Chapter 6: Emissions Inventory

6.1 Methodology

The following chapter presents our analysis of the emission impact of the 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.

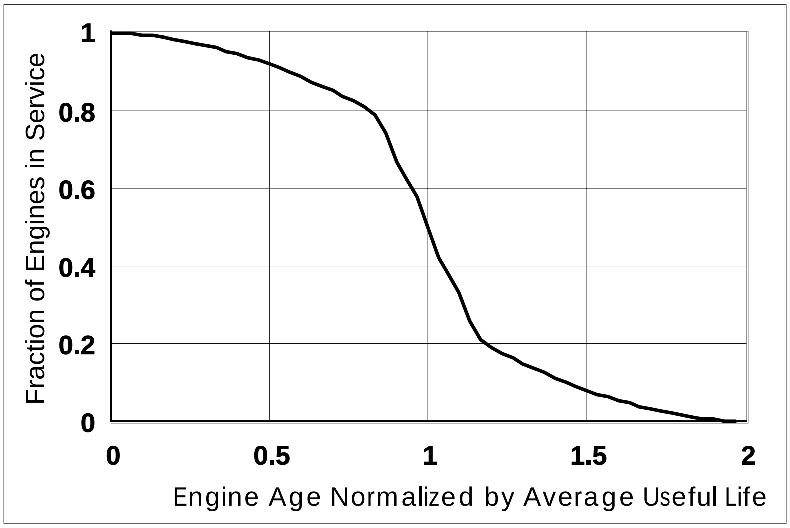
For the inventory calculations in this rule, each class of off-highway engines was divided into power ranges to distinguish between technology or usage differences in each category. Each of the engine applications and power ranges were modeled with distinct annual hours of operation, load factors, and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

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

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 emission standards combine HC and NOx, it is useful to consider the HC and NOx emission impacts separately. (As described throughout this document, the standards for all-terrain vehicles (ATVs) and off-highway motorcycles are based on a chassis test, with the standards 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:

- <u>permeation</u>: 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.

- <u>diurnal</u>: 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.

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. The evaporative emission calculations are available in spreadsheet form in the docket.[1]

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.[2]

6.1.2.1 Permeation Emissions

For our permeation emissions modeling, we used the emission data presented in Chapter 4 to determine the mass of hydrocarbons permeated through plastic fuel tanks and rubber fuel hoses on recreational vehicles. No permeation occurs through metal fuel tanks. Because permeation is very sensitive to temperature, we used Arrhenius' relationship[3] to adjust the emission factors by temperature:

$$P(T) = P_0 \times \mathrm{EXP}(-\alpha / T) \qquad \textbf{(Eq. 6-2)}$$

where:

T = absolute temperature
P(T) = permeation rate at T
P_0 and α are constants

We determined the constants by relating the equation to the known properties of materials used in fuel tanks and hoses (presented in Chapter 4). Based on data presented in Chapter 4, permeation increases by about 80 percent with each 10°C increase in temperature for high density polyethylene (HDPE). We do not have similar data for nitrile rubber used in hoses; however, in general, permeation doubles with every 10°C increase in temperature.[4] In addition, we have data on the effect of temperature on permeation through FKM which is a fluoroelastomer commonly used as a permeation barrier in hoses. This data, presented in Chapter 4, supports using the general relationship, in our modeling, of doubling permeation through hoses for every 10°C increase in temperature.

6.1.2.2 Diurnal Emissions

For diurnal emission estimates, we used the Wade equations[5,6,7] to calculate grams of hydrocarbons emitted per day per volume of fuel tank capacity. The Wade 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:

$$\text{Vapor space (ft}^3\text{)} = ((1.15 - \text{tank fill}) \times \text{tank size}) / 7.841 \qquad \textbf{(Eq. 6-3)}$$

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

$$T_1\ (°\text{F}) = (T_{max} - T_{min}) \times 0.922 + \text{Tmin} \qquad \textbf{(Eq. 6-4)}$$

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

$$V_{100}\ \text{(psi)} = 1.0223 \times \text{RVP} + [(0.0357 \text{ X RVP})/(1-0.0368 \times \text{RVP})] \qquad \textbf{(Eq. 6-5)}$$

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

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

$$D_{min}\ (\%) = E_{100} + [(262 / (0.1667 * E_{100} + 560) - 0.113] \times (100 - T_{min}) \qquad \textbf{(Eq. 6-7a)}$$

$$D_{max}\ (\%) = E_{100} + [(262 / (0.1667 * E_{100} + 560) - 0.113] \times (100 - T_1) \qquad \textbf{(Eq. 6-7b)}$$

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 6-6

$$P_I\ \text{(psi)} = 14.697 - 0.53089 \times D_{min} + 0.0077215 \times D_{min}^2 - 0.000055631 \times D_{min}^3 + 0.0000001769 \times D_{min}^4 \qquad \textbf{(Eq. 6-8a)}$$

$$P_F\ \text{(psi)} = 14.697 - 0.53089 \times D_{max} + 0.0077215 \times D_{max}^2 - 0.000055631 \times D_{max}^3 + 0.0000001769 \times D_{max}^4 \qquad \textbf{(Eq. 6-8b)}$$

$$\text{Density (lb/gal)} = 6.386 - 0.0186 \times \text{RVP} \qquad \textbf{(Eq. 6-9)}$$

$$\text{MW (lb/lb mole)} = (73.23 - 1.274 \times \text{RVP}) + [0.5 \times (T_{min} + T_1) - 60] \times 0.059 \qquad \textbf{(Eq. 6-10)}$$

$$\begin{aligned}\text{Diurnal emissions (grams)} = {} & \text{vapor space} \times 454 \times \text{density} \times [520 / (690 - 4 \times \text{MW})] \\ & \times 0.5 \times [P_I / (14.7 - P_I) + P_F / (14.7 - P_F)] \\ & \times [(14.7 - P_I) / (T_{min} + 460) - (14.7 - P_F) / (T_1 + 460)]\end{aligned} \qquad \textbf{(Eq. 6-11)}$$

where:

MW = molecular weight of hydrocarbons from equation 6-10
$P_{I/F}$ = initial and final pressures from equation 6-8

We use these same equations in our modeling of evaporative emissions from on-highway vehicles. However for on-highway applications we make a correction of 0.78 based on empirical data.[8] Because this correction is based on automotive applications we do not apply this correction factor here. Instead we use a correction factor of 0.65 which is based on the data we collected on exposed fuel tanks vented through a hose. This test data is presented in Table 6.1.2-1 compared to calculated theoretical results.

Table 6.1.2-1
Baseline Diurnal Evaporative Emission Results (varied temperature)

Fuel Tank Capacity	Evaporative HC [g/gallon/day]	Wade HC [g/gallon/day]	ratio of measured to Wade
17 gallons	1.39	2.3	0.6
24 gallons	1.5	2.3	0.65

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.

6.1.2.3 Refueling Vapor Displacement

We used the draft NONROAD model to determine the amount of fuel consumed by recreational vehicles. 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.[9] These calculations are a function of fuel vapor pressure, ambient temperature, and dispensed fuel temperature. The refueling vapor generation equation is as follows:

$$\text{Refueling vapor (g/gal)} = \text{EXP}(-1.2798 - 0.0049 \times (Td - Ta) + 0.0203 \times Td + 0.1315 \times RVP) \qquad \textbf{(Eq. 6-12)}$$

where:

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

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, an annual usage factor of 200 hours, and an average operating life of 20 years. The draft NONROAD model includes current and projected engine populations. Table 6.2.1-1 presents these population estimates for selected years. These population estimates have been updated since the NPRM using new data collected from the boating industry discussed in Chapter 2.

Table 6.2.1-1
Projected CI Recreational Marine Population by Year

Year	2000	2005	2010	2020	2030
population	261,000	301,000	340,000	419,000	497,000

We used the data presented in Chapter 4 to develop the baseline emission factors. For the control emission factors, we projected that the manufacturers will design their engines to meet the 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 standards, we used the HC and NOx data presented in Chapter 4 from CI recreational marine engines near the 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 which have been updated since the NPRM; the only significant update is to the PM deterioration factor which is now larger. 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	0.300	8.94	9.05	1.27	1.39	0.219	0.270
controlled:								
< 0.9 liters/cylinder	0.181	0.184	6.69	6.72	1.27	1.39	0.219	0.270
0.9-1.2 liters/cylinder	0.181	0.184	6.41	6.44	1.27	1.39	0.219	0.270
≥ 1.2 liters/cylinder	0.182	0.184	6.42	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 Standard

We anticipate that the standards will result in a 28 percent reduction in HC+NOx and a 25 percent reduction in PM in 2030. We are not claiming any benefits from the cap on CO emissions. The following tables present our projected exhaust emission inventories for CI recreational marine engines and the anticipated emission reductions.

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

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	1,270	1,270	0	0%
2005	1,460	1,460	0	0%
2010	1,650	1,490	159	10%
2020	2,030	1,450	575	28%
2030	2,410	1,510	899	37%

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

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	38,000	38,000	0	0%
2005	43,600	43,600	0	0%
2010	49,400	45,800	3,550	7%
2020	60,800	48,000	12,800	21%
2030	72,200	52,200	20,000	28%

Table 6.2.1-5
Projected PM Reductions for CI Recreational Marine Engines [short tons]

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	1,000	1,000	0	0%
2005	1,150	1,150	0	0%
2010	1,300	1,230	75	6%
2020	1,600	1,310	294	18%
2030	1,900	1,420	478	25%

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 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.

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 6.2.1-6 presents these results with and without the consideration of a 7 percent per year discount on the value of emission reductions.

Table 6.2.1-6
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	5.78	3.26	4.06	2.30	1.72	0.97
750 kW	7.18	4.53	5.08	3.20	2.10	1.32
Composite	2.58	1.47	1.81	1.03	0.77	0.44

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.[10] NOx data varies, but crankcase NOx emissions may be as high as HC and PM. Therefore, we use the same crankcase emission factor of 0.013 g/kW-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 must 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 increase as the engine wears. Therefore, this analysis may underestimate the benefits that would result from our crankcase emission requirements. Table 6.2.1-7 presents our estimates of the fleetwide reductions crankcase emissions from CI recreational marine engines.

Table 6.2.1-7
Crankcase Emissions Reductions from CI Recreational Marine Engines [short tons]

Calendar Year	HC+NOx	PM
2000	0	0
2005	0	0
2010	39	19
2020	145	73
2030	260	130

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.[11] 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 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	499,693	95
Generator	59	0.68	115	25.0	143,705	100
Commercial turf	28	0.60	682	3.7	55,433	0
Aerial lift	52	0.46	361	18.1	38,637	50
Pump	45	0.69	221	9.8	35,541	50
Welder	67	0.68	408	12.7	19,006	50
Baler	44	0.62	68	25.0	18,635	0
Air compressor	65	0.56	484	11.1	17,261	50
Scrubber/sweeper	49	0.71	516	4.1	13,272	50
Chipper/grinder	66	0.78	488	7.9	13,000	50
Swathers	95	0.52	95	25.0	12,030	0
Leaf blower/vacuum	79	0.94	282	11.3	11,797	0
Sprayers	66	0.65	80	25.0	9,429	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	7,427	50
Other agriculture equipment	162	0.55	124	25.0	5,488	0
Irrigation set	97	0.60	716	7.0	5,176	50
Trencher	54	0.66	402	11.3	3,622	50
Rubber-tired loader	71	0.71	512	8.8	3,172	50
Other general industrial	82	0.54	713	7.8	2,922	50

Application	Avg. Rated HP	Load Factor	Hours per Year	Average Operating Life (yrs)	2000 Population	Percent LPG/CNG
Terminal tractor	93	0.78	827	4.7	2,698	50
Bore/drill rig	78	0.79	107	25.0	2,604	50
Concrete/industrial saw	46	0.78	610	3.2	2,264	50
Rough terrain forklift	66	0.63	413	11.5	1,923	50
Other material handling	67	0.53	386	7.3	1,594	50
Ag. tractor	82	0.62	550	8.8	1,597	0
Paver	48	0.66	392	5.8	1,365	50
Roller	55	0.62	621	7.8	1,360	50
Other construction	126	0.48	371	16.8	1,275	50
Crane	75	0.47	415	15.4	1,239	50
Pressure washer	39	0.85	115	15.3	1,212	50
Paving equipment	39	0.59	175	14.5	1,107	50
Aircraft support	99	0.56	681	7.9	904	50
Gas compressor	110	0.85	6000	0.8	783	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	359	50
Hydro power unit	50	0.56	450	6.0	331	50
Surfacing equipment	40	0.49	488	6.3	313	50
Railway maintenance	33	0.62	184	13.1	276	50
Crushing/processing equip	63	0.85	241	14.6	235	50
Refrigeration/AC	55	0.46	605	10.8	169	100
Dumpers/tenders	66	0.41	127	25.0	124	0
Combines	123	0.74	125	25.0	31	0

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	224,000	232,000	240,000	261,000	294,000
LPG LSI	645,000	766,000	890,000	1,132,000	1,364,000
CNG LSI	88,000	97,000	108,000	132,000	155,000
Total LSI	957,000	1,095,000	1,238,000	1,525,000	1,813,000

Southwest Research Institute recently compiled a listing of test data from past and current testing projects.[12] 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 by fuel type. (The emission levels for gasoline engines are a population-weighted average of the water-cooled and air-cooled average emission levels, assuming air-cooled engines are 3 percent of all large spark-ignition engines, or 13 percent of gasoline large spark-ignition engines.) 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.[13] 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.[14] 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	3.9	1.26	1.3	107.2	1.35	1.45	8.4	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 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 standards and the estimated deterioration factors, assuming manufacturers will design to meet a level 10 percent below the standard to account for variability. (The emission levels for Phase 1 gasoline engines were back-calculated from a population-weighted average of the Phase 1 standards for water-cooled and air-cooled engines, assuming 13 percent of gasoline engines are air-cooled.) Given that these engines will employ a catalyst to meet the 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 meet emission standards in the event of a compliance audit.) Because the 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 Phase 1 standards for Large SI engines. The Phase 1 standards are 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 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.[15] 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	0.59	1.64	1.7	29.9	1.36	1.7	1.5	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 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 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 standards and the estimated deterioration factors, assuming manufacturers will design to meet a level 10 percent below the standard to account for variability. Given that these engines will employ a catalyst to meet the 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 meet emission standards in the event of a compliance audit.) As noted in Chapter 4, the Phase 2 CO standard for all engines (except air-cooled gasoline engines) is dependent on the HC+NOx level of the engine. For modeling purposes, we have assumed that all engines (except air-cooled gasoline engines) will certify at an equivalent HC+NOx standard of 1.7 g/kW-hr, yielding a CO standard of 7.9 g/kW-hr. Again, because the 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. (As with the Phase 1 emission factors, the emission levels for Phase 2 gasoline engines were back-calculated from a population-weighted average of the Phase 2 standards for water-cooled and air-cooled engines, assuming 13 percent of gasoline engines are air-cooled.) Table 6.2.2-5 present the zero-mile levels, deterioration factors used in the analysis of today's Phase 2 standards for Large SI engines. The Phase 2 standards are to take effect in 2004 for all engines.

Under the 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	11.9	1.36	1.0	0.7	1.15	1.0
LPG	0.1	1.64	1.0	3.9	1.36	1.0	0.9	1.15	1.0
CNG	1.6	1.64	1.0	3.9	1.36	1.0	0.9	1.15	1.0

6.2.2.1.2 Exhaust Emission Reductions Due to the 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 Phase 1 and Phase 2 standards. The tables also contain estimated emission reductions for each of the pollutants. We anticipate that the standards will result in a 92 percent reduction in exhaust HC, 91 percent reduction in NOx, and a 88 percent reduction in CO by 2020

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

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	166,000	166,000	0	0%
2005	180,000	136,000	44,000	24%
2010	197,000	59,000	138,000	70%
2020	235,000	19,000	216,000	92%
2030	274,000	17,000	257,000	94%

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

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	1,734,000	1,734,000	0	0%
2005	1,873,000	1,712,000	161,000	9%
2010	2,022,000	945,000	1,077,000	53%
2020	2,336,000	277,000	2,059,000	88%
2030	2,703,000	265,000	2,438,000	90%

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

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	308,000	308,000	0	0%
2005	348,000	273,000	75,000	21%
2010	389,000	118,000	271,000	70%
2020	472,000	43,000	429,000	91%
2030	553,000	44,000	509,000	92%

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 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 Gasoline Engines by Region

Region	Total
Northeast	87,200
Southeast	38,300
Southwest	22,700
Midwest	35,000
West	28,600
Northwest	9,200
Total	221,000

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	1.5 g/gallon/day	0.55 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.[16] 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	700	1,400	2,720	470	54,550
2005	720	1,430	2,820	480	59,100
2010	750	1,520	2,920	500	64,950
2020	810	1,680	3,171	540	77,340
2030	920	1,900	3,577	610	90,180

6.2.2.2.2 Evaporative and Crankcase Emission Reductions Due to the Requirements

We anticipate that the evaporative emission requirements for Large SI engines will result in about a 90 percent reduction in diurnal, running loss emissions, and hot soak emissions. The new requirements for Large SI equipment includes an evaporative emission standard of 0.2 grams per gallon of fuel tank capacity for 24-hour day when temperatures cycle between 72° and 96° F. In our modeling, we consider a 3.0 psi pressure relief valve. In this case, the model only accounts for hydrocarbon emissions generated at pressures greater than 3.0 psi (see Equation 7). The evaporative emission requirements are scheduled to take effect in 2007 with the Tier 2 requirements, except for the hot-soak requirements which will take effect in 2004 with the Tier 1 requirements. In addition, because the fuel consumption of Large SI engines will be reduced by 20 percent, 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 standards also require that engines have a closed crankcase. We expect the crankcase emissions will generally 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 percent. The 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 Tier 1 or Tier 2 engines. Table 6.2.2-14 presents the corresponding reductions in evaporative and crankcase emissions for Large SI engines due to the 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	700	1,400	2,720	470	54,550
2005	720	1,380	2,440	480	44,930
2010	550	1,360	1,600	370	25,170
2020	150	1,360	410	100	12,880
2030	70	1,520	260	50	9,020

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	50	380	0	14,200
2010	200	160	1,320	130	39,800
2020	670	320	2,760	450	64,500
2030	850	380	3,316	570	81,200

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 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 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 percent 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 percent 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 64.5 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 percent 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 percent 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 534 hours for gasoline equipment, 1368 hours for LPG equipment, and 1164 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 percent 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 Tier 1 and Tier 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 Tier 1 and Tier 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	3.05	2.13	6.81	4.79	7.06	4.85
Tier 1	0.74	0.51	1.86	1.30	1.83	1.24
Tier 2	0.24	0.17	0.49	0.34	0.55	0.37

* 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 Tier 1	2.31	1.62	4.94	3.50	5.24	3.61
Tier 1 to Tier 2	0.50	0.34	1.37	0.95	1.28	0.87

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

We also calculated per equipment lifetime evaporative emission reductions using an average lifetime of 13 years. For this analysis, we only consider gasoline powered equipment. We determine annual per vehicle evaporative emissions by dividing the total annual evaporative emissions for 2000 by the recreational vehicle populations shown in Table 6.2.2-9 (grown to 2000). Per vehicle emission reductions are based on the modeling described above. Table 6.2.2-18 presents these results with and without the consideration of a 7 percent per year discount on the value of emission reductions.

Table 6.2.2-18
Typical Lifetime Evaporative Emissions Per Large SI Gasoline Equipment(tons)

Evaporative Component	Baseline		Control		Reduction	
	Undiscounted	Discounted	Undiscounted	Discounted	Undiscounted	Discounted
Diurnal	0.041	0.028	0.003	0.002	0.038	0.026
Refueling	0.081	0.056	0.065	0.045	0.016	0.011
Hot Soak	0.158	0.109	0.011	0.008	0.147	0.101
Running Loss	0.027	0.019	0.002	0.001	0.025	0.017
Total	0.307	0.211	0.081	0.056	0.225	0.155

6.2.3 Snowmobile Exhaust Emissions

We projected the annual tons of exhaust HC, CO, NOx, and PM 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 and an annual usage factor of 57 hours.[17] Using historical snowmobile sales information for 1970 through 2001 and nationwide snowmobile registrations, both provided by ISMA, and the scrappage curve used in the NONROAD model, we have updated our estimate of average life from 9 years (as used in the proposal) to 13 years for this analysis.[18] The draft NONROAD model includes current and projected engine populations. The growth rates used in the NONROAD model have been updated based on historical sales information (provided by ISMA) and sales projections (developed by NERA in an analysis of the proposed snowmobile standards for ISMA).[19,20] Table 6.2.3-1 presents the snowmobile 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	1,622,000	2,000,000	2,407,000	3,089,000	3,377,000

The emission factors and deterioration factors for pre-control 2-stroke engines were developed for the Final Finding as noted above. For the control case emission factors (i.e., engines designed to comply with the Phase 1, Phase 2, or Phase 3 standards), we are projecting that manufacturers will use a mix of several different technologies that have significantly different emission characteristics. The three control technologies we believe will be used are a modified 2-stroke design, a direct injection 2-stroke engine, and a 4-stroke engine.

For the modified 2-stroke engine we assumed that manufacturers will design their engines to meet the Phase 1 standards at regulatory useful life with a small compliance margin. (Because we are not adopting a NOx standard for snowmobiles, we have assumed that NOx levels will remain at the pre-control levels for modified 2-stroke engines.) In determining the zero-mile levels of modified 2-stroke engines, we assumed a compliance margin of 20 percent to account for variability. (The 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 meet emission standards in the event of a compliance audit.) We have assumed that the deterioration rates of modified 2-strokes will stay the same as the deterioration rates for pre-control 2-stroke 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/ Technology	THC		CO		NOx		PM	
	ZML	Max DF	ZML	Max DF	ZML	Max DF	ZML	Max DF
Pre-control 2-stroke	111	1.2	296	1.2	0.9	1.0	2.7	1.2
Modified 2-stroke	53.7	1.2	147	1.2	0.9	1.0	2.7	1.2
Direct Injection 2-stroke	21.8	1.2	90	1.2	2.8	1.0	0.57	1.2
4-stroke	7.8	1.15	123	1.17	9.2	1.0	0.15	1.15

Table 6.2.3-2 contains the zero-mile level and deterioration factors for direct injection 2-stroke engines and 4-stroke engines as well. The emission levels were based on the results of testing of prototype snowmobile engines employing these technologies or other similarly sized engines employing these technologies.[21]

The Phase 1 standards are phased-in with 50% of engines for 2006 and 100% of enignes for 2007. The Phase 2 standards take effect in 2010 for all engines. The Phase 3 standards take effect in 2012 for all engines. For modeling purposes, we estimated the percent of engines that will employ each of the control technologies to comply with the Phase 1, Phase 2, and Phase 3 standards. Table 6.2.3-3 contains the technology assumptions for the base case and under the Phase 1, Phase 2, and Phase 3 standards. Currently, all engines are 2-strokes. Based on discussions with manufacturers, we have assumed that manufacturers will begin introducing a limited number of direct injection 2-strokes and some 4-strokes in the coming years.

Table 6.2.3-3
Snowmobile Engine Technology Mix Under the Base and Control Cases

Scenario	Uncontrolled 2-strokes	Modified 2-stroke	Direct Injection 2-stroke	4-stroke
Current Baseline	100%	-	-	-
2006 Baseline	86%	-	7%	7%
Phase 1 (2006)	53%	30%	8.5%	8.5%
Phase 1 (2007)	20%	60%	10%	10%
Phase 2	20%	30%	35%	15%
Phase 3	10%	20%	50%	20%

6.2.3.2 Reductions Due to the Standards

We anticipate that the standards for snowmobiles will result in a 57 percent reduction in HC, a 46 percent reduction in CO, and a 42 percent reduction in PM by the year 2020. As manufacturers adopt advanced technologies that result in significant HC, CO and PM emissions, we expect the relatively limited amount of NOx from snowmobiles to increase under the program. Tables 6.2.3-4 through 6.2.3.-7 present our projected HC, CO, NOx, and PM exhaust emission inventories for snowmobiles and the anticipated emission reductions from the Phase 1, Phase 2 and Phase 3 standards.

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

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	205,000	205,000	0	0%
2005	250,000	250,000	0	0%
2010	286,000	243,000	43,000	15%
2020	345,000	148,000	197,000	57%
2030	375,000	133,000	242,000	65%

Table 6.2.3-5
Projected CO Inventories and Reductions for Snowmobiles (short tons)

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	546,000	546,000	0	0%
2005	668,000	668,000	0	0%
2010	775,000	670,000	105,000	14%
2020	950,000	508,000	442,000	46%
2030	1,035,000	497,000	538,000	52%

Table 6.2.3-6
Projected NOx Inventories and Reductions for Snowmobiles (short tons)

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	1,400	1,400	0	0%
2005	1,900	1,900	0	0%
2010	3,000	3,500	(500)	-16%
2020	5,000	10,000	(5,000)	-101%
2030	5,500	12,100	(6,600)	-121%

Table 6.2.3-7
Projected PM Inventories and Reductions for Snowmobiles (short tons)

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	5,000	5,000	0	0%
2005	6,100	6,100	0	0%
2010	7,000	6,700	300	4%
2020	8,400	4,900	3,500	42%
2030	9,100	4,400	4,700	52%

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 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 13 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 Phase 1, Phase 2, and Phase 3 standards. (The per vehicle estimates are a weighted-average of the different technologies assumed under the base and control cases as presented earlier in Table 6.2.3-3.) Table 6.2.3-8 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 6.2.3-9 presents the corresponding lifetime HC and CO emission reductions for the Phase 1, Phase 2 and Phase 3 standards.

Table 6.2.3-8
Lifetime HC and CO Emissions from a Typical Snowmobile (tons)

Control Level	HC		CO	
	Undiscounted	Discounted	Undiscounted	Discounted
Pre-control	1.45	0.98	3.99	2.71
Phase 1	0.85	0.57	2.50	1.70
Phase 2	0.70	0.47	2.27	1.54
Phase 3	0.51	0.34	1.90	1.29

Table 6.2.3-9
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	0.40	1.49	1.01
Phase 1 to Phase 2	0.15	0.10	0.23	0.16
Phase 2 to Phase 3	0.19	0.14	0.37	0.25

6.2.4 All-Terrain Vehicle Exhaust Emissions

We projected the annual tons of exhaust HC, CO, NOx, and PM 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 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 average operating life of 13 years for ATVs.[22] Based on several surveys of ATV operators, we have revised the an annual usage factor for ATVs for this analysis to 1,570 miles per year.[23] The updated mileage analysis for ATVs is presented in detail in the appendix to this chapter. (Because the ATV standards are chassis-based standards 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 for this analysis to reflect the expected growth in ATV populations based on updated 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 percent 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 at much lower levels.[24] (The population of 2-stroke ATVs presented in Table 6.2.4-1 are for baseline population estimates. Under the 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	3,919,000	6,240,000	8,453,000	10,080,000	10,188,000
2-stroke ATVs*	690,000	1,678,000	2,461,000	3,001,000	3,036,000
All ATVs	4,609,000	7,918,000	10,914,000	13,081,000	13,224,000

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

The baseline HC, CO, and NOx 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. PM emissions were not measured in the test program. Therefore, baseline PM emission factors were based on testing of both off-highway motorcycles and pre-control on-highway motorcycles.[25] 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 standards), we assumed that the manufacturers will design their engines to meet the standards at regulatory useful life with a small compliance margin. Because we are adopting a HC+NOx standard for ATVs, 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 ATVs, we assumed a compliance margin of 20 percent to account for variability. (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 will meet emission standards in the event of a compliance audit.) Because the standards for ATVs are expected to be met by 4-stroke designs, we assumed that the deterioration rates will 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 6,214 miles (10,000 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.)

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		PM	
	ZML	Max DF	ZML	Max DF	ZML	Max DF	ZML	Max DF
Baseline/Pre-control 2-stroke	53.9	1.2	54.1	1.2	0.15	1.0	2.1	1.2
Baseline/Pre-control 4-stroke	2.4	1.15	48.5	1.17	0.41	1.0	0.06	1.2
Control/Phase 1 - 4-stroke	1.6	1.15	42.9	1.17	0.26	1.0	0.06	1.15

The Phase 1 standards are to be phased in at 50 percent in 2007 and 100 percent in 2008. However, because there are a significant number of small volume manufacturers that produce 2-stroke ATVs, and because we have compliance flexibilities for such manufacturers, we have modeled the phase in of the 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
2005	100%	0%
2006	65%	35%
2007	30%	70%
2008	15%	85%
2009	0%	100%

6.2.4.2 Reductions Due to the Standards

We anticipate that the standards for ATVs will result in a 86 percent reduction in HC, a 37 percent reduction in CO, and a 86 percent reduction in PM by the year 2020. As manufacturers convert their engines from 2-stroke to 4-stroke design and achieve these significant reductions, we expect there may be a minimal increase in NOx. Tables 6.2.4-4 through 6.2.4-7 present our projected HC, CO, NOx, and PM exhaust emission inventories for ATVs and the anticipated emission reductions from the Phase 1 standards.

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

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	89,000	89,000	0	0%
2005	200,000	200,000	0	0%
2010	291,000	198,000	92,000	32%
2020	353,000	49,000	304,000	86%
2030	357,000	40,000	317,000	89%

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

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	437,000	437,000	0	0%
2005	755,000	755,000	0	0%
2010	1,042,000	989,000	53,000	5%
2020	1,250,000	1,085,000	165,000	13%
2030	1,263,000	1,092,000	171,000	14%

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

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	3,000	3,000	0	0%
2005	4,900	4,900	0	0%
2010	6,600	5,900	(700)	-11%
2020	7,900	5,900	(2,000)	-25%
2030	8,000	6,000	(2,000)	-26%

Table 6.2.4-7
Projected PM Inventories and Reductions for ATVs (short tons)

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	3,200	3,200	0	0%
2005	7,400	7,400	0	0%
2010	10,800	7,400	3,400	32%
2020	13,100	1,800	11,300	86%
2030	13,300	1,500	11,800	89%

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 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.

As described earlier in this section, the annual usage rate for an ATV is estimated to be 1,570 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 Phase 1 standards. Table 6.2.4-8 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 6.2.4-9 presents the corresponding lifetime HC+NOx emission reductions for the Phase 1.

Table 6.2.4-8
Lifetime HC+NOx Emissions from a Typical ATV (tons)

Control Level	HC+NOx	
	Undiscounted	Discounted
Pre-control (2-stroke)	1.37	0.93
Pre-control (4-stroke)	0.07	0.05
Pre-control (Composite)	0.35	0.24
Phase 1	0.05	0.03

Table 6.2.4-9
Lifetime HC+NOx Emission Reductions from a Typical ATV (tons)

Control Increment	HC+NOx	
	Undiscounted	Discounted
Pre-control (Composite) to Phase 1	0.30	0.21

6.2.5 Off-highway Motorcycle Exhaust Emissions

We projected the annual tons of exhaust HC, CO, NOx, and PM 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 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 an updated analysis of fuel consumption and fuel use, we have revised our estimate of annual usage for off-highway motorcycles to 1,600 miles per year.[26] (The updated mileage analysis for off-highway motorcycles is presented in detail in the appendix to this chapter.) We have also revised our estimate of the average operating life of off-highway motorcycles to 12 years based on historical sales and population information provided by the Motorcycle Industry Council.[27] (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 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.) The population growth rates used in the NONROAD model have been updated based on historical sales information provided by MIC and a projected one percent growth in sales.[28]

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

Category	2000	2005	2010	2020	2030
4-stroke Off-highway Motorcycles	444,000	656,000	862,000	1,038,000	1,133,000
2-stroke Off-highway Motorcycles*	902,000	1,333,000	1,750,000	2,108,000	2,300,000
All Off-highway Motorcycles	1,346,000	1,989,000	2,612,000	3,146,000	3,433,000

* - The projected population estimates for 2-stroke off-highway motorcycles are for baseline calculations only. To meet the 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 HC, CO, and NOx emission factors used in the NONROAD model for off-highway motorcycles have been updated based on recent testing of ATVs and off-highway motorcycles as presented in Chapter 4. PM emissions were not measured in the test program. Therefore, baseline PM emission factors were based on testing of both off-highway motorcycles and pre-control on-highway motorcycles.[29] 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 will design their engines to meet the standards at regulatory useful life with a small compliance margin. Because we are adopting 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 will meet emission standards in the event of a compliance audit.) Because the standards for off-highway motorcycles are expected to be met by 4-stroke designs, we assumed that the deterioration rates will 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		PM	
	ZML	Max DF	ZML	Max DF	ZML	Max DF	ZML	Max DF
Baseline/Pre-control 2-stroke*	53.9	1.2	54.1	1.2	0.15	1.0	2.1	1.2
Baseline/Pre-control 4-stroke	2.4	1.15	48.5	1.17	0.41	1.0	0.06	1.15
Control/Phase 1 4-stroke	2.1	1.15	30.6	1.17	0.34	1.0	0.06	1.15

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

The Phase 1 standards phase in at 50 percent in 2007 and 100 percent in 2008. However, because there are a significant number of small volume manufacturers that produce off-highway motorcycles (who can take advantage of compliance flexibilities), and because competition off-highway motorcycles are exempt from the standards, we have modeled the phase in of the 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%
2008	6%	94%	49%	51%
2009+	0%	100%	46%	54%

6.2.5.2 Reductions Due to the Standards

We anticipate that the standards for off-highway motorcycles will result in a 49 percent reduction in HC, a 26 percent reduction in CO, and a 50 percent reduction in PM by the year 2020. As manufacturers convert their engines from 2-stroke to 4-stroke design and achieve these significant emission reductions, we project there may be a small increase in NOx inventories. Tables 6.2.5-4 through 6.2.5.-7 present our projected HC, CO, NOx, and PM exhaust emission inventories for off-highway motorcycles and the anticipated emission reductions from the Phase 1 standards. (The emission inventories presented below for off-highway motorcycles include competition motorcycles that will be exempt from the standards.)

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

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	97,000	97,000	0	0%
2005	143,000	143,000	0	0%
2010	188,000	151,000	36,000	19%
2020	226,000	115,000	111,000	49%
2030	246,000	121,000	126,000	51%

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

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	137,000	137,000	0	0%
2005	203,000	203,000	0	0%
2010	226,000	239,000	27,000	10%
2020	321,000	236,000	84,000	26%
2030	350,000	254,000	96,000	27%

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

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	600	600	0	0%
2005	800	800	0	0%
2010	1,100	1,200	(100)	-8%
2020	1,300	1,500	(200)	-19%
2030	1,400	1,700	(300)	-19%

Table 6.2.5-7
Projected PM Inventories and Reductions for Off-Highway Motorcycles (short tons)

Calendar Year	Baseline	Control	Reduction	% Reduction
2000	3,700	3,700	0	0%
2005	5,500	5,500	0	0%
2010	7,300	5,900	1,400	20%
2020	8,700	4,400	4,300	50%
2030	9,500	4,600	4,900	52%

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 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 1,600 miles per year and the average lifetime is estimated to be 12 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 Phase 1 standards. (Competition bikes, which are exempt from the standards, are not included in the calculations.) Table 6.2.5-8 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 6.2.5-9 presents the corresponding lifetime HC+NOx emission reductions for the Phase 1 standards.

Table 6.2.5-8
Lifetime HC+NOx Emissions from a Typical Off-highway Motorcycle (tons)*

Control Level	HC+NOx	
	Undiscounted	Discounted
Pre-control (2-stroke)	1.27	0.89
Pre-control (4-stroke)	0.06	0.04
Pre-control (Composite)	0.60	0.42
Phase 1	0.06	0.04

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

Table 6.2.5-9
Lifetime HC+NOx Emission Reductions from a Typical Off-highway Motorcycle (tons)*

Control Increment	HC+NOx	
	Undiscounted	Discounted
Pre-control (Composite) to Phase 1	0.54	0.38

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

6.2.6 Evaporative Emissions from Recreational Vehicles

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

6.2.6.1 General 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 6.2.6-1 presents the population of recreational vehicles for 1998.

Table 6.2.6-1
1998 Population of Recreational Vehicles by Region

Region	Snowmobiles	ATVs	Off-Highway Motorcycles
Northeast	954,000	1,420,000	427,000
Southeast	0	1,010,000	304,000
Southwest	11,000	363,000	109,000
Midwest	419,000	457,000	137,000
West	40,000	423,000	127,000
Northwest	140,000	249,000	75,000
Total	1,560,000	3,930,000	1,180,000

We based average fuel tank sizes on sales literature for recreational vehicles. Snowmobile fuel tanks range from 10 gallons to about 12 gallons. For ATVs, fuel tanks range from one gallon for the smaller youth models to five gallons for the larger utility models. Finally, off-highway motorcycle fuel tanks range in capacity from approximately one gallon on some smaller youth models to about three gallons on some enduro motorcycles. For this analysis, we used average fuel tank sizes of 11 gallons for snowmobiles, 4 gallons for ATVs, and 3 gallons for off-highway motorcycles.

Based on our examination of recreational vehicles, we have found that fuel hoses generally have an inside diameter of about 6 mm (1/4 inch). For ATVs, we estimate one foot of fuel line on average. For off-highway motorcycles, we estimate that they use approximately one to two feet of fuel line on average. We use 1.5 feet in our analysis. Snowmobiles are a little more complex because they use multi-cylinder engines (either two or three cylinders). For two cylinder engines we estimate two to three feet of fuel line and for three cylinder engines we estimate three to four feet of fuel line. We use 3.5 feet in our analysis.

6.2.6.2 Permeation Emissions Inventory and Reductions

Based on the data presented in Chapter 4, we developed the emission factors presented in Table 6.2.6-2. For the purposes of this modeling, fuel tank permeation rates are expressed in terms of g/gallon/day because the defining characteristic of the fuel tanks in our model is capacity. The standard requires that the fuel tanks meet an 85 percent reduction in permeation throughout its useful life. For this modeling, we assume that manufacturers will strive to achieve a 95 percent reductions from new tanks and that the permeation control will deteriorate to 85 percent by the end of the life of an average tank. Hose permeation rates are based on $g/m^2/day$. We believe that hoses designed to meet the 15 $g/m^2/day$ standard on 10 percent ethanol fuel will permeate at least 50 percent less when gasoline is used. Therefore, we model permeation from this hose to be about half of the permeation from fuel hose designed to meet 15 $g/m^2/day$ on gasoline.[1] To show the effect of temperature on permeation rates, we present emission rates at three temperatures.

Table 6.2.6-2
Fuel Tank and Hose Permeation Emission Factors

Material	23°C (73°F)	29°C (85°F)	40°C (104°F)
Polyethylene fuel tanks	0.78 g/gal/day	1.12 g/gal/day	2.08 g/gal/day
New barrier treated HDPE fuel tank	0.04 g/gal/day	0.06 g/gal/day	0.10 g/gal/day
Aged barrier treated HDPE fuel tank	0.11 g/gal/day	0.17 g/gal/day	0.31 g/gal/day
SAE R7 fuel hose	550 $g/m^2/day$	873 $g/m^2/day$	1800 $g/m^2/day$
SAE R9 barrier fuel hose	15 $g/m^2/day$	24 $g/m^2/day$	49 $g/m^2/day$
Alcohol resistant barrier fuel hose	7.5 $g/m^2/day$	12 $g/m^2/day$	25 $g/m^2/day$

Using the vehicle populations and temperature distributions discussed above, we calculated baseline and controlled permeation emission inventories for recreational vehicles. Tables 6.2.6-3 and 6.2.6-4 present our projected permeation reductions from fuel tanks and

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[1] This is appropriate because the baseline emissions are modeled based on the use of gasoline as a fuel. If we were to consider that a fraction of the fuel contains oxygenates, both the baseline and control emission inventory projections would increase.

hoses.

Table 6.2.6-3
Projected Fuel Tank Permeation Emissions from Recreational Vehicles [short tons]

Vehicle	Scenario	2000	2005	2010	2020	2030
Snow-mobiles	baseline	3,389	4,181	5,032	6,456	7,061
	control	3,389	4,181	3,586	901	746
	reduction	0	0	1,446	5,555	6,315
ATVs	baseline	3,985	6,751	9,275	11,109	11,231
	control	3,985	6,751	7,388	2,602	1,249
	reduction	0	0	1,887	8,507	9,982
OHMCs	baseline	882	1,303	1,710	2,061	2,248
	control	882	1,303	1,370	834	857
	reduction	0	0	340	1,227	1,391
Total	baseline	8,255	12,234	16,016	19,626	20,539
	control	8,255	12,234	12,343	4,337	2,851
	reduction	0	0	3,673	15,288	17,688

Table 6.2.6-4
Projected Fuel Hose Permeation Emissions from Recreational Vehicles [short tons]

Vehicle	Scenario	2000	2005	2010	2020	2030
Snow-mobiles	baseline	4,471	5,516	6,638	8,517	9,315
	control	4,471	5,516	4,361	452	127
	reduction	0	0	2,007	8,065	9,188
ATVs	baseline	4,243	7,189	9,876	11,829	11,959
	control	4,243	7,189	7,771	1,931	245
	reduction	0	0	2,105	9,898	11,714
OHMCs	baseline	1,878	2,774	3,642	4,389	4,787
	control	1,878	2,774	2,880	1,513	1,520
	reduction	0	0	762	2,876	3,268
Total	baseline	10,592	15,478	20,156	24,735	26,061
	control	10,592	15,478	15,282	3,896	1,891
	reduction	0	0	4,873	20,838	24,169

6.2.6.3 Per Vehicle Permeation Emissions

In developing the cost per ton estimates in Chapter 7, we need to know the lifetime emissions per recreational vehicle. The lifetime emissions are based on the projected lives of 9 years for snowmobiles, 13 years for ATVs, and 9 years for off-highway motorcycles. We determine annual per vehicle evaporative emissions by dividing the total annual evaporative emissions for 2000 by the recreational vehicle populations shown in Table 6.2.6-1 (grown to

2000). Competition motorcycles, which are exempt form the standards, are not included in these calculations. Per vehicle emission reductions are based on the modeling described above. Table 6.2.6-5 presents these results with and without the consideration of a 7 percent per year discount on the value of emission reductions.

Table 6.2.6-5
Typical Lifetime Permeation Emissions Per Recreational Vehicle (tons)

	Baseline		Control		Reduction	
	Undiscounted	Discounted	Undiscounted	Discounted	Undiscounted	Discounted
Snowmobiles						
Tank	0.0180	0.0140	0.0019	0.0015	0.0161	0.0125
Hose	0.0238	0.0184	0.0003	0.0003	0.0235	0.0182
Total	0.0418	0.0324	0.0022	0.0017	0.0396	0.0307
All Terrain Vehicles						
Tank	0.0114	0.0078	0.0012	0.0008	0.0102	0.0070
Hose	0.0121	0.0083	0.0002	0.0001	0.0119	0.0082
Total	0.0234	0.0161	0.0014	0.0009	0.0221	0.0152
Off-Highway Motorcycles						
Tank	0.0059	0.0046	0.0006	0.0005	0.0053	0.0041
Hose	0.0126	0.0097	0.0002	0.0001	0.0124	0.0096
Total	0.0184	0.0143	0.0008	0.0006	0.0177	0.0137

6.2.6.4 Other Evaporative Emissions

We calculated diurnal and refueling vapor loss emissions using the general inputs in section 6.2.6.1 and the methodology described in sections 6.1.2.2 and 6.2.1.3. Although we are not regulating these emissions, we present the inventory projections for comparison. Table 6.2.6-6 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. (This comparison is for illustrative purposes; as discussed above, we modeled daily temperature for 365 days over 6 regions of the U.S.) Decreasing temperature and fuel RVP and increasing fill level all have the effect of reducing the diurnal emission factor. Table 6.2.6-7 presents our diurnal emission projections.

Table 6.2.6-6
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	1.5 g/gallon/day	0.55 g/gallon/day

* Reid Vapor Pressure

Table 6.2.6-7
Projected Diurnal Emissions from Recreational Vehicles [short tons]

Calendar Year	Snowmobiles	ATVs	Off-Highway Motorcycles
2000	2,223	3,079	681
2005	2,743	5,216	1,006
2010	3,301	7,167	1,321
2020	4,235	8,584	1,592
2030	4,632	8,678	1,737

To calculate the refueling vapor displacement emissions from recreational vehicles, we needed to know the amount of fuel added to the fuel tank per year. Therefore, we used the draft NONROAD model to determine the amount of fuel consumed by recreational vehicles. We then used the amount of fuel consumed as the amount of fuel added to the fuel. Table 6.2.6-8 contains the projected refueling emission inventories for recreational vehicles.

Table 6.2.6-8
Projected Refueling Emissions from Recreational Vehicles [short tons]

Calendar Year	Snowmobiles	ATVs	Off-Highway Motorcycles
2000	1,814	928	368
2005	2,230	1,620	544
2010	2,596	1,185	684
2020	2,922	2,510	773
2030	3,120	2,532	840

Appendix to Chapter 6: ATV and Off-highway Motorcycle Usage Rates

This appendix presents the analyses used to determine the annual average usage rates for ATVs and off-highway motorcycles.

6A.1 ATV Usage

On October 5, 2001, EPA published proposed emission regulations for nonroad land-based recreational vehicles. These regulations covered snowmobiles, off-highway motorcycles, and all-terrain vehicles (ATVs). The Motorcycle Industry Council, Inc. (MIC) and the Specialty Vehicle Institute of America (SVIA) submitted comments suggesting that the EPA estimates for ATV usage had been substantially overestimated. They stated that our mileage estimate of 7,000 miles per year was too high and that based on some additional information that they had obtained, a more reasonable estimate was a lifetime average of 350 miles per year. As a result of these comments and the subsequent new information, EPA has revised it's estimate of annual ATV usage.

Background

On November 20, 2000 EPA published a Final Finding of Contribution and Advance Notice of Proposed Rulemaking (ANPRM) for large nonroad spark-ignition engines and land-based recreational vehicles. In this process, we developed emission inventories for the various engine and vehicle categories covered by both these documents. EPA developed inventories using NONROAD model, which computes emission estimates for nonroad engines at selected geographic and temporal scales. The model incorporates data on emission rates, usage rates, and vehicle population to determine annual emission levels of various pollutants.
For recreational vehicles, and more specifically ATVs, data on emission rates and usage rates was extremely limited. We approached members of the ATV industry to provide us with any data that they had on emission and usage rates. Unfortunately, all of the emission data industry had for ATVs was collected on the J1088 steady state engine test cycle rather than the FTP transient vehicle test cycle that we proposed. Industry also indicated that they didn't have any data on ATV usage rates. MIC provided survey data on off-highway motorcycle usage, but did not provide any information on ATV usage. Through our literature search, we ultimately found a study by the United States Consumer Product Safety Commission (CPSC) published in April of 1998 titled, "All-Terrain Vehicle Exposure, Injury, Death, and Risk Studies" that provided information on ATV usage. This study provided the basis for our estimate of ATV usage for the NPRM.

We did not receive any comments on our estimate of ATV usage during the comment period for the Final Finding and ANPRM . In fact, we did not receive any comments until after the Notice of Proposed Rulemaking (NPRM) was published in October of 2001.

ATV Usage in the ANPRM and NPRM

Because we received no comment or additional information for the ANPRM and NPRM, we determined that the CPSC study was the best source of information available. After converting hours of use to miles ridden, we estimated an annual average of 7,000 miles/year. A complete description of the modeling parameters for ATVs used in the NPRM is contained in an EPA memorandum entitled "Emission Modeling for Recreational Vehicles."[30]

New Information

Since the publication of the October 2001 NPRM, several new pieces of information on ATV usage have become available. These new sources consist of:

- Nationwide sources
  - ATV manufacturer warranty data
  - A Honda owner survey
  - ATV Industry Panel Survey (consisting of five ATV manufacturers)

- State studies on economic impact of ATV operation on their respective states
  - California[31]
  - Colorado[32]
  - Maine[33]
  - Michigan[34]
  - I. Utah[35]

- Instrumented ATV Usage Data (CE-CERT)
  - Speed information

Each of these sources is discussed in more detail below.

Warranty Data

One ATV manufacturer supplied ATV mileage and hour data from some its warranty claims submitted over a period of four years. The data was substantial and represented a good cross section of the country. The data is proprietary and was provided to us as confidential business information. This manufacturer does not have odometers or hour-meters on all of their ATV models, but provided data on those models equipped with an odometer or hour-meter, which happens to be only their utility models. Thus, there is no data for any of their sport models.

Intuitively, we were concerned about using data from warranty claims because of the possibility that usage data for machines that have been experiencing problems may not be reflective of how someone actually operates an ATV. Depending on the nature of the warranty claim, the ATV owner may decide to not operate their machine as much as they want because of a mechanical problem that doesn't allow the ATV to work or concern that the problem could be exacerbated by continued operation. Ultimately, because of the size of the data set, we felt we couldn't dismiss the data simply based on the fact that the data is from warranty claims. We did however have another concern with the data. The manufacturer indicated to us that they require mileage to be reported on the warranty claim form. However, discussions with several local dealers indicated something different. One dealer stated that the manufacturer had told them to record hours instead of mileage, so that they either didn't include hours or only casually added it when they remembered. Another dealer said that the manufacturer had indicated to them that neither input was important, since the warranty is based on time after purchase (e.g., six months) rather than usage and that they, therefore, entered data somewhat haphazardly, if at all. These inconsistencies raised concerns over the accuracy of the mileage and hour data. If dealerships don't pay close attention to what numbers they enter into the warranty claim forms, then the warranty data could be suspect.

To eliminate this concern and more in general as a means to provide a degree of validation to the data set used, we decided to only use data which contained both odometer and hour meter readings. This way we could compare the values and make sure that they appeared to be consistent with each other. Of the data points supplied, almost half of the data had only odometer readings, while the other half had only hour readings. There was, however, a smaller subset of data that included both types of data (approximately 3,000 data points). This data was further screened as discussed below.

Honda Study

Honda hired a contractor to perform a phone survey of Honda ATV owners to inquire as to how many total hours and miles were on their machines. The surveyor asked the owner if the odometer and hour meter on their ATV was functional. If so, they asked them to read the mileage and hour reading directly from their ATV. Honda only contacted people who had purchased utility models since they are the only ATV models Honda sells that are equipped with odometer and hour meters. The Honda survey does not contain data for sport models. Honda used the odometer and hour meter readings combined with the model year of each model to determine what the yearly mileage and hour usage was for each ATV in the survey. They had a sample size of 611 ATVs that were mostly distributed evenly and randomly across the country, thus the survey results appear to provide a national perspective.

The survey did not include any ATVs newer than 13 months or older than four years. Honda wanted data for ATVs older than 13 months because in order to determine the number of miles and hours ridden per year, they simply took the odometer or hour meter reading and divided it by the machines age. For example, a machine that had 2,000 miles and was two years old would average 1,000 miles per year. If they selected data from machines newer than a year old, they would have to extrapolate to at least a year to get the average yearly usage. They felt that extrapolating the data would be improper since it could either overestimate or underestimate the usage depending on how the owner rode their machine during the months involved. If the data was for a machine was only six months old, then the simplest way to extrapolate would be to double the mileage or hours from the first six months. There is no way of knowing whether the owner would have ridden more or less in the following six months, thus the concern with over- or underestimating the usage.

Industry Panel Survey

In 1997, five of the major ATV manufacturers conducted an industry panel survey to determine how well the survey information from the ATV exposure study performed by CPSC in the same year would correlate with their own independent, but similar survey. The purpose of the industry panel survey was to use a similar methodology and format as the CPSC study but to survey an independent random sample of ATV owners to replicate the CPSC survey . They aimed for the same approximate sample size gathered randomly from across the country. Relevant survey questions used phrasing almost identical to that used in the CPSC survey. The survey and data were provided to us on a confidential basis and cannot be shared here. However, it can be stated that the yearly hour usage results from the industry panel survey are very consistent with the CPSC study results.

State Studies

All of the state studies were done in 2000 or later and were not available at the time we originally developed our ATV usage estimates for the proposal, with the exception of the California study which was done in 1994. Three of the studies (Colorado, Maine, and Utah) were provided to us by MIC. The Michigan study was obtained by EPA after a literature search on ATV activity and usage. We were made aware of the California study through comments from the Blue Ribbon Coalition. The purpose of the state studies was to measure the economic impact of ATV and other recreational vehicle operation on the state economy. One of the results from the studies was an estimate of how often ATVs were used in the respective state for that particular year. The studies were based on user surveys that were typically mailed to registered ATV owners. Mileage estimates were typically based off a single question posed in the survey that asked the participant "How many miles did you ride your ATV in the past year?" All of the studies measured usage in miles per year. Maine also recorded information on hours per year. Average annual ATV usage from the state studies ranged from 320 mi/yr in Michigan to 1,270 mi/yr in Utah. It should be noted that according to the NONROAD model, these four states only represent approximately four percent of the total U.S. ATV population and only Michigan is in the top 20 states in ATV population.

The state studies were good for their intended purpose but since they weren't designed specifically to answer the questions at hand, they each have some shortcomings that limit their value to us. For example, all four states are cold climate states with cold winters and snow accumulation that may limit the amount of annual operation, especially compared to some of the warmer states that have higher ATV populations (e.g., Texas, Georgia, Tennessee, Alabama, etc.). The ATV industry has indicated that ATV operation is becoming very prevalent in agricultural use. Two of the states, Utah and Maine, are not large agricultural states, thus potentially resulting in a lower usage estimate than could be expected from a national study. All four of the state studies focused only on registered ATV owners. This has the potential for underestimating the number of miles ridden, since it does not provide a broad spectrum of all ATV riders in the respective state. In some states, registration is only required for use on public lands. Mileage estimates from three of the four studies were based on a single question inquiring about ATV use. There was no attempt made to verify with the respondent the accuracy of their estimate, as was done in the CPSC and Industry Panel studies. Four of the studies had discrepancies between their estimates of mileage and fuel usage. In almost each of the studies, the amount of fuel the respondents estimated they used for their ATV in one year would result in mileage results far higher than the actual mileage estimates provided by the respondents, creating a level of uncertainty about the viability of the mileage estimates. Finally, the California study combined data for ATVs with off-highway motorcycles, making it impossible to discern the mileage or fuel consumption for only ATVs.

We also obtained data from a separate report done by the State of California on ATV activity data collection. California hired the University of California, College of Engineering - Center for Environmental Research and Technology (CE-CERT) to instrument 41 ATVs and have the owners operate them in several California off-road parks and measure vehicle and engine speed.[36] This work was done to help California better estimate ATV in-use operation and emissions inventories within California. At this time, California has not completed their analysis of the data, nor have they started to develop any new modeling, so their work is unavailable as a source for ATV inventories. However, the CE-CERT draft report provides a summary of ATV activity work. They focused on measuring vehicle speed and fuel consumption.

ATV Usage Derivation Methodology for the Final Rulemaking

Criteria

In attempting to reconcile the results from the various data sets, we established three guiding criteria. The ideal data set would have all of these characteristics: 1) national scope; 2) "real" data (actual measurement readings as opposed to survey results based on recollection); and 3) a broad spectrum of ATV use (sport and utility operation). None of the existing data sets meet all three criteria. Therefore, we decided that it was important to select data sets that met two of the three criteria. Four of the data sets meet two of the above criteria. The CPSC and Industry Panel Survey data have a national scope and broad spectrum of ATV use. The warranty data and the Honda survey data are both real data that provide a national scope. The state studies, however, only provide a broad spectrum of use and many have a bias towards use on public lands. They do not provide a national scope, nor are they generally based on "real" data. Therefore, our methodology to determine ATV usage is based on the CPSC, Industry Panel Survey, warranty, and Honda data. The state studies were not used because they did not meet two of out three criteria, and as was briefly summarized above, had some shortcomings we could not resolve. Of the three criteria, we felt that data which provide a national scope was the most important, since it would remove any possible regional or state bias in ATV usage that could exist. For example, some states may have higher usage levels because of unique or appealing terrain, a large amount of public and private land available for riding on, an extended riding season due to warmer climate, or greater potential for agricultural, ranching, and hunting usage, that may not be reflected if we only use data from the four states that have performed studies on ATV usage.

Utility vs. Sport ATVs

Utility ATVs are designed for multiple purposes and are most often used for hunting and fishing, camping, yard work, farm work, as well as recreational trail riding. Sport ATVs are designed for aggressive recreational riding over rough terrain and closed courses, where higher speeds and performance are desired. According to Kawasaki, currently 75% of all ATV sales are for utility models and 25% are for sport models. Ideally, we would want the population percentage of sport and utility usage rather than sales, but this data is not available.

Hours vs. Miles

The NONROAD model uses miles per year of operation, rather than hours per year of operation, as one of the main inputs in calculating the inventory estimates for HC, CO, NOx, and PM emissions. Thus, to be consistent with the needs of the model, we were required to make sure all of the data used was in miles per year of operation. Only the Honda and warranty data had mileage data. However, all four data sets have hour data. In order to convert the hour data into mileage estimates, we had to multiply the hour values by an average ATV speed estimate.

Average Speed

Ideally, we would want to develop an estimate for the average ATV speed that includes both of the different types of models (utility and sport). Unfortunately, there wasn't a single data set that could be used to determine average speed for both types of models. The Honda and warranty data only included utility models. However, from these data sets we were able to determine average speed for a utility ATV, since the ATVs in these data sets were equipped with odometers and hour meters, which allowed us to calculate average speed. From this data we were able to determine that the average speed for utility ATVs is about 8 mi/hr.

None of the four data sets had information that would allow the calculation of average speed for sport ATV models. As discussed above, CE-CERT instrumented 41 ATVs and had the owners operate them in several California off-road parks and measure vehicle and engine speed. The off-road parks examined allowed operation over trails, desert, and sand dunes. Of the 41 instrumented ATVs, 36 were sport models and five were utility models. For the purposes of our analysis, we considered all 41 ATVs as indicative of sport operation, since the riding that occurred in these off-road parks was clearly recreational or sport, rather than utility usage. The average speed for all 41 ATVs was about 13 mi/hr.

Methodology

The data permitted us to develop a methodology that would determine fleet average miles per year by weighting separate mileage estimates for utility and sport ATVs based on average use, average speed and sales. The equation looks like this:

Utility ATVs *Sport ATVs*
(0.75)(hours/yr)(miles/hour) + (0.25)(hours/yr)(miles/hour) = Total miles/year for all ATVs

The 0.75 factor represents the percentage of total ATV sales that are for utility models, while the 0.25 factor represents the remaining percentage of sales which are for sport models. Population would have been preferable to sales, but that information was not available.

Utility ATV Estimates

To determine the mileage estimate for utility ATV models, we chose to use the data from the Honda and warranty data sets. We selected these two data sets because they both consisted entirely of data for utility ATVs. We merged both data sets and calculated the average hours per year of operation and average speed (mi/hr). Prior to merging the data sets we performed several quality checks of the data. First, we only used data that had both mileage and hour values. This was so we could calculate an average speed for utility ATVs. All of the Honda data had both values (approximately 605 data points). The warranty data had only a relatively small subset of data that contained both mileage and hours (approximately 3,000 data points). Next, we eliminated any of the warranty data that was for ATVs newer than 30 days and older than three years, consistent with MIC's analysis. We found that for the warranty data, there appeared to a significant number of data points that were duplicates (number of instances where same entry was made twice). Since some of these duplicates were for usage rates that were either very high or very low, we decided to remove all duplicates so that they would not bias the data. We also deleted any samples that had identical miles and hours figures, on the basis that these readings were probably mistakes, since it was unlikely that a rider would ride the exact same number of miles and hours per year (e.g., 500 mi/yr and 500 hr/yr). Finally, we deleted any data from both data sets that had an average speed greater than 25 mph, since information provided by the American Motorcycle Association (AMA) on ATV race track statistics indicates that for professional ATV racers, the average speed is 24 mph. Therefore, it did not seem reasonable to include data for speeds in excess of those achieved by professional ATV racers.

The combined sample size of the merged data set was 2,531. The average speed for utility ATVs from the merged data set was 8 miles per hour and the average hours of use was 151 hours per year. Our hours per year estimate for utility ATV use is corroborated by the CPSC study and information from MIC. A discussion of nonrecreational or utility use in the CPSC study states "..high use nonrecreational (utility) drivers tend to be older (36 years and up).." (See page 14 of CPSC study). MIC has stated that the average age of individuals buying utility ATV models is between 40 and 50 years old. The CPSC study indicates that for riders in the 40 to 50 year old age range, the average hourly usage was 158 hours per year (see page 27 of CPSC study).

Sport ATV Estimates

To determine the mileage estimate for sport ATV models, we used the data from the CPSC and Industry Panel Survey data sets. Since we were unable to determine average speed from these data sets, we used the average speed of 13 mph derived from the CE-CERT data for the 41 instrumented ATVs.

The CPSC and Industry Panel studies were done in 1997. Based on information from these studies, between 50%-75% of the ATVs in both studies were from the 1980-1995 model years. Between 1980 and 1990, sport ATVs were the predominant ATVs sold in the U.S. Although their sales were starting to decline in favor of utility models, sport models were still responsible for approximately 50% of all ATV sales from 1990 through 1995 and were the majority of the ATV population. Therefore, both of these studies are most likely biased towards operation with sport ATV models and should, therefore, be most representative of sport ATV operation.

The annual riding hours from both data sets was determined by multiplying results of three survey questions concerning riding patterns: (1) the number of months during which ATVs were ridden during the previous year, (2) the number of days of riding in an average month, and (3) the number of hours of riding in an average day.   The total hours per year were then calculated from the following equation.

$$\frac{hours}{year} = \frac{months}{year} \cdot \frac{days}{month} \cdot \frac{hours}{day}$$

We averaged annual rider hours from the CPSC and industry panel surveys, due to their similarities in approach and results. In deriving average estimates from each, we reviewed results for the questions used in the calculation, and modified some results that we considered implausible.   Specifically, for those records where the respondent claimed more than 10 hours of use on an average day of riding, we limited daily usage at a maximum of 10 hours. The resulting annual average usage rate was 216 hours per year.

In relation to their study objectives, the CPSC and Industry Panel studies both presented usage results for the average rider, rather than for the average ATV. In other words, results are presented as hours/rider/year, rather than hours/ATV/year. For the NPRM, we attempted to correct hours/rider to hours/ATV using the ratio of the national rider population to the total ATV population, as follows[2]:

$$\frac{hours}{ATV \cdot year} = \frac{hours}{rider \cdot year} \cdot \left(\frac{national\ rider\ \ population\ (riders)}{national\ \ ATV\ \ population\ (ATVs)} \right)$$

In this analysis, we recalculated the average usage rate (i.e., hours per rider-year) using a data set of results for individual respondents, which enabled review of individual responses, as mentioned above. To be consistent with this approach, it would be appropriate to recalculate the "correction" using individual responses, as opposed to gross national averages, as in the equation above. However, several pieces of data needed for this calculation were unavailable, specifically, the numbers of riders and ATVs in each respondent household. Accordingly, for purposes of this

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[2] In the NPRM analysis, we also applied an adjustment to subtract "inactive" riders from the total rider population. In subsequent correspondence, the author of the CPSC study indicated that such an adjustment was unnecessary, as the national population estimated in the report was intended to represent only "active riders," defined as riders who had reported using their ATVs in the previous year. Thus, the "inactive rider" adjustment is not presented here.

analysis, we assumed that rider hours as reported in the CPSC and industry panel studies were equivalent to ATV operating hours.

Mileage Estimate

By plugging in the above values derived for utility and sport ATVs average hourly operation and average speed into the equation discussed above, we were able to determine a mileage estimate for ATVs of 1,608 mile per year.

$$\underbrace{(0.75)(151\ \mathrm{hr/yr})(8\ \mathrm{mi/hr})}^{\textit{Utility ATVs}} + \overbrace{(0.25)(216\ \mathrm{hr/yr})(13\ \mathrm{mi/hr})}^{\textit{Sport ATVs}} = \mathbf{1{,}608\ mi/yr}$$

Conclusion

It is informative to consider the outcome from our methodology to the results of the studies we did not use, or the alternative application of some of the individual studies that we did use. The state studies do not have the strength of the national studies and were not used in our analysis. The state studies represent only 4% of U.S. ATV registrations and all four states are cold weather states that may not reflect winter use in warmer states. State methodologies give results of mixed value. For example, two state studies had low mileage estimates: Michigan had an estimate of 320 mi/yr and Colorado had an estimate of 610 mi/yr, while Utah had an estimate of 1,270 mi/yr which is closer to our estimate. Maine had even more mixed results. Their estimate ranged from 535 mi/yr to 1,646 mi/yr depending on which methodology they used to determine mileage, the direct question or the multiple questions. The Honda survey data had an estimate of 560 mi/yr. The warranty data had an estimate of 1,340 mi/yr. Both of these data sets included only utility ATVs. The CPSC and Industry Panel studies had hour estimates of approximately 250 hr/yr, which depending on the average speed used, can have a mileage range of 1,900 mi/yr (for the average utility ATV speed of 8 mph) to 3,150 mi/yr (for the average sport ATV speed of 13 mph). Therefore, we believe that our estimate of 1,608 miles per year is reasonable and the best estimate considering all of the available data.

There is currently no data set which alone can be characterized as providing the best estimate of ATV annual usage. All of the available data sets have some shortcomings. Looking across all of the studies considered in the analysis yields mileage estimates from 320 mi/yr to 3,150 mi/yr. It is impossible to reconcile all eight data sets and it is not analytically appropriate to average all of the data sets because they aren't all of equal strength or value. The methodology we've developed is the best way to reconcile broadly ranging data of the highest value.

6A.2 Off-Highway Motorcycle Usage

On October 5, 2001, EPA published proposed emission regulations for nonroad land-based recreational vehicles. These regulations covered snowmobiles, off-highway motorcycles, and all-terrain vehicles (ATVs). The Motorcycle Industry Council, Inc. (MIC) submitted comments suggesting that the EPA estimates for off-highway motorcycle (OHMC) usage had been overestimated. They stated that our mileage estimate of 2,400 miles per year was too high and that based on some additional information that they had obtained, a more reasonable estimate was a lifetime average of 600 miles per year. As a result of these comments and the subsequent new information, EPA has revised it's estimate of annual OHMC usage.

Background

On November 20, 2000 EPA published a Final Finding of Contribution and Advance Notice of Proposed Rulemaking (ANPRM) for large nonroad spark-ignition engines and land-based recreational vehicles. We had to develop emission inventories for the various engine and vehicle categories covered by both of these documents. EPA has developed an emissions model named NONROAD, which computes nationwide emission levels for nonroad engines. The model incorporates data on emission rates, usage rates, and vehicle population to determine annual emission levels of various pollutants. For recreational vehicles, and more specifically OHMCs, data on emission rates and usage rates was extremely limited. Because of the lack of data, we initially grouped OHMCs and ATVs together. However, as we performed literature searches and attempted to uncover additional data on OHMC emissions and activity, it became apparent that OHMCs and ATVs were used differently and unique emission rates, usage rates, and populations should be established. We approached members of the OHMC industry to provide us with any data that they had on emission and usage rates. MIC provided survey data on off-highway motorcycle usage. We also found a study done in 1999 by the Oak Ridge National Laboratory (ORNL) titled, "Fuel Used for Off-Road Recreation: A Reassessment of the Fuel Use Model" that provided information on OHMC usage. We examined these two studies to develop our estimate of OHMC usage for the November 2000, ANPRM and the October 2001, NPRM.

Off-Highway Motorcycle Usage as developed for ANPRM and NPRM

For OHMC, there were two sources of information on activity or usage rates that we examined. The first source was information provided by the motorcycle industry. MIC periodically conducts surveys to obtain diverse information on motorcycle facts, such as number of motorcycles per rider, types and makes of bikes, on-road or off-road, bike education, etc. The survey also gathers information on motorcycle usage. MIC used two methods of estimating OHMC usage from the survey results. Method one was based on the results of a single question that asks the respondent how many miles they rode their OHMC in the last year. Method two is based on the compilation of the response from three questions: 1) how many months do you ride per year, 2) how many days do you ride per month, and 3) how many miles do ride per day. The MIC estimate for method one was 222 miles per year and 1,260 miles per year for method two. MIC suggested that method one was the more appropriate estimate because method two may compound any error that exists in the results of each of the three questions. We had concerns with the results of the MIC survey because the values for method one and two were so dramatically different.

The second source of information was the 1999 ORNL study. In their study, ORNL estimated total average fuel usage for off-highway motorcycles. They provided a medium estimate of average fuel usage for OHMCs of 59 gallons per year. Data from California and some older SwRI work on OHMC emission testing suggested that the average fuel economy for OHMCs was approximately 50 miles per gallon (mpg), as tested over the FTP (a relatively non-aggressive driving cycle when compared to some OHMC uses). We determined that this estimate could be too high for actual in-use off-road operation, so we derived from the data an estimate of 40 mpg. By multiplying the average fuel used per year by the average fuel economy, we arrived at an estimate of approximately 2,400 miles per year.

OHMC Usage = (59 gallons/year)(40 miles/gallon) = 2,400 miles/year

We also found another ORNL study published in 1994 where MIC also estimated average fuel usage in their survey with a resulting mean value of 214 gallons per year.[37] If we used our estimate of 40 mpg, 214 gallons per year would yield 8,560 miles. Because of the large discrepancies in the three MIC based values, we chose to use the estimate of 2,400 miles per year.

New Information on Off-Highway Motorcycle Usage

Since the publication of the NPRM in October 2001, several new pieces of information on OHMC usage have become available. These new sources consist of state studies from California[38], Michigan[39], Oregon[40], and Utah[41] on OHMC usage (the California and Oregon studies were used in both of the ORNL studies). These studies present information on the number of miles OHMC's are ridden per year and/or the number of gallons of fuel used per year riding OHMCs. We also received information from the American Motorcycle Association (AMA) on rider surveys which attempt to quantify the number of miles ridden per year by the average OHMC rider.

Finally, we obtained new information on the fuel consumption of OHMCs. The state of California hired the University of California, College of Engineering - Center for Environmental Research and Technology (CE-CERT) to instrument a number of OHMCs that were operated in several California off-road parks and motocross tracks and measure vehicle and engine speed.[42] This work was done to help California better estimate OHMC in-use operation and emissions inventories within California. At this time, California has not completed their analysis of the data, nor have they started to develop any new modeling, so their work is unavailable as a source for OHMC emissions inventories. However, they have shared with us data on fuel consumption from the OHMC testing. We also had updated emission and fuel economy test results for 10 OHMCs tested by EPA over the FTP.

State Studies

All four of the state studies included estimates of average yearly total fuel consumption for OHMCs, but only the Michigan and Utah studies also provided estimates for average yearly mileage for OHMCs. The average yearly total fuel consumption for the four studies ranges from 32 gallons per year for Michigan to 89 gallons per year for Oregon. The average for the four studies is 57 gallons per year. Table 6A.2-1 lists the average yearly total fuel consumption for the four studies. The two states that provided estimates for average yearly mileage were Michigan and Utah. Michigan listed a yearly mileage of 494 miles per year, while Utah had a value more than twice that with 1,067 miles per year.

Table 6A.2-1
Off-Highway Motorcycle Average Gallons of Fuel Consumed and Mileage Ridden Per Year

State Study	Average Gallons Per Year	Average Mileage Per Year
Michigan	32	494
California	44	n/a
Utah	62	1,067
Oregon	89	n/a
Average	57	781

AMA Survey

AMA presented survey results from 1994, 1996, 1998, & 2000 on how many miles AMA members rode OHMCs in each of these years. The data indicates a trend toward increased mileage each year. The survey was based on a mailing to AMA members listing questions as to riding habits. AMA broke the survey results into six bins based on miles ridden in the last 12 months:

- 0 - 499 mi/yr
- 500 - 999 mi/yr
- 1,000 - 1,499 mi/yr
- 1,500 - 1,999 mi/yr
- 2,000 or more
- No answer

They determined the total number of miles ridden by taking the median value of each bin and multiplying it by the number of responses in that bin. They did this for each bin. They then summed the results for all of the bins. The summation was then divided by the total number of responses. For the bin categorizing responses of 2,000 miles or more, rather than using the median, as with the other bins, they capped the mileage at 2,000 miles. This is problematic since 19% of all responses fell into this bin. By capping the values in this bin at 2,000 miles, the estimate for this bin is too low. This would indicate that their estimate for average total OHMC miles ridden per year is also probably too low. They estimated that in 2000, the average AMA member rode 1,158 miles.

New Fuel Economy Estimates

We have tested nine OHMCs at our National Vehicle and Fuel Emissions Laboratory (NVFEL) in Ann Arbor, Michigan. We also have the fuel economy results from a test done by

California on a 1999 Yamaha WR400. All of the tests are over the transient highway motorcycle FTP test cycle. Table 6A.2-2 lists the results for the 4-stroke OHMCs. Table 6A.2-3 lists the results for the 2-stroke OHMCs.

Table 6A.2-2
FTP Fuel Economy for 4-Stroke Off-Highway Motorcycles

Manufacturer	Model	Model Year	Fuel Economy (mpg)
Yamaha	WR250F	2001	39
Yamaha	WR400	1999	55
Husaberg	FE501	2001	53
KTM	400EXC	2001	54
Average			50

Table 6A.2-3
FTP Fuel Economy for 2-Stroke Off-Highway Motorcycles

Manufacturer	Model	Model Year	Fuel Economy (mpg)
KTM	125 SX	2001	21
KTM	125 SX	2001	31
KTM	200 EXC	2001	22
KTM	250 SX	2001	18
KTM	250 EXC	2001	20
KTM	300 EXC	2001	21
Average			22

The CE-CERT data developed for the State of California was based on actual in-use fuel consumption measurements made on numerous OHMCs operated by the owners at several off-road motorcycle parks and a motocross track. The parks consisted of trail riding, desert riding, sand dune riding, and a mixture of all three. These riding scenarios could be considered closer to worst case conditions that may not be reflective of average in-use operation nationally. The results were 24 mpg for the 2-stroke machines and 27 mpg for the 4-stroke machines.

Off-Highway Motorcycle Usage Derivation Methodology for the Final Rule

Based on the new information we have received, there are two approaches we could choose to estimate annual average OHMC usage. The first would be to base the estimate on the mileage estimates presented in the Michigan, Utah, and AMA studies. The second would be to use the same methodology we used for the ANPRM and NPRM, which uses total fuel consumption from four state studies and fuel economy measurements from the California survey and EPA FTP results to estimate mileage.

The first approach appears to be limited, since the AMA study under predicts the annual mileage and since we do not have the raw data, there doesn't appear to be a method to upgrade the estimate that wouldn't be somewhat arbitrary. This leaves only the mileage per year estimates from the two state studies. There were two concerns with using the mileage estimates from the two state studies. First of all, many OHMC models are not equipped with odometers, which would make it difficult for participants responding to the state surveys to recall how many miles they actually rode. Secondly, the average gallons per year and miles ridden per year reported result in average fuel economy estimates of 15 and 17 miles per gallon. These values are considerably lower than values from the CE-CERT and EPA testing. This means that either the gallons per year estimates are high or the mileage per year estimates are low. Since we had more sources for total fuel consumption and fuel economy values based on emissions test results and actual in-use operation, it appears to be more appropriate to use the second methodology (which is based on fuel consumption), rather than the first methodology (which is based on mileage) with only two questionable data points.

The equation for estimating average annual OHMC mileage based on fuel consumption is:

OHMC Usage in miles per year = (gallons/year)(miles/gallon)

The gallons per year value is based on the average of the four state studies which is 57 gallons per year. We are not including the ORNL study directly. The ORNL study consisted of data that they had obtained from the California and Oregon studies and the MIC survey. ORNL agrees with us that they thought the MIC survey information was of limited value for the same reasons that we pointed put. To address their concern over using this data, they decided to give each of the three studies a weighted value, with the MIC and Oregon studies having lower weightings than the California study. We decided that it was more prudent to just use the California and Oregon studies in combination with the other two new state studies from Utah and Michigan, rather than include the MIC data.

For the fuel economy we had FTP results from EPA testing and in-use results from CE-CERT. Since there is no way of knowing which of these set of values are the most correct (in-use data was for relatively extreme operation) we chose to take the average of the two data sets. However, before we did this, we decided to determine the overall fuel economy for each data set based on the weighted impact of the two different types of engines, 2-stroke and 4-stroke. The current break-down of 2-stroke and 4-stroke engines in OHMCs is 67% for 2-stroke engines and 33% for 4-stroke engines. Thus, we used the following equation to estimate fuel economy:

Fuel Economy (FE) = (0.67)(2-stroke FE (mpg)) + (0.33)(4-stroke FE (mpg))

For the EPA FTP testing, the average weighted fuel economy results are the following:

FE = (0.67)(22 mpg) + (0.33)(50 mpg) = 31 mpg

For the CE-CERT in-use measurements, the average weighted fuel economy results are the following:

FE = (0.67)(24 mpg) + (0.33)(27 mpg) = 25 mpg

The average of these two data sets is 28 mpg. Combining the value of 28 mpg with the fuel consumption value of 57 gallons per year results in an average of 1,600 miles per year for OHMCs.

OHMC Usage = (57 gallons/year)(28 miles/gallon) = 1,600 miles/year

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