CHAPTER 6: Emissions Inventory

6.1 Methodology

The following chapter presents our analysis of the emission impact of the proposed standards for recreational marine, large spark-ignition equipment, snowmobiles, all-terrain vehicles, and off-highway motorcycles. We first present an overview of the methodology used to generate the emissions inventories, followed by a discussion of the specific information used in generating the inventories for each of the regulated categories of engines as well as the emission inventories. Emissions from a typical piece of equipment are also presented.

6.1.1 Off-highway Exhaust Emissions

We are in the process of developing an emission model that will calculate emissions inventories for most off-highway vehicle categories, including those in this rule. This draft model is called NONROAD. For this effort we use the most recent version of the draft NONROAD model publicly available with some updates that we anticipate will be included in the next draft release. This section gives a brief overview of the calculation methodology used in NONROAD for calculating exhaust emission inventories. Inputs and results specific to each of the off-highway categories in this rule are discussed in more detail later in this chapter. For more detailed information on the draft NONROAD model, see our website at www.epa.gov/otaq/nonrdmdl.htm.

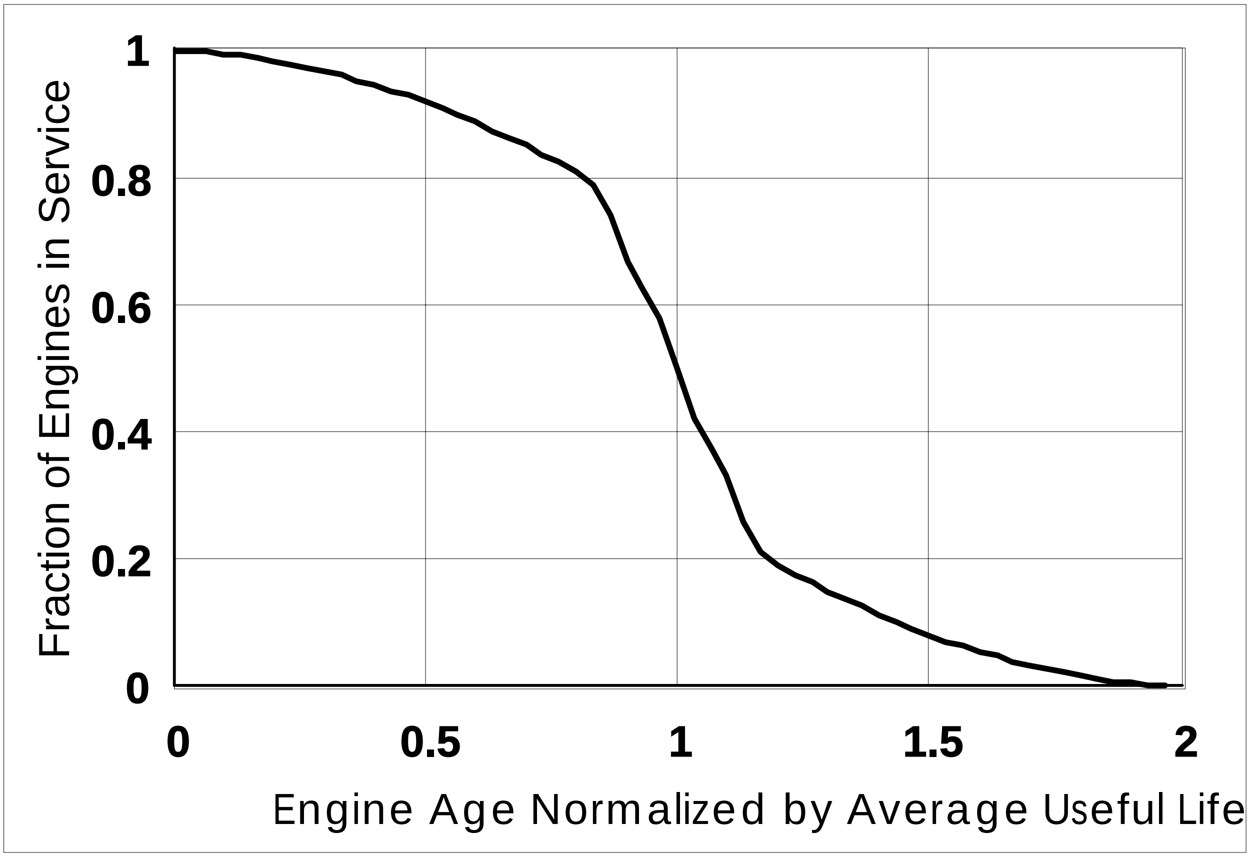
For the inventory calculations in this rule, each class of off-highway engines was divided into power ranges to distinguish between technology or usage differences in each category. Each of the engine applications and power ranges were modeled with distinct annual hours of operation, load factors, and average engine lives. The basic equation for determining the exhaust emissions inventory, for a single year, from off-highway engines is shown below:

$$Emissions = \sum_{ranges} (population \times power \times load \times annual\,use \times emission\,factor) \qquad (Eq. 6-1)$$

This equation sums the total emissions for each of the power ranges for a given calendar year. “Population” refers to the number of engines estimated to be in the U.S. in a given year. “Power” refers to the population-weighted average rated power for a given power range. Two usage factors are included; “load” is the ratio between the average operational power output and the rated power, and “annual use” is the average hours of operation per year. Emission factors are applied on a brake-specific basis (g/kW-hr) and represent the weighted value between levels from baseline and controlled engines operating in a given calendar year. Exhaust emission inventories were calculated for HC, CO, and NOx from all engines and additionally for PM from compression-ignition engines. Although some of the proposed emission standards combine HC and NOx, it is useful to consider the HC and NOx emission impacts separately. (As described throughout this document, the proposed standards for all-terrain vehicles (ATVs) and off-highway motorcycles are based on a chassis test, with the standards proposed in grams per kilometer. For these two categories of equipment, the equation used by the NONROAD model for calculating emissions is similar to Equation 6-1 except that the "load factor" and "power" terms are not included in the calculation, the "annual use" is input on a miles/year basis, and the "emission factors" are entered on a gram per mile basis.)

To be able to determine the mix between baseline and controlled engines, we need to determine the turnover of the fleet. Through the combination of historical population and scrappage rates, historical sales and retirement of engines can be estimated. We use a normalized scrappage rate and fit it to the data for each engine type on average operating life. Figure 6.1.1-1 presents the normalized scrappage curve used in the draft NONROAD model. For further discussion of this scrappage curve, see our report titled "Calculation of Age Distributions -- Growth and Scrappage," (NR-007).

Figure 6.1.1-1: Normalized Scrappage Curve



6.1.2 Off-highway Evaporative Emissions

Evaporative emissions refer to hydrocarbons released into the atmosphere when gasoline, or other volatile fuels, evaporate from a vehicle. For this analysis, we model three types of evaporative emissions:

- diurnal: These emissions are due to temperature changes throughout the day. As the day gets warmer, the fuel heats up and begins to evaporate.

- refueling: These emissions are the vapors displaced from the fuel tank when fuel is dispensed into the tank.

- permeation: These emissions are due to fuel that works its way through the material used in the fuel system. Permeation is most common through plastic fuel tanks and rubber hoses.

We are currently in the process of revising the inputs to the calculations for evaporative emissions in the draft NONROAD model. The analysis for this rule includes the inputs that we anticipate will be used in the draft NONROAD model. Because diurnal and refueling emissions are dependent on ambient temperatures and fuel properties which vary through the nation and through the year, we divided the nation into six regions and modeled each region individually for each day of the year. The daily temperatures by region are based on a report which summarizes a survey of dispensed fuel and ambient temperatures in the United States.[1]

For diurnal emission estimates, we used the Wade-Reddy equations[2,3,4] to calculate grams of hydrocarbons emitted per day per volume of fuel tank capacity. The Wade-Reddy equations are well established and are used in both the MOBILE and draft NONROAD models with an adjustment based on empirical data. These calculations are a function of vapor space, fuel vapor pressure, and daily temperature variation and are as follows:

$$\text{Vapor space (ft}^3\text{)} = ((1 - \text{tank fill}) \times \text{tank size} + 3) / 7.841 \qquad \textbf{(Eq. 6-2)}$$

where:

tank fill = fuel in tank/fuel tank capacity
tank size = fuel tank capacity in gallons

$$T_1\ (^\circ F) = (T_{max} - T_{min}) \times 0.922 + Tmin \qquad \textbf{(Eq. 6-3)}$$

where:

T_{max} = maximum diurnal temperature (°F)
T_{min} = minimum diurnal temperature (°F)

$$V_{100}\ \text{(psi)} = 1.0223 \times RVP + [(0.0357\ X\ RVP)/(1-0.0368 \times RVP)] \qquad \textbf{(Eq. 6-4)}$$

where:

V_{100} = vapor pressure at 100°F
RVP = Reid Vapor Pressure of the fuel

$$E_{100}\ (\%) = 66.401-12.718 \times V_{100} + 1.3067 \times V_{100}^{2} - 0.077934 \times V_{100}^{3} + 0.0018407 \times V_{100}^{4} \qquad \textbf{(Eq. 6-5)}$$

$$D_{min}\ (\%) = E_{100} + [(262 / (0.1667 * E_{100} + 560) - 0.113] \times (100 - T_{min}) \qquad \textbf{(Eq. 6-6a)}$$

$$D_{max}\ (\%) = E_{100} + [(262 / (0.1667 * E_{100} + 560) - 0.113] \times (100 - T_{1}) \qquad \textbf{(Eq. 6-6b)}$$

where:

$D_{min/max}$ = distillation percent at the max/min temperatures in the fuel tank
E_{100} = percent of fuel evaporated at 100°F from equation 6-5

$$P_{I}\ (psi) = 14.697 - 0.53089 \times D_{min} + 0.0077215 \times D_{min}^{2} - 0.000055631 \times D_{min}^{3} + 0.0000001769 \times D_{min}^{4} \qquad \textbf{(Eq. 6-7a)}$$

$$P_{F}\ (psi) = 14.697 - 0.53089 \times D_{max} + 0.0077215 \times D_{max}^{2} - 0.000055631 \times D_{max}^{3} + 0.0000001769 \times D_{max}^{4} \qquad \textbf{(Eq. 6-7a)}$$

$$\text{Density (lb/gal)} = 6.386 - 0.0186 \times RVP \qquad \textbf{(Eq. 6-8)}$$

$$\text{MW (lb/lb mole)} = (73.23 - 1.274 \times RVP) + [0.5 \times (T_{min} + T_{1}) - 60] \times 0.059 \qquad \textbf{(Eq. 6-9)}$$

$$\text{Diurnal emissions (grams)} = \text{vapor space} \times 454 \times \text{density} \times [520 / (690 - 4 \times MW)] \times 0.5 \times [P_{I} / (14.7 - P_{I}) + P_{F} / (14.7 - P_{F})] \times [(14.7 - P_{I}) / (T_{min} + 460) - (14.7 - P_{F}) / (T_{1} + 460)] \qquad \textbf{(Eq. 6-10)}$$

where:

MW = molecular weight of hydrocarbons from equation 6-9
$P_{I/F}$ = initial and final pressures from equation 6-7

Because these calculations were developed and verified using automotive sized fuel tanks, we ran the above equations for a 20 gallon fuel tank and then divided by 20 gallons to get emission factors on a gram per gallon basis. This ensures that the vapor space calculation gives a reasonable result.

We used the draft NONROAD model to determine the amount of fuel consumed by spark-ignition marine engines. To calculate refueling emissions, we used an empirical equation to calculate grams of vapor displaced during refueling events. This equation was developed based on testing of 22 highway vehicles under various refueling scenarios and in the benefits calculations for our onboard refueling vapor recovery rulemaking for cars and trucks.[5] These calculations are a function of fuel vapor pressure, ambient temperature, and dispensed fuel temperature. The refueling vapor generation equation is as follows:

$$\text{Refueling vapor (g/gal)} = \text{EXP}(-1.2798 - 0.0049 \times (Td - Ta) + 0.0203 \times Td + 0.1315 \times RVP) \qquad \textbf{(Eq. 6-11)}$$

where:

Td = dispensed fuel temperature (°F)
Ta = ambient fuel temperature (°F)
RVP = Reid Vapor Pressure of the fuel

Title 40, Section 80.27 of the Code of Federal Regulations specifies the maximum allowable fuel vapor pressure allowed for each state in the U.S. for each month of the year. We used these limits as an estimate of fuel vapor pressure in our calculations.

We are not aware of a model that will allow us to calculate fuel permeation from nonroad equipment. However we have limited data on the permeability of plastic fuel tanks and rubber hoses. Based on this data, and a distribution of fuel tank sizes, materials, and assumed hose lengths, we were able to estimate evaporative emissions due to permeation.

6.2 Effect of Emission Controls by Engine/Vehicle Type

The remainder of this chapter discusses the inventory results for each of the classes of engines/vehicles included in this document. These inventory projections include both exhaust and evaporative emissions. Also, this section describes inputs and methodologies used for the inventory calculations that are specific to each engine/vehicle class.

6.2.1 Compression-Ignition Recreational Marine

We projected the annual tons of exhaust HC, CO, NOx, and PM from CI recreational marine engines using the draft NONROAD model discussed above. This section describes inputs to the calculations that are specific to CI recreational marine engines then presents the results. These results are for the nation as a whole and include baseline and control inventory projections.

6.2.1.1 Inputs for the Inventory Calculations

Several usage inputs are specific to the calculations for CI recreational marine exhaust emissions. These inputs are load factor, annual use, average operating life, and population. Based on data collected in developing the draft NONROAD model, we use a load factor of 35 percent and an annual usage factor of 200 hours. We use an average operating life of 20 years for engines below 225 kW and 30 years for larger engines. The draft NONROAD model includes current and projected engine populations. Table 6.2.1-1 presents these population estimates for selected years.

Table 6.2.1-1
Projected CI Recreational Marine Population by Year

Year	*2000*	*2005*	*2010*	*2020*	*2030*
population	167,000	193,000	219,000	272,000	326,000

We used the data presented in Chapter 4 to develop the baseline emission factors. For the control emission factors, we assumed that the manufacturers would design their engines to meet the proposed standard at regulatory useful life with a small compliance margin. (The regulatory useful life is the period of time for which a manufacturer must demonstrate compliance with the emission standards.) To determine the HC and NOx split for the proposed standards, we used the HC and NOx data presented in Chapter 4 from CI recreational marine engines near the proposed standards. Consistent with our modeling of heavy-duty highway emissions, we assumed a compliance margin of 8 percent. This compliance margin is based on historical practices for highway and nonroad engines with similar technology. Engine manufacturers give themselves some cushion below the certification level on average so that engine-to-engine variability will not cause a significant number of engines to exceed the standard. Also, we used the deterioration factors in the draft NONROAD model. Table 6.2.1-2 presents the emission factors used in this analysis for new engines and for engines deteriorated to the regulatory useful life (10 years).

Table 6.2.1-2
Emission Factors for CI Recreational Marine Engines

Engine Technology	*HC [g/kW-hr]*		*NOx [g/kW-hr]*		*CO [g/kW-hr]*		*PM [g/kW-hr]*	
	new	*10 yrs*	*new*	*10 yrs*	*new*	*10 yrs*	*new*	*10 yrs*
baseline	0.295	0.304	8.94	9.06	1.27	1.39	0.219	0.225
controlled:								
< 0.9 liters/cylinder	0.183	0.184	6.72	6.76	1.27	1.39	0.219	0.225
0.9-1.2 liters/cylinder	0.183	0.184	6.40	6.44	1.27	1.39	0.219	0.225
≥ 1.2 liters/cylinder	0.183	0.184	6.40	6.44	1.27	1.39	0.181	0.184

In our analysis of the CI recreational marine engine emissions inventory, we may underestimate emissions, especially PM, due to engine deterioration in-use. We believe that current modeling only represents properly maintained engines, but may not be representative of in-use tampering or malmaintenance. However, we have not fully evaluated the limited data currently available and we are in the process of collecting more data on in-use emission deterioration. Once this has been completed we will decide whether or not we need to update our deterioration rates both in this analysis and in the Draft NONROAD model.

6.2.1.2 Reductions Due to the Proposed Standard

We anticipate that the proposed standards will result in a 41 percent reduction in HC+NOx and a 22 percent reduction in PM from new engines. Because of the long lives of these engines, even in 2030 the only about half of the fleet will be turned over to the new engines. For this reason the reductions in 2030 are only about 26 percent HC+NOx and 9 percent PM. We are not claiming any benefits from the proposed cap on CO emissions. The following charts and tables present our projected exhaust emission inventories for CI recreational marine engines and the anticipated emission reductions.

Figure 6.2.1-1: Projected National HC from CI Recreational Marine Engines

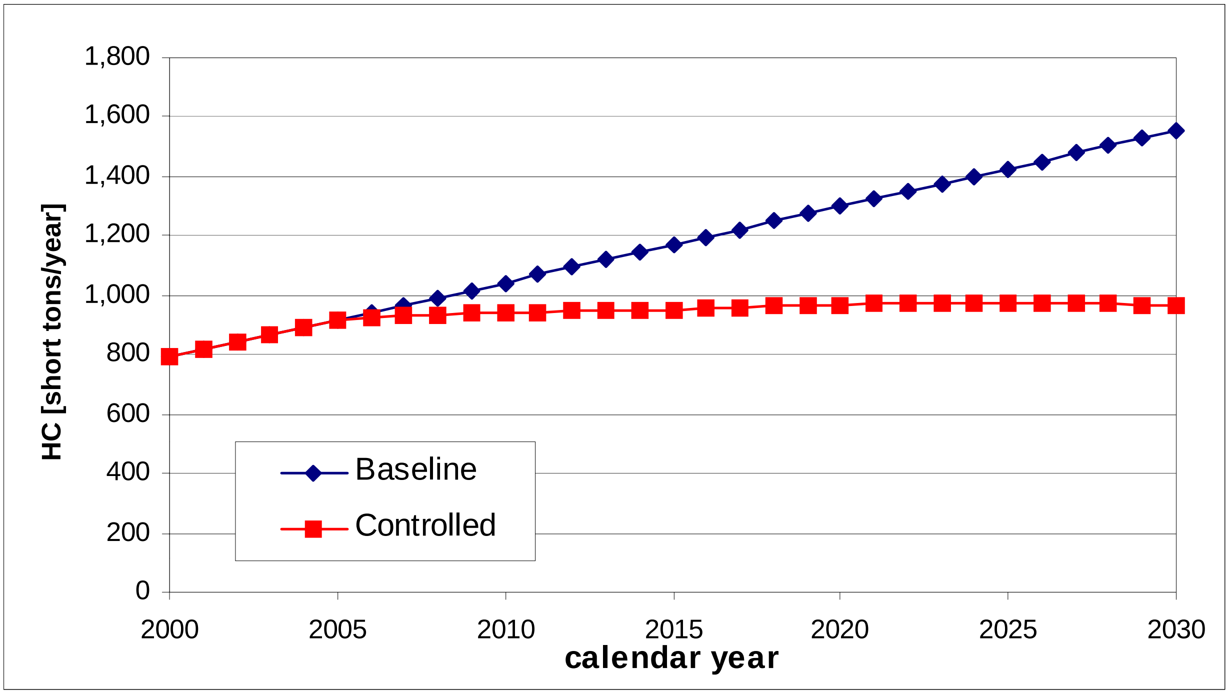


Table 6.2.1-3
Projected HC Reductions for CI Recreational Marine Engines [short tons]

Calendar Year	*Baseline*	*Control*	*Reduction*	*% Reduction*
2000	800	800	0	0%
2005	920	920	0	0%
2010	1,040	940	100	10%
2020	1,300	970	330	25%
2030	1,550	970	580	38%

Figure 6.2.1-2: Projected National NOx from CI Recreational Marine Engines

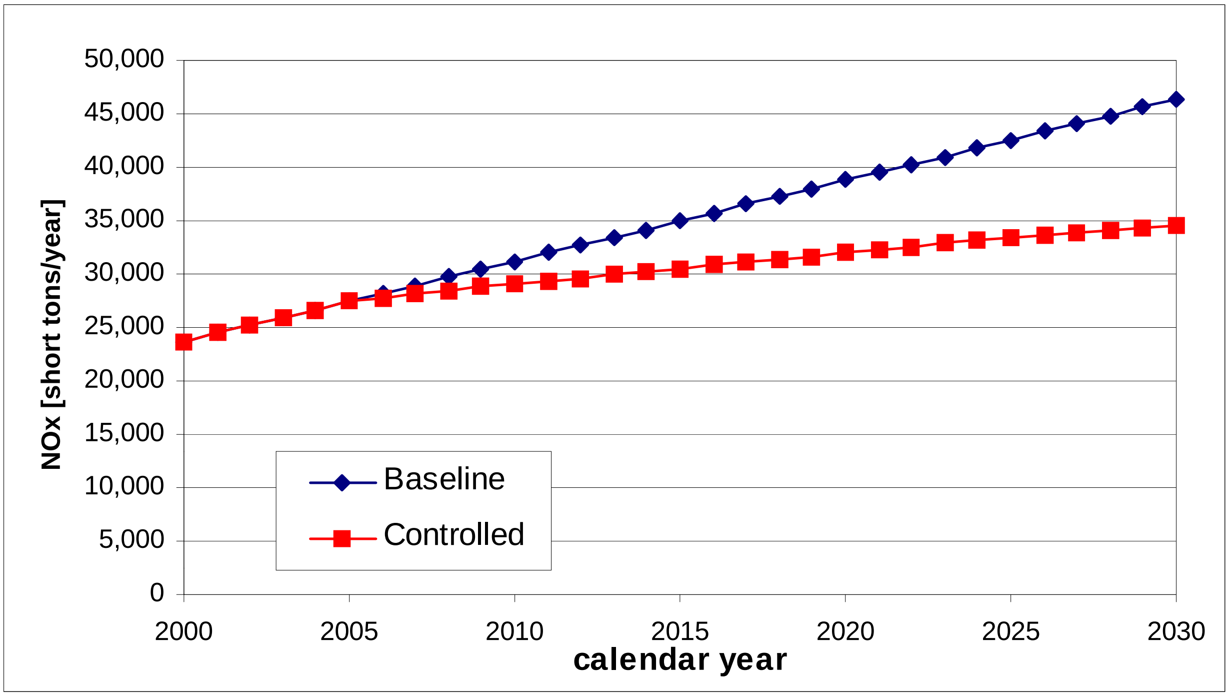


Table 6.2.1-4
Projected NOx Reductions for CI Recreational Marine Engines [short tons]

Calendar Year	*Baseline*	*Control*	*Reduction*	*% Reduction*
2000	23,700	23,700	0	0%
2005	27,400	27,400	0	0%
2010	31,200	29,000	2,110	7%
2020	38,800	32,000	6,760	17%
2030	46,300	34,500	11,800	26%

Figure 6.2.1-4: Projected National PM from CI Recreational Marine Engines

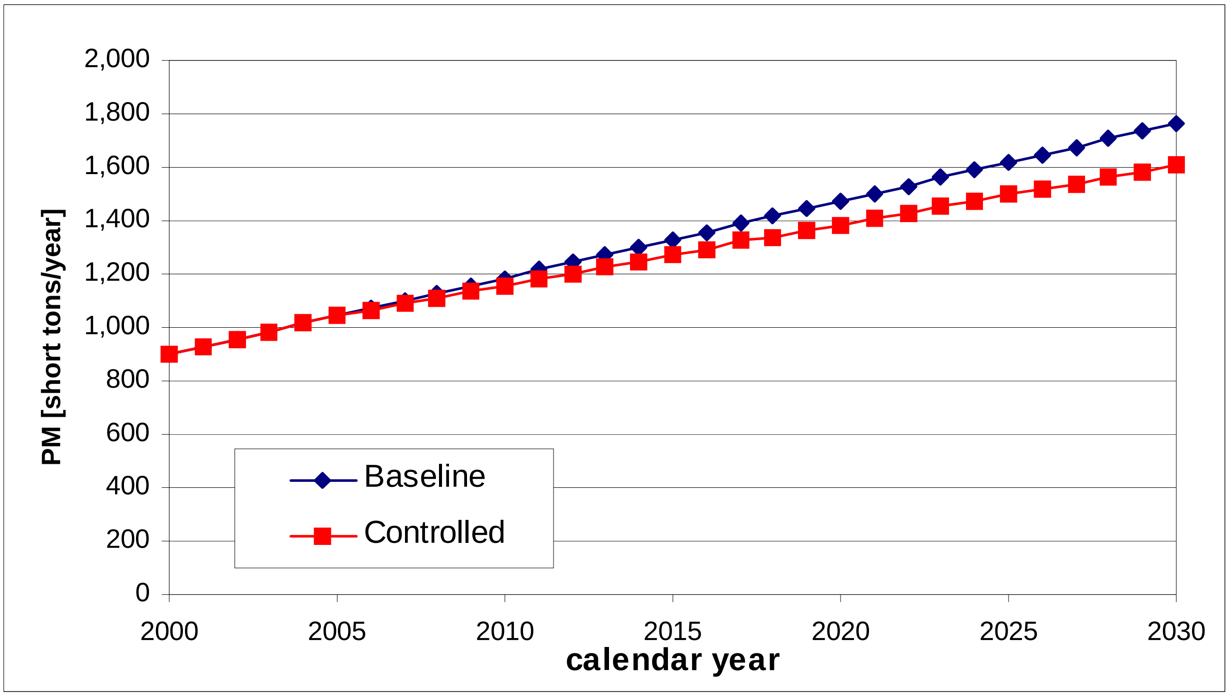


Table 6.2.1-6
Projected PM Reductions for CI Recreational Marine Engines [short tons]

Calendar Year	*Baseline*	*Control*	*Reduction*	*% Reduction*
2000	900	900	0	0%
2005	1,040	1,040	0	0%
2010	1,180	1,160	20	2%
2020	1,470	1,390	80	6%
2030	1,760	1,600	160	9%

6.2.1.3 Per Vessel Emissions from CI Recreational Marine Engines

This section describes the development of the HC plus NOx emission estimates on a per engine basis over the average lifetime of typical CI recreational marine engines. As in the cost analysis in Chapter 5, we look at three engine sizes for this analysis (100, 400, and 750 kW) as well as a composite of all engine sizes. The emission estimates were developed to estimate the cost per ton of the proposed standards as presented in Chapter 7.

The new and deteriorated emission factors used to calculate the HC and NOx emissions from typical CI recreational marine engines were presented in Table 6.2.1-2. A brand new engine emits at the zero-mile level presented in the table. As the engine ages, the emission levels increase based on the pollutant-specific deterioration factor. The load factor for these engines is estimated to be 0.35, the annual usage rate is estimated to be 200 hours per year, and the average lifetime is estimated to be 20 years for engines less than 225 kW and 30 years for larger engines.

Using the information described above and the equation used for calculating emissions from nonroad engines (see Equation 6-1), we calculated the lifetime HC+NOx emissions from typical marine engines both baseline and controlled engines. Table 6.2.1-7 presents these results with and without the consideration of a 7 percent per year discount on the value of emission reductions.

Table 6.2.1-7
Lifetime HC+NOx Emissions from Typical CI Recreational Marine Engines (tons)

Engine Size	Baseline		Control		Reduction	
	Undiscounted	Discounted	Undiscounted	Discounted	Undiscounted	Discounted
100 kW	1.44	0.82	1.01	0.57	0.43	0.24
400 kW	8.65	3.82	6.08	2.69	2.57	1.13
750 kW	16.2	7.16	11.4	5.04	4.84	2.12
Composite	5.64	2.58	3.96	1.81	1.68	0.76

6.2.1.4 Crankcase Emissions from CI Recreational Marine Engines

We anticipate some benefits in HC, NOx, and PM from the closed crankcase requirements for CI recreational marine engines. Based on limited engine testing, we estimate that crankcase emissions of HC and PM diesel engines are each about 0.013 g/kW-hr.[6] NOx data varies, but crankcase NOx emissions may be as high as HC and PM. Therefore, we use the same crankcase emission factor of 0.01 g/bhp-hr for each of the three constituents.

For this analysis, we assume that manufacturers will use the low cost option of routing crankcase emissions to the exhaust and including them in the total exhaust emissions when the engine is designed to the standards. Because exhaust emissions would have to be reduced slightly to offset any crankcase emissions, the crankcase emission control is functionally equivalent to a 100 percent reduction in crankcase emissions.

The engine data we use to determine crankcase emission levels is based on new heavy-duty engines. We do not have data on the effect of in-use deterioration of crankcase emissions. However, we expect that these emissions would increase as the engine wears. Therefore, this analysis may underestimate the benefits that would result from our crankcase emission requirements. Table 6.2.1-8 presents our estimates of the reductions crankcase emissions from CI recreational marine engines.

Table 6.2.1-8
Crankcase Emissions Reductions from CI Recreational Marine Engines

Calendar Year	*HC+NOx*	*PM*
2000	0	0
2005	0	0
2010	17	8
2020	63	32
2030	113	56

6.2.2 Large Spark-Ignition Equipment

6.2.2.1 Exhaust Emissions from Large SI Equipment

We projected the annual tons of exhaust HC, CO, and NOx from large industrial spark-ignition (SI) engines using the draft NONROAD model described above. This section describes inputs to the calculations that are specific to these engines then presents the results of the modeling.

6.2.2.1.1 Inputs for Exhaust Inventory Calculations

Several usage inputs are specific to the calculations for Large SI engines. These inputs are load factor, annual use, average operating life, and population. Because the Large SI category is made up of many applications, the NONROAD model contains application-specific information for each of the applications making up the Large SI category. Table 6.2.2-1 presents the inputs used in the NONROAD model for each of the Large SI applications. (The average operating life for a given application can vary within an application by power category. In such cases, the average operating life value presented in Table 6.2.2-1 is based on the average operating life estimate for the engine with the average horsepower listed in the table.)

The NONROAD model generally uses population data based on information from Power Systems Research, which is based on historical sales information adjusted according to survival and scrappage rates. We are, however, using different population estimates for forklifts based on a recent market study.[7] That study identified a 1996 population of 491,321 for Class 4 through 6 forklifts, which includes all forklifts powered by internal combustion engines. Approximately 80 percent of those were estimated to be fueled by propane, with the rest running on either gasoline or diesel fuel. Assuming an even split between gasoline and diesel for these remaining forklifts leads to a total population of spark-ignition forklifts of 442,000. The NONROAD model therefore uses this estimate for the forklift population, which is significantly higher than that estimated by Power Systems Research. Table 6.2.2-1 shows the estimated population figures used in the NONROAD model for each application, adjusted for the year 2000.

The split between LPG and gasoline in various applications warrants further attention.

Engines are typically sold without fuel systems, which makes it difficult to assess the distribution of engines sales by fuel type. Also, engines are often retrofitted for a different fuel after a period of operation, making it still more difficult to estimate the prevalence of the different fuels. The high percentage of propane systems for forklifts, compared with about 60 percent estimated by Power Systems Research, can be largely attributed to expenses related to maintaining fuel supplies. LPG cylinders can be readily exchanged with minimal infrastructure cost as compared to gasoline storage. Natural gas systems typically offer the advantage of pipeline service, but the cost of installing high-pressure refueling equipment is an obstacle to increased use of natural gas systems.

Some applications of nonroad SI equipment face much different refueling situations. Lawn and garden equipment is usually not centrally fueled and therefore operates almost exclusively on gasoline, which is more readily available. Agriculture equipment is predominantly powered by diesel engines. Most of these operators likely have storage tanks for diesel fuel. For those who use spark-ignition engines in addition to, or instead of, the diesel models, we would expect them in many cases to be ready to invest in gasoline storage tanks as well, resulting in little or no use of LPG or natural gas for those applications. For construction, general industrial, and other equipment, there may be a mix of central and noncentral fueling, and motive and portable equipment. We therefore believe that estimating an even mix of LPG and gasoline for these engines is most appropriate. The approximate distribution of fuel types for the individual applications used in the NONROAD model are listed in Table 6.2.2-1.

Table 6.2.2-1
Operating Parameters and Population Estimates for Various Large SI Applications

Application	Avg. Rated HP	Load Factor	Hours per Year	Average Operating Life (yrs)	2000 Population	Percent LPG/CNG
Forklift	69	0.30	1800	8.3	504,696	95
Generator	59	0.68	115	25.0	146,246	100
Commercial turf	28	0.60	682	3.7	55,433	0
Aerial lift	52	0.46	361	18.1	38,901	50
Pump	45	0.69	221	9.8	35,981	50
Welder	67	0.58	408	12.7	19,246	50
Baler	44	0.62	68	25.0	18,659	0
Air compressor	65	0.56	484	11.1	17,472	50
Scrubber/sweeper	49	0.71	516	4.1	13,363	50
Chipper/grinder	66	0.78	488	7.9	13,015	50
Swathers	95	0.52	95	25.0	12,060	0
Leaf blower/vacuum	79	0.94	282	11.3	11,797	0

Application	Avg. Rated HP	Load Factor	Hours per Year	Average Operating Life (yrs)	2000 Population	Percent LPG/CNG
Sprayers	66	0.65	80	25.0	9,441	0
Specialty vehicle/cart	66	0.58	65	25.0	9,145	50
Oil field equipment	44	0.90	1104	1.5	7,855	100
Skid/steer loader	47	0.58	310	8.3	7,436	50
Other agriculture equipment	162	0.55	124	25.0	5,501	0
Irrigation set	97	0.60	716	7.0	5,367	50
Trencher	54	0.66	402	11.3	3,627	50
Rubber-tired loader	71	0.71	512	8.8	3,177	50
Other general industrial	82	0.54	713	7.8	2,942	50
Terminal tractor	93	0.78	827	4.7	2,716	50
Bore/drill rig	78	0.79	107	25.0	2,607	50
Concrete/industrial saw	46	0.78	610	3.2	2,266	50
Rough terrain forklift	66	0.63	413	11.5	1,925	50
Other material handling	67	0.53	386	7.3	1,605	50
Ag. tractor	82	0.62	550	8.8	1,599	0
Paver	48	0.66	392	5.8	1,367	50
Roller	55	0.62	621	7.8	1,362	50
Other construction	126	0.48	371	16.8	1,276	50
Crane	75	0.47	415	15.4	1,240	50
Pressure washer	39	0.85	115	15.3	1,227	50
Paving equipment	39	0.59	175	14.5	1,109	50
Aircraft support	99	0.56	681	7.9	910	50
Gas compressor	110	0.60	6000	0.8	788	100
Front mowers	32	0.65	86	25.0	658	0
Other lawn & garden	61	0.58	61	25.0	402	0
Tractor/loader/backhoe	58	0.48	870	7.2	360	50
Hydraulic power unit	50	0.56	450	6.0	330	50
Surfacing equipment	40	0.49	488	6.3	314	50
Crushing/processing equip	63	0.85	241	14.6	235	50

Application	Avg. Rated HP	Load Factor	Hours per Year	Average Operating Life (yrs)	2000 Population	Percent LPG/CNG
Refrigeration/AC	55	0.46	605	10.8	169	100

An additional issue related to population figures is the level of growth factored into emission estimates for the future. The NONROAD model incorporates application-specific growth figures based on projections from Power Systems Research. The model projects growth rates separately for the different fuels for each application. Table 6.2.2-2 presents the population estimates of Large SI engines (rounded to the nearest 1,000 units) by fuel type for selected years.

Table 6.2.2-2
Projected Large SI Population by Year

Category	2000	2005	2010	2020	2030
Gasoline LSI	225,000	234,000	244,000	269,000	298,000
LPG LSI	653,000	789,000	927,000	1,195,000	1,440,000
CNG LSI	89,000	99,000	110,000	134,000	158,000
Total LSI	967,000	1,122,000	1,281,000	1,598,000	1,896,000

Southwest Research Institute recently compiled a listing of test data from past and current testing projects.[8] These tests were all conducted on new or nearly new engines and are used in the NONROAD model as zero-mile levels (ZML). Table 6.2.2-3 summarizes this test data. All engines were operated on the steady-state ISO C2 duty cycle, except for two engines that were tested on the steady-state D2 cycle. The results from the different duty cycles were comparable. Lacking adequate test data for engines fueled by natural gas, we model those engines to have the same emission levels as those fueled by liquefied petroleum gas (LPG), based on the similarity between engines using the two fuels (in the case of hydrocarbon emissions, the equivalence is based on non-methane hydrocarbons).

Emission levels often change as an engine ages. In most cases, emission levels increase with time, especially for engines equipped with technologies for controlling emissions. We developed deterioration factors for uncontrolled Large SI engines based on measurements with comparable highway engines.[9] Table 6.2.2-3 also shows the deterioration factors that apply at the median lifetime estimated for each type of equipment. For example, a deterioration factor of 1.26 for hydrocarbons multiplied by the emission factor of 6.2 g/hp-hr for new gasoline engines indicates that modeled emission levels increase to 7.8 g/hp-hr when the engine reaches its median lifetime. The deterioration factors are linear multipliers, so the modeled deterioration at different points can be calculated by simple interpolation.

Emissions during transient operation can be significantly higher than during steady-state operation. Based on emission measurements from highway engines comparable to uncontrolled Large SI engines, we have measured transient emission levels that are 30 percent higher for HC and 45 percent higher for CO relative to steady-state measurements.[10] The NONROAD model therefore multiplies steady-state emission factors by a transient adjustment factor (TAF) of 1.3 for HC and 1.45 for CO to estimate emission levels during normal, transient operation. Test data do not support adjusting NOx emission levels for transient operation and so a TAF of 1.0 is used for NOx emissions. Also, the model applies no transient adjustment factor for generators, pumps, or compressors, since engines in these applications are less likely to experience transient operation.

Table 6.2.2-3
Zero-Mile Level Emission Factors (g/hp-hr), Deterioration Factors (at Median Life) and Transient Adjustment Factors for Pre-Control Large SI Engines

Fuel Category	THC			CO			NOx		
	ZML	DF	TAF	ZML	DF	TAF	ZML	DF	TAF
Gasoline	6.2	1.26	1.3	203.4	1.35	1.45	7.1	1.03	1.0
LPG	1.7	1.26	1.3	28.2	1.35	1.45	12.0	1.03	1.0
CNG	24.6	1.26	1.3	28.2	1.35	1.45	12.0	1.03	1.0

As manufacturers comply with the proposed Phase 1 emission standards for Large SI engines, we expect the emission factors, deterioration factors and transient adjustment factors will be affected. To estimate the Phase 1 deterioration factors, we relied upon deterioration information for current Class IIb heavy-duty gasoline engines developed for the MOBILE6 emission model. Class IIb engines are the smallest heavy-duty engines and are comparable in size to many Large SI engines. They also employ catalyst/fuel system technology similar to the technologies we expect to be used on Large SI engines. To estimate the Phase 1 emission factors at zero miles, we back-calculated the emission levels based on the proposed standards and the estimated deterioration factors, assuming manufacturers will design to meet a level 10 percent below the proposed standard to account for variability. Given that these engines will employ a catalyst to meet the proposed standards, we believe a 10 percent compliance margin is appropriate. (Including a margin of compliance below the standards is a practice that manufacturers have followed historically to provide greater assurance that their engines would comply in the event of a compliance audit.) Because the proposed standards include an HC+NOx standard, we assumed the HC/NOx split would stay the same as pre-control engines (at the end of the regulated useful life). Table 6.2.2-4 presents the zero-mile levels, deterioration factors used in the analysis of today's proposed Phase 1 standards for Large SI engines. The Phase 1 standards are proposed to take effect in 2004 for all engines.

The transient adjustment factors for Phase 1 engines were based on testing performed at Southwest Research Institute on engines that are similar to those expected to be certified under the proposed Phase 1 standards. The testing was performed on one gasoline fueled engine and two LPG-fueled engines. A complete description of the testing performed and the results of the testing is summarized in the docket for the rulemaking.[11] Because we did not have any test results for CNG-fueled engines, the same transient adjustment factors for LPG-fueled engines were used.

Table 6.2.2-4
Zero-Mile Level Emission Factors (g/hp-hr), Deterioration Factors (at Median Life) and Transient Adjustment Factors for Phase 1 Large SI Engines

Fuel Category	THC			CO			NOx		
	ZML	DF	TAF	ZML	DF	TAF	ZML	DF	TAF
Gasoline	0.85	1.64	1.7	24.5	1.36	1.7	1.1	1.15	1.4
LPG	0.25	1.64	2.9	24.5	1.36	1.45	2.1	1.15	1.5
CNG	3.7	1.64	2.9	24.5	1.36	1.45	2.1	1.15	1.5

In a similar manner, as manufacturers comply with the proposed Phase 2 emission standards for Large SI engines, we expect the emission factors, deterioration factors and transient adjustment factors will be affected. To estimate the Phase 2 deterioration factors, we relied upon the same information noted above for Phase 1 engines. The technologies used to comply with the proposed Phase 2 standards are expected to be further refinements of the technologies we expect to be used on Phase 1 Large SI engines. For that reason, we are applying the Phase 1 deterioration factors to the Phase 2 engines. To estimate the Phase 2 emission factors at zero miles, we back-calculated the emission levels based on the proposed standards and the estimated deterioration factors, assuming manufacturers will design to meet a level 10 percent below the proposed standard to account for variability. Given that these engines will employ a catalyst to meet the proposed standards, we believe a 10 percent compliance margin is appropriate. (Including a margin of compliance below the standards is a practice that manufacturers have followed historically to provide greater assurance that their engines would comply in the event of a compliance audit.) Again, because the proposed standards include an HC+NOx standard, we assumed the HC/NOx split would stay the same as pre-control engines (at the end of the regulated useful life). Table 6.2.2-5 present the zero-mile levels, deterioration factors used in the analysis of today's proposed Phase 2 standards for Large SI engines. The Phase 2 standards are proposed to take effect in 2004 for all engines.

Under the proposed Phase 2 program for Large SI engines, the test procedure will be switched from a steady-state test to a transient test. Therefore, the in-use emission performance of Phase 2 engines should be similar to the emissions performance over the test cycle. For this reason, the transient adjustment factors for Phase 2 engines is set at 1.0 for all pollutants.

Table 6.2.2-5
Zero-Mile Level Emission Factors (g/hp-hr), Deterioration Factors (at Median Life) and Transient Adjustment Factors for Phase 2 Large SI Engines

Fuel Category	THC			CO			NOx		
	ZML	DF	TAF	ZML	DF	TAF	ZML	DF	TAF
Gasoline	0.3	1.64	1.0	13.2	1.36	1.0	0.4	1.15	1.0
LPG	3.1	1.64	1.0	1.7	1.36	1.0	1.7	1.15	1.0
CNG	0.2	1.64	1.0	1.7	1.36	1.0	1.8	1.15	1.0

6.2.2.1.2 Exhaust Emission Reductions Due to the Proposed Standards

Tables 6.2.2-6 through 6.2.2-8 present the projected HC, CO, and NOx exhaust emissions inventories respectively, assuming engines remain uncontrolled and assuming we adopt the proposed Phase 1 and Phase 2 standards. The tables also contain estimated emission reductions for each of the pollutants. We anticipate that the proposed standards will result in a 87% reduction in exhaust HC, 84% reduction in NOx, and a 92% reduction in CO.

Table 6.2.2-6
Projected HC Inventories and Reductions for Large SI Engines (short tons)

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	177,000	177,000	0	0
2005	193,000	149,000	44,000	23
2010	212,000	77,000	135,000	64
2020	252,000	32,000	220,000	87
2030	291,000	32,000	259,000	89

Table 6.2.2-7
Projected CO Inventories and Reductions for Large SI Engines (short tons)

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	2,294,000	2,294,000	0	0
2005	2,454,000	2,155,000	299,000	12
2010	2,615,000	1,152,000	1,463,000	56
2020	2,991,000	231,000	2,760,000	92
2030	3,364,000	168,000	3,196,000	95

Table 6.2.2-8
Projected NOx Inventories and Reductions for Large SI Engines (short tons)

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	306,000	306,000	0	0
2005	351,000	282,000	69,000	20
2010	397,000	152,000	245,000	62
2020	486,000	77,000	409,000	84
2030	565,000	83,000	483,000	85

6.2.2.2 Evaporative and Crankcase Emission Control from Large SI Equipment

We projected the annual tons of hydrocarbons evaporated into the atmosphere from Large SI gasoline engines using the methodology discussed above in Section 6.1.2. These evaporative emissions include diurnal and refueling emissions. Although the proposed standards do not specifically require the control of refueling emissions, we have included them in the modeling for completeness. We have also calculated estimates of hot-soak and running losses for Large SI gasoline engines using separate information on those emissions. Finally, we present crankcase emissions for all Large SI engines based on the NONROAD model. This section describes inputs to the calculations that are specific to Large SI engines and presents our baseline and controlled national inventory projections for evaporative and crankcase emissions.

6.2.2.2.1 Inputs for the Inventory Calculations

Several usage inputs are specific to the evaporative emission calculations for Large SI engines. These inputs are fuel tank sizes, population, and distribution throughout the nation. The draft NONROAD model includes current and projected engine populations for each state and we used this distribution as the national fuel tank distribution. Table 6.2.2-9 presents the population of Large SI gasoline engines for 1998.

Table 6.2.2-9
1998 Population of Large SI Engines by Region

Region	*Total*
Northeast	106,000
Southeast	46,600
Southwest	27,600
Midwest	42,500
West	34,700
Northwest	11,200
Total	269,000

The draft NONROAD model breaks this engine distribution further into ranges of engine sizes. For each of these power ranges we apply a fuel tank size for our evaporative emission calculations based on the fuel tank sizes used in the NONROAD model.

Table 6.2.2-10 presents the baseline diurnal emission factors for the certification test conditions and a typical summer day with low vapor pressure fuel and a half-full tank.

Table 6.2.2-10
Diurnal Emission Factors for Test Conditions and Typical Summer Day

Evaporative Control	*72-96 °F, 9 RVP* Fuel, 40% fill*	*60-84 °F, 8 RVP* Fuel, 50% fill*
baseline	2.3 g/gallon/day	0.84 g/gallon/day

* Reid Vapor Pressure

We used the draft NONROAD model to determine the amount of fuel consumed by Large SI gasoline engines. As detailed earlier in Table 6.2.2-1, the NONROAD model has annual usage rates for all Large SI applications. Table 6.2.2-11 presents the fuel consumption estimates we used in our modeling. For 1998, the draft NONROAD model estimated that Large SI gasoline engines consumed about 300 million gallons of gasoline.

Table 6.2.2-11
Fuel Consumption Estimates used in Refueling Calculations for Large SI Gasoline Engines

Technology	*BSFC, lb/hp-hr*
Pre-control	0.605
Tier 1/Tier 2	0.484

To estimate inventories of hot-soak and running loss emissions from Large SI gasoline engines, we applied a factor to the diurnal emissions inventory estimates based on evaporative emission inventories prepared for the South Coast Air Quality Management District.[12] The hot soak inventory was estimated to be 3.9 times as high as the diurnal inventory, and the running loss inventory was estimated to be two-thirds of the diurnal inventory. Finally, crankcase emissions (from all Large SI engines) were generated using the draft NONROAD model.

Table 6.2.2-12 contains the baseline evaporative emission and crankcase emission inventories for Large SI engines.

Table 6.2.2-12
Baseline Evaporative and Crankcase Emissions from Large SI Equipment [short tons]

Calendar Year	*Diurnal*	*Refueling*	*Hot-Soak*	*Running Loss*	*Crankcase*
2000	1,660	1,250	6,530	1,100	58,280
2005	1,730	1,300	6,790	1,150	63,620
2010	1,800	1,350	7,040	1,190	69,690
2020	1,920	1,450	7,560	1,280	82,760
2030	2,060	1,550	8,070	1,360	95,870

6.2.2.2.2 Evaporative and Crankcase Emission Reductions Due to the Proposed Requirements

We anticipate that the proposed evaporative emission requirements for Large SI engines will result in approximately a 50% reduction in diurnal and running loss emissions, and a 90% reduction in hot soak emissions. The proposed evaporative emission requirements are scheduled to take effect in 2008 with the Tier 2 requirements. In addition, because the fuel consumption of Large SI engines will be reduced by 20%, the refueling emissions will be reduced proportionally as well. The refueling benefits will be realized beginning in 2004 as the Tier 1 standards take effect. Finally, the proposed standards also require that engines have a closed crankcase. We expect the crankcase emissions will be routed to the engine and combusted, nearly eliminating crankcase emissions. For modeling purposes, we have assumed that the crankcase emissions are reduced by 90%. The proposed crankcase requirements are schedule to take effect in 2004 with the Tier 1 requirements.

Table 6.2.2-13 present the evaporative emission inventories and crankcase emissions inventories for Large SI engines based on the reductions in emissions noted above. The reductions are achieved over time as the fleet turns over to Phase 1 or Phase 2 engines. (The control inventories were projected using a separate spreadsheet analysis. A copy of spreadsheet calculating the control inventories has been placed in the docket for this rulemaking.[13]) Table 6.2.2-14 presents the corresponding reductions in evaporative and crankcase emissions for Large SI engines due to the proposed requirements.

Table 6.2.2-13
Control Case Evaporative and Crankcase Emissions from Large SI Equipment [short tons]

Calendar Year	*Diurnal*	*Refueling*	*Hot-Soak*	*Running Loss*	*Crankcase*
2000	1,660	1,250	6,530	1,100	58,280
2005	1,730	1,230	6,790	1,150	48,370
2010	1,370	1,160	4,040	910	27,010
2020	1,070	1,180	1,490	710	13,780
2030	1,060	1,240	1,020	700	9,580

Table 6.2.2-14
Reductions in Evaporative and Crankcase Emissions from Large SI Equipment [short tons]

Calendar Year	*Diurnal*	*Refueling*	*Hot-Soak*	*Running Loss*	*Crankcase*
2000	0	0	0	0	0
2005	0	70	0	0	15,240
2010	420	180	3,000	280	42,680
2020	860	270	6,070	570	68,970
2030	1,000	310	7,050	660	86,240

6.2.2.3 Per Equipment Emissions from Large SI Equipment

The following section describes the development of the HC+NOx emission estimates on a per piece of equipment basis over the average lifetime or typical Large SI piece of equipment. The emission estimates were developed to estimate the cost per ton of the proposed standards as presented in Chapter 7. The estimates are made for an average piece of Large SI equipment for each of the three fuel groupings (gasoline, LPG, and CNG). Although the emissions vary from one nonroad application to another, we are presenting the average numbers for the purpose of determining the emission reductions associated with the proposed standards from a typical piece of Large SI equipment over its lifetime.

In order to estimate the emission from a piece of Large SI equipment, information on the emission level of the engine, the power of the engine, the load factor of the engine, the annual hours of use of the engine, and the lifetime of the engine are needed. The values used to predict the per piece of equipment emissions for this analysis and the methodology for determining the values are described below.

The information necessary to calculate the HC and NOx emission levels of a piece of equipment over the lifetime of a typical piece of Large SI equipment were presented in Table

6.2.2-3 through Table 6.2.2-5. A brand new piece of equipment emits at the zero-mile level presented in the tables. As the equipment ages, the emission levels increase based on the pollutant-specific deterioration factor. Deterioration, as modeled in the NONROAD model, continues until the equipment reaches the median life of that equipment type. The deterioration factors presented in Table 6.2.2-3 through Table 6.2.2-5 when applied to the zero-mile levels presented in the same tables, represent the emission level of the engine at the end of its median life. The emissions at any point in time in between can be determined through interpolation. (For this analysis, the HC emissions from CNG engines is calculated on an NMHC+NOx basis, with NMHC emissions estimated to be 4.08% of THC emissions.)

To estimate the average power for equipment in each of the Large SI fuel groupings, we used the population estimates contained in the NONROAD model and the average horsepower information presented in Table 6.2.2-1. To simplify the calculations, we used the most common applications within each category that represent 80% or more of the fuel grouping population. For gasoline engines, the top ten applications with the highest populations were used. For LPG and CNG, the top four applications with the highest populations were used. Table 6.2.2-15 lists the applications used in the analysis.

Table 6.2.2-15
Large SI Applications Used in Per Equipment Analysis

Gasoline	LPG	CNG
Commercial Turf Equipment Balers Forklifts Aerial Lifts Pumps Swathers Leafblowers/Vacuums Sprayers Welders Air Compressors	Forklifts Generator Sets Aerial Lifts Pumps	Forklifts Generator Sets Other Oil Field Equipment Irrigation Sets

Based on the applications noted above for each fuel, we calculated the population-weighted average horsepower for Large SI equipment to be 51.6 hp for gasoline equipment, 65.7 hp for LPG equipment, and 64.6 hp for CNG equipment.

To estimate the average load factor for equipment in each of the Large SI fuel groupings, we used the population estimates contained in the NONROAD model and the load factors as presented in Table 6.2.2-1. As noted above, to simplify the calculations, we used the most common applications within each category that represent 80% or more of the fuel grouping population. Based on the most populous applications noted above, we calculated the population-weighted average load factor for Large SI equipment to be 0.58 for gasoline equipment, 0.39 for LPG equipment, and 0.49 for CNG equipment.

To estimate the average annual hours of use for equipment in each of the Large SI fuel groupings, we used the population estimates contained in the NONROAD model and the hours per year levels as presented in Table 6.2.2-1. As noted above, to simplify the calculations, we used the most common applications within each category that represent 80% or more of the fuel grouping population. Based on the most populous applications noted above, we calculated the population-weighted average annual hours of use for Large SI equipment to be 536 hours for gasoline equipment, 1365 hours for LPG equipment, and 1161 hours for CNG equipment.

Finally, to estimate the average lifetime for equipment in each of the Large SI fuel groupings, we used the population estimates contained in the NONROAD model and the average operating life information as presented in Table 6.2.2-1. As noted above, to simplify the calculations, we used the most common applications within each category that represent 80% or more of the fuel grouping population. Based on the most populous applications noted above, we calculated the population-weighted average lifetime for Large SI equipment to be 12.3 years for gasoline equipment, 12 years for LPG equipment, and 13 years for CNG equipment.

Using the information described above and the equation used for calculating emissions from nonroad equipment (see Equation 6-1), we calculated the lifetime HC+NOx emissions from typical Large SI equipment for both pre-control engines and engines meeting the proposed Phase 1 and Phase 2 standards. Table 6.2.2-16 presents the lifetime HC+NOx emissions for Large SI equipment on both an undiscounted and discounted basis (using a discount rate of 7 percent). Table 6.2.2-17 presents the corresponding lifetime HC+NOx emission reductions for the proposed Phase 1 and Phase 2 standards.

Table 6.2.2-16
Lifetime HC+NOx Emissions from Typical Large SI Equipment (tons)*

Control Level	Gasoline		LPG		CNG	
	Un-discounted	Discounted	Un-discounted	Discounted	Un-discounted	Discounted
Pre-control	3.51	2.44	6.80	4.79	7.06	4.85
Phase 1	0.75	0.51	1.86	1.30	1.83	1.24
Phase 2	0.17	0.12	0.97	0.68	1.07	0.73

* For CNG engines only, the emissions are calculated on the basis of NMHC+NOx.

Table 6.2.2-17
Lifetime HC+NOx Emission Reductions from Typical Large SI Equipment (tons)*

Control Increment	Gasoline		LPG		CNG	
	Un-discounted	Discounted	Un-discounted	Discounted	Un-discounted	Discounted
Pre-control to Phase 1	2.76	1.93	4.94	3.69	5.23	3.61
Phase 1 to Phase 2	0.58	0.39	0.89	0.62	0.76	0.51

* For CNG engines only, the reductions are calculated on the basis of NMHC+NOx.

6.2.3 Snowmobiles

We projected the annual tons of exhaust HC, and CO from snowmobiles using the draft NONROAD model discussed above. This section describes inputs to the calculations that are specific to snowmobiles then presents the results. These results are for the nation as a whole and include baseline and control inventory projections.

6.2.3.1 Inputs for the Inventory Calculations

Several usage inputs are specific to the calculations for snowmobile exhaust emissions. These inputs are load factor, annual use, average operating life, and population. Based on data developed for our Final Finding for recreational equipment and Large SI equipment, we use a load factor of 34 percent, an annual usage factor of 57 hours and an average operating life of 9 years for snowmobiles.[14] The draft NONROAD model includes current and projected engine populations. Table 6.2.3-1 presents these population estimates (rounded to the nearest 1,000 units) for selected years.

Table 6.2.3-1
Projected Snowmobile Populations by Year

Year	*2000*	*2005*	*2010*	*2020*	*2030*
population	1,571,000	1,619,000	1,677,000	1,803,000	1,931,000

The baseline emission factors and deterioration factors (for pre-control engines) were developed for the Final Finding as noted above. For the control emission factors (i.e., engines complying with the Phase 1 or Phase 2 standards), we assumed that the manufacturers would design their engines to meet the proposed standards at regulatory useful life with a small compliance margin. (Because we are not proposing a NOx standard for snowmobiles, we have assumed that NOx levels will remain at the pre-control levels for both Phase 1 and Phase 2 snowmobile engines.) For both set of proposed standards for snowmobiles, we assumed a compliance margin of 20 percent to account for variability. (The proposed standards for snowmobiles are not based on the use of catalysts. Engine out emissions tend to have more variability than the emissions coming from an engine equipped with a catalyst. For this reason, we are using a compliance margin of 20 percent. As noted earlier, including a margin of compliance below the standards is a practice that manufacturers have followed historically to provide greater assurance that their engines would comply in the event of a compliance audit.) Because the proposed standards for snowmobiles are expected to be met by mostly improved 2-stroke designs, we assumed that the deterioration rates would stay the same as the deterioration rates for pre-control engines. Table 6.2.3-2 presents the emission factors used in this analysis for new engines and the maximum deterioration factors applied to snowmobiles operated out to their median lifetime. (For the calculations, the zero-mile levels were determined based on the pro-rated amount of deterioration expected at the regulatory lifetime, which is 300 hours for snowmobiles. As noted earlier, the regulatory useful life is the period of time for which a manufacturer must demonstrate compliance with the emission standards. The median lifetime of in-use equipment is longer than the regulatory life.)

Table 6.2.3-2
Zero-Mile Level Emission Factors (g/hp-hr) and Deterioration Factors (at Median Lifetime) for Snowmobile Engines

Engine Category	*THC*		*CO*		*NOx*	
	ZML	*Max DF*	*ZML*	*Max DF*	*ZML*	*Max DF*
Baseline/Pre-control	111	1.2	296	1.2	0.9	1.0
Control/Phase 1	75	1.2	205	1.2	0.9	1.0
Control/Phase 2	56	1.2	148	1.2	0.9	1.0

The Phase 1 standards are proposed to take effect in 2006 for all engines. The Phase 2 standards are proposed to take effect in 2010 for all engines.

6.2.3.2 Reductions Due to the Proposed Standards

We anticipate that the proposed standards for snowmobiles will result in a 63 percent reduction in both HC and CO by the year 2020. We do not expect any reduction in NOx emissions from snowmobiles under the proposed program. Tables 6.2.3-3 and 6.2.3.-4 present our projected HC and CO exhaust emission inventories for snowmobiles and the anticipated emission reductions from the proposed Phase 1 and Phase 2 standards. Table 6.2.3-5 presents the projected NOx emission inventories from snowmobiles.

Table 6.2.3-3
Projected HC Inventories and Reductions for Snowmobiles (short tons)

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	200,000	200,000	0	0
2005	205,000	205,000	0	0
2010	213,000	155,000	58,000	27
2020	229,000	85,000	144,000	63
2030	245,000	88,000	157,000	64

Table 6.2.3-4
Projected CO Inventories and Reductions for Snowmobiles (short tons)

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	531,000	531,000	0	0
2005	547,000	547,000	0	0
2010	567,000	415,000	152,000	27
2020	609,000	227,000	382,000	63
2030	653,000	234,000	419,000	64

Table 6.2.3-5
Projected NOx Inventories for Snowmobiles (short tons)

Calendar Year	Baseline
2000	1,000
2005	1,000
2010	1,000
2020	2,000
2030	2,000

6.2.3.3 Per Equipment Emissions from Snowmobiles

The following section describes the development of the HC and CO emission estimates on a per piece of equipment basis over the average lifetime or a typical snowmobile. The emission estimates were developed to estimate the cost per ton of the proposed standards as presented in Chapter 7.

In order to estimate the emission from a snowmobile, information on the emission level of the engine, the power of the engine, the load factor of the engine, the annual hours of use of the engine, and the lifetime of the engine are needed. The values used to predict the per piece of equipment emissions for this analysis and the methodology for determining the values are described below.

The information necessary to calculate the HC and CO emission levels of a piece of equipment over the lifetime of a typical snowmobile were presented in Table 6.2.3-2. A brand new snowmobile emits at the zero-mile level presented in the table. As the snowmobile ages, the emission levels increase based on the pollutant-specific deterioration factor. Deterioration, as modeled in the NONROAD model, continues until the equipment reaches the median life. The deterioration factors presented in Table 6.2.3-2 when applied to the zero-mile levels presented in the same table, represent the emission level of the snowmobile at the end of its median life. The emissions at any point in time in between can be determined through interpolation.

To estimate the average power for snowmobiles, we used the population and power distribution information contained in the NONROAD model and determined the population-weighted average horsepower for snowmobiles. The population-weighted horsepower for snowmobiles was calculated to be 48.3 hp.

As described earlier in this section, the load factor for snowmobiles is estimated to be 0.34, the annual usage rate is estimated to be 57 hours per year, and the average lifetime is estimated to be 9 years.

Using the information described above and the equation used for calculating emissions from nonroad equipment (see Equation 6-1), we calculated the lifetime HC and CO emissions from a typical snowmobile for both pre-control engines and engines meeting the proposed Phase 1 and Phase 2 standards. Table 6.2.3-6 presents the lifetime HC and CO emissions for a typical snowmobile on both an undiscounted and discounted basis (using a discount rate of 7 percent). Table 6.2.3-7 presents the corresponding lifetime HC and CO emission reductions for the proposed Phase 1 and Phase 2 standards.

Table 6.2.3-6
Lifetime HC and CO Emissions from a Typical Snowmobile (tons)

Control Level	HC		CO	
	Undiscounted	Discounted	Undiscounted	Discounted
Pre-control	1.15	0.88	3.05	2.34
Phase 1	0.55	0.43	1.51	1.16
Phase 2	0.41	0.31	1.09	0.84

Table 6.2.3-7
Lifetime HC and CO Emission Reductions from a Typical Snowmobile (tons)

Control Increment	HC		CO	
	Undiscounted	Discounted	Undiscounted	Discounted
Pre-control to Phase 1	0.60	0.45	1.54	1.18
Phase 1 to Phase 2	0.14	0.12	0.42	0.32

6.2.4 All-Terrain Vehicles

6.2.4.1 Exhaust Emissions from All-Terrain Vehicles

We projected the annual tons of exhaust HC, CO, and NOx, from all-terrain vehicles (ATVs) using the draft NONROAD model discussed above. This section describes inputs to the calculations that are specific to ATVs then presents the results. These results are for the nation as a whole and include baseline and control inventory projections.

6.2.4.1.1 Inputs for the Inventory Calculations

Several usage inputs are specific to the calculations for ATV exhaust emissions. These inputs are annual use, average operating life, and population. Based on data developed for our Final Finding for recreational equipment and Large SI equipment, we use an annual usage factor of 7,000 miles and an average operating life of 13 years for ATVs.[15] (Because the ATV standards are chassis-based standard instead of engine-based, the NONROAD model has been revised to model ATVs on the basis of gram per mile emission factors and annual mileage accumulation rates. Load factor is not needed for such calculations.)

The draft NONROAD model includes current and projected engine populations. Table 6.2.4-1 presents these population estimates (rounded to the nearest 1,000 units) for selected years. The ATV population growth rates used in the NONROAD model have been updated to reflect the expected growth in ATV populations based on historic ATV sales information and sales growth projections supplied by the Motorcycle Industry Council (MIC), an industry trade organization. The growth rates were developed separately for 2-stroke and 4-stroke ATVs. Based on the sales information from MIC, sales of ATVs have been growing substantially throughout the 1990s, averaging 25% growth per year over the last 6 years. MIC estimates that growth in sales will continue for the next few years, although at lower levels of ten percent or less, with no growth in sales projected by 2005. Combining the sales history, growth projections, and information on equipment scrappage, we have estimated that the population of ATVs will grow significantly through 2010, and then grow as much lower levels. (The population of 2-stroke ATVs presented in Table 6.2.4-1 are for baseline population estimates. Under the proposed ATV standards, 2-stroke designs are expected to be phased-out as they are converted to 4-stroke designs.)

Table 6.2.4-1
Projected ATV Populations by Year

Category	*2000*	*2005*	*2010*	*2020*	*2030*
4-stroke ATVs	3,776,000	5,513,000	7,223,000	8,460,000	8,540,000
2-stroke ATVs*	673,000	1,457,000	2,057,000	2,424,000	2,445,000
All ATVs	4,449,000	6,970,000	9,280,000	10,884,000	10,985,000

* - The projected population estimates for 2-stroke ATVs are for baseline calculations only. Under the proposed Phase 1 standards, we expect all 2-stroke engines will be converted to 4-stroke designs.

The baseline emission factors used in the NONROAD model for ATVs have been updated based on recent testing of ATVs and Off-highway motorcycles as presented in Chapter 4 (sections 4.6 and 4.7). The baseline deterioration factors (for pre-control engines) were developed for the Final Finding as noted above. For the control emission factors (i.e., engines complying with the Phase 1 or Phase 2 standards), we assumed that the manufacturers would design their engines to meet the proposed standards at regulatory useful life with a small compliance margin. Because we are proposing a HC+NOx standard for ATVs, we have assumed that the HC/NOx split will remain the same as the pre-control HC/NOx split for Phase 1. For Phase 2 ATVs, we assumed the technologies expected to be used by the manufacturers would result in HC control, and so the Phase 2 NOx emission factor was kept at the Phase 1 level. For the Phase 1 standards for ATVs, we assumed a compliance margin of 20 percent to account for variability. For the Phase 2 standards for ATVs, we assumed a compliance margin of 20 percent to account for variability if a catalyst was not being used, and a compliance margin of 10 percent if a catalyst was being used. (Engine out emissions tend to have more variability than the emissions coming from an engine equipped with a catalyst. For this reason, we are using different compliance margins for catalyst and non-catalyst ATVs. As noted earlier, including a margin of compliance below the standards is a practice that manufacturers have followed historically to provide greater assurance that their engines would comply in the event of a compliance audit.) Because the proposed standards for ATVs are expected to be met by 4-stroke designs, we assumed that the deterioration rates would stay the same as the deterioration rates for pre-control 4-stroke ATVs. Table 6.2.4-2 presents the emission factors used in this analysis for new ATVs and the maximum deterioration factors for ATVs which applies at the median lifetime. (For the calculations, the zero-mile levels were determined based on the pro-rated amount of deterioration expected at the regulatory lifetime, which is 18,640 miles (30,000 kilometers) for ATVs. As noted earlier, the regulatory useful life is the period of time for which a manufacturer must demonstrate compliance with the emission standards. The median lifetime of in-use equipment is longer than the regulatory life. As noted earlier, the regulatory useful life is the period of time for which a manufacturer must demonstrate compliance with the emission standards. The median lifetime of in-use equipment is longer than the regulatory life.) For the Phase 2 standards, we have assumed that half of the ATVs will be engine recalibration and half of the engines will be recalibration plus a catalyst.

Table 6.2.4-2
Zero-Mile Level Emission Factors (g/mi) and Deterioration Factors (at Median Lifetime) for ATVs

Engine Category	*THC*		*CO*		*NOx*	
	ZML	*Max DF*	*ZML*	*Max DF*	*ZML*	*Max DF*
Baseline/Pre-control 2-stroke	55.7	1.2	52.7	1.2	0.15	1.0
Baseline/Pre-control 4-stroke	2.2	1.15	48.3	1.17	0.34	1.0
Control/Phase 1 4-stroke	2.2	1.15	31.1	1.17	0.31	1.0
Control/Phase 2 - 4-stroke plus Engine Recalibration	1.2	1.15	31.1	1.17	0.31	1.0
Control/Phase 2 - 4-stroke plus Engine Recalibration/Catalyst	0.8	1.15	31.1	1.17	0.31	1.0

The Phase 1 standards are proposed to be phased in at 50% in 2007 and 100% in 2008. The Phase 2 standards are proposed to be phased in at 50% in 2010 and 100% in 2011. However, because there are a significant number of small volume manufacturers that produce 2-stroke ATVs, and because we have proposed compliance flexibilities for such manufacturers, we have modeled the phase in of the proposed standards for the current 2-stroke ATVs based on the schedule contained in Table 6.2.4-3.

Table 6.2.4-3
Assumed Phase-In Schedule for Current 2-Stroke ATVs Used in the Modeling Runs

Model Year	Pre-control 2-stroke	Phase 1 4-stroke	Phase 2 4-stroke plus Recalibration	Phase 2 4-stroke plus Recalibration and Catalyst
2005	100%	0%	0%	0%
2006	65%	35%	0%	0%
2007	30%	70%	0%	0%
2008	15%	85%	0%	0%
2009	0%	65%	17.5%	17.5%
2010	0%	30%	35%	35%
2011	0%	15%	42.5%	42.5%
2012	0%	0%	50%	50%

6.2.4.1.2 Reductions Due to the Proposed Standards

We anticipate that the proposed standards for ATVs will result in a 84% reduction in HC and a 34% reduction in CO by the year 2020. As manufacturers convert their engines from 2-stroke to 4-stroke design, we expect there could be a minimal increase in NOx. (Because the amount of increase in the NOx inventory is so small, it is within the roundoff presented in the table below. Therefore, only the baseline NOx inventory is shown.) Tables 6.2.4-4 through 6.2.4.-6 present our projected HC, CO, and NOx, exhaust emission inventories for ATVs and the anticipated emission reductions from the proposed Phase 1 and Phase 2 standards.

Table 6.2.4-4
Projected HC Inventories and Reductions for ATVs (short tons)

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	381,000	381,000	0	0
2005	771,000	771,000	0	0
2010	1,098,000	756,000	342,000	31
2020	1,301,000	205,000	1,096,000	84
2030	1,317,000	96,000	1,221,000	93

Table 6.2.4-5
Projected CO Inventories and Reductions for ATVs (short tons)

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	1,860,000	1,860,000	0	0
2005	2,903,000	2,903,000	0	0
2010	3,901,000	3,380,000	521,000	13
2020	4,589,000	3,041,000	1,548,000	34
2030	4,641,000	2,939,000	1,702,000	37

Table 6.2.4-6
Projected NOx Inventories for ATVs (short tons)

Calendar Year	Baseline
2000	11,000
2005	16,000
2010	21,000
2020	25,000
2030	25,000

6.2.4.2 Evaporative Emissions from All-Terrain Vehicles

We projected the annual tons of hydrocarbons evaporated into the atmosphere from ATVs using the methodology discussed above in Section 6.1.2. These evaporative emissions include diurnal and refueling emissions. Although the proposed standards do not specifically require the control of refueling emissions, we have included them in the modeling for completeness. This section describes inputs to the calculations that are specific to ATVs and presents our baseline national inventory projections for evaporative emissions from ATVs.

6.2.4.2.1 Inputs for the Inventory Calculations

Several usage inputs are specific to the calculations of evaporative emissions from ATVs. These inputs are fuel tank sizes, population, and distribution throughout the nation. The draft NONROAD model includes current and projected engine populations for each state and we used this distribution as the national fuel tank distribution. Table 6.2.4-7 presents the population of ATVs for 1998.

Table 6.2.4-7
1998 Population of ATVs by Region

Region	*Total*
Northeast	1,420,000
Southeast	1,010,000
Southwest	363,000
Midwest	457,000
West	423,000
Northwest	249,000
Total	3,930,000

The draft NONROAD model breaks this engine distribution further into ranges of engine sizes. For each of these power ranges we apply a fuel tank size for our evaporative emission calculations based on the fuel tank sizes used in the NONROAD model.

Table 6.2.4-8 presents the baseline diurnal emission factors for the certification test conditions and a typical summer day with low vapor pressure fuel and a half-full tank.

Table 6.2.4-8
Diurnal Emission Factors for Test Conditions and Typical Summer Day

Evaporative Control	*72-96 ℉, 9 RVP* Fuel, 40% fill*	*60-84 ℉, 8 RVP* Fuel, 50% fill*
baseline	2.3 g/gallon/day	0.84 g/gallon/day

* Reid Vapor Pressure

We used the draft NONROAD model to determine the amount of fuel consumed by ATVs. As detailed earlier in this section, the NONROAD model has an annual usage rate for ATVs of 7,000 miles/year. Table 6.2.4-9 presents the fuel consumption estimates we used in our modeling. For 1998, the draft NONROAD model estimated that ATVs consumed about 1.4 billion gallons of gasoline.

Table 6.2.4-9
Fuel Consumption Estimates used in Refueling Calculations for ATVs

Technology	*BSFC, lb/mi*
Pre-control 2-stroke	0.197
Pre-control 4-stroke	0.332

Table 6.2.4-10 contains the diurnal and refueling emission inventories for ATVs.

Table 6.2.4-10
Projected Diurnal and Refueling Emissions from ATVs [short tons]

Calendar Year	*Diurnal*	*Refueling*
2000	2,910	6,100
2005	4,690	9,280
2010	6,280	12,200
2020	7,270	13,800
2030	7,440	14,000

6.2.4.3 Per Equipment Emissions from All-Terrain Vehicles

The following section describes the development of the HC+NOx emission estimates on a per piece of equipment basis over the average lifetime or a typical ATV. The emission estimates were developed to estimate the cost per ton of the proposed standards as presented in Chapter 7.

In order to estimate the emissions from an ATV, information on the emission level of the vehicle, the annual usage rate of the engine, and the lifetime of the engine are needed. The values used to predict the per piece of equipment emissions for this analysis and the methodology for determining the values are described below.

The information necessary to calculate the HC and NOx emission levels of a piece of equipment over the lifetime of a typical ATV were presented in Table 6.2.4-2. A brand new ATV emits at the zero-mile level presented in the table. As the ATV ages, the emission levels increase based on the pollutant-specific deterioration factor. Deterioration, as modeled in the NONROAD model, continues until the equipment reaches the median life. The deterioration factors presented in Table 6.2.4-2 when applied to the zero-mile levels presented in the same table, represent the emission level of the ATV at the end of its median life. The emissions at any point in time in between can be determined through interpolation. (The emissions for Phase 2 ATVs are based on a 50/50 weighting of the “engine recalibration” and the “engine recalibration plus catalyst” technologies presented in Table 6.2.4-2.)

As described earlier in this section, the annual usage rate for an ATV is estimated to be 7,000 miles per year and the average lifetime is estimated to be 13 years.

Using the information described above and the equation used for calculating emissions from nonroad equipment modified to remove the power and load variables (see Equation 6-1), we calculated the lifetime HC+NOx emissions from a typical ATV for both pre-control engines (shown separately for 2-stroke and 4-stroke engines and a composite weighted value) and engines meeting the proposed Phase 1 and Phase 2 standards. Table 6.2.4-10 presents the lifetime HC+NOx emissions for a typical ATV on both an undiscounted and discounted basis (using a discount rate of 7 percent). Table 6.2.4-11 presents the corresponding lifetime HC+NOx emission reductions for the proposed Phase 1 and Phase 2 standards.

Table 6.2.4-10
Lifetime HC+NOx Emissions from a Typical ATV (tons)

Control Level	HC+NOx	
	Undiscounted	Discounted
Pre-control (2-stroke) Pre-control (4-stroke) Pre-control (Composite)	6.16 0.28 1.58	4.19 0.19 1.07
Phase 1	0.28	0.19
Phase 2	0.14	0.10

Table 6.2.4-11
Lifetime HC+NOx Emission Reductions from a Typical ATV (tons)

Control Increment	HC+NOx	
	Undiscounted	Discounted
Pre-control (Composite) to Phase 1	1.30	0.88
Phase 1 to Phase 2	0.14	0.09

6.2.5 Off-highway Motorcycles

6.2.5.1 Exhaust Emissions from Off-highway Motorcycles

We projected the annual tons of exhaust HC, CO, and NOx, from off-highway motorcycles using the draft NONROAD model discussed above. This section describes inputs to the calculations that are specific to off-highway motorcycles then presents the results. These results are for the nation as a whole and include baseline and control inventory projections.

6.2.5.1.1 Inputs for the Inventory Calculations

Several usage inputs are specific to the calculations for off-highway motorcycles exhaust emissions. These inputs are annual use, average operating life, and population. Based on data developed for our Final Finding for recreational equipment and Large SI equipment, we use an annual usage factor of 2,400 miles and an average operating life of 9 years for off-highway motorcycles.[16] (Because the off-highway motorcycle standards are chassis-based standard instead of engine-based, the NONROAD model has been revised to model off-highway motorcycles on the basis of gram per mile emission factors and annual mileage accumulation rates. Load factor is not needed for such calculations.)

The draft NONROAD model includes current and projected engine populations. Table 6.2.5-1 presents these population estimates (rounded to the nearest 1,000 units) for selected years. (The population of 2-stroke off-highway motorcycles presented in Table 6.2.5-1 are for baseline population estimates. Under the proposed off-highway motorcycle standards, non-competition 2-stroke designs are expected to be phased-out as they are converted to 4-stroke designs. Competition models will remain 2-stroke designs.)

Table 6.2.5-1
Projected Off-Highway Motorcycle Populations by Year

Category	*2000*	*2005*	*2010*	*2020*	*2030*
4-stroke Off-highway Motorcycles	397,000	410,000	425,000	457,000	489,000
2-stroke Off-highway Motorcycles*	805,000	832,000	862,000	928,000	993,000
All Off-highway Motorcycles	1,202,000	1,242,000	1,287,000	1,385,000	1,482,000

* - The projected population estimates for 2-stroke off-highway motorcycles are for baseline calculations only. Under the proposed standards, we expect all non-competition 2-strokes will be converted to 4-stroke designs. All 2-stroke competition models are assumed to remain 2-strokes.

The baseline emission factors used in the NONROAD model for off-highway motorcycles have been updated based on recent testing of off-highway motorcycles and off-highway motorcycles as presented in Chapter 4 (sections 4.6 and 4.7). The baseline deterioration factors (for pre-control engines) were developed for the Final Finding as noted above. For the control emission factors (i.e., Phase 1 off-highway motorcycles), we assumed that the manufacturers would design their engines to meet the proposed standards at regulatory useful life with a small compliance margin. Because we are proposing a HC+NOx standard for off-highway motorcycles, we have assumed that the Phase 1 HC/NOx split will remain the same as the pre-control HC/NOx split. For the Phase 1 standards for off-highway motorcycles, we assumed a compliance margin of 20 percent to account for variability. (Including a margin of compliance below the standards is a practice that manufacturers have followed historically to provide greater assurance that their engines would comply in the event of a compliance audit.) Because the proposed standards for off-highway motorcycles are expected to be met by 4-stroke designs, we assumed that the deterioration rates would stay the same as the deterioration rates for pre-control 4-stroke off-highway motorcycles. Table 6.2.5-2 presents the emission factors used in this analysis for new off-highway motorcycles and the maximum deterioration factors applied to off-highway motorcycles operated out to their median lifetime. (For the calculations, the zero-mile levels were determined based on the pro-rated amount of deterioration expected at the regulatory lifetime, which is 6,210 miles (10,000 kilometers) for off-highway motorcycles. As noted earlier, the regulatory useful life is the period of time for which a manufacturer must demonstrate compliance with the emission standards. The median lifetime of in-use equipment is longer than the regulatory life.)

Table 6.2.5-2
Zero-Mile Level Emission Factors (g/mi) and Deterioration Factors (at Median Lifetime) for Off-Highway Motorcycles

Engine Category	*THC*		*CO*		*NOx*	
	ZML	*Max DF*	*ZML*	*Max DF*	*ZML*	*Max DF*
Baseline/Pre-control 2-stroke*	55.7	1.2	52.7	1.2	0.15	1.0
Baseline/Pre-control 4-stroke	2.2	1.15	48.3	1.17	0.34	1.0
Control/Phase 1 4-stroke	2.2	1.15	30.7	1.17	0.31	1.0

* - Competition models are assumed to remain at pre-control levels under the proposed program for off-highway motorcycles.

The Phase 1 standards are proposed to be phased in at 50% in 2007 and 100% in 2008. However, because there are a significant number of small volume manufacturers that produce off-highway motorcycles (who can take advantage of proposed compliance flexibilities), and because competition off-highway motorcycles are exempt from the proposed standards, we have modeled the phase in of the proposed standards for off-highway motorcycles based on the schedule contained in Table 6.2.5-3.

Table 6.2.5-3
Assumed Phase-In Schedule for Current Off-Highway Motorcycles Used in the Modeling Runs

Model Year	Current 4-stroke Off-highway Motorcycles		Current 2-stroke Off-highway Motorcycles	
	Pre-control	Phase 1	Pre-control	Phase 1
2005	100%	0%	100%	0%
2006	56%	44%	76%	24%
2007	12%	88%	53%	47%

Model Year	Current 4-stroke Off-highway Motorcycles		Current 2-stroke Off-highway Motorcycles	
	Pre-control	Phase 1	Pre-control	Phase 1
2008	6%	94%	49%	51%
2009+	0%	100%	46%	54%

6.2.5.1.2 Reductions Due to the Proposed Standards

We anticipate that the proposed standards for off-highway motorcycles will result in a 22% reduction in HC and a 26% reduction in CO by the year 2020. As manufacturers convert their engines from 2-stroke to 4-stroke design, we project there could be a small increase in NOx inventories. (Because the amount of increase in the NOx inventory is so small, it is within the roundoff presented in the table below. Therefore, only the baseline NOx inventory is shown.) Tables 6.2.5-4 through 6.2.5.-6 present our projected HC, CO, and NOx, exhaust emission inventories for off-highway motorcycles and the anticipated emission reductions from the proposed Phase 1 standards. (The emission inventories presented below for off-highway motorcycles include the competition motorcycles that would be exempt from the proposed standards.)

Table 6.2.5-4
Projected HC Inventories and Reductions for Off-Highway Motorcycles (short tons)

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	134,000	134,000	0	0
2005	138,000	138,000	0	0
2010	143,000	112,000	31,000	22
2020	154,000	77,000	77,000	50
2030	165,000	81,000	84,000	51

Table 6.2.5-5
Projected CO Inventories and Reductions for Off-Highway Motorcycles (short tons)

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	181,000	181,000	0	0
2005	187,000	187,000	0	0
2010	194,000	172,000	22,000	11
2020	208,000	154,000	54,000	26
2030	223,000	164,000	59,000	27

Table 6.2.5-6
Projected NOx Inventories for Off-Highway Motorcycles (short tons)

Calendar Year	Baseline
2000	1,000
2005	1,000
2010	1,000
2020	1,000
2030	1,000

6.2.5.2 Evaporative Emissions from Off-highway Motorcycles

We projected the annual tons of hydrocarbons evaporated into the atmosphere from off-highway motorcycles using the methodology discussed above in Section 6.1.2. These evaporative emissions include diurnal and refueling emissions. Although the proposed standards do not specifically require the control of refueling emissions, we have included them in the modeling for completeness. This section describes inputs to the calculations that are specific to off-highway motorcycles and presents our baseline national inventory projections for evaporative emissions from off-highway motorcycles.

6.2.5.2.1 Inputs for the Inventory Calculations

Several usage inputs are specific to the calculations of evaporative emissions from off-highway motorcycles. These inputs are fuel tank sizes, population, and distribution throughout the nation. The draft NONROAD model includes current and projected engine populations for each state and we used this distribution as the national fuel tank distribution. Table 6.2.5-7 presents the population of off-highway motorcycles for 1998.

Table 6.2.5-7
1998 Population of Off-Highway Motorcycles by Region

Region	*Total*
Northeast	427,000
Southeast	304,000
Southwest	109,000
Midwest	137,000
West	127,000
Northwest	75,000
Total	1,180,000

The draft NONROAD model breaks this engine distribution further into ranges of engine sizes. For each of these power ranges we apply a fuel tank size for our evaporative emission calculations based on the fuel tank sizes used in the NONROAD model.

Table 6.2.5-8 presents the baseline diurnal emission factors for the certification test conditions and a typical summer day with low vapor pressure fuel and a half-full tank.

Table 6.2.5-8
Diurnal Emission Factors for Test Conditions and Typical Summer Day

Evaporative Control	*72-96 ℉, 9 RVP* Fuel, 40% fill*	*60-84 ℉, 8 RVP* Fuel, 50% fill*
baseline	2.3 g/gallon/day	0.84 g/gallon/day

* Reid Vapor Pressure

We used the draft NONROAD model to determine the amount of fuel consumed by off-highway motorcycles. As detailed earlier in this section, the NONROAD model has an annual usage rate for off-highway motorcycles of 2,400 miles/year. Table 6.2.5-9 presents the fuel consumption estimates we used in our modeling. For 1998, the draft NONROAD model estimated that off-highway motorcycles consumed about 120 million gallons of gasoline.

Table 6.2.5-9
Fuel Consumption Estimates used in Refueling Calculations for Off-Highway Motorcycles

Technology	*BSFC, lb/mi*
Pre-control 2-stroke	0.291
Pre-control 4-stroke	0.170

Table 6.2.5-10 contains the diurnal and refueling emission inventories for off-highway motorcycles.

Table 6.2.5-10
Projected Diurnal and Refueling Emissions from Off-Highway Motorcycles [short tons]

Calendar Year	*Diurnal*	*Refueling*
2000	800	490
2005	830	510
2010	860	520
2020	920	530
2030	980	560

6.2.5.3 Per Equipment Emissions from Off-highway Motorcycles

The following section describes the development of the HC+NOx emission estimates on a per piece of equipment basis over the average lifetime or a typical off-highway motorcycle. The emission estimates were developed to estimate the cost per ton of the proposed standards as presented in Chapter 7.

In order to estimate the emissions from an off-highway motorcycle, information on the emission level of the vehicle, the annual usage rate of the engine, and the lifetime of the engine are needed. The values used to predict the per piece of equipment emissions for this analysis and the methodology for determining the values are described below.

The information necessary to calculate the HC and NOx emission levels of a piece of equipment over the lifetime of a typical off-highway motorcycle were presented in Table 6.2.5-2. A brand new off-highway motorcycle emits at the zero-mile level presented in the table. As the off-highway motorcycle ages, the emission levels increase based on the pollutant-specific deterioration factor. Deterioration, as modeled in the NONROAD model, continues until the equipment reaches the median life. The deterioration factors presented in Table 6.2.5-2 when applied to the zero-mile levels presented in the same table, represent the emission level of the off-highway motorcycle at the end of its median life. The emissions at any point in time in between can be determined through interpolation.

As described earlier in this section, the annual usage rate for an off-highway motorcycle is estimated to be 2,400 miles per year and the average lifetime is estimated to be 9 years.

Using the information described above and the equation used for calculating emissions from nonroad equipment modified to remove the power and load variables (see Equation 6-1), we calculated the lifetime HC+NOx emissions from a typical off-highway motorcycle for both pre-control engines (shown separately for 2-stroke and 4-stroke engines and a composite weighted value) and engines under the proposed Phase 1 standards. (Competition bikes, which are exempt from the proposed standards, are not included in the calculations.) Table 6.2.5-11 presents the lifetime HC+NOx emissions for a typical off-highway motorcycle on both an undiscounted and discounted basis (using a discount rate of 7 percent). Table 6.2.5-12 presents the corresponding lifetime HC+NOx emission reductions for the proposed Phase 1 standards.

Table 6.2.5-11
Lifetime HC+NOx Emissions from a Typical Off-highway Motorcycle (tons)*

Control Level	HC+NOx	
	Undiscounted	Discounted
Pre-control (2-stroke)	1.47	1.13
Pre-control (4-stroke)	0.07	0.05
Pre-control (Composite)	0.70	0.53
Phase 1	0.07	0.05

* The emission estimates do not include competition off-highway motorcycles that remain at pre-control emission levels.

Table 6.2.5-12
Lifetime HC+NOx Emission Reductions from a Typical Off-highway Motorcycle (tons)*

Control Increment	HC+NOx	
	Undiscounted	Discounted
Pre-control (Composite) to Phase 1	0.63	0.48

* The reduction estimates do not include competition off-highway motorcycles that remain uncontrolled, and therefore do not realize any emission reductions under the proposal.

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