	48,961	180	1,587	10,354
2026	744	721	49,501	183	1,599	10,529
2027	749	727	50,092	186	1,614	10,704
2028	756	733	50,716	189	1,630	10,880
2029	763	741	51,392	192	1,649	11,056
2030	772	749	52,085	195	1,669	11,232
2031	781	757	52,790	198	1,689	11,409
2032	790	766	53,510	201	1,710	11,585
2033	799	775	54,228	204	1,731	11,762
2034	808	784	54,959	207	1,753	11,938
2035	818	794	55,702	210	1,775	12,115
2036	828	803	56,444	213	1,798	12,292
2037	838	813	57,197	216	1,820	12,469
2038	849	823	57,963	220	1,844	12,646
2039	859	833	58,729	219	1,868	12,823
2040	870	844	59,506	222	1,892	13,001

Table 3.4-9b
Controlled (50-State) Emissions for Recreational Marine Diesel Engines (short tons)

Year	PM_{10}	$PM_{2.5}$	NO_x	SO_2	VOC	CO
1996	957	929	33,891	4,312	1,305	5,458
2000	1,076	1,044	38,182	4,859	1,464	6,137
2001	1,106	1,073	39,317	4,995	1,503	6,311
2002	1,137	1,103	40,452	5,145	1,542	6,484
2003	1,167	1,132	41,586	5,290	1,581	6,657
2004	1,197	1,161	42,719	5,436	1,619	6,829
2005	1,227	1,190	43,852	5,582	1,658	7,001
2006	1,236	1,199	44,383	5,622	1,667	7,173
2007	1,027	997	44,883	2,967	1,674	7,344
2008	872	846	45,350	993	1,680	7,514
2009	875	849	45,701	1,017	1,680	7,684
2010	855	829	46,018	764	1,678	7,853
2011	839	814	46,312	578	1,675	8,021
2012	816	791	46,573	311	1,671	8,189
2013	797	773	46,821	113	1,665	8,356
2014	795	772	47,060	136	1,660	8,523
2015	792	768	47,265	150	1,652	8,690
2016	788	764	47,465	153	1,645	8,857
2017	783	759	47,660	156	1,637	9,025
2018	777	753	47,825	156	1,629	9,195
2019	771	748	47,987	159	1,621	9,367
2020	766	743	48,148	162	1,614	9,541
2021	760	737	48,305	165	1,607	9,716
2022	755	732	48,485	168	1,602	9,891
2023	749	727	48,667	171	1,596	10,067
2024	745	722	48,899	174	1,593	10,243
2025	744	722	49,269	177	1,597	10,419
2026	748	726	49,813	180	1,609	10,595
2027	754	731	50,408	183	1,624	10,772
2028	760	737	51,036	187	1,640	10,949
2029	768	745	51,716	190	1,659	11,126
2030	776	753	52,413	193	1,679	11,303
2031	785	762	53,123	196	1,700	11,481
2032	794	771	53,847	199	1,721	11,658
2033	804	779	54,570	202	1,742	11,836
2034	813	789	55,305	205	1,764	12,013
2035	823	798	56,053	208	1,786	12,191
2036	833	808	56,799	211	1,809	12,369
2037	843	818	57,558	214	1,832	12,547
2038	854	828	58,329	217	1,856	12,726
2039	865	839	59,099	220	1,879	12,904
2040	876	849	59,881	223	1,904	13,082

3.5 Projected Emission Reductions from the Final Rule

Emissions from nonroad diesel engines will continue to be a significant part of the emission inventory in the coming years. In the absence of new emission standards, we expect overall emissions from nonroad diesel engines to generally decline across the nation for the next 10 to 15 years, depending on the pollutant. Although nonroad diesel engine emissions decline during this period, this trend will not be enough to adequately reduce the large amount of emissions that these engines contribute. In addition, after the 2010 to 2015 time period we project that this trend reverses and emissions rise into the future in the absence of additional regulation of these engines. The initial downward trend occurs as the nonroad fleet becomes increasingly dominated over time by engines that comply with existing emission regulations. The upturn in emissions beginning around 2015 results as growth in the nonroad sector overtakes the effect of the existing emission standards.

The engine and fuel standards in this rule will affect fine particulate matter ($PM_{2.5}$), oxides of nitrogen (NO_x), sulfur oxides (SO_2), volatile organic hydrocarbons (VOC), air toxics, and carbon monoxide (CO). For engines used in locomotives, commercial marine vessels, and recreational marine vessels, the requirements for low-sulfur fuel will affect $PM_{2.5}$ and SO_2.

This section discusses the projected emission reductions associated with this final rule. The baseline case represents future emissions with current standards. The controlled case estimates the future emissions of these engines based on the new emission standards and fuel requirements. Both 48-state and 50-state results are presented. Tables 3.5-1a and 3.5-1b present a summary of the total 48-state and 50-state emission reductions for each pollutant.

3.5.1 $PM_{2.5}$ Reductions

48-State and 50-state emissions of $PM_{2.5}$ from land-based nonroad diesel engines are shown in Tables 3.5-2a and 3.5-2b, respectively, along with estimates of the reductions from this final rule. $PM_{2.5}$ will be reduced as a result of the new PM emission standards and changes in the sulfur level in nonroad diesel fuel. The exhaust emission standards begin in 2008 for engines less than 75 hp, and are completely phased in for all hp categories by 2015. Nonroad diesel fuel sulfur is reduced to a 500 ppm standard in June of 2007, and further reduced to a 15 ppm standard (11 ppm in-use) in June of 2010. The 15 ppm standard is fully phased in starting in 2011.

Tables 3.5-2a and 3.5-2b present results for five-year increments from 2000 to 2030. Individual years from 2007 to 2011 are also included, since fuel sulfur levels are changing during this period. Emissions are projected to 2030 to reflect close to complete turnover of the fleet to engines meeting the new emission standards. For comparison purposes, emission reductions are also shown from reducing the diesel fuel sulfur level to 500 ppm in 2007 and to 15 ppm in 2010, without any new emission standards.

Table 3.5-1a
Total Emission Reductions (48-State) from the Final Rule

Year	$PM_{2.5}$	NO_x	SO_2	VOC	CO	Benzene	Formaldehyde	Acetaldehyde	1,3-butadiene	Acrolein
2000	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0
2007	10,511	0	134,388	0	0	0	0	0	0	0
2008	19,031	30	236,976	168	3,104	3	20	9	0	1
2009	19,943	70	241,719	341	6,266	7	40	18	1	1
2010	21,692	149	256,447	525	9,634	11	62	28	1	2
2011	25,154	17,830	268,989	1,139	28,704	23	134	60	2	3
2012	31,103	46,827	278,092	2,486	64,599	50	293	132	5	7
2015	53,072	193,431	297,513	8,318	198,947	166	981	441	17	25
2020	85,808	442,061	323,378	18,141	388,037	363	2,141	961	36	54
2025	110,043	613,629	349,312	25,002	521,457	500	2,950	1,325	50	75
2030	128,350	734,184	375,354	30,030	619,167	601	3,544	1,592	60	90

Table 3.5-1b
Total Emission Reductions (50-State) from the Final Rule

Year	$PM_{2.5}$	NO_x	SO_2	VOC	CO	Benzene	Formaldehyde	Acetaldehyde	1,3-butadiene	Acrolein
2000	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0
2007	10,403	0	132,998	0	0	0	0	0	0	0
2008	18,908	31	235,366	169	3,119	3	20	9	0	1
2009	19,821	72	240,084	343	6,296	7	41	18	1	1
2010	21,627	153	255,525	529	9,680	11	62	28	1	2
2011	25,142	17,951	268,613	1,146	28,871	23	135	61	2	3
2012	31,122	47,129	277,804	2,501	64,983	50	295	133	5	8
2015	53,238	194,615	297,440	8,367	200,118	167	987	443	17	25
2020	86,157	444,714	323,302	18,251	390,333	365	2,154	967	37	55
2025	110,508	617,176	349,233	25,152	524,471	503	2,968	1,333	50	75
2030	128,899	738,307	375,269	30,210	622,706	604	3,565	1,601	60	91

Table 3.5-2a
Estimated National (48-State) $PM_{2.5}$
Emissions and Reductions From Nonroad Land-Based Diesel Engines[a]

Year	$PM_{2.5}$ Emissions [short tons]				$PM_{2.5}$ Reductions [short tons]		
	Without Rule	With fuel sulfur reduced to 500 ppm in 2007; No Tier 4 standards	With fuel sulfur further reduced to 15 ppm in 2010; No Tier 4 standards	With Rule (Fuel sulfur reduced to 15 ppm in 2010; Tier 4 standards)	With fuel sulfur reduced to 500 ppm in 2007; No Tier 4 standards	With fuel sulfur further reduced to 15 ppm in 2010; No Tier 4 standards	With Rule
2000	170,774	170,774	170,774	170,774	0	0	0
2005	144,259	144,259	144,259	144,259	0	0	0
2007	135,791	128,558	128,558	128,558	7,232	7,232	7,232
2008	133,245	120,434	120,434	119,936	12,811	12,811	13,309
2009	131,044	117,938	117,938	116,896	13,106	13,106	14,148
2010	128,730	115,273	114,416	112,775	13,458	14,315	15,955
2011	127,035	113,243	111,739	107,612	13,792	15,296	19,423
2015	125,936	110,950	109,157	79,326	14,986	16,779	46,610
2020	129,058	112,595	110,625	50,065	16,463	18,433	78,993
2025	135,369	117,428	115,281	32,503	17,941	20,087	102,866
2030	142,484	123,076	120,754	21,698	19,408	21,730	120,786

[a] $PM_{2.5}$ represents 97 percent of PM10 emissions.

Table 3.5-2b
Estimated National (50-State) $PM_{2.5}$
Emissions and Reductions From Nonroad Land-Based Diesel Engines[a]

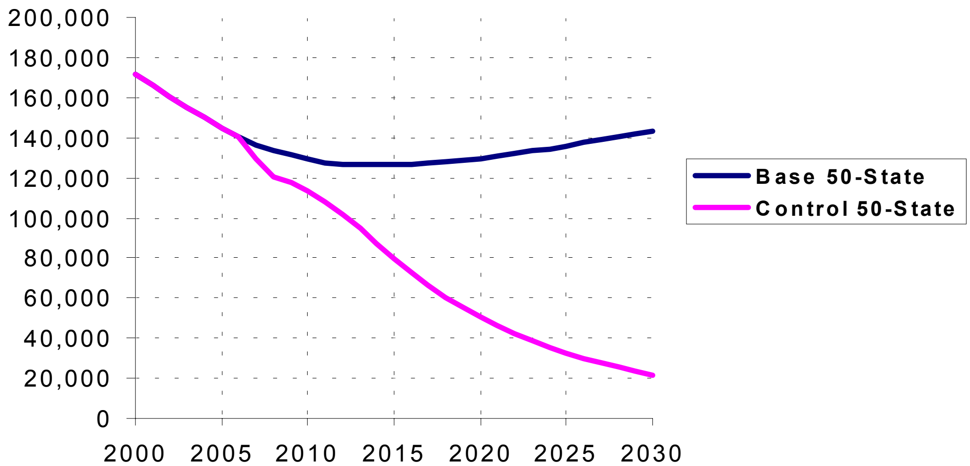
Year	$PM_{2.5}$ Emissions [short tons]				$PM_{2.5}$ Reductions [short tons]		
	Without Rule	With fuel sulfur reduced to 500 ppm in 2007; No Tier 4 standards	With fuel sulfur further reduced to 15 ppm in 2010; No Tier 4 standards	With Rule (Fuel sulfur reduced to 15 ppm in 2010; Tier 4 standards)	With fuel sulfur reduced to 500 ppm in 2007; No Tier 4 standards	With fuel sulfur further reduced to 15 ppm in 2010; No Tier 4 standards	With Rule
2000	171,575	171,575	171,575	171,575	0	0	0
2005	144,951	144,951	144,951	144,951	0	0	0
2007	136,362	129,165	129,165	129,165	7,197	7,197	7,197
2008	133,807	121,030	121,030	120,529	12,777	12,777	13,277
2009	131,598	118,526	118,526	117,479	13,071	13,071	14,118
2010	129,276	115,846	114,984	113,336	13,430	14,292	15,940
2011	127,576	113,797	112,292	108,147	13,778	15,283	19,428
2015	126,482	111,511	109,708	79,706	14,971	16,774	46,777
2020	129,628	113,181	111,200	50,285	16,447	18,428	79,343
2025	135,972	118,049	115,891	32,641	17,923	20,081	103,331
2030	143,126	123,737	121,402	21,790	19,389	21,724	121,336

[a] $PM_{2.5}$ represents 97 percent of PM10 emissions.

The benefits in the early years of the program (i.e., pre-2010) are primarily from reducing the diesel fuel sulfur level to 500 ppm. As the standards phase in and fleet turnover occurs, $PM_{2.5}$ emissions are impacted more significantly from the requirements of the final rule. $PM_{2.5}$ emissions from land-based diesel engines are projected to decrease by roughly 120,000 tons by 2030 as a result of this rule.

Figure 3.5-1 shows EPA's estimate of 50-state $PM_{2.5}$ emissions from land-based diesel engines for 2000 to 2030 with and without the new PM emission standards. We estimate that $PM_{2.5}$ emissions from this source would decrease by 85 percent in 2030.

Figure 3.5-1: Estimated Reductions in $PM_{2.5}$ Emissions From Land-Based Nonroad Engines (tons/year)



Nonroad diesel engines used in locomotives, commercial marine vessels, and recreational marine vessels are not affected by the emission standards in this rule. $PM_{2.5}$ emissions from these engines will be reduced as a result of the lower fuel sulfur levels from a current in-use average of about 2640 ppm to about 55 ppm by 2015. The estimated 48-state and 50-state reductions in $PM_{2.5}$ emissions from these engines based on the diesel fuel-sulfur requirements are given in Tables 3.5-3a and 3.5-3b, respectively. Total $PM_{2.5}$ reductions reach roughly 7,500 tons in 2030 for these engine categories.

Tables 3.5-4a and 3.5-4b present the $PM_{2.5}$ emissions and reductions for all nonroad diesel categories combined. The 50-state results are also presented graphically in Figure 3.5-2. For all nonroad diesel categories combined, the estimated reductions in $PM_{2.5}$ emissions are 86,000 tons in 2020, increasing to 128,000 tons in 2030. Simply reducing the fuel sulfur level to 500 ppm in 2007 will lead to projected $PM_{2.5}$ reductions of 23,000 tons in 2020 and 26,000 tons in 2030. Reducing the fuel sulfur level further to 15 ppm (in 2010 for land-based diesel engines and in 2012 for marine engines and locomotives) in the absence of Tier 4 standards (i.e., a fuel only program) will lead to projected $PM_{2.5}$ reductions of 25,000 tons in 2020 and 29,000 tons in 2030.

Table 3.5-3a
Estimated National (48-State) $PM_{2.5}$ Reductions
From Locomotives, Commercial Marine, and Recreational Marine Diesel Engines

Year	$PM_{2.5}$ Reductions with Rule [short tons]			
	Locomotives	Commerical Marine Diesel	Recreational Marine Diesel	Total $PM_{2.5}$ Reductions
2000	0	0	0	0
2005	0	0	0	0
2007	1,975	1,085	220	3,279
2008	3,442	1,891	389	5,722
2009	3,488	1,909	398	5,796
2010	3,458	1,882	397	5,737
2011	3,460	1,871	400	5,731
2015	3,885	2,105	473	6,463
2020	4,063	2,229	522	6,815
2025	4,240	2,366	572	7,178
2030	4,426	2,516	622	7,564

Table 3.5-3b
Estimated National (50-State) $PM_{2.5}$ Reductions
From Locomotives, Commercial Marine, and Recreational Marine Diesel Engines

Year	$PM_{2.5}$ Reductions with Rule [short tons]			
	Locomotives	Commerical Marine Diesel	Recreational Marine Diesel	Total $PM_{2.5}$ Reductions
2000	0	0	0	0
2005	0	0	0	0
2007	1,899	1,095	212	3,206
2008	3,331	1,921	378	5,630
2009	3,376	1,940	387	5,702
2010	3,372	1,927	390	5,689
2011	3,393	1,927	394	5,714
2015	3,820	2,175	467	6,462
2020	3,995	2,303	516	6,814
2025	4,168	2,445	565	7,177
2030	4,350	2,599	614	7,563

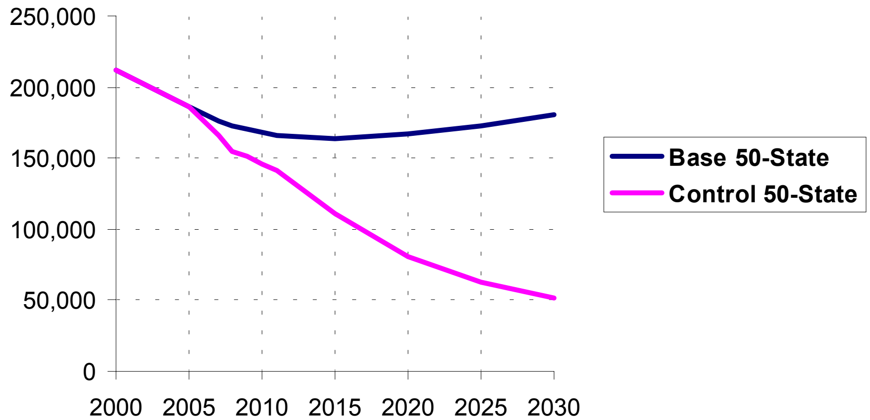
Table 3.5-4a
Estimated National (48-State) $PM_{2.5}$ Emissions and Reductions from
Land-Based Nonroad, Locomotive, Commercial Marine, and Recreational Marine Vessels

Year	$PM_{2.5}$ Emissions [short tons]				$PM_{2.5}$ Reductions [short tons]		
	Without Rule	With fuel sulfur reduced to 500 ppm in 2007; No Tier 4 standards	With fuel sulfur further reduced to 15 ppm in 2010/2012; No Tier 4 standards	With Rule (Fuel sulfur further reduced to 15 ppm in 2010/2012; Tier 4 standards)	With fuel sulfur reduced to 500 ppm in 2007; No Tier 4 standards	With fuel sulfur further reduced to 15 ppm in 2010/2012; No Tier 4 standards	With Rule (Fuel sulfur further reduced to 15 ppm in 2010/2012; Tier 4 standards)
2000	209,876	209,876	209,876	209,876	0	0	0
2005	183,831	183,831	183,831	183,831	0	0	0
2007	174,668	164,157	164,157	164,157	10,511	10,511	10,511
2008	171,591	153,058	153,058	152,560	18,533	18,533	19,031
2009	169,201	150,300	150,300	149,258	18,901	18,901	19,943
2010	166,391	147,235	146,340	144,699	19,156	20,051	21,692
2011	164,894	145,438	143,868	139,741	19,457	21,027	25,154
2012	163,784	143,965	142,054	132,681	19,819	21,730	31,103
2015	162,633	141,757	139,391	109,560	20,876	23,241	53,072
2020	165,196	142,522	139,948	79,388	22,674	25,248	85,808
2025	171,484	147,002	144,219	61,440	24,482	27,265	110,043
2030	179,173	152,873	149,880	50,824	26,300	29,293	128,350

Table 3.5-4b
Estimated National (50-State) $PM_{2.5}$ Emissions and Reductions from
Land-Based Nonroad, Locomotive, Commercial Marine, and Recreational Marine Vessels

Year	$PM_{2.5}$ Emissions [short tons]				$PM_{2.5}$ Reductions [short tons]		
	Without Rule	With fuel sulfur reduced to 500 ppm in 2007; No Tier 4 standards	With fuel sulfur further reduced to 15 ppm in 2010/2012; No Tier 4 standards	With Rule (Fuel sulfur further reduced to 15 ppm in 2010/2012; Tier 4 standards)	With fuel sulfur reduced to 500 ppm in 2007; No Tier 4 standards	With fuel sulfur further reduced to 15 ppm in 2010/2012; No Tier 4 standards	With Rule (Fuel sulfur further reduced to 15 ppm in 2010/2012; Tier 4 standards)
2000	211,688	211,688	211,688	211,688	0	0	0
2005	185,555	185,555	185,555	185,555	0	0	0
2007	176,250	165,847	165,847	165,847	10,403	10,403	10,403
2008	173,154	154,747	154,747	154,247	18,407	18,407	18,908
2009	170,750	151,976	151,976	150,929	18,774	18,774	19,821
2010	167,923	148,844	147,944	146,296	19,079	19,979	21,627
2011	166,416	146,990	145,419	141,274	19,426	20,997	25,142
2012	165,298	145,510	143,591	134,176	19,788	21,707	31,122
2015	164,133	143,289	140,897	110,894	20,843	23,236	53,238
2020	166,719	144,080	141,477	80,562	22,639	25,242	86,157
2025	173,075	148,630	145,816	62,567	24,445	27,259	110,508
2030	180,851	154,591	151,565	51,953	26,260	29,287	128,899

Figure 3.5-2: Estimated Reductions in $PM_{2.5}$ Emissions From Land-Based Nonroad Engines, CMVs, RMVs, and Locomotives (tons/year)



3.5.2 NO_x Reductions

Tables 3.5-5a and 3.5-5b show the estimated 48-state and 50-state NO_x emissions in five-year increments from 2000 to 2030 with and without this rule. The 50-state results are shown graphically in Figure 3.5-3. We estimate that NO_x emissions from these engines will be reduced by 62 percent in 2030.

We note that the magnitude of NOx reductions determined in the final rule analysis is somewhat less than what was reported in the proposal's draft RIA, especially in the later years when the fleet has mostly turned over to Tier 4 designs. The greater part of this is due to the fact that we have deferred setting a long-term NOx standard for mobile machinery over 750 hp to a later action. When this future action is completed, we would expect roughly equivalent reductions between the proposal and the overall final program, though there are some other effects reflected in the differing NOx reductions as well, due to updated modeling assumptions and the adjusted NOx standards levels for engines over 750 hp. Preamble Section II.A.4 contains a detailed discussion of the NOx standards we are adopting for engines over 750 hp, and the basis for those standards.

NO_x emissions from locomotives, commercial marine diesel vessels, and recreational marine diesel vessels are not affected by this rule.

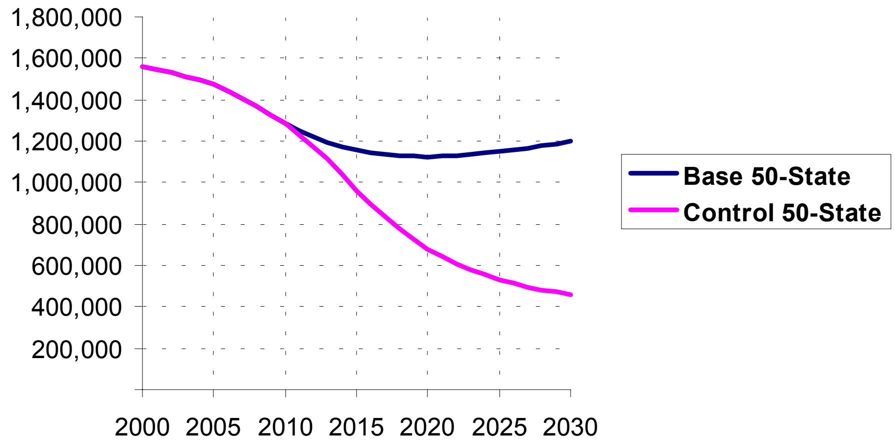
Table 3.5-5a
Estimated National (48-State) NO_x Emissions
and Reductions From Nonroad Land-Based Diesel Engines

Year	NO_x Emissions Without Rule [short tons]	NO_x Emissions With Rule	NO_x Reductions With Rule
2000	1,550,355	1,550,355	0
2005	1,467,547	1,467,547	0
2010	1,278,038	1,277,888	149
2015	1,152,199	958,769	193,431
2020	1,119,481	677,420	442,061
2030	1,192,833	458,649	734,184

Table 3.5-5b
Estimated National (50-State) NO_x Emissions
and Reductions From Nonroad Land-Based Diesel Engines

Year	NO_x Emissions Without Rule [short tons]	NO_x Emissions With Rule	NO_x Reductions With Rule
2000	1,558,392	1,558,392	0
2005	1,475,092	1,475,092	0
2010	1,284,510	1,284,357	153
2015	1,158,023	963,408	194,615
2020	1,125,276	680,563	444,714
2030	1,199,225	460,918	738,307

Figure 3.5-3: Estimated Reductions in NOx Emissions From Land-Based Nonroad Engines (tons/year)



3.5.3 SO_2 Reductions

As part of this final rule, sulfur levels in fuel will be significantly reduced, leading to large reductions in nonroad diesel SO_2 emissions. By 2007, the sulfur in diesel fuel used by all nonroad diesel engines will be reduced to 500 ppm. By 2010, the sulfur in diesel fuel used by nonroad land-based engines will be further reduced to 15 ppm. By 2012, the sulfur in diesel fuel used by marine engines and locomotives will also be reduced to 15 ppm.

48-State and 50-state emissions of SO_2 from land-based nonroad diesel engines are shown in Tables 3.5-6a and 3.5-6b, respectively, along with estimates of the emission reductions resulting from this final rule. Results are presented for five-year increments from 2000 to 2030. Individual years from 2007 to 2011 are also included, since fuel sulfur levels are changing during this period. SO_2 will be reduced due to the changes in the sulfur level in nonroad diesel fuel. For comparison purposes, emission reductions are also shown from reducing the diesel fuel sulfur level to 500 ppm beginning in June of 2007, without any new emission standards or any additional sulfur level reductions.

Table 3.5-6a
Estimated National (48-State) SO_2
Emissions and Reductions From Nonroad Land-Based Diesel Engines

Year	SO_2 Emissions [short tons]			SO_2 Reductions [short tons]	
	Without Rule	With fuel sulfur reduced to 500 ppm in 2007	With Rule (Fuel sulfur reduced to 15 ppm in 2010)	With fuel sulfur reduced to 500 ppm in 2007	With Rule
2000	161,977	161,977	161,977	0	0
2005	185,287	185,287	185,287	0	0
2007	189,511	97,142	97,142	92,370	92,370
2008	194,019	30,359	30,359	163,660	163,660
2009	198,526	31,064	31,064	167,462	167,461
2010	197,829	25,835	14,881	171,993	182,948
2011	198,415	22,119	2,853	176,296	195,562
2015	215,699	24,045	992	191,654	214,707
2020	237,044	26,425	986	210,619	236,057
2025	258,360	28,801	1,019	229,559	257,341
2030	279,511	31,159	1,074	248,352	278,437

Table 3.5-6b
Estimated National (50-State) SO_2
Emissions and Reductions From Nonroad Land-Based Diesel Engines

Year	SO_2 Emissions [short tons]			SO_2 Reductions [short tons]	
	Without Rule	With fuel sulfur reduced to 500 ppm in 2007	With Rule (Fuel sulfur reduced to 15 ppm in 2010)	With fuel sulfur reduced to 500 ppm in 2007	With Rule
2000	162,920	162,920	162,920	0	0
2005	186,368	186,368	186,368	0	0
2007	189,505	97,580	97,580	91,926	91,926
2008	194,013	30,786	30,786	163,227	163,227
2009	198,521	31,501	31,501	167,019	167,019
2010	197,795	26,159	15,145	171,637	182,651
2011	198,360	22,238	2,961	176,122	195,400
2015	215,641	24,175	997	191,466	214,644
2020	236,982	26,568	991	210,414	235,990
2025	258,294	28,957	1,024	229,337	257,270
2030	279,442	31,328	1,080	248,114	278,362

The benefits in the early years of the program (i.e., pre-2010) are from reducing the diesel fuel sulfur level to 500 ppm. Reducing the diesel fuel sulfur level to 15 ppm in June of 2010 proportionately reduces SO_2 further. Total 50-state SO_2 emissions are projected to decrease by 278,000 tons in 2030 as a result of this final rule. Note that SO_2 emissions continue to increase over time due to the growth in the nonroad sector.

Nonroad diesel engines used in locomotives, commercial marine vessels, and recreational marine vessels are also affected by the new fuel sulfur requirements. The estimated 48-state and 50-state reductions in SO_2 emissions from these engines based on the new requirements for diesel fuel are given in Tables 3.5-7a and 3.5-7b, respectively. Total 50-state SO_2 reductions reach 96,000 tons in 2030 for these nonroad diesel engine categories.

Tables 3.5-8a and 3.5-8b present the SO_2 emissions and reductions for all nonroad diesel categories combined. The 50-state results are also presented graphically in Figure 3.5-4. For all nonroad diesel categories combined, the estimated 50-state reductions in SO_2 emissions resulting from the final rule are 323,000 tons in 2020, increasing to 375,000 tons in 2030. Simply reducing the fuel sulfur level to 500 ppm in 2007 will result in SO_2 reductions of 289,000 tons in 2020 and 336,000 tons in 2030.

Table 3.5-7a
Estimated National (48-State) SO_2 Reductions
From Locomotives, Commercial Marine, and Recreational Marine Diesel Engines

Year	SO_2 Reductions with Rule [short tons]			
	Locomotives	Commerical Marine Diesel Vessels	Recreational Marine Diesel Vessels	Total SO_2 Reductions
2000	0	0	0	0
2005	0	0	0	0
2007	25,305	13,899	2,814	42,018
2008	44,107	24,238	4,972	73,316
2009	44,700	24,465	5,093	74,257
2010	44,306	24,108	5,085	73,499
2011	44,334	23,980	5,112	73,426
2015	49,779	26,977	6,049	82,806
2020	52,070	28,564	6,686	87,320
2025	54,328	30,319	7,324	91,971
2030	56,720	32,234	7,963	96,917

Table 3.5-7b
Estimated National (50-State) SO_2 Reductions
From Locomotives, Commercial Marine, and Recreational Marine Diesel Engines

Year	SO_2 Reductions with Rule [short tons]			
	Locomotives	Commerical Marine Diesel Vessels	Recreational Marine Diesel Vessels	Total SO_2 Reductions
2000	0	0	0	0
2005	0	0	0	0
2007	24,329	14,025	2,718	41,072
2008	42,683	24,621	4,834	72,139
2009	43,258	24,855	4,952	73,065
2010	43,207	24,685	4,983	72,875
2011	43,481	24,695	5,037	73,213
2015	48,954	27,867	5,975	82,797
2020	51,196	29,511	6,604	87,311
2025	53,404	31,325	7,235	91,963
2030	55,742	33,302	7,863	96,907

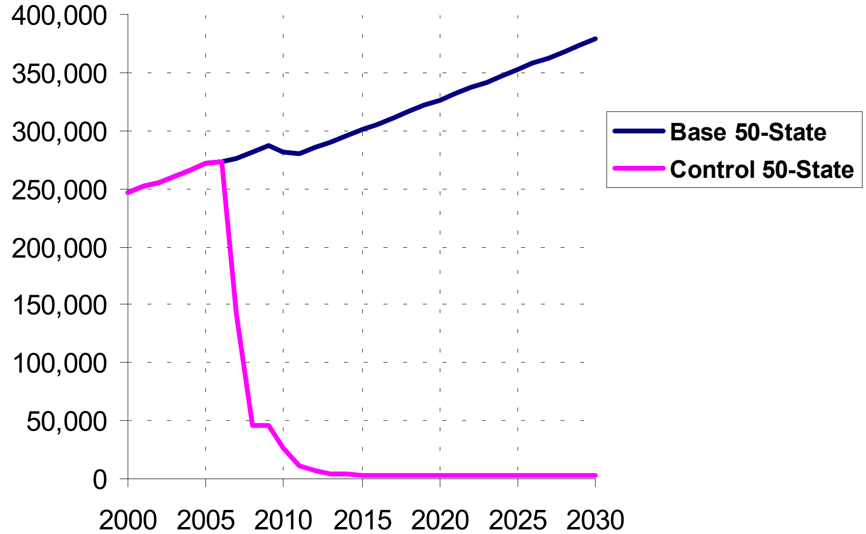
Table 3.5-8a
Estimated National (48-State) SO_2 Emissions and Reductions from
Land-Based Nonroad, Locomotive, Commercial Marine, and Recreational Marine Vessels

Year	SO_2 Emissions [short tons]			SO_2 Reductions [short tons]	
	Without Rule	With fuel sulfur reduced to 500 ppm in 2007	With fuel sulfur further reduced to 15 ppm in 2010/2012	With fuel sulfur reduced to 500 ppm in 2007	With fuel sulfur further reduced to 15 ppm in 2010/2012
2000	244,599	244,599	244,599	0	0
2005	269,288	269,288	269,288	0	0
2007	275,416	141,029	141,029	134,388	134,388
2008	280,983	44,007	44,007	236,976	236,976
2009	286,606	44,887	44,888	241,719	241,719
2010	281,867	36,860	25,420	245,007	256,447
2011	280,031	31,152	11,041	248,879	268,989
2012	285,277	31,735	7,185	253,542	278,092
2015	300,552	33,434	3,039	267,118	297,513
2020	326,514	36,322	3,136	290,192	323,378
2025	352,585	39,218	3,273	313,367	349,312
2030	378,793	42,128	3,439	336,665	375,354

Table 3.5-8b
Estimated National (50-State) SO_2 Emissions and Reductions from
Land-Based Nonroad, Locomotive, Commercial Marine, and Recreational Marine Vessels

Year	SO_2 Emissions [short tons]			SO_2 Reductions [short tons]	
	Without Rule	With fuel sulfur reduced to 500 ppm in 2007	With fuel sulfur further reduced to 15 ppm in 2010/2012	With fuel sulfur reduced to 500 ppm in 2007	With fuel sulfur further reduced to 15 ppm in 2010/2012
2000	247,010	247,010	247,010	0	0
2005	271,841	271,841	271,841	0	0
2007	275,397	142,399	142,399	132,998	132,998
2008	280,964	45,598	45,598	235,366	235,366
2009	286,588	46,503	46,503	240,085	240,084
2010	281,828	37,802	26,303	244,026	255,525
2011	279,976	31,486	11,363	248,490	268,613
2012	285,221	32,075	7,418	253,147	277,804
2015	300,494	33,788	3,054	266,706	297,440
2020	326,450	36,701	3,149	289,749	323,302
2025	352,519	39,625	3,286	312,894	349,233
2030	378,722	42,565	3,453	336,157	375,269

Figure 3.5-4: Estimated Reductions in SO_2 Benefits From Reducing Fuel Sulfur for Land-Based Nonroad Engines, CMVs, RMVs, and Locomotives (tons/year)



3.5.4 VOC and Air Toxics Reductions

Tables 3.5-9a and 3.5-9b show our projection of the 48-state and 50-state reductions in VOC emissions expected from implementing the new NMHC emission standards.

Although this final rule does not include specific standards for air toxics, these pollutants decrease as manufacturers take steps to meet the NMHC emission standards. Tables 3.5-10a and 3.5-10b show our estimate of reduced emissions of benzene, formaldehyde, acetaldehyde, 1,3-butadiene, and acrolein. We base these numbers on the assumption that air toxic emissions are a constant fraction of hydrocarbon exhaust emissions.

Table 3.5-9a
VOC Reductions (48-State) from Land-Based Nonroad Diesel Engines

Calendar Year	VOC Without Rule [short tons]	VOC With Rule [short tons]	VOC Reductions With Rule [short tons]
2000	199,887	199,887	0
2005	163,663	163,663	0
2010	129,711	129,186	525
2015	107,084	98,766	8,318
2020	97,513	79,372	18,141
2025	94,975	69,973	25,002
2030	96,374	66,344	30,030

Table 3.5-9b
VOC Reductions (50-State) from Land-Based Nonroad Diesel Engines

Calendar Year	VOC Without Rule [short tons]	VOC With Rule [short tons]	VOC Reductions With Rule [short tons]
2000	200,903	200,903	0
2005	164,505	164,505	0
2010	130,388	129,859	529
2015	107,647	99,281	8,367
2020	98,037	79,786	18,251
2025	95,490	70,338	25,152
2030	96,900	66,690	30,210

Table 3.5-10a
Air Toxic Reductions (48-State) (tons/year)

Year		Benzene	Formaldehyde	Acetaldehyde	1,3-butadiene	Acrolein
2000	Base	3,998	23,587	10,594	400	600
	Control	3,998	23,587	10,594	400	600
	Reduction	0	0	0	0	0
2005	Base	3,273	19,312	8,674	327	491
	Control	3,273	19,312	8,674	327	491
	Reduction	0	0	0	0	0
2007	Base	3,007	17,742	7,969	301	451
	Control	3,007	17,742	7,969	301	451
	Reduction	0	0	0	0	0
2010	Base	2,594	15,306	6,875	259	389
	Control	2,584	15,244	6,847	258	388
	Reduction	11	62	28	1	2
2015	Base	2,142	12,636	5,675	214	321
	Control	1,975	11,654	5,235	198	296
	Reduction	166	981	441	17	25
2020	Base	1,950	11,507	5,168	195	293
	Control	1,587	9,366	4,207	159	238
	Reduction	363	2,141	961	36	54
2025	Base	1,900	11,207	5,034	190	285
	Control	1,399	8,257	3,709	140	210
	Reduction	500	2,950	1,325	50	75
2030	Base	1,927	11,372	5,108	193	289
	Control	1,327	7,829	3,516	133	199
	Reduction	601	3,544	1,592	60	90

Table 3.5-10b
Air Toxic Reductions (50-State) (tons/year)

Year		Benzene	Formaldehyde	Acetaldehyde	1,3-butadiene	Acrolein
2000	Base Control Reduction	4,018 4,018 0	23,707 23,707 0	10,648 10,648 0	402 402 0	603 603 0
2005	Base Control Reduction	3,290 3,290 0	19,412 19,412 0	8,719 8,719 0	329 329 0	494 494 0
2007	Base Control Reduction	3,023 3,023 0	17,834 17,834 0	8,010 8,010 0	302 302 0	453 453 0
2010	Base Control Reduction	2,608 2,597 11	15,386 15,323 62	6,911 6,883 28	261 260 1	391 390 2
2015	Base Control Reduction	2,153 1,986 167	12,702 11,715 987	5,705 5,262 443	215 199 17	323 298 25
2020	Base Control Reduction	1,961 1,596 365	11,568 9,415 2,154	5,196 4,229 967	196 160 37	294 239 55
2025	Base Control Reduction	1,910 1,407 503	11,268 8,300 2,968	5,061 3,728 1,333	191 141 50	286 211 75
2030	Base Control Reduction	1,938 1,334 604	11,434 7,869 3,565	5,136 3,535 1,601	194 133 60	291 200 91

3.5.5 CO Reductions

Tables 3.5-11a and 3.5-11b show the estimated 48-state and 50-state emissions of CO from land-based diesel engines in five-year increments from 2000 to 2030 with and without the final rule. Although there are no Tier 4 CO standards, CO is estimated to decrease by 90 percent with the advent of trap-equipped engines (corresponding to the start of 0.02 or 0.01 g/hp-hr PM standards). We estimate that 50-state CO emissions from these engines will decrease by 623,000 tons in 2030.

CO emissions from locomotives, commercial marine diesel vessels, and recreational marine diesel vessels are not affected by this rule.

Table 3.5-11a
Estimated National (48-State) CO
Emissions and Reductions From Nonroad Land-Based Diesel Engines

Year	CO Emissions Without Rule [short tons]	CO Emissions With Rule [short tons]	CO Reductions With Rule [short tons]
2000	916,507	916,507	0
2005	763,062	763,062	0
2010	687,234	677,599	9,634
2015	674,296	475,349	198,947
2020	697,630	309,593	388,037
2030	786,181	167,014	619,167

Table 3.5-11b
Estimated National (50-State) CO
Emissions and Reductions From Nonroad Land-Based Diesel Engines

Year	CO Emissions Without Rule [short tons]	CO Emissions With Rule [short tons]	CO Reductions With Rule [short tons]
2000	921,226	921,226	0
2005	766,944	766,944	0
2010	690,829	681,150	9,680
2015	677,918	477,800	200,118
2020	701,445	311,112	390,333
2030	790,547	167,841	622,706

3.5.6 $PM_{2.5}$ and SO_2 Reductions from the 15 ppm Locomotive and Marine (LM) Fuel Program

Tables 3.5-12a and 3.5-12b provide the 48-state and 50-state $PM_{2.5}$ and SO_2 emissions and reductions from reducing locomotive and marine fuel sulfur from 500 ppm to 15 ppm in 2012. This is referred to as the 15 ppm LM fuel program. The reductions are shown relative to the full engine and fuel program for land-based diesel engines, and locomotive and marine fuel sulfur control to 500 ppm starting in 2007. To model the reductions for this program, the in-use fuel sulfur levels in Chapter 7 were used. The 15 ppm LM fuel program provides additional $PM_{2.5}$ reductions of approximately 400 tons by 2030, and additional SO_2 reductions of approximately 5,300 tons by 2030.

Table 3.5-12a
Estimated National (48-State) $PM_{2.5}$ and SO_2 Emissions and Reductions from a 15 ppm Locomotive and Marine (LM) Fuel Program

Year	Emissions (short tons)				Reductions (short tons)	
	Land-based full engine and fuel program; LM fuel sulfur reduced to 500 ppm in 2007		Land-based full engine and fuel program; LM fuel sulfur further reduced to 15 ppm in 2012		LM fuel sulfur reduced from 500 ppm to 15 ppm in 2012	
	$PM_{2.5}$	SO_2	$PM_{2.5}$	SO_2	$PM_{2.5}$	SO_2
2000	209,876	244,599	209,876	244,599	0	0
2005	183,831	269,288	183,831	269,288	0	0
2010	144,667	24,864	144,667	24,864	0	0
2012	133,144	11,639	132,755	7,269	389	4,370
2015	110,027	8,285	109,613	2,977	414	5,308
2020	79,870	8,517	79,450	3,139	420	5,378
2030	51,296	8,925	50,882	3,621	414	5,304

Table 3.5-12b
Estimated National (50-State) $PM_{2.5}$ and SO_2 Emissions and Reductions from a 15 ppm Locomotive and Marine (LM) Fuel Program

Year	Emissions (short tons)				Reductions (short tons)	
	Land-based full engine and fuel program; LM fuel sulfur reduced to 500 ppm in 2007		Land-based full engine and fuel program; LM fuel sulfur further reduced to 15 ppm in 2012		LM fuel sulfur reduced from 500 ppm to 15 ppm in 2012	
	$PM_{2.5}$	SO_2	$PM_{2.5}$	SO_2	$PM_{2.5}$	SO_2
2000	211,688	247,010	211,688	247,010	0	0
2005	185,555	271,841	185,555	271,841	0	0
2010	146,152	25,793	146,152	25,793	0	0
2012	134,509	11,871	134,137	7,567	372	4,305
2015	111,240	8,308	110,825	2,989	415	5,319
2020	80,915	8,537	80,495	3,153	420	5,385
2030	52,279	8,935	51,866	3,640	413	5,294

3.5.7 SO_2 and Sulfate PM Reductions from Other Nonhighway Fuel

The fuel sulfur requirements in this rule are also expected to indirectly affect diesel fuel for other nonhighway end uses. This includes any application other than land-based nonroad engines, locomotives, or marine vessels. Tables 3.5-13a and 3.5-13b provide the 48-state and 50-state estimates of fuel volumes, fuel sulfur levels, and SO_2 emissions and reductions for diesel fuel for other nonhighway end uses. Tables 3.5-14a and 3.5-14b provide similar information for sulfate PM emissions and reductions. Details regarding the estimated volumes and fuel sulfur levels can be found in Chapter 7.

The tables show the incremental reductions from controlling fuel sulfur: 1) to 500 ppm in 2007 for land-based, locomotive, and marine use (the 500 ppm NRLM fuel program), 2) further control to 15 ppm in 2010 for land-based use only, and 3) further control to 15 ppm in 2010 for locomotive and marine use (the 15 ppm LM fuel program).

SO_2 emissions are calculated similarly to the commercial marine and locomotive categories, as described in Section 3.1.3. We estimate that 99 percent of the sulfur in other nonhighway fuel is emitted in the form of SO_2 and 1 percent in the form of sulfate PM.[13]

For the incremental step of reducing LM fuel sulfur from 500 ppm to 15 ppm, heating oil related benefits dominate those related to the LM fuel itself. This occurs because the final rule prohibits the use of downgraded distillate in NRLM fuel starting in mid-2010 in the Northeast/Mid-Atlantic area, while this fuel would be able to be used in LM fuel in this area under a 500 ppm cap. When this downgraded distillate cannot be used in LM fuel, it will shift to the heating oil market. The downgrade contains between 31 (highway-based) and 435 ppm (jet-based) sulfur, well below that of heating oil. Thus, the sulfur content of heating oil decreases significantly in the Northeast/Mid-Atlantic area with a 15 ppm cap on LM fuel.

Chapter 8 provides details regarding the estimated number of gallons of downgrade shifted to the heating oil market and the corresponding sulfur content of this downgrade. The resulting SO_2 and sulfate PM emission reductions for the 15 ppm LM program given in Chapter 8 are reproduced here. The 48-state and 50-state reductions for the 15 ppm LM program are the same, since the benefits only occur in the Northeast/Mid-Atlantic area, which does not include Alaska or Hawaii.

Total SO_2 reductions in 2030 for other nonhighway uses are estimated to be 19,000 tons with the full fuel program. Of that, approximately 6,300 tons are due to the 500 ppm NRLM fuel program and 12,000 tons are due to the 15 ppm LM fuel program. Total sulfate PM reductions in 2030 are estimated to be 670 tons with the full fuel program. Of that, approximately 220 tons are due to the 500 ppm NRLM fuel program and 420 tons are due to the 15 ppm LM fuel program. These reductions are not included in Tables 3.5-1a and 3.5-1b.

Table 3.5-13a

Estimated National (48-State) SO_2 Emissions and Reductions from Other Nonhighway Fuel [a]

		Sulfur (ppm)				SO_2 Emissions (tons/year)				Incremental SO_2 Reductions (tons/year)			
Year	Volume (10^6 gals)	Base	500 ppm NRLM Fuel Program (Control to 500 ppm in 2007)	500 ppm NRLM Fuel Program and NR only to 15 ppm in 2010	Full Fuel Program (NR Control to 15 ppm in 2010; LM in 2012)	Base	500 ppm NRLM Fuel Program (Control to 500 ppm in 2007)	500 ppm NRLM Fuel Program and NR only to 15 ppm in 2010	Full Fuel Program (NR Control to 15 ppm in 2010; LM in 2012)	500 ppm NRLM Fuel Program	500 ppm NRLM Fuel Program and NR only to 15 ppm in 2010	15 ppm LM Fuel Program (LM to15 ppm in 2012)	Full Fuel Program
2000	10,471	2,871	2,871	2,871	2,871	211,286	211,286	211,286	211,286	0	0	0	0
2005	10,174	2,871	2,871	2,871	2,871	205,291	205,291	205,291	205,291	0	0	0	0
2007	10,058	2,858	2,671	2,671	2,671	202,026	188,820	188,820	188,820	13,206	0	0	13,206
2008	10,000	2,858	2,534	2,534	2,534	200,866	178,086	178,086	178,086	22,780	0	0	22,780
2009	9,943	2,858	2,534	2,534	2,534	199,713	177,064	177,064	177,064	22,649	0	0	22,649
2010	9,886	2,724	2,530	2,530	2,530	189,258	175,775	175,773	175,773	13,483	2	0	13,486
2011	9,829	2,628	2,527	2,527	2,527	181,561	174,572	174,568	174,568	6,989	4	0	6,993
2012	9,772	2,628	2,527	2,527	--	180,519	173,570	173,566	168,683	6,949	4	4,884	11,837
2015	9,605	2,628	2,527	2,515	--	177,429	170,599	169,830	160,886	6,830	768	8,944	16,542
2020	9,333	2,628	2,527	2,515	--	172,394	165,758	165,012	155,190	6,636	747	9,822	17,204
2025	9,068	2,628	2,527	2,515	--	167,503	161,055	160,330	149,494	6,448	725	10,836	18,009
2030	8,811	2,628	2,527	2,515	--	162,751	156,486	155,781	143,852	6,265	705	11,929	18,899

[a] NRLM refers to land-based diesel engines, locomotives, and recreational and commercial marine vessels.
NR refers to land-based diesel nonroad engines.
LM refers to locomotives, recreational and commercial marine vessels.

Table 3.5-13b
Estimated National (50-State) SO_2 Emissions and Reductions from Other Nonhighway Fuel [a]

Year	Volume (10^6 gals)	Sulfur (ppm)				SO_2 Emissions (tons/year)				Incremental SO_2 Reductions (tons/year)			
		Base	500 ppm NRLM Fuel Program (Control to 500 ppm in 2007)	500 ppm NRLM Fuel Program and NR only to 15 ppm in 2010	Full Fuel Program (NR Control to 15 ppm in 2010; LM in 2012)	Base	500 ppm NRLM Fuel Program (Control to 500 ppm in 2007)	500 ppm NRLM Fuel Program and NR only to 15 ppm in 2010	Full Fuel Program (NR Control to 15 ppm in 2010; LM in 2012)	500 ppm NRLM Fuel Program	500 ppm NRLM Fuel Program and NR only to 15 ppm in 2010	15 ppm LM Fuel Program (LM to15 ppm in 2012)	Full Fuel Program
2000	10,819	2,859	2,859	2,859	2,859	217,431	217,431	217,431	217,431	0	0	0	0
2005	10,512	2,859	2,859	2,859	2,859	211,262	211,262	211,262	211,262	0	0	0	0
2007	10,392	2,846	2,666	2,666	2,666	207,911	194,712	194,712	194,712	13,199	0	0	13,199
2008	10,332	2,846	2,533	2,533	2,533	206,717	183,944	183,944	183,944	22,773	0	0	22,773
2009	10,273	2,846	2,533	2,533	2,533	205,531	182,889	182,889	182,889	22,642	0	0	22,642
2010	10,214	2,717	2,529	2,529	2,529	195,041	181,561	181,559	181,559	13,481	2	0	13,483
2011	10,155	2,624	2,526	2,526	2,526	187,310	180,321	180,317	180,317	6,989	4	0	6,993
2012	10,097	2,624	2,526	2,526	--	186,235	179,286	179,282	174,399	6,949	4	4,884	11,837
2015	9,924	2,624	2,526	2,515	--	183,047	176,217	175,448	166,504	6,830	768	8,944	16,542
2020	9,643	2,624	2,526	2,515	--	177,853	171,217	170,471	160,649	6,636	747	9,822	17,204
2025	9,369	2,624	2,526	2,515	--	172,807	166,359	165,634	154,798	6,448	725	10,836	18,009
2030	9,103	2,624	2,526	2,515	--	167,904	161,639	160,934	149,006	6,265	705	11,929	18,899

[a] NRLM refers to land-based diesel engines, locomotives, and recreational and commercial marine vessels.
NR refers to land-based diesel nonroad engines.
LM refers to locomotives, recreational and commercial marine vessels.

Table 3.5-14a
Estimated National (48-State) Sulfate Emissions and Reductions from Other Nonhighway Fuel [a]

Year	Volume (10^6 gals)	Sulfur (ppm)				Sulfate Emissions (tons/year)				Incremental Sulfate Reductions (tons/year)			
		Base	500 ppm NRLM Fuel Program (Control to 500 ppm in 2007)	500 ppm NRLM Fuel Program and NR only to 15 ppm in 2010	Full Fuel Program (NR Control to 15 ppm in 2010; LM in 2012)	Base	500 ppm NRLM Fuel Program (Control to 500 ppm in 2007)	500 ppm NRLM Fuel Program and NR only to 15 ppm in 2010	Full Fuel Program (NR Control to 15 ppm in 2010; LM in 2012)	500 ppm NRLM Fuel Program	500 ppm NRLM Fuel Program and NR only to 15 ppm in 2010	15 ppm LM Fuel Program (LM to15 ppm in 2012)	Full Fuel Program
2000	10,471	2,871	2,871	2,871	2,871	7,470	7,470	7,470	7,470	0	0	0	0
2005	10,174	2,871	2,871	2,871	2,871	7,258	7,258	7,258	7,258	0	0	0	0
2007	10,058	2,858	2,671	2,671	2,671	7,142	6,675	6,675	6,675	467	0	0	467
2008	10,000	2,858	2,534	2,534	2,534	7,101	6,296	6,296	6,296	805	0	0	805
2009	9,943	2,858	2,534	2,534	2,534	7,061	6,260	6,260	6,260	801	0	0	801
2010	9,886	2,724	2,530	2,530	2,530	6,691	6,214	6,214	6,214	477	0	0	477
2011	9,829	2,628	2,527	2,527	2,527	6,419	6,172	6,172	6,172	247	0	0	247
2012	9,772	2,628	2,527	2,527	--	6,382	6,136	6,136	5,964	246	0	173	418
2015	9,605	2,628	2,527	2,515	--	6,273	6,031	6,004	5,688	241	27	316	585
2020	9,333	2,628	2,527	2,515	--	6,095	5,860	5,834	5,487	235	26	347	608
2025	9,068	2,628	2,527	2,515	--	5,922	5,694	5,668	5,285	228	26	383	637
2030	8,811	2,628	2,527	2,515	--	5,754	5,532	5,507	5,086	221	25	422	668

[a] NRLM refers to land-based diesel engines, locomotives, and recreational and commercial marine vessels.
NR refers to land-based diesel nonroad engines.
LM refers to locomotives, recreational and commercial marine vessels.

Table 3.5-14b
Estimated National (50-State) Sulfate Emissions and Reductions from Other Nonhighway Fuel [a]

		Sulfur (ppm)				Sulfate Emissions (tons/year)				Incremental Sulfate Reductions (tons/year)			
Year	Volume (10^6 gals)	Base	500 ppm NRLM Fuel Program (Control to 500 ppm in 2007)	500 ppm NRLM Fuel Program and NR only to 15 ppm in 2010	Full Fuel Program (NR Control to 15 ppm in 2010; LM in 2012)	Base	500 ppm NRLM Fuel Program (Control to 500 ppm in 2007)	500 ppm NRLM Fuel Program and NR only to 15 ppm in 2010	Full Fuel Program (NR Control to 15 ppm in 2010; LM in 2012)	500 ppm NRLM Fuel Program	500 ppm NRLM Fuel Program and NR only to 15 ppm in 2010	15 ppm LM Fuel Program (LM to15 ppm in 2012)	Full Fuel Program
2000	10,819	2,859	2,859	2,859	2,859	7,687	7,687	7,687	7,687	0	0	0	0
2005	10,512	2,859	2,859	2,859	2,859	7,469	7,469	7,469	7,469	0	0	0	0
2007	10,392	2,846	2,666	2,666	2,666	7,350	6,884	6,884	6,884	467	0	0	467
2008	10,332	2,846	2,533	2,533	2,533	7,308	6,503	6,503	6,503	805	0	0	805
2009	10,273	2,846	2,533	2,533	2,533	7,266	6,466	6,466	6,466	800	0	0	800
2010	10,214	2,717	2,529	2,529	2,529	6,895	6,419	6,419	6,419	477	0	0	477
2011	10,155	2,624	2,526	2,526	2,526	6,622	6,375	6,375	6,375	247	0	0	247
2012	10,097	2,624	2,526	2,526	--	6,584	6,338	6,338	6,166	246	0	173	418
2015	9,924	2,624	2,526	2,515	--	6,471	6,230	6,203	5,887	241	27	316	585
2020	9,643	2,624	2,526	2,515	--	6,288	6,053	6,027	5,680	235	26	347	608
2025	9,369	2,624	2,526	2,515	--	6,109	5,881	5,856	5,473	228	26	383	637
2030	9,103	2,624	2,526	2,515	--	5,936	5,715	5,690	5,268	221	25	422	668

[a] NRLM refers to land-based diesel engines, locomotives, and recreational and commercial marine vessels.
NR refers to land-based diesel nonroad engines.
LM refers to locomotives, recreational and commercial marine vessels.

3.6 Emission Inventories Used for Air Quality Modeling

The emission inputs for the air quality modeling are required early in the analytical process to conduct the air quality modeling and present the results. The air quality modeling was based on a preliminary control scenario. Since the preliminary control scenario was developed, we have gathered more information regarding the technical feasibility of the standards (see Section III of the preamble for the final rule and Chapter 4 of the Final RIA). As a result, we have revised the Tier 4 emission standards for land-based diesel engines. We have also made changes to the fuel provisions of the rule for locomotives and diesel marine vessels. This section describes the changes in the inputs and resulting emission inventories between the preliminary baseline and control scenarios used for the air quality modeling and the updated baseline and control scenarios in this final rule. This section will focus on the four nonroad diesel categories that are affected by the new emission standards and/or the fuel sulfur requirements: land-based diesel engines, recreational marine diesel engines, commercial marine diesel engines, and locomotives.

The methodology used to develop the emission inventories for the air quality modeling is first briefly described, followed by comparisons of the preliminary and final baseline and control inventories.

3.6.1 Methodology for Emission Inventory Preparation

Air quality modeling was performed for calendar years 1996, 2020, and 2030. For these years, county-level emission estimates were developed by Pechan under contract to EPA. These inventories account for county-level differences in fuel characteristics and temperature. The NONROAD model was used to generate the county-level emission estimates for all nonroad sources, with the exception of commercial marine engines, locomotives, and aircraft. The methodology has been documented in detail.[10]

For the nonroad diesel categories affected by the final rule, the only fuel characteristic that affects emissions is the fuel sulfur level. The specific pollutants affected by fuel sulfur level are PM and SO_2. To develop the county-level emission estimates for each baseline and control inventory, one diesel fuel sulfur level was used to characterize all counties outside California. A separate diesel fuel sulfur level was used to characterize all counties within California. Diesel emissions as modeled are not affected by ambient temperature.

3.6.2 Baseline Inventories

Table 3.6-1 presents the preliminary 48-state baseline inventories used for the air quality modeling. These are an aggregation of the county-level results. Results expressed as short tons are presented for 1996, 2020, and 2030 for the land-based diesel, recreational marine diesel, commercial marine diesel, and locomotive categories. The pollutants include $PM_{2.5}$, NO_x, SO_2, VOC, and CO. VOC includes both exhaust and crankcase emissions.

Table 3.6-1
Modeled 48-State Baseline Emissions
Preliminary Baseline Used for Air Quality Modeling

Applications	Year	NO_x [short tons]	$PM_{2.5}$ [short tons]	SO_2 [short tons]	VOC [short tons]	CO [short tons]
Land-Based Diesel Engines	1996	1,583,641	178,500	172,175	221,398	1,010,501
	2020	1,144,686	127,755	308,075	97,113	702,145
	2030	1,231,981	143,185	360,933	97,345	793,899
Recreational Marine Diesel Engines	1996	19,438	511	2,535	803	3,215
	2020	34,814	876	4,562	1,327	5,537
	2030	41,246	1,021	5,418	1,528	6,464
Commercial Marine Diesel Engines [a]	1996	960,153	37,203	37,252	31,613	126,523
	2020	819,544	42,054	43,028	37,362	160,061
	2030	815,162	46,185	48,308	41,433	176,708
Locomotives	1996	921,556	22,396	57,979	48,381	112,171
	2020	612,722	17,683	62,843	36,546	119,302
	2030	534,520	16,988	70,436	31,644	119,302

[a] Includes emissions from vessels using both diesel and residual fuel, with the exception of SO_2. For the pollutants other than SO_2, it was not possible to separate emissions from diesel-fueled and residual-fueled vessels.

For the final baseline inventories, we have made minor changes to the diesel fuel sulfur levels. The diesel fuel sulfur inputs used for the preliminary and final baseline inventories are provided in Table 3.6-2. The diesel fuel sulfur level for land-based diesel engines is now reduced from 2500ppm to roughly 2200ppm, beginning in 2006. Both the preliminary and final sulfur levels account for spillover of highway fuel, but the preliminary sulfur levels did not properly account for the 15ppm highway fuel sulfur content control phase-in beginning in 2006. The diesel fuel sulfur levels for marine engines and locomotives are now higher prior to 2009 and lower beginning in 2010.

Table 3.6-2
Modeled Baseline In-Use Diesel Fuel Sulfur Content
Final Baseline vs. Preliminary Baseline Used for Air Quality Modeling

Applications	Final Baseline		Preliminary Baseline	
	Fuel Sulfur ppm	Calendar Year	Fuel Sulfur ppm	Calendar Year
Land-Based Diesel Engines	2283	through 2005	2500[a]	all years
	2249	2006		
	2224	2007-2009		
	2167	2010		
	2126	2011+		
Commercial and Recreational Marine Engines and Locomotives	2637-2641	through 2005	2500[a]	all years
	2616	2006		
	2599	2007-2009		
	2444	2010		
	2334-2350	2011		

[a] 2500ppm is the 48-state average diesel fuel sulfur level, based on 2700ppm in 47 states and 120ppm in California.

For the nonroad land-based diesel category, the preliminary inventories were generated with the draft NONROAD2002 model. For the final inventory, the draft NONROAD2004 model was used. The changes from draft NONROAD2002 to draft NONROAD2004 are described in Section 3.1.1.8. The net difference in land-based diesel emissions with the two model versions is generally within 3 percent, with the direction and variation of the change dependent on the calendar year and pollutant of interest. Apart from the model changes, the lower fuel sulfur levels will serve to reduce the PM and SO_2 baseline inventories in 2020 and 2030. Table 3.6-3 compares the preliminary and final 48-state baseline scenario inventories for land-based diesel engines, as well as recreational marine diesel engines, commercial marine diesel engines, and locomotives.

For recreational marine diesel engines, the preliminary inventories were generated with the draft NONROAD2002 model. For the final inventory, the draft NONROAD2004 model was used. The changes from draft NONROAD2002 to draft NONROAD2004 are more substantial for this category. The recreational marine populations, median life, and deterioration factors for HC and NO_x were revised to match what was used in the 2002 final rulemaking that covers large spark ignition engines (>25 hp), recreational equipment, and recreational marine diesel engines (>50 hp). The exhaust emission factors for HC, NO_x, and PM were also revised in draft NONROAD2004 to reflect the final standards.

For locomotives, there have been reductions to the fuel volume estimates used to calculate emissions for this category. For the preliminary inventory development, railroad distillate values were taken from the EIA Fuel and Kerosene Supply 2000 report. Fuel consumption specific to locomotives was calculated by subtracting the rail maintenance fuel consumption as generated by the draft NONROAD2002 model from the EIA railroad distillate estimates.

For the final inventory, the EIA railroad distillate estimates were taken from the EIA Fuel and Kerosene Supply 2001 report. The estimates were first adjusted to estimate the fraction of distillate that is diesel fuel. The diesel fraction used was 0.95 for railroad distillate. Fuel consumption estimates from rail maintenance were then subtracted. The estimate of rail maintenance fuel consumption was also revised by assuming these engines consume one percent of the total railroad diesel fuel estimate, rather than using the estimate derived from draft NONROAD2002. The revised estimate of rail maintenance fuel consumption is roughly half of the NONROAD-derived estimate; however, the rail maintenance portion of the total railroad diesel fuel consumption is small, so this change alone does not significantly affect the resulting locomotive estimate. The derivation of diesel fractions and the revised estimate of rail maintenance fuel consumption is documented in Chapter 7.

There have also been reductions to the fuel volumes assigned to commercial marine vessels. For the preliminary inventory development, vessel bunkering distillate values were taken from the EIA Fuel and Kerosene Supply 2000 report. Fuel consumption specific to commercial marine vessels was calculated by subtracting the recreational marine fuel consumption as generated by the draft NONROAD2002 model from the EIA vessel bunkering estimates.

For the final inventory, the EIA vessel bunkering distillate estimates were taken from the EIA Fuel and Kerosene Supply 2001 report. The vessel bunkering distillate estimates were first adjusted to estimate the fraction of distillate that is diesel fuel. The diesel fraction used was 0.90 for vessel bunkering distillate. Fuel consumption estimates from recreational marine engines were then subtracted. The estimate of recreational marine fuel consumption was that generated by the draft NONROAD2004 model. These revised fuel volumes were used to generate SO_2 and sulfate PM estimates for commercial marine diesel engines in the final inventory. Emission estimates for other pollutants emitted by commercial marine vessels were also revised in the final inventory to reflect the January 2003 final rule for Category 3 commercial marine residual engines.

As a result, differences in total emissions between the final and preliminary baseline scenarios are generally within 10 percent. Exceptions include $PM_{2.5}$ and SO_2. Total $PM_{2.5}$ emissions are higher with the final baseline scenario, in part due to the upward revision of the $PM_{2.5}$ fraction of total PM.from 92 to 97 percent. Total SO_2 emissions are lower, due to reductions in fuel volumes for some categories and reductions in fuel sulfur levels.

Table 3.6-3
Modeled 48-State Emission Impact Due to Changes in Baseline

Applications	Year	NO_x [short tons]			VOC Emissions [short tons]			CO [short tons]		
		Final	Preliminary	Difference	Final	Preliminary	Difference	Final	Preliminary	Difference
Land-Based Diesel Engines	1996	1,564,904	1,583,641	-18,737 (-1.2%)	220,971	221,398	-427 (0.0%)	1,004,586	1,010,501	-5,915 (-0.6%)
	2020	1,119,481	1,144,686	-25,205 (-2.2%)	97,513	97,113	400 (0.4%)	697,630	702,145	-4,515 (-0.6%)
	2030	1,192,833	1,231,981	-39,148 (-3.2%)	96,374	97,345	-971 (1.0%)	786,181	793,899	-7,718 (-1.0%)
Recreational Marine Diesel Engines	1996	33,679	19,438	14,241 (73.3%)	1,297	803	494 (61.5%)	5,424	3,215	2,209 (68.7%)
	2020	47,847	34,814	13,033 (37.4%)	1,604	1,327	277 (20.9%)	9,482	5,537	3,945 (71.2%)
	2030	52,085	41,246	10,839 (26.3%)	1,669	1,528	141 (9.2%)	11,232	6,464	4,768 (73.8%)
Commercial Marine Diesel Engines[a]	1996	823,905	960,153	-136,248 (-14.2%)	28,986	31,613	-2,627 (-9.1%)	108,883	126,523	-17,640 (-13.9%)
	2020	943,560	819,544	124,016 (15.1%)	41,588	37,362	4,226 (11.3%)	150,562	160,061	-9,499 (-5.9%)
	2030	1,117,848	815,162	302,686 (37.1%)	52,880	41,433	11,447 (27.6%)	178,360	176,708	1,652 (0.9%)
Locomotives	1996	934,070	921,556	12,514 (1.4%)	38,035	48,381	-10,346 (-21.4%)	92,496	112,171	-19,675 (-17.5%)
	2020	508,084	612,722	-104,638 (-17.1%)	30,125	36,546	-6,421 (-17.6%)	99,227	119,302	-20,075 (-16.8%)
	2030	481,077	534,520	-53,443 (-10.0%)	28,580	31,644	-3,064 (-9.7%)	107,780	119,302	-11,522 (-9.7%)
Total	1996	3,356,558	3,484,788	-128,230 (-3.7%)	289,289	302,195	-12,906 (-4.3%)	1,211,389	1,252,410	-41,021 (-3.3%)
	2020	2,618,972	2,611,766	7,206 (0.3%)	170,830	172,348	-1,518 (0.9%)	956,901	987,045	-30,144 (-3.1%)
	2030	2,843,843	2,622,909	220,934 (8.4%)	179,503	171,950	7,553 (4.4%)	1,083,553	1,096,373	-12,820 (-1.2%)

a To provide direct comparisons, for pollutants other than SO_2, emissions include vessels using both diesel and residual fuels.

Table 3.6-3 (cont.)
Modeled 48-State Emission Impact Due to Changes in Baseline

Applications	Year	$PM_{2.5}$ Emissions [short tons]			SO_2 [short tons]		
		Final	Preliminary	Difference	Final	Preliminary	Difference
Land-Based Diesel Engines	1996	186,507	178,500	8,007 (4.5%)	143,572	172,175	-28,603 (-16.6%)
	2020	129,058	127,755	1,303 (1.0%)	237,044	308,075	-71,031 (-23.1%)
	2030	142,484	143,185	-701 (-0.5%)	279,511	360,933	-81,422 (-22.6%)
Recreational Marine Diesel Engines	1996	923	511	412 (80.6%)	4,286	2,535	1,751 (69.1%)
	2020	1,261	876	385 (43.9%)	6,850	4,562	2,288 (50.2%)
	2030	1,371	1,021	350 (34.3%)	8,158	5,418	2,740 (50.6%)
Commercial Marine Diesel Engines [a]	1996	33,908	37,203	-3,295 (-8.9%)	30,136	37,252	-7,116 (-19.1%)
	2020	52,197	42,054	10,143 (24.1%)	29,268	43,028	-13,760 (-32.0%)
	2030	70,319	46,185	24,134 (52.3%)	33,020	48,308	-15,288 (-31.6%)
Locomotives	1996	22,266	22,396	-130 (-0.6%)	56,193	57,979	-1,786 (-3.1%)
	2020	17,213	17,683	-470 (-2.7%)	53,352	62,843	-9,491 (-15.1%)
	2030	16,025	16,988	-963 (-5.7%)	58,103	70,436	-12,333 (-17.5%)
Total	1996	243,604	238,610	4,994 (2.1%)	234,187	269,941	-35,754 (-13.2%)
	2020	199,729	188,368	11,361 (6.0%)	326,514	418,508	-91,994 (-22.0%)
	2030	230,199	207,379	22,820 (11.0%)	378,792	485,095	-106,303 (-21.9%)

[a] To provide direct comparisons, for pollutants other than SO_2, emissions include vessels using both diesel and residual fuels.

3.6.3 Control Inventories

Table 3.6-4 presents the preliminary 48-state control inventories used for the air quality modeling. These are an aggregation of the county-level results. Results expressed as short tons are presented for 2020 and 2030 for the land-based diesel, recreational marine diesel, commercial marine diesel, and locomotive categories. Results are not presented for 1996, since controls will affect only future-year emission estimates.

Table 3.6-4
Modeled 48-State Controlled Emissions
Preliminary Control Scenario Used for Air Quality Modeling

Applications	Year	NO_x [short tons]	$PM_{2.5}$ [short tons]	SO_2 [short tons]	VOC [short tons]	CO [short tons]
Land-Based Diesel Engines	2020	481,068	36,477	1,040	73,941	249,734
	2030	222,237	14,112	1,159	63,285	133,604
Recreational Marine Diesel Engines	2020	34,814	552	20	1,327	5,537
	2030	41,246	636	24	1,528	6,464
Commercial Marine Diesel Engines	2020	819,544	38,882	184	37,362	160,061
	2030	815,162	42,625	206	41,433	176,708
Locomotives	2020	612,722	13,051	272	36,546	119,302
	2030	534,520	11,798	305	31,644	119,302

The certification standards used for the preliminary and final control scenarios are provided in Tables 3.6-5 and 3.6-6, respectively. In general, the preliminary control scenario is more stringent in terms of levels and effective model years for PM and NO_x than the final control scenario for all horsepower categories. The NMHC standard is 0.14 g/hp-hr with both scenarios for <750 hp engines, although the phase-in of this standard is later in the final control scenario. The final control scenario also has a transitional NMHC standard of 0.30 g/hp-hr for engines over 750 hp. There are no Tier 4 CO standards in both control scenarios, although CO is assumed to be reduced 90 percent in both scenarios with the advent of trap-equipped engines (corresponding to the start of 0.02 or 0.01 g/hp-hr PM standards). As a result, the final standards will increase the emissions of PM, NO_x, NMHC, and CO in 2020 and 2030 relative to the preliminary standards.

Table 3.6-5
Preliminary Tier 4 Emission Standards Used for Air Quality Modeling

Engine Power	Emission Standards g/hp-hr					Model Year
	transitional or final	PM	NO_x	NMHC	CO	
hp <25	transitional	0.01	5.6 [a,b]		6.0/4.9 [b]	2010
	final	0.01	0.30	0.14	6.0/4.9 [b]	2012
25 ≤ hp < 50	transitional	0.01	5.6 [a,b]		4.1 [b]	2010
	final	0.01	0.30	0.14	4.1 [b]	2012
50 ≤ hp < 100	transitional	0.01	3.5 [a,b]		3.7 [b]	2010
	final	0.01	0.30	0.14	3.7 [b]	2012
100 ≤ hp < 175	transitional	0.01	3.0 [a,b]		3.7 [b]	2010
	final	0.01	0.30	0.14	3.7 [b]	2012
175 ≤ hp < 750	transitional	0.01	3.0 [a,b]		2.6 [b]	2009
	final	0.01	0.30	0.14	2.6 [b]	2011
hp ≥ 750	transitional	0.01	4.8 [a,b]		2.6 [b]	2009
	final	0.01	0.30	0.14	2.6 [b]	2011

[a] This is a combined NMHC + NO_x standard.
[b] This emission standard is unchanged from the level that applies in the previous model year. For engines below 25 hp, the CO standard is 6.0 g/hp-hr for engines below 11 hp and 4.9 g/hp-hr for engines at or above 11 hp. There are no Tier 4 CO standards.

Table 3.6-6
Tier 4 Emission Standards

Engine Power	Emission Standard (g/hp-hr)					Model Year(s)
	transitional or final	PM	NO_x [a]	NMHC [a]	CO [d]	
hp <25	final	0.30	5.6 [b,c]		6.0/4.9 [c]	2008
25 ≤ hp < 75	transitional	0.22	5.6/3.5 [b,c]		4.1/3.7 [c]	2008-2012
	final	0.02	3.5 [b]		4.1/3.7 [c]	2013
75 ≤ hp < 175	transitional	0.01	0.30 (50%)	0.14 (50%)	3.7 [c]	2012-2013
	final	0.01	0.30	0.14	3.7 [c]	2014
175 ≤ hp < 750	transitional	0.01	0.30 (50%)	0.14 (50%)	2.6 [c]	2011-2013
	final	0.01	0.30	0.14	2.6 [c]	2014
hp ≥ 750 except Generator sets	transitional	0.075	2.6	0.30	2.6 [c]	2011-2014
	final	0.03	2.6	0.14	2.6 [c]	2015
Generator sets 750 ≤ hp ≤ 1200	transitional	0.075	2.6	0.30	2.6 [c]	2011-2014
	final	0.02	0.50	0.14	2.6 [c]	2015
Generator sets hp > 1200	transitional	0.075	0.50	0.30	2.6 [c]	2011-2014
	final	0.02	0.50	0.14	2.6 [c]	2015

[a] Percentages are model year sales fractions required to comply with the indicated NO_x and NMHC standards, for model years where less than 100 percent is required. For a complete description of manufacturer options and alternative standards, refer to Section II of the preamble.
[b] This is a combined NMHC + NO_x standard.
[c] This emission standard level is unchanged from the level that applies in the previous model year. For 25-75 hp engines, the transitional NMHC + NO_x standard is 5.6 g/hp-hr for engines below 50 hp and 3.5 g/hp-hr for engines at or above 50 hp. For engines under 75 hp, the CO standard is 6.0 g/hp-hr for engines below 11 hp, 4.9 g/hp-hr for engines 11 to under 25 hp, 4.1 g/hp-hr for engines 25 to below 50 hp and 3.7 g/hp-hr for engines at or above 50 hp.
[d] There are no Tier 4 CO standards. The CO emission standard level is unchanged from the level that applies in the previous model year.

The diesel fuel sulfur inputs used for the preliminary and final control scenarios are provided in Tables 3.6-7 and 3.6-8, respectively. For land-based diesel engines, the modeled in-use diesel fuel sulfur content is 11 ppm in 2020 and 2030 for both scenarios. For recreational marine engines, commercial marine engines and locomotives, the modeled in-use diesel fuel sulfur content is 11 ppm in 2020 and 2030 for the preliminary control scenario, but 55 ppm in 2020 and 2030 for the final control scenario. As a result, the fuel sulfur levels required by the final rule will serve to increase the PM and SO_2 control inventories for the recreational marine, commercial marine, and locomotive categories in 2020 and 2030. This will be offset slightly by the reduced fuel volumes assigned to the commercial marine and locomotive categories.

Table 3.6-7
Modeled 48-State In-Use Diesel Fuel Sulfur Content Used for Air Quality Modeling

Applications	Standards	Modeled In-Use Fuel Sulfur Content, ppm	Calendar Year
All Diesel Categories	Baseline + hwy 500 ppm "spillover"	2500	through 2005
	Baseline + hwy 15 ppm "spillover"	2400	2006-2007
	June intro of 15 ppm	1006	2008
	Final 15 ppm standard	11	2009

Table 3.6-8
Modeled 48-State In-Use Diesel Fuel Sulfur Content

Applications	Calendar Year(s)	Modeled In-Use Fuel Sulfur Content, ppm
Land-based, all power ranges	through 2005	2283
	2006	2249
	2007	1140
	2008-2009	348
	2010	163
	2011-2013	31
	2014	19
	2015+	11
Recreational and Commercial Marine Diesel Engines and Locomotives	through 2000	2641
	2001	2637
	2002-2003	2638
	2004-2005	2639
	2006	2616
	2007	1328
	2008-2009	408
	2010	307
	2011	234
	2012	123
	2013	43
	2014	51
	2015-2017	56
	2018-2038	56
	2039-2040	55

To adjust PM emissions for these in-use fuel sulfur levels, the adjustment is made relative to the certification diesel fuel sulfur levels in the model. The modeled certification diesel fuel sulfur inputs used for the preliminary and final control scenarios are provided in Tables 3.6-9 and 3.6-

10, respectively. For 2020 and 2030, the certification diesel fuel sulfur levels are the same for both the preliminary and final control scenarios.

Table 3.6-11 compares the preliminary and final 48-state control scenario inventories for land-based diesel engines, recreational marine diesel engines, commercial marine diesel engines, and locomotives. Results are presented for $PM_{2.5}$, NO_x, SO_2, VOC, and CO emissions.

For land-based diesel engines, emissions of $PM_{2.5}$, NO_x, VOC, and CO emissions are higher for the final control scenario. This is due to the less stringent emission standards. There were no differences in either the in-use or certification diesel fuel sulfur levels in 2020 and 2030 for this category. The minor difference in SO_2 emissions between the preliminary and final scenarios is attributed to differences in the version of the NONROAD model used and aggregation of county-level runs for the preliminary scenario compared with using one national level run for the final control scenario.

The recreational marine, commercial marine, and locomotive categories are controlled in both scenarios; however, the in-use fuel sulfur level is 11 ppm for the preliminary control scenario and 56 ppm for the final control scenario. This directly affects the SO_2 emissions. Accordingly, the SO_2 emissions for these categories are higher for the final control scenario.

For the recreational marine category, differences are also attributed to the version of the NONROAD model used. For the commercial marine category, the final control scenario now accounts for the latest rulemaking inventories, as well as updated fuel volumes. For locomotives, the final control scenario incorporates updated fuel volume estimates.

Table 3.6-9
Modeled Certification Diesel Fuel Sulfur Content Used for Air Quality Modeling

Engine Power	Standards	Modeled Certification Fuel Sulfur Content, PPM	Model Year
hp <50	Tier 2	2000	through 2009
	Tier 4[a]	15	2010
50 ≤ hp < 175	Tier 3	2000	through 2009
	Tier 4[a]	15	2010
175 ≤ hp < 750	Tier 3	2000	through 2008
	Tier 4[a]	15	2009
hp ≥ 750	Tier 2	2000	through 2008
	Tier 4[a]	15	2009

[a] Tier 4 refers to both transitional and final standards.

Table 3.6-10
Modeled Certification Diesel Fuel Sulfur Content

Engine Power	Standards	Modeled Certification Fuel Sulfur Content, PPM	Model Year
hp <75	Tier 2	2000	through 2007
	transitional	500	2008
	final	15	2013
75 ≤ hp < 100	Tier 3 transitional[a]	500	2008-2011
	final	15	2012
100 ≤ hp < 175	Tier 3	2000	2007-2011
	final	15	2012
175 ≤ hp < 750	Tier 3	2000	2006-2010
	final	15	2011
hp ≥ 750	Tier 2	2000	2006-2010
	final	15	2011

[a] The emission standard here is still Tier 3 as in the Baseline case, but since the Tier 3 standard begins in 2008 for 50-100 hp engines it is assumed that this new technology introduction will allow manufacturers to take advantage of the availability of 500 ppm fuel that year.

Table 3.6-11
Modeled 48-State Emission Impact Due to Changes in Control Scenario

Applications	Year	NO_x [short tons]			$PM_{2.5}$ [short tons]			SO_2 [short tons]		
		Final	Preliminary	Difference	Final	Preliminary	Difference	Final	Preliminary	Difference
Land-Based Diesel Engines	2020	677,420	481,068	196,352 (40.8%)	50,065	36,477	13,588 (37.3%)	986	1,040	-54 (-5.2%)
	2030	458,649	222,237	236,412 (106%)	21,698	14,112	7,586 (53.8%)	1,074	1,159	-85 (-7.3%)
Recreational Marine Diesel Engines	2020	47,847	34,814	13,033 (37.4%)	738	552	186 (33.7%)	164	20	144 (720%)
	2030	52,085	41,246	10,839 (26.3%)	749	636	113 (17.8%)	195	24	171 (713%)
Commercial Marine Diesel Engines [a]	2020	943,560	819,544	124,016 (15.1%)	49,968	38,882	11,086 (28.5%)	703	184	519 (282%)
	2030	1,117,848	815,162	302686 (37.1%)	67,804	42,625	25,179 (59.1%)	786	206	580 (282%)
Locomotives	2020	508,084	612,722	-104,638 (-17.1%)	13,149	13,051	98 (0.8%)	1,282	272	1,010 (371%)
	2030	481,077	534,520	-53,443 (-10.0%)	11,599	11,798	-199 (-1.7%)	1,384	305	1,079 (354%)

[a] To provide direct comparisons, for pollutants other than SO_2, emissions include vessels using both diesel and residual fuels.

Table 3.6-11, continued

Applications	Year	VOC [short tons]			CO [short tons]		
		Final	Preliminary	Difference	Final	Preliminary	Difference
Land-Based Diesel Engines	2020	79,372	73,941	5,431 (7.3%)	309,593	249,734	59,859 (24.0%)
	2030	66,344	63,285	3,059 (4.8%)	167,014	133,604	33,410 (25.0%)
Recreational Marine Diesel Engines	2020	1,604	1,327	277 (20.9%)	9,482	5,537	3,945 (71.2%)
	2030	1,669	1,528	141 (9.2%)	11,232	6,464	4,768 (73.8%)
Commercial Marine Diesel Engines [a]	2020	41,589	37,362	4,227 (11.3%)	150,562	160,061	-9,499 (-5.9%)
	2030	52,880	41,433	11,447 (27.6%)	178,360	176,708	1,652 (0.9%)
Locomotives	2020	30,125	36,546	-6,421 (-17.6%)	99,227	119,302	-20,075 (-16.8%)
	2030	28,580	31,644	-3,064 (-9.7%)	107,780	119,312	-11,532 (-9.7%)

[a] To provide direct comparisons, for pollutants other than SO_2, emissions include vessels using both diesel and residual fuels.

Chapter 3 References

1. U.S. Environmental Protection Agency. *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling: Compression Ignition*. NR-009b. Assessment & Standards Division, Office of Transportation & Air Quality. Ann Arbor, MI. November, 2002. (Docket A-2001-28, Document II-A-29)

2. U.S. Environmental Protection Agency. *Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling*. NR-005b. Assessment & Standards Division, Office of Transportation & Air Quality. Ann Arbor, MI. May, 2002. (Docket A-2001-28, Document II-A-30)

3. U.S. Environmental Protection Agency. *Nonroad Engine Population Estimates*. NR-006b. Assessment & Standards Division, Office of Transportation & Air Quality. Ann Arbor, MI. July, 2002. (Docket A-2001-28, Document II-A-31)

4. U.S. Environmental Protection Agency. *Nonroad Engine Growth Estimates*. NR-008b. Assessment & Standards Division, Office of Transportation & Air Quality. Ann Arbor, MI. May, 2002. (Docket A-2001-28, Document II-A-32)

5. U.S. Environmental Protection Agency. *Calculation of Age Distributions in the Nonroad Model: Growth and Scrappage*. NR-007a Assessment & Standards Division, Office of Transportation & Air Quality. Ann Arbor, MI. June, 2002. (Docket A-2001-28, Document II-A-33)

6. U.S. Environmental Protection Agency. *Conversion Factors for Hydrocarbon Emission Components*. NR-002. Assessment and Standards Division, Office of Transportation & Air Quality. November, 2002. (Docket A-2001-28, Document II-A-34)

7. U.S. Environmental Protection Agency. *Recommended revision of the fraction of diesel particulate emissions mass less than 2.5 microns in size.* Memo to the docket from Bruce Cantrell. October 17, 2003. (Docket A-2001-28, Document IV-B-21)

8.U.S. Environmental Protection Agency. *Control of Emissions From Nonroad Large Spark-Ignition Engines, and Recreational Engines (Marine and Land-Based); Final Rule*. 67 FR 68241-68290. November 8, 2002. (Docket Number A-2001-01, Document V-B-05)

9. U.S. Environmental Protection Agency. *Documentation For Aircraft, Commercial Marine Vessel, Locomotive, and Other Nonroad Components of the National Emissions Inventory, Volume I - Methodology.* Emission Factor and Inventory Group, Emissions Monitoring and Analysis Division. November 11, 2002. (ftp://ftp.epa.gov/EmisInventory/draftnei99ver3/haps/documentation/nonroad/)

10. U.S. Environmental Protection Agency. *Control of Emissions From Nonroad Large Spark-Ignition Engines, and Recreational Engines (Marine and Land-Based); Final Rule*. 67 FR 68241-68290. November 8, 2002. (Docket Number A-2001-01, Document V-B-05)

11. E. H. Pechan & Associates, Inc. *Procedures for Developing Base Year and Future Year Mass Emission Inventories for the Nonroad Diesel Engine Rulemaking*. Prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. February, 2003.

12. U.S. Environmental Protection Agency. *Control of Emissions of Air Pollution from 2004 and Later Heavy-Duty Highway Engines and Vehicles*. Office of Air and Radiation. July, 2000. (Docket Number A-99-06, Document IV-A-01)

13. John E. Batey and Roger McDonald. *Advantages of Low Sulfur Home Heating Oil*. Interim Report of Compiled Research, Studies, and Data Resources. National Oilheat Research Alliance and U.S. Department of Energy. December, 2002. (E-Docket Number OAR-2003-0012-0933)