Control of Emissions from Marine SI and Small SI Engines, Vessels, and Equipment

Final Regulatory Impact Analysis

Chapter 11
Regulatory Alternatives

Assessment and Standards Division
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CHAPTER 11: Regulatory Alternatives

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Our program represents a blend of exhaust and evaporative emission standards for small nonroad spark-ignition (SI) engines used in land-based or auxiliary marine applications, and also recreational Marine SI engines. We believe that the combination of emission standards and their associated timing are superior to the alternative program options we considered given their feasibility, cost, and environmental impact. In this chapter we present and discuss the options that we evaluated in order to make this determination.

Section 11.1 presents each element of our requirements and discusses a variety of specific alternatives that are either less and more stringent. After this initial assessment, options that merit a more rigorous examination are identified for analysis in subsequent sections. Section 11.2 describes the cost of the selected options for each affected engine or system. Section 11.3 presents the emissions inventory impacts associated with each option. Section 11.4 describes the cost effectiveness ($/ton of emission reduced) of the selected options. Finally, we present our assessment of the rationale, feasibility, and issues associated with each alternative in Section 11.5.

The costs, emission reductions, and cost effectiveness of the options analyzed in Sections 11.2 through 11.5 are incremental to the base case (i.e., current requirements) ignoring this rule, unless otherwise specified. For example, the more stringent recreational marine exhaust standards for OB/PWC are evaluated as follow-on requirements to the new requirements and would begin in a later year. Therefore, the analysis for that option reflects only the more stringent subsequent standards.

For the more stringent options, it is important to note that the analyses depend on data supporting them. Generally, a scenario was picked for analysis because there was evidence to suggest that controls such as those identified in the write-ups could be technically feasible at some point in the future. However, there is some uncertainty with regard to the technical feasibility of implementing the standards or requirements across all products, the level of the potential standards selected for analysis (if applicable), the timing for potential introduction, and the costs of control. However, while these standards were ultimately not selected as the basis for this rule, it appears that in some cases they could form the basis for potential future rulemaking actions.

11.1 Identification of Alternative Program Options

This section provides our description of potential options for each element of our rule. Options that do not merit further consideration are eliminated and those that warrant additional analysis in subsequent sections are identified.

11.1.1 Alternative Exhaust Emission Requirements

11.1.1.1 Small SI Engine HC+NOx Standards

11.1.1.1.1 Class I

We considered, but rejected, a less stringent HC+NOx emission standard for Class I spark-ignition engines. The standard of 10 g/kW-hr is readily achievable with reasonably priced emission control technology. Furthermore, the lead time for implementing the standard in 2012 is adequate for applying the catalyst-based technology that will be used on many of these engines. A less stringent emission standard would not be consistent with the requirements of section 213 of the Clean Air Act.

A more stringent standard was also considered. Under this option an 8 g/kW-hr HC+NOx standard would be implemented. For purposes of this analysis we elected to begin the requirement in the 2015 model year. Due to the technical design relationship between the engine and running loss control requirement we modeled running loss controls to start in 2015 as well. This standard represents about a 50 reduction from the existing Phase 2 standard, rather than the approximately 38 percent reduction associated with the final standards. As analyzed this option also provides 3 more years of lead time. We believe that manufacturers of side-valve (SV) engines would choose to convert these families to overhead-valve (OHV) designs. The emissions from OHV engine are typically lower and deteriorate less than SV engines and thereby result in the need for only a slightly more active catalyst and improved cooling relative to the technology changes needed for the final standards. Cooling for the slightly more active OHV catalyst would be supplied by the engine improvements anticipated for this rule, such as include optimized head design for cooling and fan design for cooling air generation. The slightly more active catalyst can be achieved with either a larger volume and/or a more active mix of precious metals in the catalyst substrate. It may be possible for SV engines to meet the more stringent emission standards using catalysts. For SV engines the catalysts would likely need to be larger and more active. This would result in higher costs and greater catalyst heat generation which may or may not be able to be handled by the engine's cooling system.

11.1.1.1.2 Class II

For Class II spark-ignition engines, we considered an alternative program option that was less stringent than the final standards. However, for the same reasons previously stated for Class I engines, we rejected this alternative from further consideration; the standards are readily achievable at a reasonable cost within the lead time provided. A less stringent standard, such as one at a level not depending on catalyst technology, would not have been consistent with section 213 of the Clean Air Act.

An alternative for a more stringent exhaust HC+NOx emission standard would be 4.0 g/kW-hr along with a delay in the corresponding running loss requirement such that engine changes are made at one time. For analytical purposes we started this requirement in 2015, four years beyond that for the new standard. Such an exhaust emission standard represents a 67 percent reduction relative to the existing Phase 2 standard, rather than the 34 percent reduction associated with the new standards. It also provides four more years of lead time; a phase-in could be needed since implementation would require the equipment manufacturers involvement for non-integrated products. In order to achieve the 4.0 g/kW-hr HC+NOx emission standard, we expect manufacturers would need to make widespread use of closed loop control EFI and three-way catalysts. The EFI systems would keep engine air-to-fuel mixture closer to stoichiometry and provide an optimum environment for the maximum reduction in HC+NOx by a three way catalyst. Changes to the catalyst would likely involve a more active mix of precious metals in the catalyst substrate. In addition, engine upgrades would be required in some of the Class II engines commonly used in residential lawn care equipment.

11.1.1.2 Marine Auxiliary Engine CO Standard

The standards for marine auxiliary engines include a CO standard that would require the use of highly efficient catalytic control. This standard would require the use of technology to meet emission levels demanded by the market. Manufacturers of gasoline marine generators are equipping their engines with catalysts for the primary purpose of reducing ambient CO concentrations around boats. Therefore, we do not believe that it would be useful to consider a less stringent standard which could enable market penetration of new engine offerings which potentially endanger public health. At the same time, the standard is very stringent and manufacturers are already designing for reductions which are more than 95 percent below the current CO emission standard. A more stringent standard would do little more to push technology. Thus, we do not believe that it would be useful to analyze a more stringent standard.

11.1.1.3 Outboard/Personal Watercraft (OB/PWC) Engine HC+NOx and CO Emission Standards

The standards for OB/PWC are based on technology that manufacturers are already certifying and selling nationwide. To meet the new requirements, manufacturers would continue to sell this technology and discontinue their sale of high-emitting old technology carbureted two-stroke engines. Because the standards can be met with existing technology, we do not believe that there is an alternative between the new standards and the current standards which would be consistent with the CAA section 213 requirement. Therefore, we did not analyze a less stringent alternative.

For a more stringent alternative, we considered an addition tier of standards beginning in 2012. For OB/PWC engines greater than 40 kW these would be at a level of 10 g/kW-hr. For engines less than 40 kW, we use an equation of 28 - 0.45 × rated power(kW) to maintain a continuous curve function. This alternative also considers a lower CO standard of 200 g/kW-hr for engines greater than 40 kW with an adjusted standard of 500 - 7.5 × rated power(kW) for engines less than 40 kW to maintain a continuous standard function. Such standards would be consistent with currently certified emission levels from some four-stroke outboard engines. Although many four-stroke engines may be able to meet a 10 g/kW-hr standard with improved engine calibration, it is not clear that all engines could meet this standard without applying yet unproven catalyst technology in this application. To model this scenario, we evaluated the costs and emission reductions that could be achieved through the combined use of calibrated four-stroke engines and four-stroke engines with catalytic control. This analysis applied catalytic control to larger OB/PWC engines, which already use or are expected to use electronic fuel injection.

11.1.1.4 Sterndrive/Inboard (SD/I) Engine HC+NOx and CO Standards

For the purposes of this analysis, we subdivided the SD/I category into traditional and high-performance engine categories. Based on our definitions, high-performance engines have a rated power greater than or equal to 373 kW (500 hp).

11.1.1.4.1 SD/I <373 kW

In developing regulatory alternatives for SD/I engines, we considered both what was achievable without catalysts and what could be achievable with larger, more efficient catalysts than those we evaluated in our test programs.

With regard to a less stringent option, we considered non-catalyst based standards to be implemented in the 2010 model year. Chapter 4 presents data on SD/I engines equipped with exhaust gas recirculation (EGR). HC+NOx emission levels below 10 g/kW-hr were achieved for each of the engines. CO emissions ranged from 25 to 185 g/kW-hr. For this less stringent alternative, we consider standards of 10 g/kW-hr HC+NOx and 150 g/kW-hr CO. The current California HC+NOx standard for these engines is 160 g/kW-hr.

For a more stringent option, we considered more stringent catalyst-based standards. Many of the SD/I marine engines with catalysts described in Chapter 4 had HC+NOx emission rates appreciably below 5 g/kW-hr, even with deteriorated catalysts. In the development testing for this rulemaking, we did not investigate larger catalysts for SD/I applications. The goal of the development testing was to demonstrate catalysts that would work within the packaging constraints associated with water jacketing the exhaust and fitting the engines into engine compartments on boats. However, we did perform testing on engines equipped with both catalysts and EGR. These engines showed emission results in the 2-3 g/kW-hr range. We expect that these same reductions could be achieved more simply through the use of larger catalysts or catalysts with higher precious metal loading. As a more stringent regulatory alternative, we considered a standard of 2.5 g/kW-hr HC+NOx, with no change in the CO standard, based on the use of larger catalysts. To account for additional development work that would need to be performed by manufacturers to achieve a lower standard than the existing California standard, we consider a later implementation date of 2012 for this more stringent alternative with no standard before that time.

11.1.1.4.2 SD/I ≥373 kW

For high-performance SD/I marine engines, we originally proposed a standard based on the use of catalysts and then considered a less stringent alternative based on engine fuel system upgrades, calibration, or other minor changes such as an air injection pump rather than catalytic control. However, manufacturers commented that catalysts are not be practical for these engines due to the high exhaust flow rates, high emission rates, and low useful life period between rebuild. In the final rule, we are establishing standards that can be met through the use of engine controls, similar to the alternative standard that was analyzed in the proposal. Because we do not consider catalyst-based standards to be feasible for high-performance engines at this time, we are not modeling a more stringent alternative.

11.1.2 Alternative Evaporative Emission Requirements

11.1.2.1 Small SI Engines

For Small SI engines, we are finalizing both permeation and venting emission standards. The permeation standards are for fuel tanks and fuel lines. We believe that the standards are reflective of available technology and represent a step change in emissions performance. Venting emissions include diurnal breathing losses, diffusion, and running loss emissions. For non-handheld Small SI engines (i.e., Classes I and II), we are finalizing standards for running loss[1] but not for diurnal emissions. We are not finalizing any type of venting emissions control for handheld equipment.

For a less stringent alternative, we considered not requiring running loss emission control for non-handheld Small SI engines. These requirements would be deleted from the rule and thus modeled as being deleted in the years otherwise required.

For a more stringent alternative, we considered applying running loss and diurnal standards to handheld equipment and setting a diurnal standard for non-handheld (Classes I and II). In these alternatives, we consider an implementation date of 2012 for handheld and Class I equipment, and a date of 2011 for Class II equipment.

11.1.2.2 Marine

Similar to the analysis described above for Small SI equipment, we base the less stringent and more stringent regulatory alternatives on changes in the venting emission standards. For marine vessels, we are adopting diurnal emission standards for all vessel types. For portable fuel tanks and PWC fuel tanks, the control technology of a sealed system with pressure relief is fairly straightforward and commonly used today. However, we anticipate that the diurnal emissions standards for vessels with installed fuel tanks would be based on the use of passively purged carbon canisters. For a less stringent alternative, we consider not setting a diurnal emission standard for marine vessels.[2] For a more stringent scenario, we consider a diurnal requirement wherein boat builders would be required to employ active purge of carbon canister with installed tanks. This means that, when the engine is operating, it would draw air through the canister to purge the stored hydrocarbons. These purged gasoline vapors would be used in the engine as

[1] We anticipate that running loss control measures will also reduce diffusion emissions.

[2] Note that PWC already meet the standard and would not be affected differently for the less stringent standard. PWC use sealed systems with pressure relief to prevent fuel spillage during operation.

fuel.

11.1.3 Summary of Alternative Standards

Table 11.1-1 and Table 11.1-2 show the alternative program options that were selected above for further consideration.

Table 11.1-1: Exhaust Alternative Program Options for Quantitative Analysis

Source	Alt	Target	Standard	less/ more	Alternative Description
Exhaust	1	Class I	• 10 g/kW-hr HC+NOx • Begins 2012	more	• 8 g/kW-hr HC+NOx • Begins 2015 in lieu of standard
	2	Class II	• 8 g/kW-hr HC+NOx • Begins 2011	more	• 3.5 g/kW-hr HC+NOx • Begins 2015 in lieu of standard
	3	OB/PWC	• Decreases with power output (P) • 2008 California HC+NOx equation • CO g/kW-hr equation is 500-5Pfor <40 kW • 300 g/kW-hr CO for >40kW • Begins 2010	more	< 40kW • power output (P) • HC+NOx g/kW-hr equation is 28-0.45P • COg/kW-hr equation is 500-7.5P > 40 kW • 10 g/kW-hr HC+NOx • 200 g/kW-hr CO •Both begin 2012 in addition to 2010 standards
	4	SD/I <373 kW	• 5 g/kW-hr HC+NOx • 75 g/kW-hr CO • Begins 2010[a]	less	• 10 g/kW-hr HC+NOx • 150 g/kW-hr CO • Same effective dates as standard
	5			more	• 2.5 g/kW-hr HC+NOx • 75 g/kW-hr CO • Begins 2012 in lieu of standards[a]

[a] 2011 for certain engine blocks. Does not include small business flexibilities that will delay the effective date of the requirements for some companies.

Table 11.1-2: Evaporative Alternative Program Options for Quantitative Analysis

Source	Alt	Target	Standard	less/ more	Alternative Description
Evap	6	HH diurnal/ running loss	• None	more	• Begins 2012
	7	Class I & Class II running loss	• Running loss is a "zero emission" design standard • Class I begins 2012 and Class II begins 2011	less	• No running loss
	8	Class I & Class II diurnal	• None	more	• Requirement would begin in 2012 for Class I and 2011 for Class II
	9	Installed marine fuel tank diurnal	• 0.4g/gal/day HC trailerable boat • 0.16 g/gal/day HC non-trailerable boat • Begins 2011	less	• No diurnal for 2010
	10			more	• More stringent test procedure. If charcoal canister is used, active purge required. • Would begin 2011
	11	Portable marine fuel tank diurnal	• Diurnal is a "zero emission" design standard • Begins 2010	less	• No diurnal

11.2 Cost per Engine

This section describes the estimated cost of complying with the alternative program options. We developed the costs for individual technologies using estimates from ICF Incorporated,[1,2,3] conversations with manufacturers, other information including the published literature, and our best technical judgment. Also, the cost estimates for the alternatives rely heavily on the methodology and in some cases the actual cost data, used to characterize the standards. For ease of presentation, we have not repeated the methodology or those detailed cost data here. Instead, we focus on presenting information regarding the requirements or changes that we expect will be needed to comply with the alternative options. The reader is encouraged to refer to Chapter 6 for more information. Finally, we did not specifically analyze the incremental costs of setting standards which would not result in technology which would allow certification in all 50 states (a harmonized program).

The costs of complying with the alternative program options are presented as incremental to the base case (current requirements) without considering the final standard. The only exception to this is the second phase of OB/PWC standards where costs are incremental to the final standard. The alternatives and the requisite technology are described in Section 11.1. Further, results are provided as the average cost per affected engine and the total net present value (NPV) for a 30-year period beginning in 2008. The NPV estimates are based on a seven percent discount rate. All costs are in 2005 dollars.

11.2.1 Costs for Exhaust Emission Standards

11.2.1.1 More Stringent Small SI Engine HC+NOx Standards

11.2.1.1.1 Class I

Meeting more stringent standards would require OHV engines to use a slightly larger or more active catalyst than for the final standards. For current SV engines they would need to utilize larger and more active catalysts than considered in the analysis for the final standards, or convert to OHV design and use a slightly larger catalyst or more active catalyst than for the final standards.

The cost for the SV sized catalyst is outlined in Chapter 6. The cost for the conversion from SV to OHV design is drawn from ICF International's 2006 report "Small SI Engine Technologies and Costs[4]," and is listed as $9.42 in variable costs per engine, $2,010,147 in tooling changes and design and development, as well as $15 million in facility upgrades per Class I SV engine family. The 2005 EPA certification database lists five SV engine families certified to Phase 2 of which two engines have OHV engine designs in the same power range and one engine family is listed as a small volume engine family. The remaining two engine families have sales estimates in the millions of engines. As a result, fixed costs are applied two engine families and variable costs are applied to all SV engines.

The cost for improvements in OHV current engine designs includes improved cylinder head design for improved engine cooling, redesign of the engine flywheel to provide optimum cooling for the catalyst muffler as well as carburetor improvements. Research and development and tooling for these changes are estimated at $456,450 per engine family as shown in Chapter 6.

Upgrades in catalysts for OHV engines include additional precious metal for more active catalysts. The catalyst estimates for the SV engine families, that are replaced by OHV engine families, are also replaced with the OHV catalyst costs. These costs for improved OHV engines, upgraded catalysts for OHV engines are included in Table 11.2-1 together with those for SV engines.

11.2.1.1.2 Class II

Technologies for the more stringent option include improved engine design (redesign of cooling fins, fan design, combustion chamber design), closed loop control electronic fuel injection (EFI), catalysts and pressurized oil lube system for engines intended for residential use. The fixed costs for improved engine design are $456,000 per engine family and include R&D and tooling costs, as listed in Chapter 6. The same Chapter lists EFI variable costs at $79 per engine when it includes the credit for the removal of the carburetor. The fixed costs for closed loop fuel injection design is estimated at $103,000 per engine family. Increased catalyst efficiency is achieved through use of a larger catalyst and increased precious metal loading at an estimated increased catalyst cost of $4 (1000 hr engine) - $16 (250 hr engine) per engine. A pressurized lube oil system is listed by ICF[5] to be $15.48 in variable costs and $210,000 in fixed costs per engine family for the residential engines which often do not use it in today's design. Overall, fuel savings would be increased due to the application of electronic fuel injection to all Class II engines.

**Table 11.2-1: Small SI Per-Engine Cost Estimates (Without Fuel Savings)
Sales Weighted Averages**

	Short Term (years 1-5)	Long Term (years 6-10)
Standard		
Class I	$10-$26	$10-$12
Class II	$17-$60	$12-$30
More Stringent		
Class I	$17-$23	$12-$18
Class II	$110-$149	$76-$89

11.2.1.2 Outboard/Personal Watercraft (OB/PWC) Engine HC+NOx and CO Emission Standards

We believe that, to meet the more stringent alternative considered here, manufacturers would need to convert their product lines primarily to a mix of calibrated four-stroke engines and engines equipped with catalysts. To model this approach, we looked at a technology mix that would achieve the 10 g/kW-hr HC+NOx limit, with appropriate considerations given to emissions deterioration rates and compliance margins. This technology mix was developed by assuming that all carbureted two-stroke engines would be removed from the fleet and replaced with four-stroke engines. All engines over 75 kW (100 hp) were modeled as using catalytic control. Detailed costs for converting engines from two-stroke to four-stroke and for equipping OB/PWC engines with catalysts are presented in Chapter 6. Table 11.2-2 compares the average per-engine equipment costs for the primary and the more stringent alternatives for OB/PWC engines.

Table 11.2-2: OB/PWC Per-Engine Cost Estimates (Without Fuel Savings)
Sales Weighted Averages

		Short Term (years 1-5)	Long Term (years 6-10)
Standard	OB PWC	$291 $359	$224 $272
More Stringent	OB PWC	$388 $528	$275 $392
Incremental Cost[a]	OB PWC	$102 $169	$51 $120

[a] Incremental cost is presented here because the more stringent alternative for OB/PWC includes the primary standard in 2010 plus a second, more stringent, standard in 2012.

We did not model differences in fuel savings between the primary and more stringent alternatives. The fuel savings for all three alternatives primarily come from the replacement of carbureted two-stroke engines with cleaner engine designs. In both the primary and more stringent scenarios, we model the discontinuation of sales of carbureted two-stroke engines.

11.2.1.3 Sterndrive/Inboard (SD/I) Engine HC+NOx and CO Emission Standards

With regard to the less stringent alternative, Chapter 4 presents costs for using exhaust gas recirculation (EGR) on SD/I engines. To estimate the costs for the less stringent alternative, all SD/I engines less than 373 kW were modeled to be equipped with electronic closed loop control fuel injection and EGR.

For the more stringent case, we consider a larger catalyst size with a higher precious metal loading for engines. Specifically, for engines less than 373 kW, we model a 25 percent larger catalyst and an additional 25 percent precious metal loading. We do not model a difference in fuel consumption for any of these scenarios because, in each case, all engines are anticipated to use electronic fuel injection. Table 11.2-3 compares the per-engine cost estimates for the primary, less stringent, and more stringent alternatives. As discussed above, we do not including high-performance engines in this analysis.

Table 11.2-3: SD/I <373 kW Per-Engine Cost Estimates (Without Fuel Savings)
Sales Weighted Averages

	Short Term (years 1-5)	Long Term (years 6-10)
Standard	$355	$266
Less Stringent	$200	$149
More Stringent	$431	$333

11.2.2 Costs for Evaporative Emission Standards

11.2.2.1 Small SI Engine

For the less stringent case, we simply subtract the costs of running loss controls for non-handheld equipment. For the more stringent case, we add the incremental costs of diurnal emission control for all nonhandheld engines and diurnal emission and running loss control for handheld engines. These technology costs are presented in Chapter 6. Table 11.2-4 compares the per-equipment cost estimates for the primary, less stringent, and more stringent alternatives.

Table 11.2-4: Evaporative Small SI Per-Equipment Cost Estimates (Without Fuel Savings) Sales Weighted Averages

		Short Term (years 1-5)	Long Term (years 6-10)
Standard	Aggregate	$3.27	$2.46
	Handheld	$0.82[a]	$0.69[a]
	Class I	$3.05	$2.20
	Class II	$6.73	$5.16
Less Stringent		$1.86	$1.34
Aggregate		$0.82[a]	$0.69[a]
	Handheld	$1.13	$0.67
	Class I	$4.50	$3.38
	Class II		
More Stringent	Aggregate	$6.76	$5.25
	Handheld	$4.40	$3.55
	Class I	$6.01	$4.57
	Class II	$11.08	$8.64

[a] Values reflect the final permeation standards. These costs are used in the alternative analysis only to develop aggregate values for comparison purposes.

Table 11.2-5 presents the fuel savings for the three alternatives, based on the evaporative emission reductions for each of the scenarios. Because evaporative emissions are basically gasoline vapor lost to the atmosphere, these hydrocarbon reductions can be directly translated to gasoline savings using a gasoline cost of $1.81 per gallon. Cost savings are presented both with a 3 percent and a 7 percent discount factor over the life of the equipment.

Table 11.2-5: Projected Evaporative Fuel Savings for Small SI Equipment Sales Weighted Averages

		Lifetime Gallons Saved	Discounted Cost Savings 3 percent	7 percent
Standard	Aggregate	1.4	$2.36	$2.17
	Handheld	0.2	$0.33	$0.31
	Class I	0.8	$1.41	$1.31
	Class II	4.7	$6.53	$5.96
Less Stringent		0.9	$1.53	$1.41
Aggregate		0.2[a]	$0.33[a]	$0.31[a]
	Handheld	0.5	$0.92	$0.85
	Class I	3.0	$4.16	$3.80
	Class II			
More Stringent	Aggregate	1.5	$2.63	$2.41
	Handheld	0.3	$0.49	$0.46
	Class I	0.9	$1.53	$1.41
	Class II	5.3	$7.32	$6.69

[a] Values reflect the final permeation standards. These costs are used in the alternative analysis only to develop aggregate values for comparison purposes.

11.2.2.2 Marine

For the less stringent case, we simply subtract the costs of diurnal emission controls from marine vessels with installed and portable fuel tanks. For the more stringent case, we add the incremental costs of actively purged diurnal emission control for vessels with installed fuel tanks. These technology costs are presented in Chapter 6. Table 11.2-6 compares the per-equipment cost estimates for the primary, less stringent, and more stringent alternatives. Cost savings are presented both with a 3 percent and a 7 percent discount factor over the life of the vessel.

Table 11.2-6: Per-Vessel Cost Estimates (Without Fuel Savings)
Sales Weighted Averages

		Short Term (years 1-5)	Long Term (years 6-10)
Standard	Aggregate	$55	$45
	portable	$12	$8
	PWC	$17	$11
	installed	$74	$62
Less Stringent	Aggregate	$33	$27
	portable	$11	$7
	PWC	$17[a]	$11[a]
	installed	$42	$36
More Stringent	Aggregate	$69	$56
	portable	$12[a]	$8[a]
	PWC	$17[a]	$11[a]
	installed	$94	$77

[a] Values reflect the final permeation and diurnal standards. These costs used in the alternative analysis only to develop aggregate values for comparison purposes.

Table 11.2-7 presents the fuel savings for the three alternatives. These fuel savings are based on the evaporative emission reductions for each of the scenarios. Because evaporative emissions are basically gasoline vapor lost to the atmosphere, preventing these hydrocarbon emissions can be directly translated to gasoline savings using a gasoline cost of $1.81 per gallon.

Table 11.2-7: Projected Evaporative Fuel Savings for Marine Vessels Sales Weighted Averages

		Lifetime Gallons Saved	Discounted Cost Savings 3 percent	7 percent
Standard	Aggregate	28	$42	$33
	portable	13	$20	$17
	PWC	9	$14	$12
	installed	38	$54	$42
Less Stringent		20	$30	$24
Aggregate		11	$17	$14
	portable	9[a]	$14[a]	$12[a]
	PWC	26	$37	$29
	installed			
More Stringent	Aggregate	30	$44	$34
	portable	13[a]	$20[a]	$17[a]
	PWC	9[a]	$14[a]	$12[a]
	installed	39	$57	$44

[a] Values reflect the final permeation and diurnal standards. These costs used in the alternative analysis only to develop aggregate values for comparison purposes.

11.2.3 Cost Summary of Regulatory Alternatives

Table 11.2-8 summarizes the average cost per engine for the various alternative program options described above. The costs presented are for the short term and do not include fuel savings.

Table 11.2-8: Engine Cost Summary Range for Alternative Program Options ($/Engine) Sales Weighted Averages of Short-Term Costs without Fuel Savings, 2005$

Source	Alt	Target	Standard	Scenario	Alternative
Exhaust	1	Class I	$10-$26	more	$17-$23
	2	Class II	$17-$60	more	$110-$149
	3[a]	OB/PWC	$-	more	$70
	4	SD/I <373 kW	$360	less	$216
	5			more	$435
Evap	6[b]	HH	$-	more	$3.58
	7	Class I & Class II	$4.32	less	$2.30
	8[b]	Class I & Class II	$-	more	$3.45
	9	Installed marine fuel tank	$74	less	$42
	10			more	$94
	11	Portable marine fuel tank	$12	less	$11

[a] Costs are presented incremental to the standards for OB/PWC because, for this alternative, a second stage of standards is considered in 2012 beyond the final standards.
[b] Only considers standards for venting emission control which are not in the final standards. The venting emission standards considered here are diurnal for Class I and Class II and diurnal/running loss for handheld.

Table 11.2-9 summarizes the 30-year net present value for costs for the standards and the various alternative program options described in Table 11.2-1. Cost results are provided as the total net present value (NPV) for a 30-year period. The NPV estimates are based on a 7 percent discount rate. These costs do not include fuel savings. Table 11.2-10 presents the same information with a 3 percent discount rate.

Table 11.2-9: 30-Year Net Present Value Cost Summary for Alternative Program Options with a 7 Percent Discount Rate (Million 2005$)

Source	Alt	Target	Standard	Scenario	Alternative
Exhaust	1	Class I	$1,228	more	$1,558
	2	Class II	$1,146	more	$4,040
	3[a]	OB/PWC	$-	more	$347
	4	SD/I <373 kW	$343	less	$194
	5			more	$388
Evap	6[b]	HH	$-	more	$318
	7	Class I & Class II	$718	less	$394
	8[b]	Class I & Class II	$-	more	$570
	9	Installed marine fuel tank	$250	less	$144
	10			more	$310
	11	Portable marine fuel tank	$8	less	$7

[a] Costs are presented incremental to the final standards for OB/PWC because, for this alternative, a second stage of standards is considered in 2012 beyond the final standards.
[b] Only considers standards for venting emission control which are not in the final standards. The venting emission standards considered here are diurnal for Class I and Class II and diurnal/running loss for handheld.

Table 11.2-10: 30-Year Net Present Value Cost Summary for Alternative Program Options with a 3 Percent Discount Rate (Million 2005$)

Source	Alt	Target	Standards	Scenario	Alternative
Exhaust	1	Class I	$2100	more	$2,944
	2	Class II	$1831	more	$7,366
	3[a]	OB/PWC	$-	more	$556
	4	SD/I <373 kW	$541	less	$304
	5			more	$626
Evap	6[b]	HH	$-	more	$544
	7	Class I & Class II	$1,180	less	$630
	8[b]	Class I & Class II	$-	more	$962
	9	Installed marine fuel tank	$413	less	$239
	10			more	$512
	11	Portable marine fuel tank	$12	less	$11

[a] Costs are presented incremental to the standards for OB/PWC because, for this alternative, a second stage of standards is considered in 2012 beyond the final standards.
[b] Only considers standards for venting emission control which are not in the final standards. The venting emission standards considered here are diurnal for Class I and Class II and diurnal/running loss for handheld.

11.3 Emission Reduction

This section describes the estimated emission reductions associated with each of the alternative program options. We developed these estimates using the NONROAD emissions inventory model and methodology described in Chapter 3. The modeling inputs for alternative options are provided in Appendix 11A and Appendix 11B.

The incremental emission reductions of complying with the alternative program options are presented as incremental to the base case without the final standards. The only exception to this is the second phase of OB/PWC standards. The alternatives and the requisite technology are described in Section 11.1. Further, emission inventory results are provided as the total net present value (NPV) for a 30-year period. The NPV estimates are calculated based on both a 7 percent and a 3 percent discount rate. Small SI and Marine SI emission reductions are presented separately in Tables 11.3-1 and 11.3-2.

Table 11.3-1: 30-Year Net Present Value Emission Reduction Summary for Alternative Program Options with a 7 Percent Discount Rate (Million Tons)

Source	Alt	Target	Standard	Scenario	Alternative
Exhaust	1	Class I	0.73	more	0.63
	2	Class II	1.05	more	1.27
	3[a]	OB/PWC	0	more	0.26
	4	SD/I <373 kW	0.33	less	0.22
	5			more	0.32
Evap	6[b]	HH	0	more	0.04
	7	Class I & Class II	1.04	less	0.63
	8[b]	Class I & Class II	0	more	0.12
	9	Installed marine fuel tank	0.36	less	0.26
	10			more	0.38
	11	Portable marine fuel tank	0.07	less	0.06

[a] Tons reduced are presented incremental to the standards for OB/PWC because, for this alternative, a second stage of standards is considered in 2012 beyond the final standards.

[b] Only considers standards for venting emission control which are not in the final standards. The venting emission standards considered here are diurnal for Class I and Class II and diurnal/running loss for handheld.

Table 11.3-2: 30-Year Net Present Value Emission Reduction Summary for Alternative Program Options with a 3 Percent Discount Rate (Million Tons)

Source	Alt	Target	Standard	Scenario	Alternative
Exhaust	1	Class I	1.33	more	1.22
	2	Class II	1.90	more	2.52
	3[a]	OB/PWC	0	more	0.50
	4	SD/I <373 kW	0.64	less	0.42
	5			more	0.65
Evap	6[b]	HH	0	more	0.07
	7	Class I & Class II	1.83	less	1.09
	8[b]	Class I & Class II	0	more	0.21
	9	Installed marine fuel tank	0.70	less	0.50
	10			more	0.73
	11	Portable marine fuel tank	0.13	less	0.11

[a] Tons reduced are presented incremental to the standards for OB/PWC because, for this alternative, a second stage of standards is considered in 2012 beyond the final standards.

[b] Only considers standards for venting emission control which are not in the final standards. The venting emission standards considered here are diurnal for Class I and Class II and diurnal/running loss for handheld.

11.4 Cost Effectiveness

This section describes the cost effectiveness associated with each of the alternative program options. The costs are expressed as millions of dollars and the emission reductions are in terms of short tons. All results are presented as incremental to the base case without the final standards. The only exception to this is the second phase of OB/PWC standards where the values are calculated based on costs and emission reductions incremental to the final standards. Tables 11.4-1 and 11.4-2 present cost per ton estimates, using both a 7 percent and a 3 percent discount rate, for Small SI engines/equipment and Marine SI engines/vessels as outlined in Table 11.2-1.

Table 11.4-1: Comparison of Cost Effectiveness for Final Standards and Alternatives Without Fuel Savings, 7 Percent Discount Rate ($/ton) 2005$

Source	Alt	Target	Standard	Scenario	Alternative
Exhaust	1	Class I	$1,680	more	$2,540
	2	Class II	$1,086	more	$3,170
	3[a]	OB/PWC	$790	more	$1,340
	4	SD/I <373 kW	$1,030	less	$880
	5			more	$1,210
Evap	6[b]	HH	NA	more	$8,150
	7	Class I & Class II	$690	less	$630
	8[b]	Class I & Class II	NA	more	$4,900
	9	Installed marine fuel tank	$690	less	$550
	10			more	$820
	11	Portable marine fuel tank	$115	less	$120

[a] Cost effectiveness of more stringent alternative is presented incremental to the standards for OB/PWC because, for this alternative, a second stage of standards is considered in 2012 beyond the final standards.
[b] Only considers standards for venting emission control which are not in the final standards. The venting emission standards considered here are diurnal for Class I and Class II and diurnal/running loss for handheld.

Table 11.4-2: Comparison of Cost Effectiveness for Final Standards and Alternatives Without Fuel Savings, 3 Percent Discount Rate ($/ton) 2005$

Source	Alt	Target	Standard	Scenario	Alternative
Exhaust	1	Class I	$1,580	more	$2,410
	2	Class II	$965	more	$2,930
	3[a]	OB/PWC	$670	more	$1100
	4	SD/I <373 kW	$840	less	$720
	5			more	$970
Evap	6[b]	HH	NA	more	$7,620
	7	Class I & Class II	$640	less	$580
	8[b]	Class I & Class II	NA	more	$4560
	9	Installed marine fuel tank	$590	less	$500
	10			more	$700
	11	Portable marine fuel tank	$100	less	$100

[a] Cost effectiveness of more stringent alternative is presented incremental to the standards for OB/PWC because, for this alternative, a second stage of standards is considered in 2012 beyond the final standards.
[b] Only considers standards for venting emission control which are not in the final standards. The venting emission standards considered here are diurnal for Class I and Class II and diurnal/running loss for handheld.

Ideally, this analysis would include an assessment of the monetized benefits which would potentially accompany each alternative as was provided in Chapter 8. This would provide further information for decision making and comparison to the final program. Unfortunately, the emissions data needed to conduct such an analysis, such as the potential PM benefits for the more stringent exhaust emission scenarios, is not available for this NPRM. This limits the utility of any comparisons which could be made since monetized benefits are partially dependent on PM health benefits.

11.5 Summary and Analysis of Alternative Program Options

This section presents a comparative summary of the important aspects related to the various alternative program options and our rationale for not pursuing an option relative to the final standards.

11.5.1 Exhaust Emission Standards

11.5.1.1 Small SI Engine HC+NOx Standards

11.5.1.1.1 Class I

This alternative considers a more stringent standard of 50 percent HC+NOx emission reduction beginning in 2015 for Phase 3 Class I engines instead of a reduction of 38 percent beginning in 2012 . While these emission standards may be feasible, it is clearly in the in the longer term relative to the timing of the final standards. For analytical purposes the time line to begin implementation of the new standards was set at the 2015 model year. This is three model years past the implementation year for the final standards. For the analytical period we considered, the final standards provide more emission reductions than the alternative by 202,600 tons between 2012 and 2020. Postponing the exhaust emission standards to 2015 could likely also lead to postponing controls on running loss emissions with an additional loss of 47,000 tons of control. States with air quality problems would benefit from emission reductions in an earlier time frame. Thus, while both approaches are cost effective, we elected to go with the 38 percent reduction in 2012. In the context of section 213(a)(3) of the Clean Air Act, it represents the most stringent standards feasible within the lead time considered.

11.5.1.1.2 Class II

This alternative considers a more stringent standard of 4 g/kW-hr HC+NOx , a reduction of about 67 percent for Class II engines over phase 2. These standards assume the use of closed loop electronic fuel injection and catalysts on all Class II engines. We are expecting engine manufacturers to meet the final standards by applying closed loop EFI on a portion of their V-twin engines and for the engine manufacturers or equipment manufacturers to use catalytic mufflers on the remaining engines. While these emission standards may be feasible it is clearly in the in the longer term relative to the timing of the final standards. For analytical purposes the time line to begin implementation of the new standards was set at the 2015 model year. This is four model years past the implementation year for the final standards. For the 30 year analytical period we considered, the final rule provides fewer overall emission reductions than the alternative, but between 2011 and 2020 the final rule gives 150,300 tons more reduction than the alternative assuming that running loss control is also postponed to begin in the 2015 model year. States with air quality problems would benefit from emission reductions in an earlier time frame. Thus, while both approaches are cost effective, we elected to go with the 34 percent reduction in 2011. In the context of section 213(a)(3) of the Clean Air Act, it represents the most stringent standards feasible within the lead time considered.

11.5.1.2 Outboard/Personal Watercraft (OB/PWC) Engine HC+NOx and CO Emission Standards

We analyzed the costs and emission reductions associated with more stringent standards for OB/PWC engines. We have concerns with this second tier of OB/PWC standards at this time. While some four-stroke engines may be able to meet a 10 g/kW-hr standard with improved calibrations, it is not clear that all engines could meet this standard without applying catalyst technology. Direct injection two-strokes engines would face additional challenges. At this time, we believe it is not appropriate to base standards in this rule on the use of catalysts for OB/PWC engines. Although this technology may be attractive in the longer term, little development work has been performed on the application of 3-way catalysts to OB/PWC engines. For this alternative, our modeling assumes all OB/PWC engines which need to can successfully apply aftertreatment technology.

11.5.1.3 Sterndrive/Inboard (SD/I) Engine HC+NOx and CO Emission Standards

With regard to less stringent standards, we believe that EGR would be a technologically feasible and cost-effective approach to reducing emissions from SD/I marine engines. However, we believe that greater reductions could be achieved through the use of catalysts. We considered basing an interim standard on EGR, but were concerned that this would divert manufacturers' resources away from catalyst development and could have the effect of delaying emission reductions from this sector. Setting a less stringent standard would likely be inconsistent with the requirements of section 213 of the Clean Air Act because at least one SD/I engine manufacturer offers a compliant product for sale in the US. In the NPRM we do ask for comment on a short-phase-in to deal with a change in the engine a supplier's product lines.

With regard to more stringent requirements, we do not believe that they would necessarily lead to any further significant emission reductions in HC+NOx. Because this is the first generation of emission standards for this category of recreational marine engines, we believe that most manufacturers will strive to achieve emission levels below the final standards to give them certainty that they will pass the standards in-use, especially as catalysts on SD/I engines are a new technology. Therefore, we do not believe that it is necessary at this time to consider a lower standard for these engines.

11.5.2 Evaporative Emission Standards

11.5.2.1 Small SI Engine

We analyzed requiring diurnal and running loss control from handheld equipment in 2012. Even though it would be feasible from a strict technical perspective it is not a attractive option at this time. Fuel tanks from this equipment are very small, most less than one liter, and, with the exception of commercial equipment, their use is less than 15 hours per year. Adding hardware to control diurnal and running loss emissions would add weight which could be problematic on handheld equipment. In addition, it could create the potential for fuel leaks in equipment which can be used in rotated and inverted positions in the field. In addition, this option does not appear cost effective. For these reasons we elected not to pursue it.

With regard to controlling running loss emissions control from non-handheld equipment we believe it is feasible at a relatively low cost. Running loss emissions can be controlled by sealing the fuel cap and routing vapors from the fuel tank to the engine intake. This emission control approach is relatively straight-forward and inexpensive and do not have the weight and in-use position issues such as mentioned above for handheld equipment. Deleting the requirement does not meaningfully improve the cost effectiveness. Not finalizing these requirements would be inconsistent with the section 213 of the Clean Air Act.

California requires control diurnal fuel tank emissions from Class I and Class II equipment as part of its overall fuel evaporative certification requirements. California requires an active purge of the control system. We evaluated the alternative of adding a diurnal requirement like that in California. Even though it would be feasible from a strict technical perspective it is not a attractive option at this time. While workable, there are some important issues would need to be resolved for diurnal emission control, such as cost, packaging, and vibration. Also, California requires an active purge, but we believe that a substantial reduction on the order of 50 percent could be achieved with a less complicated and less expensive passive purge approach. Finally, the cost and cost effectiveness of this program sub-element are of concern given the relatively low emissions levels (on a per-equipment basis) from such small fuel tanks. Overall, we do not consider this to be an attractive option at this time for Small SI engines as a group.

11.5.2.2 Marine

Although we considered the alternative of not requiring diurnal emission control for installed fuel tanks, we believe that carbon canisters are feasible for boats at relatively low cost. Carbon canisters have been installed on fourteen boats by industry in a pilot program intended to demonstrate the feasibility of this technology. The final standards are achievable through engineering design-based certification with canisters that are much smaller than the fuel tanks. In addition, sealed systems, with pressure control strategies would be accepted under the engineering design-based certification provisions. Eliminating these requirements would not meaningfully affect the cost effectiveness of the marine evaporative program. Not finalizing these controls would be inconsistent with the requirements of section 213 of the Clean Air Act.

We also considered the feasibility of requiring the use of carbon canisters with active purging to control diurnal emissions. However, we are concerned that active purging would occur infrequently due to the low hours of operation per year seen by many boats. In addition, active purge adds complexity into the system in that the engine must be integrated into the control strategy. This could end up involving engine, tank, and vessel manufacturers in certification processes. Although we did not model it, this approach would undoubtedly require more lead time to implement because it is more complex and involves more entities. Based on data presented in Chapter 5, carbon canisters can be used to reduce emissions by more than 50 percent with passive purging. This passive purging occurs during the normal tank breathing process caused by ambient temperature changes without creating any significant pressure in the fuel tank. The small additional benefit of an actively purged diurnal control system would likely not justify the cost and complexity of implementing such a system, even though it appears to be cost effective.

Portable marine fuel tanks are used in vessels with outboard motors. Many of these tanks employ self-sealing vents which close the tank to the atmosphere when it is not in-use. This is quite straightforward, and it can be applied to all such tanks in the future for a reasonable cost. Not finalizing these controls would be inconsistent with the requirements of section 213 of the Clean Air Act.

APPENDIX 11A: Emission Factors for the Less Stringent Alternative

11A.1 Exhaust Emission Factors and Deterioration Rates

11A.1.1 Small SI Exhaust

No less stringent exhaust emission standards were quantitatively analyzed for either Class I or Class II Small SI engines.

11A.1.2 Marine SI Exhaust

In the less stringent alternative, the same standards are considered for OB/PWC engines as for the primary scenario. However, for SD/I engines, we consider less stringent standards. As discussed above, these standards are based on the use of EGR for SD/I engines less than 373 kW and engine calibration for larger engines. For engines less than 373 kW we considered less stringent alternative standards of 10 g/kW-hr HC+NOx and 150 g/kW-hr CO for SD/I engines less than 373 kW. For high-performance engines, we did not model alternative scenarios, as discussed above. Because these emission factors are based on engine-out emissions, we use the same deterioration factors (DF) as for the baseline case. Table A-1 presents the zero-hour SD/I emission factors and the accompanying deterioration factors used to model the less stringent alternative.

Table 11A-1: Less Stringent Alternative EFs [g/kW-hr] and DFs for SD/I

Engine Category	HC		NOx		CO		BSFC
	EF	DF	EF	DF	EF	DF	
<373 kW SD/I	4.05	1.26	4.00	1.03	96.3	1.35	345

11A.2 Evaporative Emission Factors

As discussed above, no changes in the hose and tank permeation standards were considered in the less stringent alternative. The less stringent scenario was modeled for Small SI equipment by using the baseline running loss and diffusion rates for Class I and Class II equipment. For marine, the less stringent alternative was modeled by using the baseline diurnal emission rates for vessels with installed fuel tanks.

APPENDIX 11B: Emission Factors for the More Stringent Alternative

11B.1 Exhaust Emission Factors and Deterioration Rates

11B.1.1 Small SI Exhaust

For analytical purposes, we identified a more stringent program option of 8 g/kW-hr HC+NOx standard for Class I engines that would be implemented beginning in 2015. This standard represents about a 50 reduction from the existing Phase 2 standard, rather than the approximately 38 percent reduction associated with the final rule. The option also provides 3 more years of lead time. For Class II engines, we identified an alternative for a more stringent exhaust HC+NOx emission standard of 4.0 g/kW-hr beginning in 2015. (This option also includes an associated delay in the corresponding running loss requirement such that engine changes are made simultaneously.) Such an exhaust emission standard represents a 67 percent reduction relative to the existing Phase 2 standard, rather than the 34 percent reduction associated with the final rule.

In modeling this more stringent option, we assumed the same phase-in schedule that reflects a number of flexibilities for engine and equipment manufacturers, and allows them to sell some Phase 2 compliant engines in the early years of the program. We also assumed that Class I side-valve technology would be completely replaced with overhead valve designs, and that all of the Class II engines would require closed loop control electronic fuel injection (EFI). Since EFI equipped engines enjoy a 10 percent fuel consumption advantage over their carbureted counterparts, we also revised the brake-specific fuel consumption (BSFC) for Class II engines. The new BSFC value is 0.666 lb/hp-hr.

All the modeling inputs were developed using a methodology consistent with that described in Chapter 3 of this draft RIA. The alternative emission standards and phase-in assumptions are shown in Table B-1. The emission factors are shown in Table B-2.

Table 11B-1: More Stringent Phase 3 Emission Standards and Implementation Schedule for Class I and II Small SI Engines (g/kW-hr or Percent)

Engine Class	Requirement	2015	2016	2017	2018	2019+
Class I	HC+NOx	8	8	8	8	8
	Required Sales Percentage	95	95	100	100	100
Class II	HC+NOx	4	4	4	4	4
	Required Sales Percentage	83	83	93	93	100

Table 11B-2: More Stringent Phase 3 Modeling Emission Factors for Small SI Engines (g/KW-hr)

Class/ Technology	HC ZML	HC "A"	NOx ZML	NOx "A"	CO ZML	CO "A"
Class I - SV	4.48	1.011	1.12	0.470	319.76	0.070
Class I -	4.07	1.011	1.53	0.470	325.06	0.070
Class II	2.13	1.011	0.67	0.470	391.13	0.080

11B.1.2 Marine SI Exhaust

For OB/PWC engines, the more stringent alternative considers exhaust emissions standards that are about 40 percent lower for HC+NOx and about 30 percent lower for CO than the final standard. The more stringent alternative emission standards are modeled as a second phase of standards, beyond the primary, beginning in 2012. In determining the combined HC+NOx emission factor, we used the final emission standards with a 10 percent compliance margin (with deterioration factor applied). To determine the NOx emission factors, we used certification data and other emissions data presented in Chapter 4, to determine the sales weighted average NOx for low emission technologies in each power bin. HC was then determined as the difference between the HC+NOx and the NOx emission factors. Because we are finalizing the same standards for OB and PWC and because they use similar engines, we use the same HC+NOx emission factors and deterioration factors for both engine types. Because the final CO standard primarily acts as a cap on CO for many of the engines, the CO emission factors differ somewhat for CO based on data in the certification database for low CO engines. We use the same deterioration rates as in the primary case. Table B-3 presents the zero-hour OB/PWC emission factors used in analyzing the more stringent alternative.

Table B-3: More Stringent Alternative Emission Factors for OB/PWC [g/kW-hr]

Power Bin	HC	NOx	CO		BSFC
			OB	PWC	
0-2.2 kW	11.7	3.02	362	426	563
2.3-4.5 kW	10.9	2.25	238	359	560
4.6-8.2 kW	10.5	3.50	195	162	555
8.3-11.9 kW	9.0	4.22	165	154	552
12.0-18.6 kW	9.5	2.69	137	145	543
18.7-29.8 kW	7.5	3.55	120	137	528
29.9-37.3 kW	5.7	3.70	114	137	507
37.4-55.9 kW	5.2	3.38	115	137	471
55.9-74.6 kW	5.2	3.38	115	137	471
74.7-130.5 kW	5.4	3.13	101	135	415
130.6+ kW	6.3	2.30	93	119	387

For SD/I engines greater than 373 kW, we did not model the use of catalysts for reasons discussed above. However, for SD/I engines less than 373 kW, we considered a more stringent HC+NOx standard of 2.5 g/kW-hr. To model this standard, we used zero-hour emission factors of 0.90 g/kW-hr HC and 0.80 g/kW-hr NOx. No changes were made in other emission factors for this more stringent alternative. In addition, the same deterioration factors were used here as in the primary alternative.

11B.2 Evaporative Emission Factors

As discussed above, no changes in the hose and tank permeation standards were considered in the more stringent alternative. The more stringent scenario modeled for Small SI equipment by considering diurnal standards beginning in 2011 for Class II and 2012 for handheld and Class I equipment. This diurnal emission standards was modeled using a 60 percent reduction from baseline. Also, the more aggressive option for Class II exhaust standards was modeled as also including a corresponding delay in the running loss requirement such that engine changes are made simultaneously.

For marine, the more stringent alternative was a standard requiring active purging of canisters for vessels with installed fuel tanks. This was modeled by using a 70 percent reduction in diurnal emissions compared to the baseline.

Chapter 11 References

1. "Small SI Engine Technologies and Costs, Final Report," ICF International, August 2006.

2. "Marine Outboard and Personal Watercraft SI Engine Technologies and Costs," ICF Consulting, prepared for the U.S. Environmental Protection Agency, July 2006, Docket Identification EPA-HQ-OAR-2004-0008-0452.

3. "Sterndrive and Inboard Marine SI Engine Technologies and Costs," ICF Consulting, prepared for the U.S. Environmental Protection Agency, July 2006, Docket Identification EPA-HQ-OAR-2004-0008-0453.

4. "Small SI Engine Technologies and Costs, Final Report," ICF International, August 2006.

5. "Small SI Engine Technologies and Costs, Final Report," ICF International, August 2006.