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Executive Summary

EPA is adopting new standards for emissions of oxides of nitrogen, hydrocarbons, and carbon monoxide from several categories of engines. This Final Regulatory Support Document provides technical, economic, and environmental analyses of the new emission standards for the affected engines. The anticipated emission reductions will translate into significant, long-term improvements in air quality in many areas of the U.S. Overall, the requirements will dramatically reduce individual exposure to dangerous pollutants and provide much needed assistance to states and regions facing ozone and particulate air quality problems that are causing a range of adverse health effects, especially in terms of respiratory impairment and related illnesses.

Chapter 1 reviews information related to the health and welfare effects of the pollutants of concern. Chapter 2 contains an overview of the affected manufacturers, including some description of the range of engines involved and their place in the market. Chapter 3 covers a broad description of engine technologies, including a wide variety of approaches to reducing emissions. Chapter 4 summarizes the available information supporting the specific standards we are adopting, providing a technical justification for the feasibility of the standards. Chapter 5 applies cost estimates to the projected technologies. Chapter 6 presents the calculated contribution of these engines to the nationwide emission inventory with and without the standards. Chapter 7 compares the costs and the emission reductions for an estimate of the cost-effectiveness of the rulemaking. Chapter 8 presents our Final Regulatory Flexibility Analysis, as called for in the Regulatory Flexibility Act. Chapters 9 and 10 describe the societal costs and benefits of the rulemaking. Chapter 11 presents a range of regulatory alternative we considered in developing the final rule.

There are three sets of engines and vehicles covered by the new standards. The following paragraphs describe the different types of engines and vehicles and the standards that apply.

<u>Emission Standards</u>

Large industrial spark-ignition engines

These are spark-ignition nonroad engines rated over 19 kW used in commercial applications. These include engines used in forklifts, electric generators, airport ground service equipment, and a variety of other construction, farm, and industrial equipment. Many Large SI engines, such as those used in farm and construction equipment, are operated outdoors, predominantly during warmer weather and often in or near heavily populated urban areas where they contribute to ozone formation and ambient CO and PM levels. These engines are also often operated in factories, warehouses, and large retail outlets throughout the year, where they contribute to high exposure levels to personnel who work with or near this equipment as well as to ozone formation and ambient CO and PM levels. In this rulemaking, we call these “Large SI” engines.

We are adopting two tiers of emission standards for Large SI engines. The first tier, scheduled to start in 2004, sets standards of 4 g/kW-hr (3 g/hp-hr) for HC+NOx and 50 g/kW-hr (37 g/hp-hr) for CO. These standards are the same as those adopted earlier by the California Air Resources Board.

Starting in 2007, the Tier 2 emission standards fall to 2.7 g/kW-hr (2.0 g/hp-hr) for HC+NOx emissions and 4.4 g/kW-hr (3.3 g/hp-hr) for CO emissions. However, we are including an option for manufacturers to certify their engines to different emission levels to reflect the inherent tradeoff of NOx and CO emissions and to add an incentive for HC+NOx emission reductions below the standard. Generally this involves meeting a less stringent CO standard if a manufacturer certifies an engine with lower HC+NOx emissions. Table 1 shows several examples of possible combinations of HC+NOx and CO emission standards. The highest allowable CO standard for duty-cycle testing is 20.6 g/kW-hr (15.4 g/hp-hr), which corresponds with HC+NOx emissions below 0.8 g/kW-hr (0.6 g/hp-hr).

Table 1
Samples of Possible Alternative
Emission Standards for Large SI Engines(g/kW-hr)*

	HC+NOx	CO
Duty-cycle testing	2.70	4.4
	2.20	5.6
	1.70	7.9
	1.30	11.1
	1.00	15.5
	0.80	20.6
Field testing	3.80	6.5
	3.10	8.5
	2.40	11.7
	1.80	16.8
	1.40	23.1
	1.10	31.0

*As described in the Final Regulatory Support Document and the regulations, the values in the table are related by the following formula: $(HC+NOx) \times CO^{0.784} = 8.57$. These values follow directly from the logarithmic relationship presented with the proposal in the Draft Regulatory Impact Analysis. The analogous formula for field-testing standards is $(HC+NOx) \times CO^{0.791} = 16.78$.

In addition, Tier 2 engines must have engine diagnostic capabilities that alert the operator to malfunctions in the engine's emission-control system. Gasoline-fueled Tier 2 engines will also be required to reduce evaporative emissions. The field-testing procedures and standards in this final rule make it possible for the manufacturer to easily test engines to meet the requirements of the in-use testing program for showing that engines undergoing several years of normal operation in the field continue to meet emission standards.

Nonroad recreational engines and vehicles

These are spark-ignition nonroad engines used primarily in recreational applications. These include off-highway motorcycles, all-terrain-vehicles (ATVs), and snowmobiles. Some of these engines, particularly those used on ATVs, are increasingly used for commercial purposes within urban areas, especially for hauling loads and other utility purposes. These vehicles are typically used in suburban and rural areas, where they can contribute to ozone formation and ambient CO and PM levels. They can also contribute to regional haze problems in our national and state parks. Tables 2 and 3 show the exhaust and permeation emission standards that apply to recreational vehicles.

Table 2
Recreational Vehicle Exhaust Emission Standards

Vehicle	Model Year	Emission standards		Phase-in
		HC g/kW-hr	CO g/kW-hr	
Snowmobile	2006	100	275	50%
	2007 through 2009	100	275	100%
	2010	75	275	
	2012*	75	200	
		HC+NOx g/km	CO g/km	
Off-highway Motorcycle	2006	2.0	25.0	50%
	2007 and later	2.0	25.0	100%
ATV	2006	1.5	35.0	50%
	2007 and later	1.5	35.0	100

* or equivalent per Section 1051.103; the long term program includes a provision which acts to cap NOx emission rates

Table 3
Permeation Standards for Recreational Vehicles

Emission Component	Implementation Date	Standard	Test Temperature
Fuel Tank Permeation	2008	1.5 $g/m^2/day$	28°C (82°F)
Hose Permeation	2008	15 $g/m^2/day$	23°C (73°F)

Recreational marine diesel engines

These are marine diesel engines used on recreational vessels such as yachts, cruisers, and other types of pleasure craft. Recreational marine engines are primarily used in warm weather and therefore contribute to ozone formation and PM levels, especially in marinas, which are often located in nonattainment areas.

Table 4
Recreational Marine Diesel Emission Limits and Implementation Dates

Displacement [liters per cylinder]	Implementation Date	HC+NOx g/kW-hr	PM g/kW-hr	CO g/kW-hr
power ≥ 37 kW 0.5 ≤ disp < 0.9	2007	7.5	0.40	5.0
0.9 ≤ disp < 1.2	2006	7.2	0.30	5.0
1.2 ≤ disp < 2.5	2006	7.2	0.20	5.0
2.5 ≤ disp	2009	7.2	0.20	5.0

Projected Impacts

The following paragraphs and tables summarize the projected emission reductions and costs associated with the emission standards. See the detailed analysis later in this document for further discussion of these estimates.

Tables 5 and 6 contain the projected emissions from the engines subject to this action. Projected figures compare the estimated emission levels with and without the emission standards for 2020.

Table 5
2020 HC and NOx Projected Emissions Inventories (thousand short tons)

Category	Exhaust HC*			Exhaust NOx		
	base case	with standards	percent reduction	base case	with standards	percent reduction
Industrial SI >19kW	318	34	89	472	43	91
Snowmobiles	358	149	58	5	10	(101)
ATVs	374	53	86	8	6	25
Off-highway motorcycles	232	117	50	1.3	1.5	(19)
Recreational Marine diesel	2.0	1.5	28	61	48	21
Total	1,284	355	72	547	109	80

* The estimate for Industrial SI >19kW includes both exhaust and evaporative emissions. The estimates for snowmobiles, ATVs and Off-highway motorcycles includes both exhaust and permeation emissions.

Table 6
2020 Projected CO and PM Emissions Inventories (thousand short tons)

Category	Exhaust CO			Exhaust PM		
	base case	with standards	percent reduction	base case	with standards	percent reduction
Industrial SI >19kW	2,336	277	88	2.3	2.3	0
Snowmobiles	950	508	46	8.4	4.9	42
ATVs	1,250	1,085	13	13.1	1.9	86
Off-highway motorcycles	321	236	26	8.7	4.4	50
Recreational Marine diesel	9	9	0	1.6	1.3	18
Total	4,866	2,115	56	34.2	14.8	57

Table 7 summarizes the projected costs to meet the emission standards. This is our best estimate of the cost associated with adopting new technologies to meet the emission standards. The analysis also considers total operating costs, including maintenance and fuel consumption. In many cases, the fuel savings from new technology are greater than the cost to upgrade the engines. All costs are presented in 2001 dollars.

Table 7
Estimated Average Cost Impacts of Emission Standards

Standards	Dates	Increased Production Cost per Vehicle*	Lifetime Operating Costs per Vehicle (NPV)
Large SI exhaust	2004	$611	$-3,981
Large SI exhaust	2007	$55	$0
Large SI evaporative	2007	$13	$-56
Snowmobile exhaust	2006	$73	$-57
Snowmobile exhaust	2010	$131	$-286
Snowmobile exhaust	2012	$89	$-191
Snowmobile permeation	2008	$7	$-11
ATV exhaust	2006	$84	$-24
ATV permeation	2008	$3	$-6
Off-highway motorcycle exhaust	2006	$155	$-48
Off-highway motorcycle permeation	2008	$3	$-5
Recreational marine diesel	2006	$346	—

*The estimated long-term costs decrease by about 35 percent. Costs presented for the Large SI and snowmobile second-phase standards are incremental to the first-phase standards.

We also calculated the cost per ton of emission reductions for the standards. For snowmobiles, this calculation is on the basis of HC plus NOx emissions and CO emissions. For all other engines, we attributed the entire cost of the program to the control of ozone precursor emissions (HC or NOx or both). A separate calculation could apply to reduced CO or PM emissions in some cases. Assigning the full compliance costs to a narrow emissions basis leads to cost-per-ton values that underestimate of the value of the program.

Table 8 presents the discounted cost-per-ton estimates for the various engine categories and standards being adopted. Reduced operating costs more than offset the increased cost of producing the cleaner engines for Large SI and snowmobile engines. The overall fuel savings associated with the standards being adopted are greater than the total projected costs to comply with the emission standards.

Table 8
Estimated Cost-per-Ton of Emission Standards

Standards	Dates	Discounted Reductions per Vehicle (short tons)*	Discounted Cost per Ton of HC+NOx		Discounted Cost per Ton of CO	
			Without Fuel Savings	With Fuel Savings	Without Fuel Savings	With Fuel Savings
Large SI exhaust (Composite of all fuels)	2004	3.07	$240	($1,150)	—	—
Large SI exhaust (Composite of all fuels)	2007	0.80	$80	$80	—	—
Large SI evaporative	2007	0.13	$80	($280)	—	—
Snowmobile exhaust	2006	HC: 0.40 CO: 1.02	$90	$20	$40	$10
Snowmobile exhaust	2010	HC: 0.10	$1,370	$0	—	—
Snowmobile exhaust	2012	CO: 0.25	—	—	$360	$0
Snowmobile permeation	2008	0.03	$210	($150)	—	—
ATV exhaust	2006	0.21	$400	$290	—	—
ATV permeation	2008	0.02	$180	($180)	—	—
Off-highway motorcycle exhaust	2006	0.38	$410	$280	—	—
Off-highway motorcycle permeation	2008	0.01	$230	($140)	—	—
Recreational marine diesel	2006	0.44	$670	$670	—	—
Aggregate	—	—	$240	($280)	$80	($20)

* HC reductions for evaporative and permeation, and HC+NOx reductions for exhaust (except snowmobiles where CO reductions are also presented).

Economic Impact Analysis

We performed an analysis to estimate the economic impacts of this final rule on producers and consumers of recreational marine diesel vessels (specifically, diesel inboard cruisers), forklifts, snowmobiles, ATVs, off-highway motorcycles, and society as a whole. This economic impact analysis focuses on market-level changes in price, quantity, and economic welfare (social gains or costs) associated with the regulation. A description of the methodology used can be found in Chapter 9 of this document.

We did not perform an economic impact analysis for categories of Large SI nonroad engines other than forklifts, even though those other Large SI engines are also subject to the standards contained in this final rule. This was due to the large number of different types of equipment that use Large SI engines and data availability constraints for those market segments. For the sake of completeness, the following analysis reports separate estimates for Large SI engines other than forklifts. Engineering costs are assumed to be equal to economic costs for those engines. This approach slightly overestimates the social costs associated with the relevant standards.

Based on the estimated regulatory costs associated with this rule and the predicted changes in prices and quantity produced in the affected industries, the total estimated annual social gains of the rule in the year 2030 is projected to be $553.3 million (in 2000 and 2001 dollars). The net present value of the social gains for the 2002 to 2030 time frame is equal to $4.9 billion. The social gains are equal to the fuel savings minus the combined loss in consumer and producer surplus (see Table 9), taking into account producers' and consumers' changes in behavior resulting from the costs associated with the rule.[1] Social gains do not account for the social benefits (the monetized health and environmental effects of the rule).

Table 9
Surplus Losses, Fuel Efficiency Gains, and Social Gains/Costs in 2030[a]

Vehicle Category	Surplus Losses in 2030 ($millions)	Fuel Efficiency Gains in 2030 ($millions)	Social Gains/Costs in 2030[b] ($millions)
Recreational marine diesel vessels	$6.6	$0	($6.6)
Forklifts	$47.8	$420.1	$372.3
Other Large SI[c]	$48.1	$138.4	$90.3
Snowmobiles	$41.9	$135.0	$93.1
ATVs	$47.2	$51.4	$4.2
Off-highway motorcycles	$25.0	$25.2	$0.2
All vehicles total	$216.6	$770.1	$553.3
NPV of all vehicles total[d]	$3,231.4	$8,130.3	$4,898.9

[a] Figures are in 2000 and 2001dollars.
[b] Figures in this column exclude estimated social benefits. Numbers in parentheses denote social costs.
[c] Figure is engineering costs; see Section 9.7.6 of Chapter 9 for explanation.
[d] Net Present Value is calculated over the 2002 to 2030 time frame using a 3 percent discount rate.

For most of the engine categories contained in this rule, we expect there will be a fuel savings as manufacturers redesign their engines to comply with emission standards. For ATVs and off-highway motorcycles, the fuel savings will be realized as manufacturers switch from two-stroke to four-stroke technologies. For snowmobiles, the fuel savings will be realized as manufacturers switch some of their engines to more fuel efficient two-stroke technologies and some of their engines to four-stroke technologies. For Large SI engines, the fuel savings will be realized as manufacturers adopt more sophisticated and more efficient fuel systems; this is true for all fuels used by Large SI engines. Overall, we project the fuel savings associated with the anticipated changes in technology to be about 800 million gallons per year once the program is

[1] Consumer and producer surplus losses are measures of the economic welfare loss consumers and producers, respectively are likely to experience as a result of the regulations. Combined these losses represent an estimate of the economic or social costs of the rule. Note that for the Large SI and recreational vehicle rules, fuel efficiency gains must be netted from surplus losses to estimate the social costs or social gains (in cases where fuel efficiency gains exceed surplus losses) attributable to the rules.

fully phased in. These savings are factored into the calculated costs and costs per ton of reduced emissions, as described above.