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Final Regulatory Impact Analysis

Phase 2: Emission Standards for New Nonroad Nonhandheld Spark-Ignition Engines At or Below 19 Kilowatts

FINAL REGULATORY IMPACT ANALYSIS

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New Nonroad Nonhandheld Spark-Ignition Engines
At or Below 19 Kilowatts

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ACKNOWLEDGMENTS

PHASE 2 NONHANDHELD

EPA reviewed the technical feasibility for this rulemaking in light of actions with the industry and the California ARB in March 1998. The emission standards for small spark ignition engines set by California ARB were reviewed by EPA. EPA followed up with discussions with the major stakeholders of engine manufacturers as to their agreement for incorporating emission reduction technologies for tighter standards for Class I. EPA understood that tighter standards would mean the requirement of longer lead times and those have been incorporated in this FRM. EPA acknowledges the hard work, now and in the future, that the engine and equipment manufacturers will undertake in order to assure their part of providing clean air.

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Chapter 1: Introduction

This Regulatory Impact Analysis (RIA) contains the supporting information and analysis for this Phase 2 final rulemaking. The information was gathered from sources including the Regulatory Negotiation (1993-1996), industry meetings (1993-1998), EPA contracts, comments to the NPRM and discussions with manufacturers and inventors. The Regulatory Negotiation task groups provided information on test procedure, technologies, compliance programs and costs. Industry provided data on the in-use deterioration characteristics of Phase 1 engines from their own test programs and on costs of technologies to the consumer. EPA contracts provided information on available technologies, costs of technology changes and regulatory impacts for small volume entities. Comments to the NPRM provided information on a number of issues including the timeframe for certain technologies, costs of technologies, costs of testing, the need for additional nonhandheld classes, etc. Discussions with manufacturers and inventors since the publication of the NPRM provided EPA with information on the latest in emission reduction technologies and costs. All of this information is utilized in the chapters of this RSD as described below.

Chapter 2 contains a summary of the work done by the Test Procedure Task Group of the Regulatory Negotiation Committee, as it relates to the rule, as well as the test procedure changes for this final rulemaking. The work by the

Task Group included an investigation into the differences in emission results when small engines[1] are tested on steady state and transient test cycles. The outcome for this final rule is the use of the Phase 1 steady state test procedure with several adjustments including 1) engines equipped with engine speed governors must utilize the governor during the test cycle (with some modifications to test cycle requirements as commented by EMA in docket A-96-55 item #IV-D-12), and 2) measures are included for natural gas fueled nonhandheld engines for measuring methane emissions.

Chapter 3 of this RSD presents the supporting rationale for the level of the standards for this final rulemaking including a comparison of cost estimates for various technologies. Information on technologies was provided by several sources including the Technology Subgroup of the Regulatory Negotiation, an EPA work assignment with SwRI and discussions with manufacturers and inventors. The Technology Subgroup of the Regulatory Negotiation investigated a number of engine emission reducing technologies for the exhaust system and fuel system of small SI engines. The results of the research and testing during these years revealed that some technologies required other engine improvements to be achieved prior to their use (such as catalysts), some technologies were currently too expensive compared to the price of the engine (such as fuel injection on a Class I consumer engine) and some were in the pre-prototype stages and required additional development before they can be relied upon (such as a fuel vaporization design for Class I SV engines). In 1996, EPA conducted a work assignment with SwRI to investigate Phase 1 engines and identify the features of low and high emitting handheld and nonhandheld engines. Discussions with inventors gave insight into the possibilities of nontraditional

[1] The small engines were tested in Phase 1 and “future technology” configurations.

technologies, however these are not included as a basis for this rulemaking since they are not yet proven technologies.

Cost information was submitted to EPA by industry groups, individual companies and through a work assignment with ICF, Incorporated (docket A-93-29, item II-A-04), herein referred to as the "1996 Cost Study". Information on costs was pulled from each source and updated through discussions with industry after the NPRM was published in order to best represent the likely costs that could be incurred as a result of the new standards being finalized for this industry.

Chapter 4, and Appendix B, contain the data and analysis behind the estimated costs for the technologies for this rule. The impact of technology changes to the Phase 1 engine families are based on review of the Phase 1 certification database and the final regulatory programs. The number of nonhandheld engine families that are likely to be improved are estimated based on the use of ABT by the engine manufacturers[2] and the layout of a manufacturer's current product offering with respect to the ability to accumulate a number of credits by changing a minimum number of engine families. Technology improvements for nonhandheld engines include conversion of engine families from SV to OHV design and improvements in OHV emission performance. Costs assumed for each technology are also presented in this chapter.

Chapter 5 contains the detail of each compliance program and outlines the costs assumed for each program. The programs for this final rulemaking include certification and production line testing. One major assumption made here for the majority of these programs is the useful lives that would be chosen by engine

[2] The ABT calculation is performed for each engine manufacturer given the information in the Phase 1 certification database of which some is confidential.

manufacturers for their engine families. This was done based on the market focus of the engine manufacturers from low cost to high durability to automotive related. Appendix C contains the spreadsheets for this analysis.

Chapter 6 contains a description of the methodology used to calculate anticipated emission reductions and fuel savings as a result of this final rulemaking. Appendix F contains related data used in EPA's NONROAD Model. The new engine HC, NOx and CO emission rates for the Phase 1 baseline were based on the Phase 1 HC, NOx and CO standards (based on the Phase 1 certification database as of September 1998) and in-use deterioration characteristics were based on information provided in EPA's Phase 1 model[3]. Phase 2 new engine HC, NOx and CO emission rates were based on the Phase 2 standards[4] and anticipated HC / NOx split based on anticipated emission reduction technologies. The in-use emission deteriorations were based on the expected technologies. Impacts on brake specific fuel consumption rates were based on those used for the Phase 1 rulemaking and anticipated fuel savings from Phase 2 technologies.

Chapter 7 contains the aggregate cost analysis for this rulemaking and Appendix E contains the corresponding spreadsheets. The cost estimates

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3 EPA used the NONROAD model for this rulemaking and therefore incorporated the methodology in that model. The in-use deterioration rates provided by some industry members, based on accelerated aging, were not used in place of some deterioration estimates in the Phase 1 model. In nearly all classes and engine designs, with the exception of Class I SV engines in which the deterioration factor is higher than that in industry data, the deteriorations were similar. The change in the Class I SV df may be acceptable for the NONROAD model is to account for real world in-use and most Class I engines are consumer use for which data was not available by the industry.

4 In the case of Class I OHV engines, the Phase 2 standard is the same as the Phase 1 baseline.

presented in Chapters 4 and 5 are used to calculate these costs which include uniform annualized costs for variable and fixed costs per class, average cost per equipment per class and overall cost effectiveness. The cost effectiveness with fuel savings and a 20 year annualized cost analysis are also presented.

Chapter 8 outlines the analysis of impacts on small entities for this rule. The work for this analysis was completed through a work assignment with ICF, Incorporated in 1997 and additional work by EPA in 1998. Through this work, EPA analyzed the expected impact on small production volume engine and equipment manufacturers based on the final standards and programmatic content of this rulemaking[5]. Based on the phase-in, ABT, and a number of flexibilities including reduced compliance demonstration burden and additional lead time, it is anticipated that the impact on small volume manufacturers and small volume models will be minimal.

Chapter 9 contains the background information and analysis on useful lives and regulatory flexibility parameters. The standards in this final rulemaking are to be met by engines based on the emissions at the end of the useful life of the engine. Three choices of useful lives for nonhandheld (Class I: 125, 250 and 500 and for Class II: 250, 500, 1000). These options were based on useful life information by CARB, OPEI and EPA's own analysis. The production volume cutoffs for the various flexibilities for this rulemaking were based on the information available in the 1996 PSR OELINK database. Chapter 9 contains the rationale behind the decisions for each flexibility cutoff.

[5] This includes certification and production line testing.

Chapter 2: Exhaust Emission Test Cycle and Test Procedures

2.1 Introduction

In order for EPA to successfully regulate exhaust emissions from small nonroad engines, the Agency strives to establish test procedures and cycles which ensure technologies used by manufacturers not only meet the emission standards when tested over the required test procedures, but also result in a predictable emission reduction in actual use. Test procedures are specified to a level of detail necessary to produce accurate, repeatable results.

2.2 Phase 1 test procedures and test cycle

The Phase 1 test procedure is described in 40 CFR Part 90, Subparts D and E. The Phase 1 test procedure is based upon well established and accepted on-highway exhaust emission methods and equipment, with some modification to take into account the unique nature of small SI engines. The procedures are designed to accurately measure engine emission performance. A description of the Phase 1 test cycles and procedures were included in the final RSD for the

Phase 1 rule. (Ref. 1) The Phase 1 test cycles (two for nonhandheld) are comprised of a series of steady state 'modes'. A mode is a specified engine speed and load condition, during which the engine is stabilized and emissions are sampled. The emission results for all of the modes are combined using 'weighting factors' into a single number for each pollutant.

Two distinct cycles (sets of modes) are used for small non-handheld engines: (1) engines used in non-handheld intermediate speed applications; and (2) engines used in non-handheld rated speed applications. The test cycle for non-handheld intermediate speed engines consists of six different speed/load modes, five load conditions that span the load range of the engine at intermediate speed and one no-load condition at idle speed. The test cycle for non-handheld rated speed applications also consists of six different modes, five load conditions at rated speed and one no-load condition at idle speed.

The Agency determined during the Phase 1 rulemaking, based on the information available at the time, that for the range of technologies expected to be used to meet the Phase 1 standards, that the Phase 1 test cycle and weighting factors were appropriate.

2.3 Agency review of Phase 1 test cycle and procedure for final Phase 2 rule

Prior to proposing Phase 2 emission standards for small nonroad engines, the Agency first undertook, with the cooperation of the engine industry and members of the Negotiated Rulemaking Committee, a test program to determine if the Phase 2 rule should contain a change in the test cycle. The Agency has found for other mobile source categories that steady-state test cycles often do not result in real in-use emission reductions and that 'transient' test cycles which more closely mimic real world operating conditions are necessary. A transient cycle means a combination of speed and/or load conditions which vary with time, such as the on-highway Federal Test Procedure for light-duty vehicles.

During the Reg/Neg process the Agency expressed concerns regarding the ability of the Phase 1 steady-state test cycles to adequately predict in-use emission reductions for a Phase 2 rule which would result in different engine technologies being employed. The Reg/Neg committee established a Test Procedure Task Group to examine the existing Phase 1 test cycle and procedure and make recommendations to the committee regarding any appropriate changes. (Ref. 2) The Test Procedure Task Group established two subgroups to examine the Phase 1 steady state non-handheld and handheld test cycles.

2.3.1 Review of Non-handheld Test Cycle

The Test Procedure Task Group established a Nonhandheld Subgroup, consisting of one EPA technical staff person and two industry engineers, to develop and carry-out a test program to determine if "future" technology non-handheld engine emission reductions could be predicted with the use of a steady state test cycle or if a transient test cycle was necessary. This task group undertook a test program lasting several months which included; development of a transient test cycle and procedure, development of a comparable steady state test cycle, development of a "future" technology engine, and completing a series of emission tests. The work done by the Nonhandheld Subgroup is well documented in their final report. (Ref. 3)

The Nonhandheld Subgroup developed a representative transient cycle based on field data for a walk-behind rotary mower application, referred to as the grass cutting duty cycle (GCDC). The Nonhandheld Subgroup also developed a steady-state cycle with a comparable load-factor to the GCDC which could be used for comparative purposes. The Nonhandheld Subgroup utilized three test engines for comparison testing between transient and steady-state operations; two baseline technology engines and one future technology engine. The baseline engines were single-cylinder OHV walk-behind mower engines The future technology was based on the same model, but with an experimental carburetor and accelerator pump which allowed the engine to perform at enleaned air-fuel ratios and rely on the accelerator pump for accelerations. Table 2-01 contains a summary of the relevant data from the Nonhandheld Subgroup final report regarding the comparison between steady-state and transient results.

Table 2-01

Summary of Results from Nonhandheld Transient/Steady State Cycle Program

Test Engine	**Cycle**	**Avg. HC (g/kW-hr**	**Avg. NOx (g/kW-hr)**	**Avg. CO (g/kW-hr)**
Engine #1	steady-state	10.50	3.06	322
Engine #1	transient	10.50	3.34	272
Engine #2	steady-state	16.43	2.37	441
Engine #2	transient	17.90	2.04	453
Engine #3, Enleaned w/Accelerator Pump	steady-state	5.61	5.47	83
Engine #3, Enleaned w/Accelerator Pump	transient	5.31	3.88	51

The steady-state cycle results shown in Table 2-01 are based on the Nonhandheld Subgroup's steady-state cycle which was developed to have the same load factor as the transient GCDC. As discussed in Chapter 3 of this RIA, the Agency is finalizing standards for Class I and Class II engines which can be met by clean OHV technology such as the OHV technology used in Engine #3. Therefore, based on the relatively minor differences in HC and NOx emissions between the steady-state and transient cycles for Engine #3, and the appearance that the steady state cycle is a worst case test, the Agency concludes a steady-state cycle is appropriate for Phase 2 nonhandheld engines.

During discussions with nonhandheld engine manufacturers within the Test Procedure Task Group, engine manufacturers and the Agency generally agreed that the Phase 1 test procedure practice of using fixed throttle operation during the steady state cycle was not considered an ideal test method for characterizing real-world emissions from engines equipped with engine rotational speed governors. For Phase 1 engines, 40 CFR 91.409 allows a manufacturer to choose between using the engines speed governor or using an external throttle controller to maintain engine speed and load. The Agency is concerned that as standards become more stringent the potential negative effects from artificial control of an engines throttle valve may become increasingly important.

Based on discussion during the meetings of the Test Procedure Task Group and the Agency’s desire to maintain an appropriate relationship between the Federal Test Procedure and real world operation, the Agency is finalizing that Phase 2 Class I and II engines equipped with engine speed governors must utilize the governor during the test cycle with a few exceptions. For Phase 2 Class I and Class II engines equipped with an engine speed governor, the governor must be used to control engine speed during all test cycle modes except for Mode 1 or Mode 6, and no external throttle control may be used that interferes with the function of the engine’s governor. For Phase 2 Class I and Class II engines equipped with an engine speed governor, a controller may be used to adjust the governor setting for the desired engine speed in Modes 2-5 or Modes 7-10. For Phase 2 Class I and Class II engines equipped with an engine speed governor, during Mode 1 or Mode 6 fixed throttle operation may be used to determine the 100% torque value. The changes are contained in final regulatory modifications to Subpart E of 40 CFR Part 90.

2.4 Additional changes to Phase 1 test procedure

In order to accommodate the final optional non-methane hydrocarbon (NMHC) standard for natural gas fueled nonhandheld engines, the Agency is proposing to incorporate by reference the appropriate sections from 40 CFR Part 86 which relate to the measurement of methane emissions from spark-ignited engines. These appropriate sections were published as part of a final rulemaking titled "Standards for Emissions From Natural Gas-Fueled, and Liquefied Petroleum Gas-Fueled Motor Vehicles and Motor Vehicle Engines, and Certification Procedures for Aftermarket Conversions" see 59 FR 48472, published on September 21, 1994. The specific sections being incorporated can be found in the final regulatory language contained in this proposal at §90.301(d) and §90.401(d).

Chapter 2 References

1. "Regulatory Support Document, Control of Air Pollution, Emission Standards for New Nonroad Spark-Ignition Engines at or Below 19 kiloWatts" US EPA, May 1995, EPA Air Docket A-93-25, Docket Item #V-B-01.

2. Handouts and Notes from all Meetings of the Test Procedure Task Group held during the Phase 2 Regulatory Negotiation are available in EPA Air Docket A-93-92.

3. "Transient Versus Steady State Test Procedure Evaluation of Small Utility Engines", EPA Air Docket A-93-29, Docket Item II-M-27.

Chapter 3: Technologies and Standards

3.1 Introduction

Section 213(a)(3) of the Clean Air Act as amended in 1990 presents statutory criteria that EPA must evaluate in determining standards for nonroad engines and vehicles. The standards must "achieve the greatest degree of emission reduction achievable through the application of technology which the Administrator determines will be available for the engines or vehicles to which such standards apply, giving appropriate consideration to the cost of applying such technology within the period of time available to manufacturers and to noise, energy, and safety factors associated with the application of such technology." This chapter presents the technical analyses and information that form the basis of EPA's determination that the final emission standards are technically achievable accounting for all the above factors.[6] Specific areas of discussion include a basic description of the technologies examined, current status of the technology in the existing market, new and in-use emission performance of each technology, impact of the engine technology on equipment design and use, and impact of the technology on noise, safety, and energy. Finally, this chapter concludes with a discussion of the final standards and how

[6] While costs are listed in this chapter, they are used for comparison of technologies only. Chapter 4 lists the costs used in the analysis for this rulemaking.

these standards meet the statutory criteria.

3.2 Technologies

Section 3.2. contains emission reduction projections and per engine cost estimates on the several types of technologies the Agency considered during the development of the Phase 2 standards.

3.2.1 Conversion of SV to OHV Design for 4-Stroke Engines

The way for manufacturers of large volumes of Class I and Class II SV engines to meet the Phase 2 standards, on average, is to reduce the emissions from their large production SV engine families. One way is to convert their existing SV engine designs to cleanly designed OHV.

3.2.1.1 Description of Technology for SV to OHV Conversion -- In this analysis, the Agency considered the conversion not simply to OHV technology, but to emissions optimized OHV engines, which would incorporate designs for improved new engine and in-use emission performance beyond existing Phase 1 technology OHV engines. The new OHV engines would have similar new and in-use emission performance as the improved Phase 1 OHV engines described in Section 3.2.2.

3.2.1.2 Current State of Technology Development for SV to OHV Conversion -- OHV design and manufacturing information is well known by manufacturers of small Class I and II engines. Therefore the Agency believes design and manufacturing techniques for OHV engines are also well known to small engine manufacturers.

3.2.1.3 Description of 4-stroke SV Technology -- Four stroke Otto-cycle side-valve (SV) engines utilize four distinct strokes to complete a combustion cycle (i.e., intake, compression, expansion, and exhaust). Additional information regarding the 4-stroke Otto-cycle can be found in ICF, 1996 (see reference 1 of this Chapter). In a SV 4-stroke Otto-cycle engine, the intake and exhaust valves are located to one side of the combustion chamber, with the valve stems located below the combustion chamber. In order to accommodate the location of the intake and exhaust valve, the combustion chamber is relatively long and flat, as compared to a 4-stroke over-head valve design (see Section 3.2.2, "Improvements to Existing 4-stroke OHV Engines").

3.2.1.3.1 Uncontrolled and Phase 1 Technology SV Engines -- The Agency presented information on uncontrolled SV Class I and Class II emission rates in the RSD for the Phase 1 rule (see ref. 7 to this Chapter). The Agency estimated the new engine HC+NOx emissions for uncontrolled Class I and Class II SV engines to be 55 g/kW-hr and 16 g/kW-hr respectively. The Phase 1 HC+NOx standards for Class I and II engines are 16.1 and 13.4 g/kW-hr, respectively.

Information on the in-use deterioration of uncontrolled SV engines is somewhat limited, however, the Agency estimated at the time of the Phase 1 rule that HC emissions increased by a factor of 2.1 and NOx decreased by approximately 60 percent during the lifetime of an engine (see ref. 7 to this Chapter). Much more data is available on Phase 1 SV technology in-use emission performance. In 1996, the Agency received information from several engine manufacturers regarding the in-use performance of Phase 1 technology Class I and II engines, both SV and OHV designs. This in-use manufacturer controlled field data was collected by several manufacturers who hired an independent contractor, Air Improvement Resources (AIR), to evaluate the data.(Ref. 1) AIR analyzed deterioration information from 39 Class I SV engines and 25 Class II SV engines. These engines were aged to a range of in-use hours, between 20 and 300 hours for the Class I engines, and between 110 and 450 hours for the majority of Class II SV engines. (Two Class II SV engines exceeded 1,000 hours of use.) AIR analyzed the HC+NOx deterioration data from these engines, along with data from new engine quality audit data, manufacturer sales information, and individual engine manufacturer's engineering judgement. AIR determined the best fit to the deterioration data was of the form:

$$HC + NOx\ Deterioration\ Factor = 1 + CONSTANT \times \sqrt{Engine\ Hours}$$

AIR's results indicate that the HC+NOx deterioration factor (DF) is 1.9 for a Phase 1 Class I SV engine at 66 hours[7] of use, and 1.6 for a Phase 1 Class II SV engine at 250 hours of use.

While the final rulemaking has set the minimum useful life hours for Class I at 125 hours, AIR did not perform an analysis at this number of hours since this number was not being considered at the time. Therefore, in order to verify the AIR data, the Agency analyzed a subset of the data examined by AIR, namely, the field tested engine data at 66 hours and then at 125 hours. To do this, EPA performed an ordinary least square analysis of HC+NOx deterioration factor (DF) versus usage in hours for the square root of hours function shown above. The Agency's results predict that the Class I SV HC+NOx DF at 66 hours is 1.9, and the Class II SV HC+NOx DF at 250 hours is 1.6. The Agency's analysis produced very similar results to the AIR analysis. Based on discussions with several of the engine manufacturers who provided test data to AIR, the Agency believes that the majority of the field aged engines used in this study would be

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[7] The 66 hours is used as a reference point between AIR analysis and EPA analysis. The analysis is then used to determine a deterioration factor at 125 hours which AIR did not analyze.

considered typical engines used in residential applications where the engines are designed for relatively low useful lives.

Now that the AIR analysis is verified, a DF for Phase 2 Class I SV engines can be determined for the minimum useful life of 125 hours. The deterioration factor calculation, as listed in the equation above, is based on the constant times the square root of the number of hours. Using the constants, for HC and NOx, calculated from all of the data EPA analyzed for the 66 hour case (0.13 for HC and .02 for NOx) the individual deterioration factors calculate to 2.45 for HC and 1.224 for NOx. Splitting the Phase 1 standard with the HC/NOx split found in the EPA Phase 1 certification database (16.1 => 11.27HC, 4.83 NOx), results in a HC+NOx value of 33.5 g/kWh, and a df of 2.1 for HC+NOx. For Phase 2 Class II SV engines, multiplying the DF times estimate at 250 hours times the Phase 1 standards is 21.4 g/kW-hr (i.e., 1.6*13.4 g/kW-hr). These results are a conservative estimate of the in-use emission rate of Phase 1 SV engines since they are based on using the standard as the new engine value rather than an engine specific emission level.

3.2.1.4 Description of 4-stroke Over-head Valve Technology -- Four-stroke over-head valve (OHV) engine designs have intake and exhaust valves located above the cylinder head and combustion chamber, rather than to the side of the cylinder head as in SV engine designs. Additional information describing the design details of 4-stroke OHV, as well as 4-stroke SV is available in the 1996 ICF report (ref. 1 to this Chapter).

3.2.1.4.1 Uncontrolled and Phase 1 Technology OHV Engines-- During the development of the Phase 1 regulation the Agency had little information regarding the in-use HC and NOx exhaust emission performance of OHV technology. In fact, most of the Agency's assumptions regarding OHV deterioration were based on data from SV technology (see ref. 7 to this Chapter).

In 1996, the Agency received information from several engine manufacturers regarding the in-use performance of Phase 1 technology Class I and II engines, both SV and OHV designs (see ref. 14 to this Chapter). Air Improvement Resources (AIR) analyzed deterioration information from 12 Class I OHV engines and 35 Class II OHV engines. These engines were aged to a range of in-use hours, between 120 and 300 hours for the Class I OHV engines, and between 180 and 475 hours for the Class II OHV engines. AIR analyzed the HC+NOx deterioration data from these engines, along with data from new engine quality audit data, manufacturer sales information, and individual engine manufacturer's engineering judgement. AIR determined the best fit to the deterioration data was of the form;

$$HC + NOx\ Deterioration\ Factor = 1 + CONSTANT \times \sqrt{Engine\ Hours}$$

AIR's results indicate that the HC+NOx deterioration factor (DF) is 1.4 for a Phase 1 Class I OHV engine at 66 hours of use, and 1.4 for a Phase 1 Class II OHV engine at 250 hours of use.

As it did for SV engines, the Agency verified AIR's analysis by analyzing a subset of the data examined by AIR, namely, the field tested engine data. EPA performed an ordinary least square analysis of HC+NOx deterioration factor (DF) versus usage in hours for the square root of hours function shown above. The Agency's results predict that the Class I OHV HC+NOx DF is 1.35 at 66 hours, and the Class II OHV HC+NOx DF is 1.73 at 250 hours. The Agency's analysis produced very similar results to the AIR analysis for a Class I OHV engine, but higher results for a Class II OHV engine. The Agency believes the difference in the Class II OHV DF estimate is likely a result of the different methodologies used by AIR and by EPA. Specifically, the Agency's analysis did not include new engine quality audit data, manufacturer sales information, or individual engine manufacturer's engineering judgement. Due to the similarities in the HC+NOx DF estimate for the Class I OHV, and the Class I and II SV engines (see Section 3.2.1.3), the Agency is comfortable relying on the industry estimate for Class II OHV engines.

As noted in 3.2.1.3.1 on SV engines, the EPA is finalizing a minimum useful life of 125 hours for Class I engines. Therefore the DF for HC and NOx need to be calculated from the analysis of the data by EPA. EPA determined constants of .05 for HC and .03 for NOx separately for use in the modeling of emissions. Using these constants in the equation above, the deterioration factors calculate to 1.56 for HC and 1.335 for NOx. Splitting the Phase 1 standard with the HC / NOx split found in the EPA Phase 1 certification database (12.1 => 11.27HC, 4.34 NOx), results in a HC+NOx value of 23.4 g / kW-hr and an overall HC+NOx DF of 1.5. The Class II OHV estimate at 250 hours is 18.8 g / kW-hr (i.e., 1.4*13.4 g / kW-hr). Multiplying these DFs times the Phase 1 standards results in a conservative estimate of the in-use emission rate of Phase 1 OHV engines.

A number of engine families will have longer useful lives than those analyzed above and are typically manufactured with commercial use of the engine in mind. Based on discussions with several of the engine manufacturers who provided test data on Class II engines to AIR, the Agency believes that the majority of the field aged engines used in this study would be considered typical of those engines used in residential applications which are designed for relatively low useful lives. However, at the Agency's request, manufacturers identified a small sample of Class II OHV engines which were considered to have design characteristics representative of a 500 hour useful life engine. A discussion of the EPA analysis of this data is contained in the public docket for this rule.(Ref. 2) This analysis indicates an HC+NOx DF on the order of 1.2 at 500 hours. The Agency's conclusion, based on this very small data set, is that

Class II OHV engines designed for a 500 hour useful life had very similar, and perhaps better, HC+NOx deterioration at 500 hours compared to Class II OHV engines designed for a 250 hour useful life. Unfortunately, the AIR data set did not contain field aged data on Class I OHV engines which have design characteristics representative of a 250 or 500 hours useful life engine, nor did it contain field aged data on Class II OHV engines with design characteristics representative of 1,000 hour useful life engines. The data set did contain(data on two field aged SV engines at or over 1000 hours. The DFs seen from these engines averaged 1.3 for HC+NOx.

3.2.1.5 Exhaust Emission Performance and Costs of SV to OHV Conversion -- EPA believes the information contained in Section 3.2.2 on the emission performance of improved OHV engines is also appropriate for the new OHV engines which have been converted from SV designs. As stated in Section 3.2.2.3.1, the Agency estimates a Class I OHV engine can achieve an in-use emission rate between 15.5 and 16.9 g/kW-hr at 125 hours, and Class II OHV engines can achieve an in-use emission rate between 11.7 and 12.8 g/kW-hr at 250 hours.

In the draft RSD, the Agency relied on the cost estimates contained in Chapter 3 of the 1996 ICF report (see ref. 1 to this Chapter) of converting existing SV production capabilities to OHV manufacturing. However, EPA received comments from one large engine manufacturer of SV engines asserting that the cost estimates contained in the draft RSD analysis did not accurately reflect those costs that would be incurred to convert from SV to OHV engines. EPA has updated the cost estimates based on submitted data from the two largest SV engine manufacturers on the expected cost of conversion from SV to OHV engine designs.

Table 3-01 contains a summary of the cost estimates for both variable manufacturing costs and fixed costs for converting from SV to OHV technology. Variable manufacturing costs include includes material costs, components costs, and manufacturing labor. Fixed cost estimates include engineering costs, changes to technical support training and manuals, and changes in tooling costs.

TABLE 3-01

Summary of per Engine Cost for Conversion from SV to OHV Technology by Class

Conversion of Phase 1 SV Engines to OHV Technology	Class I	Class II
Variable Costs	$13.68	$22.00
Fixed Costs[8]	$16,770,000	$18,440,000

3.2.1.6 Impact on Equipment Design and Use of SV to OHV Conversion -- SV and OHV engines are similar in many ways from an overall packaging perspective. The Agency expects that for many applications, new OHV designs will present no changes for equipment manufacturers from a design perspective. However, for some equipment types, the change in cylinder head configuration for the OHV design or increases in cylinder head and/or exhaust gas temperature will require changes in equipment design. Section 4.4.1. of this RIA, contains a detailed description of the equipment design changes the Agency would expect to see as a result of conversion from SV to OHV engine design.

8 The costs were then accounted for those engine families that were likely to require new production facilities and averaged over all SV engine families that were assumed to be improved (note the production volume of smaller SV engine families may be covered by production capacity in existing similar OHV engine families - this accounted for one engine family in Class I and no engine families in Class II).

The Agency expects no changes in the operational characteristics of equipment as a result of the conversion from SV to OHV technology. From the perspective of the user, SV and OHV engines should perform the same way with respect to power generation.

3.2.1.7 Technology Impact on Noise, Safety, and Energy for SV to OHV Conversion -- The Agency expects no significant changes in the noise or operational safety of engines from the conversion of SV engines to OHV technology. OHV engines are widely used in the nonhandheld market, and there are no technical reasons the Agency is aware of which would cause an increase in noise, or present an unsafe technology, from of the conversion of SV technology to OHV engines.

The Agency would expect improvements in fuel economy from the conversion of SV engines to OHV technology. Section 4.6.1 of this RIA contains additional information on the expected fuel savings from the conversion to OHV technology. OHV engines are more fuel efficient than SV designs, and the Agency expects to see approximately a 15 percent reduction in the fuel consumption from OHV engines compared to SV engines.

3.2.2 Improvements to Existing 4-stroke Over-head Valve Engines

3.2.2.1 Description of 4-stroke Over-head Valve Technology -- The reader is referred to section 3.2.1.4 for a description of 4-stroke Overhead Valve technology.

3.2.2.2 Current State of Development for OHV Technology -- OHV engine designs have been manufactured and sold for use in nonhandheld applications for many years. According to sales information available from Power Systems Research (see ref. 13 to this Chapter), OHV engines represented less than 1 percent of Class I engine sales prior to 1986, but since that time they have grown to represent between 10 and 15 percent of total U.S. sales for the past eight years. In the 1970's and 1980's, Class II engines were predominantly SV technology. Beginning in 1985, OHV engines have steadily increased as a percentage of Class II sales, averaging approximately a 3 percent increase per year. By 1995 OHV engines represented approximately 35 percent of Class II engine sales. Manufacturers have had many years experience in designing and producing OHV technology.

3.2.2.3 Exhaust Emission Performance and Costs of OHV Technology -- The reader is referred to section 3.2.1.4.1 for this information.

3.2.2.3.1 Improvements to Phase 1 Technology OHV Engines -- The Agency considered several improvements to Phase 1 OHV technology during the development of the Phase 2 nonhandheld rulemaking. Based on information contained in a 1996 ICF report (see ref. 1 of this Chapter), and a 1996 report prepared by Southwest Research Institute (see ref. 3 of this Chapter), several improvements to Phase 1 OHV technology were considered, a summary of which is provided here. For Class I, approximately 15 percent of the production is made up of OHV technology and approximately half of the OHV engine families are estimated to already be below the final Phase 2 standard. For Class II, 54 percent of the production are OHV technology and approximately half of the OHV engine families are estimated to be below the final Phase 2 standard.

One area considered by the Agency was improvements to combustion chamber design and intake systems. Improvements to combustion chamber designs can result in more complete combustion of the air/fuel mixture, and may improve the engines ability to operate at leaner air/fuel mixtures (see Chapter 5.1 of ref. 1 of this chapter, and Chapter 6 of ref. 3 of this chapter). Redesigning the intake system can result in additional charge swirl within the combustion chamber for a more homogenous charge which, in turn, can result in more complete combustion.

The Agency also considered improvements to the piston and piston ring design, and cylinder bore smoothness. The objective of these improvements would be to improve oil control. Poor oil control can result in the formation of combustion chamber deposits, which will increase the in-use emissions from an engine (see Chapter 5.1 of Ref. 1 of this chapter, and Chapter 6 of Ref. 3 of this chapter). Some Phase 1 OHV engines have likely already incorporated improvements to improve oil control. However, for those engine models which have not, the Agency believes improvements to the piston and piston ring design may be necessary to reduce oil consumption. In addition, improvements to cylinder roundness and finish may also be required to reduce oil consumption.

The 1996 ICF report contains a detailed discussion of the per engine costs of applying these improvements to Phase 1 technology Class I and II OHV engines (see Chapter 5 of Ref. 1 of this chapter). As presented in the 1996 ICF report, per engine costs are affected by engine family production volumes. ICF analyzed costs for engine families based on production volumes of 35,000 units, 200,000 units and 1,200,000 units for nonhandheld engines. The Agency believes the 1.2 million estimate is not appropriate for nonhandheld Class I or II engines, because there are no OHV engine families being produced with annual production volumes near 1.2 million. Table 3-04 presents a summary of the per-engine costs associated with improvements to nonhandheld OHV technology.

TABLE 3-02
Estimated per Engine Costs for Improvements to Class I and Class II OHV Engines (Variable and Capital Costs)

Improvements to Phase 1 Class I and II OHV Engines	Per Engine Costs for Family w/ 35,000 Units Annual Production	Per Engine Costs for Family w/ 200,000 Units Annual Production
Combustion and Intake Systems	$3.05	$0.53
Piston and Ring Designs	$4.60	$2.67

The improvements the Agency has examined for OHV engines would be expected to reduce new engine and in-use HC+NOx emission deterioration. Based on the information presented in Table 3-02, the Agency estimates that improvements to a Class I or Class II OHV engine could cost up to between $3.20 and $7.65 per engine, depending on the improvements required and the annual production volume of the engine family. The Agency estimates these improvements would reduce the Phase 1 OHV new engine HC+NOx values 10 percent for Class I and Class II engines . The Agency also estimates an improve in-use deterioration of Phase 1 Class I OHV engines to an average HC+NOx df level of 1.4 for Class I and 1.3 for Class II.

Appendix B contains a list of engine families certified under the EPA's Phase 1 program. The Agency also has access to manufacturers' production volume projections (which manufacturers have asked to be treated confidentially) for each engine family. As of September, 1998, 61 Class I engine families (8.4 million engines) and 152 Class II engine families (3.1 million engines) had been certified. Based on historical sales data this would appear to be the majority of nonhandheld engines sold in a single year. Using the estimated production information, the sales weighted HC+NOx certification level is 11.2 g/kW-hr for Class I OHV engines, and 9.1 g/kW-hr for Class II OHV engines. Based on the Agency's experience with on-highway engines, the Agency estimates a typical compliance margin used by manufacturers to be between 10 and 20 percent. By achieving lower new engine levels and a reduced HC+NOx DF, combined with a compliance margin between 10 and 20 percent and the sales weighted Phase 1 certification levels, the Agency estimates improvements to OHV engines would achieve an in-use emission rate between 15.5 and 16.9 g/kW-hr at 125 hours for Class I engines, and between 11.7 and 12.8 g/kW-hr at 250 hours for Class II OHV engines. (The range presented is based on an estimated manufacturer compliance margin of 10% for the lower value and 20% for the upper value.) It should be noted that only about 15 percent of Class I engines currently certified to the Phase 1 regulation are OHV technology. The performance of these specific Class I engines may not be representative of what would occur if all Class I engines were converted to OHV technology.

3.2.2.4 Impact on Equipment Design and Use -- As discussed previously, OHV technology has been used for many years in nonhandheld equipment. The improvements to OHV technology described in this section would have no negative impacts on nonhandheld equipment design and use, since most of the improvements discussed are internal to the engine and would not effect the overall shape or functionality of the engine with respect to its use in a piece of equipment.

3.2.2.5 Technology Impact on Noise, Safety, and Energy -- The Agency expects no negative impacts on the noise level or the operational safety from improvements to Phase 1 technology OHV engines. As discussed in Section 3.2.2.3, the Agency considered internal improvements to OHV engines, which would have no impact on noise levels or safety.

The Agency expects no significant changes in the energy consumption from improvements to Phase 1 technology OHV engines. The improvements considered by the Agency (see Section 3.2.5.3) would reduce the in-use HC and NOx deterioration of the engines, but would have only marginal, if any, effects on fuel consumption.

3.2.3 Application of Catalytic Convertors to 4-stroke Nonhandheld Engines

3.2.3.1 Description of Catalyst Technology -- Catalytic convertors are add-on devices used to lower exhaust emissions from engines after they exit the combustion chamber. Typically, a catalyst consists of a ceramic or metallic support (often called the substrate), that is coated with a wash-coat which contains catalytic material (typically a rare-earth element such as platinum, rhodium and / or palladium). The catalytic material initiates a chemical reaction which can oxidize hydrocarbons and carbon monoxide, and it can reduce oxides of nitrogen.

Additional information regarding the fundamentals of catalytic convertors, and information specific to catalyst and small engines can be found in "Report - Exhaust Systems Subgroup of the Technology Task Group", a report published by a task group established during the Regulatory Negotiation for Small Engine Phase 2 Rulemaking.(Ref. 3)

3.2.3.2 Current State of Catalyst Technology Development -- Historical data indicate that catalysts have seen limited use on small engines in the U.S. Prior to EPA or California ARB small engine regulations, catalysts were used in limited numbers on some types of indoor equipment, such as indoor propane fueled floor buffers (also called floor burnishers). Certification information from EPA's Phase 1 program indicates that a small number of Class II engine families have also been certified using catalyst technology on 4-stroke SV engines in tillers and pumps. The projected sales for these engines represent less than 1 percent of nonhandheld engine sales.

3.2.3.3 Exhaust Emission Performance of Catalysts -- The report entitled "Report - Exhaust Systems Subgroup of the Technology Task Group" (Ref. 10) contains a summary of new engine data on the HC and NOx reduction potential from the application of catalysts to 4-stroke small SI engines. The majority of these engines were uncontrolled or Phase 1 technology gasoline engines with a prototype catalyst added on. The application of catalysts to these small gasoline 4-stroke engines showed reductions of 40 to 80 percent in new engine HC emissions and reductions of 20 to 80 percent for NOx emissions. However, for some 4-stroke engines NOx emissions increased 25 to 50 percent. Based on this information, the Agency estimates that catalyst technology has the potential to reduce new engine HC+NOx emissions from 4-stroke engines by 20 to 80 percent from uncontrolled and Phase 1 technology.

The reductions in HC and NOx described above are reductions in the new engine emission rates of small engines. The in-use performance of catalysts can degrade from several mechanisms, including the physical deterioration of the substrate from mechanical shock, vibration, and extreme temperatures, and the deactivation of the catalyst material from chemical poisoning (such as sulfur in the oil). There is limited data on the deterioration of catalysts on small engines due to the limited use of catalysts to date. Only in the past 2-4 years have catalysts been used on nonhandheld equipment.[9] Data on the catalysts from these engines are not available and therefore research data is the only information available to determine the deterioration of catalysts in-use. Three pieces of research data describe the range of results seen to date on the

[9] As of November 17, 1998, it is known that catalysts are used on 150,000 nonhandheld equipment in Europe and 100,000 lawnmowers in the US.

deterioration of catalyst on small engines and they include one SAE paper and two correspondence from MECA to the EPA. The 1994 SAE paper includes information on catalysts aged on uncontrolled engines.[10] The data shows that the catalysts' HC+NOx conversion efficiency decreases by an average of 73% after 120 hours (Ref. 4). The paper described the main reason for this large degradation to be poisoning accumulation based on high oil consumption typical of small SI engines. The oil consumption can increase the rate of poison deposition in the catalyst washcoat that will plug up the pore mouth and impede catalyst performance. The paper continues to state that work needs to be done to produce a safe and functional catalyst design for ULGE engines. Some areas where additional efforts need to be expended include 1) leaner running air cooled engines, 2) low cost fuel management systems, 3) improve engine oil consumption, 4) catalyst durability and thermal stability, 5) thermal control and lock out devices, 6) high temperature mounting systems, and 7) cooling air management and heat shielding. The first set of data from MECA regarding catalyst deterioration on a 5.5hp Class I OHV engine(Ref. 5) shows that after 100 hours, HC conversion efficiency is decreased by 44% and NOx conversion is decreased 26% (values are read from a graph). The author states that better HC conversion can be obtained with additional air added to the system. The second set of MECA data, also on a 5.5hp Class I engine, was on a catalyst system that was optimized for HC. Results showed an approximate 15% decrease in HC and 61% decrease in NOx[11](Ref. 6) after 100 hours. Sufficient data was not provided

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[10] The engines were Class II SV engines of 319cc which emitted 10-20% above the Phase 1 standard. The size of the engine was determined by questioning the catalyst manufacturer author of the paper.

[11] The data indicates that the catalyst changed from a reducing catalyst (where the oxygen is taken from the NOx) to an oxidizing catalyst (where the oxygen is taken from additional oxygen present in the exhaust and CO is also converted) during

in this last item to know if it was a SV or OHV engine or to calculate its combined HC+NOx emission deterioration.

3.2.3.4 Cost Estimates of Catalysts Systems -- Costs are available from two sources for this final rule and include 1) the ICF 1996 report (see reference 1 to this Chapter - the costs of applying a catalyst to a 2-stroke engine were estimated), and 2) MECA's comments submitted in the response to the NPRM.

For the ICF data, the Agency estimates the costs of applying a catalyst to a 4-stroke engine would be similar to the 2-stroke estimate, particularly for the engineering research and development work. However, the catalyst would likely be larger for a nonhandheld 4-stroke engine in order to handle the increased exhaust gas flow rate from the larger nonhandheld engines, and therefore one would expect the costs to be higher.[12] ICF considered the costs for both a metallic substrate and for a ceramic substrate, with the estimated cost of a metallic substrate being substantially more. Table 3-02 is a summary of the cost information contained in the ICF 1996 report for ceramic catalyst and 4-stroke engines. Based on discussions with industry and MECA during the Reg Neg Exhaust System Technology Task Group work, it is believed that metallic catalysts are only required in handheld equipment where the vibrational characteristics of the equipment require a more durable substrate and therefore ICF's estimates for metallic catalysts are not included in the table.

MECA provided NPRM comments on the cost of catalysts, of several conversion efficiencies, for Class I and II. Table 3-03 presents a summary of the

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the 100 hour test.

[12] A detailed analysis of the costs associated with applying a catalyst to nonhandheld engines was not performed, so these numbers should only be considered rough estimates, and not as reliable as the estimates for 2-stroke engine.

data supplied by MECA. MECA states that the costs may decrease over time if catalyst technology is encouraged to develop. MECA's cost estimates do not include any other costs of the catalyst system or for the steps to install the catalyst on the engine.

TABLE 3-02

Summary of ICF per Engine Cost Estimate for Application of a Catalyst to a Non-handheld 4-stroke Engine (data from ICF, 1996**)**

Cost Item	Engine Family Annual Production = 90,000, ceramic substrate	Engine Family Annual Production = 400,000, ceramic substrate
Catalyst	$4.00	$4.00
Catalyst Assembly Labor	$0.58	$0.58
Catalyst Fixed Cost	$1.20	$0.30
Muffler / Heat Shield Hardware Cost	$0.90	$0.90
Muffler / Heat Shield Fixed Costs	$0.98	$0.24
Total	$7.66	$6.02

TABLE 3-03

Summary of MECA per Engine Cost Estimate for Catalyst of Specific Conversion Efficiency per Class

UNITS	Class I 4-5 hp 25% at 250 hours	Class I 4-5 hp 40% at 250 hours	Class II 12-14hp 25% at 250 hours	Class II 12-14hp 40% at 250 hours
2,000	--	--	$8.80	$10.99
10,000	$4.00	$4.94	--	--
several million	$2.69	$3.10	$6.17	$6.92

By combining Tables 3-02 and Table 3-03 and by using the MECA data for the cost of the catalyst piece (washcoat and substrate), it can be calculated that the cost of adding a catalyst and hardware to a 4-stroke engine is estimated to be between $4.71 and $8.60 per Class I engine, and $8.19 to $14.65 per Class II engine depending on the percent conversion efficiency at the end of an engine's useful life and the annual production of the engine family. This does not include any engine modifications that must be made to incorporate catalyst technology as outlined in 3.2.3.3.

3.2.3.5 Impact on Equipment Design and Use of Catalyst -- The use of catalysts would affect the muffler design of small engines. Mufflers would need redesigns in order to house the convertor, as well as additional heat shielding or other safety shields to protect the user from excessive muffler skin temperature. In addition, the muffler design may need to be modified in order to accommodate increased exhaust gas temperature.

3.2.3.6 Catalyst Technology Impact on Noise, Safety, and Energy -- The Agency would expect little impact on engine noise from the application of catalysts to small engines. If any impact on noise did occur, it is likely the catalyst plus a redesigned muffler would act to lower the noise generated by an engine, since the catalyst would absorb and not generate sound.

Engine manufacturers have raised concerns regarding the safety of catalysts on small engines. The principle concerns relate to increases in muffler skin temperature and exhaust gas temperature from the use of a catalyst. This could be especially troublesome in equipment which encase the engine and muffler in a shroud and are used in grassy environments. The heat increase within the piece of equipment may result in an extremely hot environment which may result in poor running of the engine, potential melting of the plastic shroud and potential fire due to the presence of grass. Equipment which do not house the engine and muffler within the equipment, such as a lawnmower may be able to successfully use a catalyst. This has been proven through sale of lawnmowers with catalysts in Europe.

The addition of a catalyst would have no significant impact on the energy consumption of an engine. Catalysts are add-on devices which would have minimal, if any, impact on the engine's air/fuel ratio or power output, and therefore no change in fuel consumption would be anticipated.

3.2.4 Discussion of Other Engine Technologies

The standard for Class I engines (with ABT) is 16.1 and it is implemented in 2007, with new engine families required to meet the standard after 2003. This lead time allows the manufacturers to acquire the large amount of tooling and building of facilities, if necessary, to produce engines to meet this standard. The time also allows engine manufacturers to develop alternative technologies to meeting the standard. Several potential inventor technologies are described in the sections below.

3.2.4.1 Vaporizing Carburetion -- In August 1995, as part of investigating technologies for the Phase 2 Reg/Neg, the EPA assembled a report on emission testing of a B&S Quantum engine using a vaporizing carburetion technology (Ref. 7). The vaporizing carburetor was a box add-on device which used a hair dryer to heat the inlet air (which could later be provided by the engine exhaust or cylinder head). The inventor stated in the report that "the technology allows the engine to operate stably at lean burn air/fuel ratios at partial power and provides richer air/fuel ratios for full power and engine warm-up." The inventor also stated that "the use of the technology is expected to result in longer engine useful life due to clean operation and less carbon buildup on engine pistons, valves and surfaces within the combustion chamber itself."

The testing revealed that the technology was able to achieve low emission levels on a SV engine, see Table 3-04. Power differences were seen to differ only 5.9% at mode 2 (75% load), between the baseline and prototype engine, and were the same as the baseline for the remaining modes. The exhaust temperature increased 105 degrees C from baseline in modes 3-7 of the test procedure while the cylinder head temperatures were observed to be nearly the same on average. The device ran rich at wide open throttle in order to sustain power.

Table 3-04

Vaporizing Carburetor Technology On a B&S SV Engine (g/kW-hr)
Average of Three Tests Each

	HC	NOx	CO
Baseline	18.4	2.5	459
With technology	8.4	3.7	116
% Difference	54%	-48%	75%

Further development of the technology was needed in order to produce a production ready engine with the technology. Testing showed that engine operation was rough as the torque was less consistent with the technology than the baseline engine. This was noted by the inventor as it was having difficulties in maintaining consistent A/F delivery to the engine with its current prototype. It was also noted that the achievable idle speed with the technology result in erratic engine operation. The inventor said it had not seen this result prior to applying the technology to the engine and it may be due to improvements made in the SV engine in order to meet California ARB and EPA regulations. Nothing else has been submitted to EPA to date by the company following this testing.

In late summer 1998, EPA learned of another vaporizing carburetor concept. The technology is a much simpler concept than that tested during the Phase 2 Reg/Neg and it has been used successfully in performance machines such as snowmobiles (which was confirmed)(Ref. 8) and motor cross bikes. As stated in the brochure, "The Super Cycler works in the last few centimeters of the intake tract to further enhance the production and delivery of super-cooled, completely phase-shifted vapor. The device allows the return pulse to feed its energy into the next intake pulse, adding both completely phase shifted vapor and return pulse energy to each succeeding intake pulse. The high frequency reverse wave energy created by piston reciprocation pounds its way back toward the center of the carburetor along the edges of the manifold and carburetor outlet where it is directed into a narrow outer chamber created by the Super Cycler. This high-velocity pulse then bounces back toward the direction of positive flow and into the rushing positive ulse through a series of holes drilled in the section of the Super Cycler closest to the throttle valve. The Super Cycler utilizes the return pulse as a self-powered mini supercharger, setting up a kind of pulse driven feeding frenzy in the intake manifold that is reponsible in part for the increase in power. The function of the Super Cycler is based on Boswell's discovery that the return pulse is strongest in the boundary layer next to the venturi wall. The return pulse is channeled into the narrow Cycler chamber where it is reflected back through a series of holes creating a reverse pulse-powered velocity booster" (Ref. 9).

While the device has been used in production on some high performance 2-stroke applications, which run at approximately 10,000 rpm, it has not yet been proven in the marketplace to be applicable or effective to the small 4-stroke engines covered by this rulemaking, which run at lower speeds (approximately 3,200 rpm). While EPA has not done any independent testing on the device, it is assumed that, if successfully applied, the emission results will be similar to those seen in Table 3-03 based on the fact that the combustion chamber sees similar vaporized fuel.

3.2.4.2 Spark Ignition Technologies -- During the summer of 1998, one company presented EPA with information on a spark ignition technology that it had developed(Ref. 10). It is a very simple technology and may result in some emission benefits in terms of improved emission deterioration in 4-stroke engines. Versions of the technology are in the marketplace today, however the inventors have investigated those technologies and note that theirs has some benefits that have not yet been included in previous designs.

The inventors of the technology have performed a number of tests of the technology on 2-stroke and 4-stroke engines. While they have seen a notable benefit in new engine values on 2-stroke engines, they have not observed the same in 4-stroke engines. The company claims there are benefits to the use of the device in 4-stroke applications, however, it found that benefits were limited in side valve engines. This is believed to be consistent with the combustion theory surrounding the benefits of the device. The L-head or side valve engine configuration compresses the ability of the flame front to spread into the combustion chamber and therefore inherently limits the combustion propagation characteristics of any ignition device in such an engine. The tests have confirmed significantly improved BSFC and it is believed that the absence or reduction of combustion chamber deposits over time would contribute to improved emission deterioration over time. Although no tests have been performed to confirm this on 4-stroke engines, some tests have been performed on 2-stroke engines. Examination of the piston face revealed less combustion chamber deposits than an engine without the device.

It is expected that the technology may result in some improved emission deterioration, although not yet proven on 4-stroke engines, and therefore engine manufacturers may choose the technology where this is needed. It is not known how much emission improvement can be obtained in 4-stroke engines, however it may provide enough benefit that a lesser number of engine families may have to be improved in order to meet the average standard.

3.2.4.3 Other Technologies -- The Agency is aware there are additional technologies not discussed in this RIA. These include electronic fuel injection, three-way catalyst with closed loop air/fuel control, and fuel vaporization.

The Agency has not afforded these technologies the same in-depth analysis given presented in Sections 3.2.1 thru 3.2.4 for a variety of reasons. These include factors such as unknown emission performance, no in-use performance data, unknown application to small engine equipment, and unknown or high costs. In summary, EPA is not able, at this point, to determine that these technologies are widely available to the extent needed in order to base an emissions standard on them.

3.3 Final Exhaust Emission Standards

This section contains information the Agency used to determine the appropriate standards contained in the final regulations. Additional information is contained in the Preamble for this Rulemaking.

3.3.1 Final HC+NOx Standards for Class I Engines

The Agency is adopting a corporate average exhaust emission level of 16.1g/kW-hr HC+NOx for Class I engines beginning with all new engine families produced after August 1, 2003 and with every manufacturer certifying, on average, after August 1, 2007. This final standard is applicable for all three useful life categories of 125, 250, and 500 hours. The Agency has performed an analysis using the existing Phase 1 certification data (which contains production projections that manufacturers have asked to be treated confidentially) combined with reasonable assumptions for in-use deterioration. This analysis indicates a standard of 16.1 g/kW-hr is achievable through conversion to clean OHV engine design and by internal improvements to some existing Phase 1 OHV engines. Manufacturers will need to make improvements and major retooling of engine production lines will be required. The use of ABT across Classes I and II provides manufacturers with flexibility for determining the most appropriate expenditure of resources when deciding which engine families will need specific improvements to meet the final levels. The time between the finalization of this rule and August 1, 2007 will be sufficient for manufacturers to meet the final HC+NOx level.

3.3.2 Final HC+NOx Standards for Class II Engines

The Agency is adopting a corporate average HC+NOx emission standard of 12.1 g/kW-hr which will be phased in over five years, beginning in model year 2001. The HC+NOx phase-in standards are 18.0g/kW-hr in model year 2001, 16.6 in 2002, 15.0 in 2003, and 13.6 in 2004. These standards are applicable for all three useful life categories of 250, 500, and 1000 hours. Based on the information presented in this Chapter, the Agency believes an in-use level of 12.1g/kW-hr can be met by the conversion of Phase 1 SV engines to OHV technology (see Section 3.2.6), and by internal improvements to some existing Phase 1 OHV engines (see Section 3.2.5).

The final standards require significant production line changes for the majority of Class II engine manufacturers to convert existing SV models to OHV designs, as well as modifications to a number of Phase 1 OHV models which may need internal improvements to meet the 12.1 g/kW-hr level. To accommodate a smooth transition of existing SV engine family production lines to the new OHV technology or other comparably clean technology, the Agency is adopting the five year phase-in period noted above. The Agency expects the final standards for Class II engines will result in increased penetration of and conversion to clean OHV technology by 2005. However, the rulemaking does not preclude other technologies from meeting the final standard.

The Agency recognizes that there are large differences in technology mixes currently being produced by Class II engine manufacturers. Some Class II engine manufacturers have already made significant investments in OHV technology prior to and during the Phase 1 program. For some of these manufacturers, the standards in the early years of the Phase 2 phase-in (i.e., the 2001 standard of 18g/kW-hr and the 2002 standard of 16.6 g/kW-hr) may not require additional reductions in Class II engine emissions beyond what manufacturers may currently achieve with ome engine families. At the same time, the Phase 1 standards do not require a shift to clean, durable OHV technology or comparably clean technology, and several Class II engine manufacturers currently produce a significant number of SV engines. For manufacturers who are relying on SV technology, the final phase-in schedule will allow them to shift their production to new, cleaner technology which is capable of meeting the 2005 standard of 12.1g/kW-hr. The Agency believes the phase-in standards will address the inequities among manufacturers' current technology mixes but will also require manufacturers to produce the clean, durable 12.1g/kW-hr engines in 2005. Manufacturers have indicated the early banking provisions will result in pulling ahead clean technology and ease the transition to the 12.1 standard. However, due to the wide discrepancy between manufacturers current technology mix, some manufacturers may generate significant credits during the phase-in period. The Agency has performed an analysis, based on Federal Phase 1 certification data, which indicates under some conditions early banking would result in significant credits being generated during the phase-in period which may in fact undermine the 12.1g/kW-hr standard in model year 2005. To assure this does not occur, the Agency has finalized certain restrictions for Class II engines in the ABT program, as discussed in the Preamble, Section IV.A.5.

Chapter 3 References

1. "Tier 1 Deterioration Factors for Small Nonroad Engines", Sept., 1996, a report by Air Improvement Resources, available in EPA Air Docket A-96-55, Docket Item II-D-11.

2. "Summary of EPA Analysis of Nonhandheld Engine Hydrocarbon and Oxides of Nitrogen Exhaust Emission Deterioration Data for 500 Hour Useful Life Class II OHV Engines", EPA Memorandum, August 4, 1997, available in EPA Air Docket A-96-55, Docket Item # II-B-02.

3. "Exhaust Systems Subgroup of the Technology Task Group - Report", September 25, 1995, available in EPA Air Docket A-95-55, Docket Item # II-D-17.

4. "Exhaust Emission Control of Small 4-Stroke Air Cooled Utility Engines An Initial R&D Report", SAE 941807.

5. Letter from Bruce Bertelsen of MECA to Bob Larson of the EPA, October 19, 1998, EPA Air Docket A-96-55, Item # IV-G-25.

6. "Phase 2 Emission Standards for New Nonroad Spark Ignition Engines at or Below 19 Kilowatts, Air docket No. A-96-55", MECA, March 13, 1998, EPA Air Docket A-96-55, Docket Item # IV-D-13.

7. "Emission Testing Report Vaporizing Carburetor On Briggs and Stratton Quantum Engine", US. EPA, August 1995, EPA Air Docket A-96-55, Docket Item #(yet to be assigned)

8. Conversation between Cheryl Caffrey and David Wahl Regarding the Boswell Energy System technology on snowmobiles, December 15, 1998, EPA Air Docket A-96-55, Docket Item # (yet to be assigned).

9. "The Boswell Technology", Boswell Fuel Systems, EPA Air docket A-96-55, Docket Item #IV-D-24.

10. "Technical Summary and Report Spark Ignition Device Research", Pyrotek, Inc., November 13, 1998, EPA Air Docket A-96-55, Docket Item # IV-G-29.

Chapter 4: Technology Market Mix and Cost Estimates for Small SI Engines and Related Equipment

This chapter analyses the variable costs and fixed costs per engine family modified in each class. This chapter also presents a "schedule" for how these engine modifications are phased-in. These costs are costs to manufacture.

Clean Air Act section 213(a)(3) requires that EPA must consider cost in adopting standards that achieve the greatest degree of emission reduction. This Chapter and Appendix C present the Agency's estimation of costs for expected technologies including associated variable costs (hardware and production), fixed costs (production and research and development), related equipment costs, engine fuel savings and engine compliance costs. Details of the methodology for determining the compliance costs are presented in Chapter 5.

To calculate estimated costs incurred by engine manufacturers, market mix[13] percentage estimates for pre-Phase 2 (Phase 1) and Phase 2 engines are first determined. This is done by determining the Phase 1 engine market mix from sales estimates provided by manufacturers as part of their 1998 model year certification applications. Analysis of this data formed the assumed product mix

13 Market mix is the percentage of engines of specific engine design sold in the marketplace (ex: 4-stroke SV and 4-stroke OHV) compared to others in the same Class.

that will be in place as a result of the Phase 1 rulemaking. A comparison was then made to the assumed product mix (including technical enhancements) that would need to be in place to meet the Phase 2 standards. A description of the methodologies and resultant market mixes for these estimates are described in 4.1. Engine Technology Market Mix Estimates.

Many of the emission reduction technologies assumed feasible for this rule include changes in manufacturer production, such as the number of tools and changes in the die designs. The following definitions were utilized to separate costs for emission reduction technologies into variable hardware, variable production, fixed production and fixed research and development. Variable hardware costs are those costs which are associated with pieces of hardware added to an engine. Examples include rocker arms and push rods that are added to an engine that is converted from SV to OHV. Variable production costs are those costs which relate to inputs in production. These costs consist of additional production tasks, such as assemblers for additional components for an OHV line which were not in place for assembly of a side valve line. Variable hardware and production costs are determined by estimating variable costs for each emission reduction technology and applying those costs to that portion of the Phase 2 product mix assumed to have required that technical change. The methodology for estimating variable hardware and production costs for applying emission control technology are presented in 4.2. Variable Hardware and Production Cost Estimates per Engine Class.

Fixed production costs are those costs which are related to added or modified piece(s) of machinery to an existing engine line due to this final rule, such as tooling and die design changes. Fixed costs of research and development are those costs associated with development of engine and engine component designs to meet emission standards. These costs are incurred prior to production and amortized for recovery over 5 years and therefore do not apply on a per engine basis as do variable cost estimates. Discussion of the methodology utilized to estimate fixed costs are presented in 4.3. Fixed Production and Research and Development Cost Estimates per Engine Class.

Engines are utilized in equipment which may require alterations due to changes in the engines required to meet the Phase 2 final standards. A discussion of equipment impacts is presented in 4.4 Equipment Cost Estimates. Lastly, Section 4.5 details fuel savings and changes in power expected with the Phase 2 engine technologies. Cost impacts from changes in maintenance, engine durability and life expectancy were not quantified or included in this cost analysis. Since the quality of the Phase 2 engines is expected to be better than comparable Phase 1 engines, these factors are should improve in ways which directly benefit the consumer but information was insufficient to quantify these benefits.

4.1 Engine Technology Market Mix Estimates

Market mix estimates consist of the number of engine families and sales estimates of engine designs (i.e., side valve, overhead valve, 2-stroke, etc.) per class (i.e., Classes I-II). Market mixes are determined for the 1998 model year (to characterize technology under the Phase 1 regulation) and the first year of full implementation of the Phase 2 emissions regulation. The following describes the methodology used to estimate market mix and emission reduction technologies for small nonhandheld SI engines. This analysis includes only those engine families and production volumes certified to EPA's Phase 1 standard as of September 1998. This does not include engine production volumes intended for sale in California since California also regulates these engines. A summary of results are in Tables 4-01 to 4-04 with manufacturer specific details and emission data in Appendix B Manufacturer and Product Summary.

4.1.1 Phase 1 Market Mix

The most accurate and up-to-date information source on engine families and manufacturers in the marketplace today is the EPA Phase 1 engine certification list. The list, as of September 1998, was utilized to estimate the number of engine families per engine design and technology for Classes I-II[14] as shown in Table 4-01 (Table B-01 in Appendix B contains breakout per manufacturer) . Table 4-02 summarizes the sales in each engine class per engine design.

Table 4-01

Phase 1 Technology Mix
Engine Families per Technology Type

CLASS	SV	OHV	SV w/ cat	OHV w/ cat*	TBI on OHV	2-stroke	TOTAL
I	18	40	--	--	--	3	61
II**	25	118	2	5	2	--	152
TOTAL	43	158	2	5	2	3	213

* These engines include propane engines that are installed in equipment used indoors and must work to allow facilities to meet OSHA time measured safety levels for CO.

** There is one OHV engine with EGR used on a utility vehicle.

14 There are special cases in which engines do not have to meet the Phase 1 standards. These include engines utilized solely in wintertime equipment, such as snowblowers and ice augers, that only have to meet the CO standard. Two- stroke Class I engines are under a special program to be phased-out over a period of years and need only meet the handheld standards.

Table 4-02

Assumed Phase 1 Sales per Class and Technology Type
Phase 1 Database as of September 1998

CLASS	SV	OHV	SV w/ cat	OHV w/cat	TBI on OHV	2-stroke	TOTAL
I	7,222,296	1,182,196	--	--	--	conf	8,404,492+
II	1,427,337	1,697,306	conf	3,125	conf	--	3,127,768+
TOTAL	8,649,633	2,879,502	conf	3,125	conf	conf	11,532,260*

* This number does not include the number of engines that are used in snowblowers that do nothave to meet the HC+NOx standards.
Some of the blocks state "conf" to honor confidentiality if only one or two companies contribute to the total number of engine families in that block.

4.1.2 Phase 2 Market Mix

To determine the Phase 2 market mix, information was collected on potential emission reduction technologies and then the likely percentage usages of such technologies, as required by the Phase 1 engines, were estimated using averaging, banking and trading within each Class per manufacturer.

4.1.2.1 Potential Emission Reduction Technologies -- Potential emission reduction technologies were based on information provided in a work assignment with SwRI(Ref. 1). SwRI compared the characteristics of engines that were below the Phase 2 standards to those engines that were above the Phase 2 standards and provided a list of characteristics/technologies of low emitting engines. EPA supplemented this analysis with one additional Phase 2 technology tested during the Phase 2 Reg/Neg and compiled a list, see Table 4-03.

Table 4-03

Potential Emission Reduction Technologies

ENGINE TECHNOLOGY	POTENTIAL TECHNOLOGIES
4 stroke SV	OHV technology Vaporizing Carburetion[15]
4 stroke OHV	Improved induction systems and combustion chamber design Carburetor enleanment and improved engine cooling Improved tolerances for carburetor with more precise air/fuel control and reduced part to part variability Optimized ignition timing Flex head valves, improved cylinder structural integrity, modified valve placement Intake valve stem seals Design improvements that reduce cylinder distortion Reduced manufacturing tolerances Use of piston oil control ring

This cost analysis uses a portion of these technologies per engine design per engine class. This is based on a comparison of deteriorated emission data, based on the EPA Phase 1 certification database and deterioration factors presented in Chapter 3, to the final Phase 2 standards, see Table 4-04. The following describes the rationale behind the estimation of use of these technologies by engine Class and engine technology. It should be noted that while these engine technologies are focused on reducing HC+NOx emissions, it is expected that CO emissions will decrease due to further enleanment of the engines due to internal engine improvements made to decrease HC+NOx.

4.1.2.1.1 Class I -- The majority of engines in Class I are produced for the low cost consumer market and are of side valve design (86% SV). Many

[15] Still a developing technology. See section 3.2.4.1 for discussion.

internal engine design improvements, such as material selection, enleanment, and valve placement, have been made on a large portion of these engines in order to meet the Phase 1 new engine emission regulations. To meet the standards in this final Phase 2 regulation, EPA estimates that Class I SV engines will be converted to OHV technology for improved fuel combustion efficiency.[16] Components on the low cost engines may also need to be improved in order to increase emission durability. Improvements to the carburetor, combustion chamber and intake will reduce new engine emissions while oil control rings and valve stem seals will improve emissions durability by lowering combustion chamber deposits from the seepage of oil. Some Class I OHV engines may also utilize these technologies to decrease emissions and increase durability to meet the Phase 2 standards.

4.1.2.1.2 Class II -- Class II engines are nearly equal in number of engine population of four-stroke side valve and overhead valve designs. While there are durable side valve engine families in this class, particularly those geared towards commercial applications, it is expected that most of Class II SV engines will convert to a clean durable OHV emission performance technology. Some small volume Class II SV families may continue to be produced with manufacturers taking advantage of ABT to cover thier likely higher emissions. However, this cost saving opportunity is not evaluated in this analysis.

Current OHV engines will be improved by lowering new engine levels and improved emission durability. Improvements in combustion chamber design and intake system will allow the engines to run more efficiently and thereby lower new engine emissions. Improvements in emission durability will

16 The vaporizing carburetion technology discussion in 3.2.4.1 has not yet been proven applicable to this industry and therefore is not used as the basis of this cost analysis.

be achieved by refinement of piston profile and improved piston ring specifications to reduce oil seepage into the combustion chamber.

Table 4-04

ASSUMED TECHNOLOGY IMPROVEMENTS FOR THIS ANALYSIS

CLASS	ENGINE DESIGN	ASSUMED TECHNOLOGIES
I	4 stroke - SV	Conversion to Clean OHV
	4 stroke - OHV	Piston and Piston Ring Improvements Improved Combustion and Intake System
	2 stroke	None necessary (engines being phased out through Phase 1 process)
II	4 stroke - SV	Conversion to Clean OHV
	4 stroke - OHV	Piston and Piston Ring Improvements Improved Combustion and Intake System

4.1.2.2 Engine Families Selected for Emission Improvement -- The Phase 1 certification database was utilized in the analysis to determine the number of engine families and corresponding production volume that would need to incorporate emission improvements.[17] Refer to Tables B-02 through B-06 in Appendix B for specific emission data per engine manufacturer per engine family. Note also that the analysis for this document assumes that all engines that are assumed to require emission reduction technology, per class and engine design, will utilize the same set of technologies.

[17] The database contains several entries per engine family as manufacturers show that the engine family meets the emission standard among its adjustable parameters (particularly the carburetor). For such engine families, the maximum emission rate for HC+NOx was utilized in setting the point at which the engine family emitted for Phase 1.

4.1.2.2.1 Nonhandheld -- The emission standards for Class I engines are fully implemented in 2007. The emission standards for Class II engines are phased in from 2001-2005. ABT across classes is allowed in this final rule, however, EPA performed the analysis for each class separately since the path to be chosen by each manufacturer is unknown. The EPA Phase 1 certification database as of September 1998 was used as the basis of manufacturers, engine families, emission data, rated power and production. The following paragraphs describe the methodology used to analyze the data for engines in Classes I and II.

The Phase 1 standards are new engine standards and therefore a deterioration factor must be applied to the engine families in order to acquire a number to which the Phase 2 standards can be compared. For Class I engines, deterioration factors of 1.50 for overhead valve engines, 2.1 for side valve engines and 1.6 for propane engines with a catalyst[18] were used (see Chapter 3 for the basis of these values). The Averaging, Banking, and Trading (ABT) equation was then applied to each engine manufacturer's set of engine families.[19] The ABT calculation is (Standard-FEL)*Power(Maximum Modal)*Useful Life*Load Factor *Production.

If a manufacturer's resultant ABT calculation was negative (ie: needed

[18] Industry submitted data analyzed by AIR was the basis from which the df's for OHV and SV engines were determined. SAE 932445 presents test results on a Class II propane engine with air/fuel ratio control and 3-way catalyst. Results show 1.6 deterioration of HC+NOx at 300 hours and 1.8 deterioration of HC+NOx at 500 hours. It is assumed that all propane engines certified to Phase 1 that have extremely low CO emissions will utilize such a system for they are marketed for indoor use.

[19] This ABT program allows engine manufacturers some flexibility as they optimize their choice of engine families to meet or exceed the Phase 2 standard. It is available only to nonhandheld engine families.

credits), then it was assumed that the manufacturer would focus on improving the engine families that produced the greatest need for credits such that it would receive the largest benefit for the improvements to the engine family. In making this determination, families were ranked according to the combination of emission level and production volume such that the highest ranked family would provide the greatest assumed emission benefit when modified to comply with the emission standard. The chosen engine family was assumed to have an FEL just below the standard (15.4 g/kWh), and the manufacturer's production weighted emission average was recalculated.[20] This was done for as many engine families as necessary until the engine manufacturer's ABT calculation was above zero. The expected technologies for these engines include conversion to OHV or improved OHV and therefore the Phase 2 market mix for Class I is changed. The most notable change is the conversion of Class I SV to OHV. EPA's analysis showed that 11 SV engine families would be converted to OHV and 8 OHV engine families would be improved. These engine families account for 87.5% of the engines in this Class.

The standard for nonhandheld Class II engines is also a production weighted average standard; however the standard is sequentially tightened over a phase-in period from 2001-2005. The analysis was performed in the same manner as for Class I engines for each implementation year; however the deterioration factor applied to SV engines in this class was 1.6, OHV was 1.4 (see Chapter 3 for the basis of these values) and 1.8 for propane engines with a catalyst. The market mix for these engines is expected to change as SV engine

[20] This is a conservative assumption since application of these technologies would be expected to result in emission levels somewhat below 22.5 g/kWh thus questioning greater emission benefit than assumed by this calculation.

families are converted to OHV engine families during the phase-in. This analysis assumes that all SV engine families that are converted to OHV do result in a new engine family and that existing OHV production does not fulfill the need of the discontinued SV engine families. Class II engines also include SV and OHV engines that utilize catalysts, OHV engines that use Throttle Body Injection and EGR. Based on review of the Phase 1 certification database of emission data, it is calculated that 4 SV engine families would convert to OHV, 18 OHV engine families are to be improved, and five of the OHV engines converted to LPG for indoor use will need slight emission improvement. It is assumed that the LPG converters would be able to achieve emission reductions through use of emission reduced OHV engines and through optimization of their LPG regulation and catalyst system. The engine families incorporating emission reduction represent 47% of the engines in this Class.

Table 4-05 contains the resultant assumed phase-in of engine families per class per phase-in year, if applicable, and the corresponding technology change.[21] Table 4-06 contains the resultant number of engines that correspond to those engine families being improved. Table 4-07 shows the resultant assumed Phase 2 market mix for Class II engines.

[21] A special provision for small engine families of SV design exists for this rulemaking. The provision is that Class II engine families under 1000 engines are allowed to meet a higher standard of 24 g/kWh. This analysis found two small SV engine families.

Table 4-05

ASSUMED PHASE-IN SCHEDULE OF ENGINE FAMILY CHANGES
(Number of Engine Families)

CLASS	Specific Technology Change	2001	2002	2003	2004	2005	2006	2007
I	SV to OHV	--	--	--	--	--	--	11
	Improved OHV	--	--	--	--	--	--	8
II	Improved OHV	0	0	3	6	14	--	--
	SV to OHV	0	1	0	1	2	--	--

Note that not all engine families need improvement, therefore the numbers in this table do not add up to the numbers in Table 4-01.

Table 4-06

Production Volume (and % of Total) Represented by Engine Families

CLASS	Specific Technology Change	Full Implementation (1998 Sales Estimates)		
		# of Engines	% Within Tech Within Class	% Within Class
I	SV to OHV	6,975,149	97%	83%
	Improved OHV	381,405	52%	5%
II	SV to OHV	1,040,615	74%	33%
	Improved OHV	362,498	20%	12%

Table 4-07

Phase 2 Technology Mix in 2007
Engine Families Per Technology Type

CLASS	SV	OHV	SV w/ cat	OHV w/ cat*	TBI on OHV	2-stroke	TOTAL **
I	7	51	--	--	--	--	61
II***	21	122	2	5	2	--	152
TOTAL	28	173	2	5	2	3	213

* These engines include propane engines that are installed in equipment used indoors and must work to allow facilities to meet OSHA time measured safety levels for CO.
** This analysis assumes the same number of engine families before and after Phase 2. There is the possibility that some engine families may be dropped or some may be combined in order to reduce costs.
*** There is one OHV engine with EGR used on a utility vehicle.

Table 4-08

Assumed Phase 2 Sales per Class and Technology Type
(Based on Phase 1 Database as of September 1998)

CLASS	SV***	OHV	SV w/ cat	OHV w/cat	TBI on OHV	2-stroke	TOTAL *
I	247,147	8,157,345	--	--	--	conf**	8,404,492+
II	386,722	2,737,921	conf	3,125	conf	--	3,127,768+
TOTAL	633,869	10,895,266	conf	3,125	conf	conf	11,532,260

* This analysis assumes no loss in engine sales
** Some of the blocks state "conf" to honor confidentiality if only one or two companies contribute to the total number of engine families in that block.
***SV families <1000 units, those that are geared solely to snowblowers, and several others remain unchanged.

4.2 Variable Hardware and Production Cost Estimates per Engine Class

EPA developed cost estimates for variable hardware and production costs for Phase 2 engines. The cost estimates were taken from the cost report from ICF and EF&EE (Ref. 2) and manufacturer information for the variable hardware cost and production cost for each emission reduction technology per class and engine design (see Tables 4-09 and 4-10).

Table 4-09 lists the assumed variable hardware and production costs for each technology per engine class and engine design. The ICF and EF&EE cost study was used for cost estimates in the NPRM. ICF's cost estimate for SV to OHV conversion for nonhandheld engines have been adjusted since the NPRM. EPA received comments by one large manufacturer which pointed out several major items that were left out of the ICF cost study. As a result, EPA calculated a sales weighted average of the data for capital costs and variable costs for conversion from SV to OHV for Class I and II from manufacturer cost data of several companies.

Estimated costs for improved OHV engines were taken from ICF and EF&EE's report for several production model volumes. This analysis uses only one production volume estimate for all engine families per class per engine design. This was determined by choosing the production volume estimate that best represents the sales estimates presented in the Phase 1 certification database sales estimates.

Table 4-09

Estimated Variable Hardware Costs for Technology Changes

CLASS	ENGINE DESIGN	SPECIFIC TECHNOLOGY	HARDWARE VARIABLE ($)	PRODUCTION VARIABLE($)	TOTAL VARIABLE
I	Improved OHV	Piston and Piston rings improvement	$2.25	$0.00	$2.25
		Improved Combustion and Intake System	$0.00	$0.00	$0.00
	SV to OHV	Additional parts in OHV, assembly	$4.56	$9.12	$13.68
II	OHV	Piston and Piston rings improvement	$2.25	$0.00	$2.25
		Improved Combustion and Intake System	$0.00	$0.00	$0.00
	SV to OHV	Additional parts in OHV, assembly	$7.33	$14.67	$22.00

NOTE: Technology changes with $0.00 indicate that there is no variable cost assumed for this technology.

4.3 Fixed Production and Research and Development Cost Estimates per Engine Class

Many of the technology changes required to meet Phase 2 standards require the manufacturer to expend capital on production and research and development. Production costs include new tooling machines, molds, dies and other equipment needed to produce the changed or additional parts; the costs of changing the production line to accommodate the changes in the assembly process and in the size and number of parts; and the costs of updating parts lists. Research and development costs include engineering time and resources spent to investigate emissions on current engines, and design and prototyping of engine design changes and/or emission reduction technology. At the first sign of stringent regulations by the California ARB, small engine manufacturers have already begun research and development activities to address emission reductions on a portion of their production. EPA has not removed any costs for manufacturers to meet California ARB's standards for 2000 and beyond since costs to apply the technologies to nationwide sales is a substantial investment.[22] If EPA were to remove any costs associated with CARB Tier II, the research and development costs for engines used in CARB's preempted farm and construction applications would still be applied to the federal rule.

Review and analysis of EPA Phase 1 certification database indicate that Class I engines will require R&D for a limited number of existing engine families, see Table 4-04. The technologies are already known for OHV engines are currently produced, however in lower volumes. Steps for emission durability are known by the fact that commercial market engines have shown lower deterioration than consumer use products(Ref. 3).

Cost information was taken from the 1996 cost study by ICF and EF&EE as well as manufacturer data. The manufacturer data was used to estimate the cost of conversation from SV to OHV engine designs and the ICF and EF&EE cost estimates were used for improved OHV design. The report by ICF and EF&EE contain estimates for several sizes of engine families, 1.2 million, 200,000 and 35,000. The estimated sizes of engine families is mostly used by ICF and EF&EE to calculate fixed cost/engine for their report. This analysis uses Phase 1 engine family production data which varies from engine family to engine family and therefore the cost estimates are not influenced very much by the choice of

[22] If EPA were not setting such standards, it is possible that manufacturers would just manufacture a portion of their product line for the California market.

engine family size in the ICF and EF&EE report. In cases in which it did affect the base estimate (ie: more machines required for the 200,000 case versus the 35,000 case), the cost estimate for the 200,000 case was used for all Class I engine families and the 35,000 case was used for all Class II engine families as described below. This analysis amortizes all costs to 5 years whereas the ICF and EF&EE report amortizes most costs to 5 years and tooling costs to 10 years.

For Class I and Class II, several SV engine families are expected to be converted to OHV design and an even larger number of OHV families are expected to incorporate emission improvements. For the cost of conversion from SV to OHV engine design per class, EPA examined confidential data from two manufacturers to obtain an average capital cost which would at least be representative for these manufacturers. The Phase 1 database was then examined for any other engine manufacturers that would be expected to convert an engine family from SV to OHV design. For Class I two SV engine families are produced by other manufacturers and, for Class II, one SV engine family. However, due to the low volumes of these engine families, it was assumed that the lines would not be updated, but that production on existing OHV lines would be increased to take over the loss of SV production. The number of engine families that would be expected to convert from SV to OHV was multiplied by the average capital cost per engine family and then that number was divided by the total Phase 1 SV engine families to arrive at an average cost of conversion per Phase 1 SV family.[23]

Improvements in new engine and emission durability for OHV will also

[23] This was done due to the fact that the cost effectiveness spreadsheet (found in Appendix E) multiplies the capital costs times the number of SV engine families to be improved regardless of whether they will actually be converted to OHV or discontinued.

likely require some fixed costs for improved combustion chamber and intake system, and improved piston and ring design and bore smoothness. Eight Class I and 22 Class II OHV families assumed to require emission improvements. Seven of eight Class I families and all of the Class II families were close to the 35,000 case.[24] Therefore, the 35,000 case was used for all engine families in Class I. Cost estimates for the changes assumed for these engines did not differ between the 200,000 and 35,000 cases for the combustion chamber redesign and intake system. The cost was $395,000 per engine family. Cost estimates for the piston, ring design and bore smoothness technologies was $310,000. The 35,000 case was $75,000 less than the 200,000 case.[25]

Costs that were limited in the analysis include any additional label lettering, updated service manuals (writers, documentation) and seminars for dealers and training for technicians. Updated service manuals and training were limited due to the possibility that industry will find more inexpensive ways to meet the Phase 2 regulations and therefore, any overestimation of cost would account for these costs. It is also expected that the service manual updates and trainings can be incorporated during the phase-in years and prior to the phase-in years as these activities take place due to ongoing manufacturer model changes.[26]

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24 It should be noted that 13 Class II and one Class I engine family were less than 3,000 units and therefore one could consider whether the full changes contemplated here would be incurred by these engine families.

25 The piston improvement, from die-cast to permanent-mold casting, for a more heat tolerant (less distortion) design assumed purchasing pistons from an outside source. If an engine manufacturer produced the pistons itself, the cost may be lower.

26 The majority of technologies for the nonhandheld engines are currently being utilized in engine families and therefore are not new to the technicians or dealers.

The extra lettering on the label was not included for there are several options available to the manufacturer which include use of California ARB's label nationwide. While the California ARB label is not yet complete, there is discussion of a much simplified label being used.

Table 4-10

ASSUMED FIXED COSTS FOR NONHANDHELD PER MODEL($)*

CLASS	ENGINE DESIGN	TECHNOLOGY	FIXED PRODUCTION	FIXED R&D	TOTAL FIXED COSTS
I	SV	SV to OHV	$16,770,000	$0	$16,770,000
	OHV	Improved Combustion and Intake System	$110,000	$185,000	$295,000
		Improved Piston and Ring Design and Bore Smoothness	$65,000	$245,000	$310,000
II	SV	SV to OHV	$18,440,000	$0	$18,440,000
	OHV	Improved Combustion and Intake System	$110,000	$185,000	$295,000
		Improved Piston and Ring Design and Bore Smoothness	$65,000	$245,000	$310,000

*Per engine family as determined in this analysis.

The cost estimate for research and development cost for improved combustion chamber and intake system for Class II OHV engines has been modified from the cost estimate in the ICF and EF&EE cost study. In the report, ICF and EF&EE estimate that two engineer years would be required to carry out the research development and design work involved in improving combustion and intake systems for the OHV engines based. This is based on the assumption that engine manufacturers have more experience with SV than OHV engines. EPA's review of the Phase 1 certification database, in comparison to the Phase 2 standard, shows that majority of engine manufacturers with the OHV experience will be incorporating this technology. As a result, the cost estimate has been reduced from $200,000 to $100,000 for the engineering portion of the total research and development cost for this technology.

4.4 Equipment Cost Estimates

Small engines are utilized in a wide variety of equipment from lawnmowers to garden tractors and generator sets, see Table 4-11

Table 4-11
Common Equipment Types Per Class

Class I	Class II
mowers tiller snowblower generator	tractor mower comm turf generator snowblower pumps

The wide variety of equipment designs, and the varying ease of designing equipment which use small SI engines, presents a challenge when estimating costs for these classes of engines. Thereby, the analyses have been performed on the most common equipment types for each class as shown in Table 4-11 Data for the analysis is provided by the 1996 PSR OELINK database(Ref. 4), the EPA Phase 1 certification database and the ICF cost study (Ref. 2). Results from this analysis are shown in Table 4-12. These estimates are an average over all equipment engine families, types and sales per class. The actual cost increase will depend on the equipment application and flexibility of the original equipment design to incorporate a new engine.

It should be noted that this analysis has assumed the full cost of die replacement and this likely results in overestimated costs. Changes to an equipment manufacturers line may be made more economical with planning. For instance, the timing of new dies in relation to the useful life of the existing dies can minimize an equipment manufacturer's costs. According to ICF, typical equipment dies last 3-10 years and produce upwards of 250,000 units. Due to the fact that there is substantial lead time for this rulemaking as well as the phase-in period for incorporation of OHV class II engines, it is expected that equipment manufacturers will purchase new dies near or at the end of the useful life of their existing dies. Equipment manufacturers will likely have to work closely with engine manufacturers to ensure the availability of OHV engine designs in a reasonable time frame for equipment engineering requirements. The majority of the nonhandheld industry manufacturer either the engine or the equipment.

Estimates for equipment changes have been based on the estimated engine changes for Class I and Class II engines which are the conversion of large production SV engine families to OHV [27] and improved OHV. Changes for equipment using Class I or Class II SV engines are expected to range from nothing at all to extensive, depending on the particular design of the piece of equipment and current engine design used in the piece of equipment. The main reason for equipment changes is that the OHV engines are taller than SV engines due to the fact that the valve train is not on the side of the engine block but in the cylinder head. Based on the ICF report (Ref. 2), some equipment will require

[27] Although it is possible that in the 8 years following the required implementation date, industry will develop a solution alternatively to conversion to OHV.

that OHV engines be reoriented 90 degrees from the SV engine so that the cylinder is parallel to the center line of the equipment. This requires changes including mounting holes, controls, exhaust and oil drains. Lawn tractors traditionally have a hood covering over the engine and thereby the hood will need to be lengthened. A new injection molding die to create a redesigned plastic hood is assumed to be required. Other costs are similar to the rear engine rider. Lawn and garden tractors typically always have the cylinder head facing forward and have room under the hood to handle a V-twin OHV engine. Generators and pumps are usually encased in frames that hold the engine and other parts of the equipment. The taller OHV may require that the frame or case around the equipment be redesigned, developed, tooled and fabricated. The fuel tank may also need to be redesigned and possibly the muffler relocated. No costs were assumed for equipment currently using Class I or Class II OHV engines for changes to these engines are expected to be minor and internal, thereby not influencing outer dimensions or operating parameters.

Data on the number of equipment manufacturers that use Class I or Class II SV engines, and the number of models per manufacturer, was obtained from the 1996 PSR database. For Class I, EPA utilized the contents of the PSR database which pertained to equipment manufacturers using Class I SV engines.[28] For Class II, EPA utilized only the high volume equipment producers (account for approximately 95% of the engines) from the PSR database as the basis of the costs for this rule. This decision was based on EPA's work with ICF, to analyze the impacts on small production volume equipment manufacturers who were thought to be using Class II SV engines(2). This analysis revealed that the

[28] Discussions with several Class I equipment manufacturers revealed that large volume consumer focused businesses may incur design changes due to their equipment design to be unique in the marketplace. Manufacturers of niche markets may incur less costs in switching from SV or OHV engine due to their need to be flexible in the marketplace.

majority of small business equipment companies had already switched from SV to OHV engines for market competitive reasons (2) or were out of business. A summary of the costs used for this analysis is presented in Table 4-14.

Table 4-12

ESTIMATED COSTS PER NONHANDHELD EQUIPMENT APPLICATION

Application[29]	Fixed Costs (per line)	Variable Costs (per Unit)	Equipment Changes
Walk Behind Lawnmowers	$70,000	$0	Engineering work and die replacement to redesign deck if not sufficient space for OHV engine
Rear Engine Riders	$50,000	$0	mounting holes, longer control wires, modified exhaust/air filter positioning, and relocation of oil drains
Commercial Turf 12hp >12 to 16hp 16 to 25 hp	 $1,000 $600,000 $100,000	 $0 $0 $12	-mounting holes, controls, exhaust and oil drains -new injection molding die to create a redesigned plastic hood -additional baffling
Other Agricultural Equip	$100,000	$0	
Leaf Blower/Vacuum	$50,000	$0	
Tillers	$50,000	$0	Modified exhaust positioning, relocation of oil drains, and a redesigned baffle
Generator Sets	$100,000	$0	Frame or case be redesigned, developed, tooled and fabricated. Redesigned fuel tank and relocated muffler
Pumps	$50,000	$0	
Roller, Concrete Saw	$50,000	$0	
Other	$50,000	$0	

Source: ICF report (Ref. 5)and equipment manufacturer discussions

29 No costs are assumed for modifications to snowblowers for they are not required to use engines certified to the HC+NOx standards due the special provision in the Phase 2 rulemaking.

4.5 Fuel Savings and Impacts on Performance

Section 213(a)(3) of the 1990 Clean Air Act Amendments requires that EPA consider factors including energy, noise and safety associated with the application of technologies estimated for this rulemaking. This section discusses EPA's assessment of the effects of this proposal on energy (i.e., fuel economy) and power. Impacts on noise, safety and maintenance can be found in Chapter 3.

4.5.1 Fuel Consumption

EPA estimates that the conversion of SV engine designs to OHV engine designs or the use of other emissions technologies to reduce new engine out emissions and emissions durability, will result in a decrease in fuel consumption.

Estimates for Phase 2 engines were based on the estimated fuel consumption from Phase 1 engines found in the Phase 1 Regulatory Support Document (see Table 4-15) Tables 4-13 and 4-14 contain information found on brake specific fuel consumption of typical Class II OHV that are close to the Phase 2 standard and Class II SV engines. Industry has also submitted a limited amount of BSFC information on Phase 1 engines. All of this information was considered and fuel consumption values for Phase 2 OHV and SV engines were determined, see Table 4-19. Note that the value for Class II SV engines does not change from the value used in Phase I. This is based on the fact that the NONROAD model, that calculates emission benefits and fuel savings, considers that all SV engines will become OHV engines or have OHV like characteristics (ie: emission benefits, fuel usage, etc.). Fuel savings for Class I SV conversion to

OHV were assumed to be the same as those for Class II SV engines. Also, no assumption was used for changes in fuel consumption as engines age over time.

Table 4-13

Fuel Consumption of OHV Class II Engines
Close to the Phase 2 Standard

ENGINE	BSFC (g/kWh)	Reference
11 hp (HC+NOx emissions 1.3 g/kWh above Phase 2 stds with assumed 1.3 df)	493	SAE 910560
200cc, 4.5 hp (close in cc to a Class II engine)	447	EMA/EPA Round Robin Testing (avg of 10 mfr's and 2 engines) , 1997
570cc, 13 hp	465	EMA/EPA Round Robin Testing (avg of 6 mfr's and 2 engines), 1997

There is no BSFC data in the EPA Phase 1 certification database.

Table 4-14

Fuel Consumption of SV Class II Engines
(Engine Meets Phase 1 Standards)

ENGINE	BSFC (g/kWh)	Reference
465cc, 6.7 hp	520	Phase 1 RSD, Table 1-11

There is no BSFC data in the EPA Phase 1 certification database.

The values listed in Tables 4-15 contain the fuel consumption values utilized to estimate fuel savings. These data were inputted into the NONROAD model to calculate the fuel savings per year for all equipment types given scrappage rates, growth, engine power, engine load factor, residential or commercial usage and useful life. Additional calculations for number of barrels reduced and resultant cost savings are presented in Chapter 7 on Aggregate Costs and Economic Analysis.

Table 4-15

Phase 1 and Phase 2 Fuel Consumption Estimates Per Engine Per Class (g/kWh)

CLASS	SV	OHV	OTHER
I	560	475	475
II	528	450	450

Source: Small Engine Phase 1 RSD(Ref. 6)

4.5.2. Power

For Class I and II engines, power is expected to increase, however this is partially influenced by market demands which the industry stated has been asking for more powerful engines.

Chapter 4: References

1. "Investigation and Analysis of Low Emitting Small Spark-Ignited Engine Designs <19KW", Southwest Research Institute, SWRI Report 7633-807, October 1996, EPA Air Docket A-93-29, Docket Item #II-A-03.

2. ICF and Engine, Fuel and Emissions Engineering, Incorporated; "Cost Study For Phase Two Small Engine Emission Regulations", Draft Final Report, October 25, 1996, EPA Air Docket A-93-29, Docket Item #II-A-04.

3. "Tier 1 Deterioration Factors for Small Nonroad Engines", Sept., 1996, a report by Air Improvement Resources, available in EPA Air Docket A-96-55, Docket Item II-D-11.

4. Power Systems Research, OELINK database, St. Paul, Minnesota, 1996.

5. ICF Incorporated, "Small Business Impact Analysis of New Emission Standards for Small Spark-Ignition Nonroad engines and Equipment", Final report, September 1997, EPA Air Docket A-96-55, Docket Item # II-A-01.

6. US EPA, "Regulatory Impact Analysis and Regulatory Support Document Control of air Pollution; Emission Standards for New Nonroad Spark-Ignition Engines At or Below 19 Kilowatts", May 1995, EPA Air Docket A-93-25, Docket Item # V-B-01.

Chapter 5: Compliance Program Costs

The Phase 1 rule is a "certification only" rule in that the standards need only be met at certification, prior to production, and the engine families are subject to SEA. This final Phase 2 regulation brings the concepts of useful life and emission deterioration to the emission regulation of small spark ignited engines at or below 19kW. These program elements work to assure that actual production engines meet standards throughout their useful lives.

The costs accounted for in this chapter are those costs that are incurred in this rulemaking for certification and compliance. Appendix C contains the detailed cost spreadsheet results for each compliance program. A summary of the cost results for each program per engine class and the overall cost methodology is included at the end of this chapter. Reductions in costs allowed under the regulations for small volume engine manufacturers or small volume engine families are not accounted for in this analysis.

5.1 Background

General assumptions and cost estimates for the various compliance programs for nonhandheld engines are described herein.

5.1.1 Engine Families

The program costs are calculated on the number of engine families per class. The number of engine families per class is obtained from the EPA's Phase

1 certification database as of September 1998 (Appendix C contains nonconfidential database information). While this is a reliable source for the number of engine families for the Phase 1 program, EPA expects that manufacturers, during the years in which the Phase 2 program is implemented, may reduce the number of engine families in response to the added cost of the Phase 2 requirements, or increase the number of engine families in response to new market opportunities. However, it is difficult to predict the change in the number of engine families at this time. Consequently, this analysis makes no assumption as to a different number of engine families per class from the Phase 1 database. The costs associated with record keeping requirements for each program is included in the ICR submitted with this rulemaking.

5.1.2 Alternative Fueled Engine Families

EPA's Phase 1 database shows that there are several engine families of the same engine displacement and technology that are certified on gasoline and alternative fuels (LPG, CNG). Each of these engine families are accounted for in all compliance programs. The alternative fuels often require specific fuel metering systems and run leaner than gasoline, therefore new engine settings and deterioration are likely different comparing engine families operating on gasoline with those operating with alterantive fuel.

5.1.3 Assumed Costs

Each engine family must be bench aged to the chosen useful life. Emission testing will be performed after initial break-in and at the end of the engine aging. Costs used in this analysis are listed in Table 5-01. Small volume engine families and engine families of small volume manufacturers may utilize assigned deterioration factors for the specific engine design. This analysis assumes that no small volume engine family or small volume engine manufacturer uses an assigned df. Therefore, this analysis is a worst case scenario that is based on over-compliaince with the regulations, rather than on the minimum costs actually imposed by the rule.

Table 5-01

Common Costs Among Compliance Programs

TOPIC	ESTIMATE	RESOURCE
Hours for break-in	Class I - 4.4 Class II - 4.8	Average from EPA Phase 1 certification database.
Bench age ($/hour)	$15.00	EMA/OPEI NPRM Comments
Emission test ($)	$300.00	EPA estimate from "Cost Study for Phase Two Small Engine Emission Regulations", ICF and EF&EE, October 25, 1996 (1).

5.2 Certification

The Phase 2 rule continues the fundamental certification program that began in Phase 1. The most significant additional component to certification that affects all engines under Phase 2 is the need to predict emissions for an engine family to its full useful life. This can be done, for all engine classes, through bench aging up to the chosen useful life hours. Aging an engine can also be done on a piece of equipment operating in a normal in-use situation. A manufacturer choosing to age its engine in such a manner might reduce the cost to the engine manufacturer as the in-use evaluation could be coupled with other needs. However, this potentially lower cost option is not analyzed here since the costs to the manufacturer would vary greatly. A deterioration factor must also be established for the engine family to be used in conducting the Production Line Testing program, and, therefore, the engine must be tested two times. The first time is just after break-in and the second is at the end of its useful life.

5.2.1 Cost Inputs and Methodology

The number of engine families chosen for the various useful lives was determined through examination of EPA's Phase 1 certification database, as of September 1998, and assumptions of each engine manufacturer's market tendencies (see Tables 5-02 and 5-03). For the Class I 125 hour and Class II 250 hour categories, EPA included engine manufacturers who sold primarily to the consumer market. For the Class I 500 and Class II 1000 hour categories, EPA included primarily the engine manufacturers that sold to the commercial market and/or were related to the automotive industry. The engine manufacturers that were not related to the automotive industry and sold residential/commercial type engines were included in the middle categories of 250 and 500 hours for Class I and II, respectively. This analysis assumes carryover of certification after the phase-in of the Phase 2 standards. Table 5-02 contains the estimates used in this analysis.

EPA assumes that complete re-certification (i.e., not including carryover) occurs once for all engine families and twice for a percentage of Class II engine families. This is assumed due to two factors, 1) the presence of an averaging, banking and trading program not available in Phase 1 requires all engine families must be certified the first year to which they are applicable, whether or not they are in their final Phase 2 configuration, and 2) Class II standards become more stringent from 2001-2005 and not all engine families need be emission improved in the first year of implementation. EPA has based the percentage of recertified Class II engine families based on an analysis of each manufacturers' Phase 1 certification information and some assumed engine df's. EPA assumes carryover for certification will be used until the engines are updated.

Costs for the emission tests, break-in hours, and bench aging (on an engine dynamometer) are listed in Table 5-01. A summary of the costs per year (2001-2007) per class for certification requirements are listed in Table 5-04. Certification costs are treated as fixed costs and are amortized at a rate of 7% over 5 years.

Table 5-02

Number of Phase 1 Certification Families per Useful Life Category Assumptions

Nonhandheld

CURRENT CLASS	USEFUL LIVES			
	125	250	500	1000
I-SV	16	2	0	--
I-OHV	11	11	18	--
II-SV	--	13	13	1
I-OHV	--	20	73	32

This analysis accounts for those SV engine families assumed to be converted to OHV for Phase 2.

5.3 Averaging, Banking and Trading

Averaging, banking and trading (ABT) will enable manufacturers to comply with the HC + NOx standard on a production-weighted average basis. By essentially allowing a manufacturer to produce some engines that exceed the standards when it can generate or obtain offsetting credits from engines that are below the standards, the ABT program will reduce the capital costs of complying with the Phase 2 standards. Manufacturers will be able to distribute capital across engine families to obtain the most cost effective emission reductions, as long as the ABT calculation is acceptable to prove compliance to the standards. The optional ABT program adds no costs to the certification process, but does necessitate limited tracking of engines for credit accounting purposes. Related costs are addressed in the certification ICR's for this program. While the program for ABT is optional for all engine manufacturers, this analysis assumes that all engine manufacturers will utilize this option. The analysis also assumes that manufacturers will work to optimize the number of engine families that will need to be improved to meet the emission standards in this final rulemaking. Optimization is achieved by choosing those engine families that have high emission rates and high production volumes that will result in influencing the manufacturers' production weighted average the most.

5.4 Production Line Testing

5.4.1 Rationale for Production Line Testing

The certification testing program is performed on prototype engines selected to represent an engine family. A certificate of conformity indicates that a manufacturer has demonstrated its ability to design engines that are capable of meeting standards. Production line testing indicates whether a manufacturer is able to translate those designs into actual mass production engines that meet standards.

Manufacturer run Production Line Testing (Cum Sum) is a new program to the EPA requirements for small engines. Therefore all of the costs are allocated to the Phase 2 program. Note that engine manufacturers will be conducting quality audit testing for CARB and the same data will be acceptable EPA's PLT program[30]. However, it is likely that manufacturers do not sell all of their product line for use in California and therefore will incur additional costs to test their whole product line. Since the estimated volume per engine family per manufacturer produced for sale in California is unknown, and likely varies amongst engine manufacturers, no costs were subtracted for CARB quality audit testing; therefore PLT program costs are likely an overestimation of the real costs incurred under this rulemaking.

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[30] If the data are from 50 state engine families sold nationwide and if the test engines are appropriately selected and tested.

5.4.2 Cost Inputs and Methodology

EPA's analysis assumes that all engine manufacturers will conduct PLT for all engine families and that it is to be conducted on each engine family certified to the standard each year.[31] Testing will be performed on 2-30 engines. A value of 7 tests per engine family are assumed for this analysis.[32] PLT is performed on new engines and therefore an initial engine break-in and emission test is required.

For Class I engine families, all new engine families after August 1, 2003 are to meet the new standard and each manufacturer is to meet the standard by 2007, on average, for its entire Class I product line. This analysis assumes that no new engine families will be certified between 2003 and 2007 and that all will begin in 2007.[33] Therefore, PLT begins in 2007 in this analysis for Class I engine families; see Table 5-03.

For Class II engines, the PLT program begins in 2001 for all engine families and all must be certified to Phase 2 standards, on average, in 2001 , see Table 5-03. The Class II standard is tightened from the years 2001-2005. To meet the decreasing standards, it is assumed that an equal number of Class II OHV design engine families will increase as to the number of Class II SV design engine families that will decrease. As explained in 5.1.1, this analysis assumes that the

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[31] The rule, however, allows some relief from PLT testing for families subjected to in-use testing.

[32] A number of 7 was chosen based on the fact that industry has been doing quality audit data for California ARB and it is assumed that by the time this rulemaking is in place that manufacturers will have made adjustments in their production for meeting this requirement on the minimum number of engines possible. While 2 is the minimum number, a number of 7 allows for some leeway.

[33] Since the California ARB standardshas this provision beginning in 2002, it is expected there will be very few new engine families near the 2003 timeframe.

overall number of engine families will stay the same as the number for Phase 1 certification (as of September 1998).

The average break-in hours for each engine per class, emission test costs and break-in costs were utilized in this analysis as described in Table 5-01. A summary of the costs per year (2001-2027) per class for the requirements in this section are listed in Table 5-05.

Table 5-03

Assumed Engine Family Eligible for PLT Testing Per Class Per Year

YEAR	I	II
2001	--	152
2002	--	152
2003	--	152
2004	--	152
2005	--	152
2006	--	152
2007	58	152

PLT performed for each engine family, regardless if same engine certified with various fuel specifications.
The number of engine families is obtained from EPA's Phase 1 certification database as of September 1998.

5.5 Voluntary In-Use Testing

5.5.1 Rationale for Voluntary In-Use Testing

This rule does not include any required in-use testing on Phase 2 certified engine families, however, it does include a provision for a percentage of voluntary in-use testing in lieu of a percentage of mandatory PLT testing. Costs for this program (engine selection, aging and emission testing) are not accounted for in this analysis for several reasons. The first is that manufacturers have claimed that in-use testing is very costly, especially when compared to a one time new engine test as is done in PLT. Therefore, manufacturers would be reluctant to conduct such a test unless it was in conjunction with other in-use evaluation. If a manufacturer does decide to submit data from in-use testing, manufacturers will likely take it from in-house durability test programs. This testing is no additional cost to the manufacturer with the exception of one emission test, which is already accounted for in this analysis under PLT. Since the amount of emission testing reuqired under this voluntary in-use testing program would be less than typically expected under the PLT program, manufacturers electing to pursue this option would likely benefit from a lower program cost than estimated here.

5.6 Summary Tables

5.6.1 Cost Methodology

The costs for each program were estimated in 1997. A 4% inflation rate is included for each year to apply 1997 costs to future years[34]. Tables 5-04 to 5-05 present the estimated costs per compliance program as incurred through 2012 (see Appendix C for complete analysis to 2027 in the form of recovered costs). The total estimated compliance program costs are presented in Table 5-06. The administrative costs for these programs are included in the ICRs for this final rulemaking.

Chapter 7 determines the uniform annualized cost and cost per engine for this rulemaking (with costs as recovered).

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[34] Based on an average of the percentage change in consumer prices from 1984-1993. (Source: Statistical Abstract of the United States 1994, September 1994 from the U.S. Department of Commerce)

Table 5-04
Resultant Fixed Certification Costs Per Class Per Year
As Incurred, With Inflation

CLASS I	CLASS II
$0	$1,628,805
$0	$5,168
$0	$29,108
$0	$63,383
$0	$136,705
$0	$0
$319,964	$0

Table 5-05
Resultant Production Line Testing Costs
As Incurred, With Inflation

YEAR	CLASS I	CLASS II
2001	$0	$583,733
2002	$0	$607,085
2003	$0	$631,334
2004	$0	$656,581
2005	$0	$682,877
2006	$0	$817,771
2007	$312,500	$850,464
2008	$325,019	$884,535
2009	$338,003	$919,871
2010	$351,536	$956,700
2011	$365,597	$994,966
2012	$380,206	$1,034,725

Table 5-06
Total Compliance Program Costs Per Class
As Recovered, With Inflation

Year	Class I	Class II
2001	$0	$980,984
2002	$0	$1,004,335
2003	$0	$1,028,584
2004	$0	$1,053,832
2005	$0	$1,113,468
2006	$0	$851,112
2007	$390,536	$883,805
2008	$403,055	$917,876
2009	$416,039	$953,212
2010	$429,572	$956,700
2011	$443,633	$994,966
2012	$380,206	$1,034,725

Chapter 5: References

1. ICF and Engine, Fuel and Emissions Engineering, Incorporated; "Cost Study For Phase Two Small Engine Emission Regulations", Draft Final Report, October 25, 1996, EPA Air Docket A-93-29, Docket Item #II-A-04.

Chapter 6: Environmental Benefit

This chapter presents the methodology used by EPA to quantify the emission reduction benefits that would be realized through the adopted Phase 2 HC+ NOx in-use emission standards for small SI Nonhandheld (NHH) engines. Benefits, in terms of HC+NOx emission reductions, are presented in the form of aggregate benefits by engine class. These benefits are estimated in terms of future 49-state emission reductions from affected small SI engines used in a variety of equipment types. Estimated benefits illustrate the potential future effect of the adopted standards on the emission inventory. Air quality benefits are discussed qualitatively for all pollutants.

Many of the detailed results discussed below are presented in separate tables included in Appendix F. EPA has replaced the model that it used in the NPRM analysis with a new computer model called the NONROAD model, to predict the emissions impact of the new standards that have been finalized. Much of the information used in the new NONROAD model is the same as the information used in the NSEEM model for the NPRM. The following sections highlight areas where differences exist between modeling performed for the proposal and that for the final rulemaking.

For a complete description of EPA's NONROAD model, the reader is referred to the technical reports and program documentation prepared by EPA in support of NONROAD model development. Copies of the technical reports and model documentation are available at EPA's web site for nonroad modeling--- http://www.epa.gov/omswww/nonrdmdl.htm.

6.1 Estimated Emissions Reductions

To estimate the average annual emissions at baseline (Phase 1), EPA calculated the tons per year estimates based on revised Phase 1 Emission Factors. The in-use factors have now been determined as a multiplicative rather than an additive (as was the case for the Phase 1 rule-making) function of new engine emission factors and a deterioration factor which is a function of engine hours of use. As before, total emissions are calculated for each type of equipment using the equation :

$$MASS_{i,j}=N_{i,j}\times HP_{i,j}\times LOAD_i\times HOURS_i\times EF_{i,j}$$

In the above equation,

$N_{i,j}$	-	nationwide population of i^{th} equipment type using engine j
$Hp_{i,j}$	-	average rated horsepower of engine j used in equipment type i
$LOAD_i$	-	ratio (%) between average operational power output and rated power for the i^{th} equipment type
$HOURS_i$	-	average annual hours of usage for the i^{th} equipment type
$EF_{i,j}$	-	brake specific in-use emission rate (kilowatts/hr) for engine type j used in equipment i
$MASS_{i,j}$	-	annual nationwide emissions (grams) for the j th engine type used in equipment i

For the benefits analysis described here, EPA performed separate calculations for the major equipment categories, each one of which is equipped with one or more of 6 different engine types with average power ratings as displayed in Table F-01. Population and activity information used to construct the inventories relied predominantly on data available in a commercially available marketing research data base that includes most types of nonroad equipment (1). This information is presented in Tables F-02 and F-03.

6.1.1 Aggregate HC+ NOx Reductions

The calculation of aggregate HC+ NOx reductions is described in this section. The calculation takes into account U.S. population of small SI NHH engine/equipment types, hours of use, average power rating and related equipment scrappage rates as described below. Along with estimated values for Phase I in-use engine emission rates and adopted Phase II in-use engine emissions standards, EPA has determined nationwide annual emissions under the baseline and controlled scenarios through calendar year 2027.

6.1.1.1 In-use Population --In order to estimate future emission totals, some projections of future populations of Phase1 and Phase 2 controlled engines are needed. The NONROAD model has determined population estimates of nonroad equipment covered by the adopted standards using certain growth factors. For the base population estimates, the NONROAD model uses the 1996 population estimates from the Power Systems Research (PSR) PartsLink database, with the exception of lawnmower engines. For this category of engines a reality check was done using the certification database from Phase 1 production estimates for 1998 lawnmowers. For this rule making, the population estimates were adjusted to exclude engines that are covered by California's Small Off-Road regulations.

6.1.1.2 Growth Estimates -- The NONROAD model projects future year (post-base year) equipment populations by applying a growth rate to the base year equipment population. The determination of the growth rate uses a methodology which is different from that used for the Phase 1 rule making. For a detailed description of population growth in the various categories of Nonhandheld Equipment the reader is referred to an AWMA paper presented by EPA at the AWMA Emission Inventory Conference, New Orleans, LA on 12/9/98 titled "Geographic Allocation and Growth in EPA's Nonroad Emission Inventory Model".

However, it should be recognized that, while national growth is measured at the level of the economy as a whole, growth in specific areas of the country is likely to vary from area to area in response to the specific demographic and commercial trends in those areas. These effects should be taken into account in estimating growth at the local level.

6.1.1.3 Scrappage-- The NONROAD model uses a scrappage curve to determine the proportion of equipment that has been scrapped as a function of equipment age. The default scrappage curve used in the NONROAD model is based on a cumulative Normal Distribution representing accumulated scrappage at various ages. The scrappage curve is scaled to the average lifetime of the equipment such that half of the units sold in a given year are scrapped by the time those units reach the average expected life and that all units are scrapped at twice the average life expectancy. The median life of the different Nonhandheld equipment types are presented in Table F-03.

6.1.1.4 Emission Factors -The in-use emission factors for the pre-control (Phase 1) scenario were recalculated based on revised new engine values obtained from EPA 1998 Phase 1 Certification database. For the current (Phase 2) scenario, the new engine emission factor values were back-calculated using 1) the adopted in-use emission factors (Phase 2 standards) and 2) a multiplicative deterioration factor determined from the AIR database as described in sections 3.2.131 and 3.2.141.

The deterioration factors developed by AIR for Phase 1 engines were not used in the NONROAD database for the Phase 2 rulemaking for they were based on accelerated aging and not real world consumer use[1]. The deterioration values for HC, NOx and CO were taken from the original Phase 1 rulemaking. The ratio of maximum emission level and the new engine level, from Phase 1 engines in the Phase 1 rulemaking, was used as a multiplicative deterioration factor in the NONROAD model. This value was used in the nonroad model DF equation, see below, to equal “1+A”. This methodologyfor determining deterioration factors was applied to both Phase 1 and Phase 2 scenarios and was used only for HC and CO. Aall NOx deterioration factors were set to 1.0 based on recent data, from AIR, which shows that NOx does not necessarily decrease over time.

The exhaust emission factors for HC, NOx and CO along with those for Fuel Consumption are displayed in Table F-04. The table also lists the value of the constant A, the slope of the deterioration factor equation for all NHH engines, which takes the form:

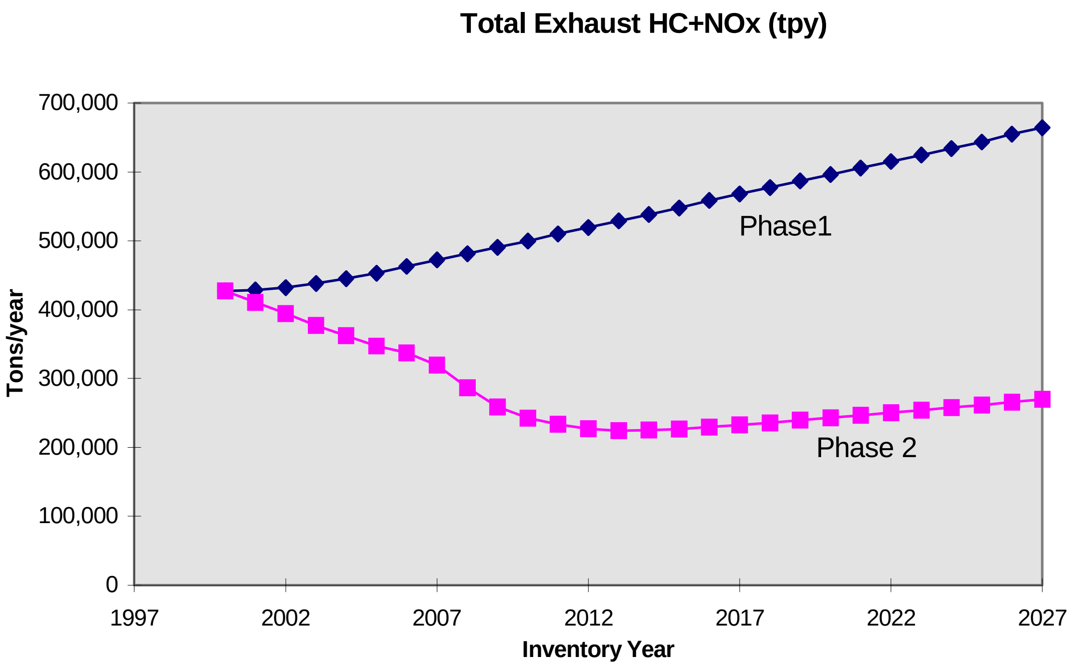
$$DF = 1 + A*(Agefactor)^{0.5} \quad \text{for agefactor} < 1.0$$
$$= 1 + A \quad \text{for agefactor} >= 1.0$$

For a detailed explanation of the deterioration factor function, the reader is referred to EPA's technical report no. NR-011 , titled "Emission Deterioration Factors for the NONROAD Emissions Model".

6.1.1.5 Emissions reductions -- EPA calculated baseline emissions using revised in-use emission factors for Phase 1. To obtain average annual emissions for engines controlled to the levels required to comply with EPA's final Phase2 emission standards , emissions were recalculated using post-control activity and in-use Phase 2 emission factors (Table F-04).

Table F-05 presents total annual nationwide emissions from engines addressed in this rule under both the baseline (Phase1) and the controlled (Phase 2) scenario. These are shown graphically in Figure 4-01 below.

Figure 4-01



In Figure 4-01, the annual benefit of the adopted regulation in terms of reduction in total exhaust HC+NOx is indicated by the difference between the upper and lower curves. The area between the curves represents the net benefit of the regulation during the time required for the nonroad small SI NHH engine and equipment fleet to completely turn over. The averaged results indicate that the standards represent on average a 59.4% reduction in annual HC+NOx emissions from NHH engines from Phase 1 levels to which the standards apply, by year 2027.

In addition, the adopted rule is expected to reduce Fuel Consumption in NHH engines by an additional 15% from Phase1 levels by year 2027 . This will have a beneficial impact on HC refueling losses.

6.2 Air Quality Benefits

Air quality benefits associated with reduction in VOC emissions are discussed in this section. Health and welfare effects of the pollutants as they impact on ozone formation are described.

6.2.1 VOC

EPA expects that reducing VOC emissions from small nonroad spark ignition engines will help to mitigate the health and welfare impacts of ambient HC on urban and regional tropospheric ozone formation and transport.

6.2.1.1 Health and Welfare Effects of VOC Emissions--VOC is the general term used to denote volatile organic compounds, a broad class of pollutants encompassing hundreds of specific toxic compounds, primarily Benzene and 1,3 Butadiene as well as aldehydes and gasoline vapors. As stated previously, VOC is a precursor to ozone for which the EPA has established a NAAQS. Measures to control VOC emissions should reduce emissions of hazardous air pollutants (HAPs). However, the magnitude of reduction will depend on whether the control technology reduces the individual HAPs in the same proportion that total VOCs are reduced. Since nonroad engines have significant VOC impacts , they are expected to have significant impacts on HAPs as well.

At elevated concentrations, VOC, a precursor to ozone, can adversely affect human health, agricultural production and environmental welfare. EPA is examining new directions and long-term efforts toward VOC reductions as well as approaches that are largely untried. One such step is the establishment of the new national ambient air quality standards (NAAQS), promulgated on July 17, 1997 for ground-level ozone. EPA phased out and replaced the previous 1-hour primary ozone standard (health-based) with a new 8-hour standard in order to protect against longer exposure periods. The new 8-hour standard is set at 0.08

parts per million(ppm) and is defined as a "concentration-based" form. EPA also replaced the previous secondary standard (to protect the environment, including agricultural crops, national parks, and forests) with a standard identical to the new primary standard.

Nonroad sources contribute substantially to summertime VOC and NOx emissions and winter CO emissions. The median contribution of total nonroad emissions to VOC and NOx inventories in summer, and CO inventories in winter, ranges from 7.4-12.6% VOC, 14.5-17.3% NOx, and 5.2-9.4% winter CO, depending on the area [4]. The lawn and garden equipment category is a major contributor to summertime VOC emissions, accounting for a median ranging from 2.4% to 4.7% of the total VOC inventory in tons per summer day, depending on the area.

6.2.2 Benzene

Benzene is a clear, colorless, aromatic hydrocarbon which has a characteristic odor. It is both volatile and flammable. Benzene contains 92.3% carbon and 7.7% hydrogen with the resulting chemical formula C6H6. Benzene is present in both exhaust and evaporative emissions. Data show the benzene level of gasoline to be about 1.5%. Some exhaust benzene is unburned fuel benzene. Some benzene also forms from engine combustion of non-aromatic fuel hydrocarbons. The fraction of benzene in the exhaust varies depending on control technology and fuel composition and is generally about 3 to 5%. The fraction of benzene in the evaporative emissions also depends on control technology and fuel composition and is generally about 1%.

Mobile sources account for approximately 65% of the total benzene emissions, of which 30% can be attributed to nonroad mobile sources (5). For nonroad engines, benzene was estimated to be about 3.0% of VOC emissions and 1.7% of evaporative VOC emissions. The split between exhaust and evaporative benzene emissions was assumed to be 80% exhaust to 20%

evaporative. Thus, the overall benzene fraction of nonroad VOC emissions was estimated to be 2.7%.

6.2.2.1 Projected Benzene Emission Reductions--Nonroad engines account for approximately 20% of the total benzene emissions with 45% attributed to highway motor vehicles and 35% to stationary sources. Many of the stationary sources attributed to benzene emissions are industries producing benzene as a by-product or use benzene to produce other chemicals.

Since benzene levels generally decrease proportionally to overall HC emissions, once newer emission control technology is applied, the amount of benzene produced by new small SI engines should be reduced further from Phase 1 after this new rule becomes effective.

6.2.2.2 Health Effects of Benzene Emissions--Health effects caused by benzene emission differ based on concentration and duration of exposure. EPA's Total Exposure Assessment Methodology (TEAM) Study identified the major sources of exposure to benzene for much of the U.S. population. These sources turn out to be quite different from what had previously been considered as important sources. The study results indicate that the main sources of human exposure are associated with personal activities, not with the so-called "major point sources". The results imply that personal activities or sources in the home far outweigh the contribution of outdoor air to human exposure to benzene. Since most of the traditional sources exert their effect through outdoor air, some of the nonroad small SI engine sources could explain the increased personal exposures observed. The TEAM Study is described in detail in a four-volume EPA publication (6) and in several journal articles (7-8) .

The average ambient level of benzene ranges from 4.13 to 7.18 $\mu g/m^3$, based on urban air monitoring data. A crude estimate of ambient benzene contributed by < 19kW SI engine sources can be calculated by multiplying the total ambient concentration by the percentage of nonroad engine-produced benzene. This figure must be adjusted then to reflect time spent indoors and in other micro environments by using the factor developed in the Motor-Vehicle-Related Air Toxics Study. Applying the nonroad adjustment factor of .25 and integrated adjustment factor of .622 to reflect only nonroad exposure to benzene, the range becomes .642 to 1.12 $\mu g/m^3$.

Based on data from EPA's NEVES(4), the exhaust and crankcase emissions from a 2.9 kW (3.9 hp) lawnmower with a 4-stroke engine contain 3.5 grams of benzene. A 2.9 kW (3.9 hp), 2-stroke lawnmower exhaust has 17 grams of benzene. A small, 2.2 kW (3 hp) chainsaw emits 28.2 grams of benzene per hour, compared to a large, 4.5 kW (6 hp) chainsaw that emits 40.8 grams per hour. No study as yet has been conducted on the health effects of benzene emissions specifically from small SI engines.

A separate study conducted at Southwest Research Institute (SWRI) reported a 2-stroke, 4.5 kW(6hp) moped engine fueled with industry average unleaded gasoline emitted 2,260 mg/hph of benzene. A 4-stroke walk-behind mower powered by an overhead valve, 2.6 kW (3.5 hp) engine emitted 690 mg/hph of benzene when fueled with average unleaded gasoline.

Concentration and duration of exposure to benzene are especially important to consider in the case of small SI engine applications, since the operator is typically in the direct path of the exhaust given out by the engine. Rate of dilution of the exhaust by the air surrounding the engine depends on local weather conditions.

6.2.2.3 Carcinogenicity of Benzene and Unit Risk Estimates--The International Agency for Research on Cancer (IARC), classified benzene as a Group I carcinogen . A Group I carcinogen is defined as an agent that is carcinogenic to humans. IARC (1987) based this conclusion on the fact that numerous case reports and follow-up studies have suggested a relationship between exposure to benzene and the occurrence of various types of leukemia. The leukemogenic (i.e., the ability to induce leukemia) effects of benzene exposure were studied in 748 white males employed from 1940-1949 in the manufacturing of rubber products in a retrospective cohort mortality study (9). Statistics were obtained through 1975. A statistically significant increase in the incidence of leukemia was found by comparison to the general U.S. population. The worker exposures to benzene were between 100 ppm and 10 ppm during the years 1941-1945. There was no evidence of solvent exposure other than benzene. In addition, numerous investigators have found significant increases in chromosomal aberrations of bone marrow cells and peripheral lymphocytes from workers with exposure to benzene (IARC 1982).

Exposure to benzene has also been linked with genetic changes in humans and animals. EPA has concluded that benzene is a Group A, known human carcinogen based on sufficient human epidemiologic evidence demonstrating an increased incidence of nonlymphocytic leukemia from occupational inhalation exposure. The supporting animal evidence showed an increased incidence of neoplasia in rats and mice exposed by inhalation and gavage. EPA (10) calculated a cancer unit risk factor for benzene of $8.3x10^{-6}$ $(\mu g/m^3)^{-1}$ based on the results of the above human epidemiological studies in benzene-exposed workers in which an increase of death due to nonlymphocytic leukemia was observed. EPA's National Center for Environmental Assessment (NCEA) of the office of Research and Development (ORD) has recently announced a Notice of Peer-Review Workshop and Public Comment Period to review an external review draft document titled, *Carcinogenic Effects of Benzene: An update (EPA/600/P-97/001A).* EPA will consider comments and recommendations from the workshop and the public comment period in document revisions.

The California Department of Health Services (DHS, 1984), which provides technical support to CARB, has also determined that there is sufficient evidence to consider benzene a human carcinogen. CARB performed a risk assessment of benzene that was very similar to EPA's risk assessment. The CARB risk estimate is actually a range, with the number calculated by EPA serving as the lower bound of cancer risk and a more conservative (ie., higher) number, based on animal data , serving as the upper bound of cancer risk. The CARB potency estimate for benzene ranges from $8.3x10^{-6}$ to $5.2x10^{-5}$ μg / m^3.

A number of adverse noncancer health effects have also been associated with exposure to benzene. People with long-term exposure to benzene at levels that generally exceed 50 ppm (162,500 μg / m^3) may experience harmful effects on the blood-forming tissues, especially the bone marrow. These effects can disrupt normal blood production and cause a decrease in important blood components, such as red blood cells and blood platelets, leading to anemia and a reduced ability to clot. Exposure to benzene at comparable or even lower levels can be harmful to the immune system, increasing the chance for infection and perhaps lowering the body's defense against tumors by altering the number and function of the body's white blood cells. In studies using pregnant animals, inhalation exposure to benzene in the range of 10-300 ppm (32,500-975,000 μg / m^3) indicates adverse effects on the developing fetus, including low birth weight, delayed bone formation, and bone marrow damage.

6.2.3 1,3- Butadiene

1,3-Butadiene is a colorless, flammable gas at room temperature with a pungent, aromatic odor, and a chemical formula C_4H_3. 1,3-Butadiene is insoluble in water and because of its reactivity is estimated to have a short atmospheric lifetime. The actual lifetime depends upon the conditions at the time of release, such as the time of day, intensity of sunlight, temperature etc. 1,3-Butadiene is formed in vehicle exhaust by the incomplete combustion of the fuel and is assumed not to be present in vehicle evaporative and refueling emissions. The contribution of 1,3 -butadiene from Nonroad Sources to Nationwide Toxic Emissions Inventory is 21.2% (5).

6.2.3.1 Projected 1,3-Butadiene Emission Reductions--Current EPA estimates (5) indicate that mobile sources account for approximately 68% of the total 1,3-butadiene emissions, out of which 31% can be attributed to nonroad mobile sources. The remaining 1,3-butadiene emissions come from stationary sources mainly related to industries producing 1,3-butadiene and those industries that use 1,3-butadiene to produce other compounds. 1,3-Butadiene emissions appear to increase roughly in proportion to exhaust hydrocarbon emissions. Since hydrocarbons are decreased by the use of a catalyst on a motor vehicle, 1,3-butadiene emissions are expected to decrease proportionally with the use of any emission control technology that decreases total hydrocarbon emission.

6.2.3.2 Health Effects of 1,3 - Butadiene Exposure--The annual average ambient level of 1,3-butadiene ranges from 0.12 to 0.56 µg/m^3. According to data from EPA's NEVES, 1,3-Butadiene content in exhaust and crankcase from a 2.9 kW (3.9 hp), 4-stroke lawnmower is approximately 1.5 gms/hr of usage. For a 2.9 kW (3.9 hp), 2-stroke lawnmower, 1,3-butadiene content in exhaust is 7.0 grams per hour. Butadiene emitted from small, 2.2 kW (3hp) chainsaw is approximately 12.2 grams per hour from a large 4.5 kW (6 hp) chainsaw.

A separate study conducted at SwRI revealed a 2-stroke, 4.5 kW (6 hp) moped engine emitted 207 mg/kW-hr (154 mg/hp-hr) when fueled with industry average unleaded gasoline. A 2.6 kW (3.5 hp) overhead valve, walk-behind mower emitted 209 mg/kW-hr (156 mg/hp-hr) of 1,3-butadiene when fueled with industry average unleaded gasoline. Since 1,3-butadiene levels normally decrease proportional to overall hydrocarbons once emission control technology is applied, 1,3-butadiene levels are expected to be less from new small SI engines after this rule becomes effective . This, in turn, will reduce risk of exposure to 1,3-butadiene produced by these sources.

Since the operator of a small SI NHH engine- equipped application is typically near the equipment while it is in use, the concentration of toxic pollutants in the exhaust and their health effects need to be investigated. Although the air around the engine quickly dilutes the exhaust, the rate of dilution depends on the weather conditions.

6.2.3.3 Carcinogenicity of 1,3-Butadiene--Long-term inhalation exposure to 1,3-butadiene has been shown to cause tumors in several organs in experimental animals. Epidemiologic studies of occupationally exposed workers were inconclusive with respect to the carcinogenicity of 1,3-butadiene in humans. Based on the inadequate human evidence and sufficient animal evidence, EPA has concluded that 1,3-butadiene is a Group B2, probable human carcinogen. IARC has classified 1,3-butadiene as a Group 2A, probable human carcinogen. EPA calculated a cancer unit risk factor of $2.8X10^{-4}$ $(\mu g/m^3)^{-1}$ for 1,3-butadiene based on the results of a study in mice in which an increase in the incidence of tumors in the lung and blood vessels of the heart, as well as lymphomas were observed. EPA's Office of Research and Development is currently in the process of releasing an updated 1,3-butadiene risk assessment factor.

Exposure to 1,3-butadiene is also associated with adverse noncancer health effects. Exposure to high levels (on the order of hundreds of thousands ppm) of this chemical for short periods of time can cause irritation of the eyes, nose, and throat, and exposure to very high levels can cause effects on the brain leading to respiratory paralysis and death. Studies of rubber industry workers who are chronically exposed to 1,3-butadiene suggest other possible harmful effects including heart disease, blood disease, and lung disease. Studies in animals indicate that 1,3-butadiene at exposure levels of greater than 1,000 ppm (2.2X106 $\mu g/m^3$) may adversely affect the blood-forming organs. Reproductive and developmental toxicity has also been demonstrated in experimental animals exposed to 1,3-butadiene at levels greater than 1,000 ppm.

6.2.4 CO

The Clean Air Act directs the Administrator of the EPA to establish National Ambient Air Quality Standards (NAAQS) for several widespread air pollutants, based on scientific criteria and allowing for an adequate margin of safety to protect public health. The current primary and secondary NAAQS for CO are 35ppm for a 1-hour average and 9ppm for an 8-hour average.

According to the Nonroad Study, a 4-stroke, 2.9 kW (3.9 hp) lawnmower engine emits 1051.1 g/hr CO while a 2-stroke, 2.9 kW (3.9 hp) engine meets 1188.4 g/hr CO. A separate study conducted at SwRI revealed that a 2-stroke moped engine fueled with typical unleaded gasoline emits 184 g/Kw-hr (137 g/hp-hr) of CO. A 4-stroke, 2.6 kW overhead valve, walk-behind mower fueled with typical unleaded gasoline emits 480 g/kW hr (358 g/hp-hr) of CO.

Although the final Phase 2 emission standards for nonhandheld small SI engines does not include significantly more stringent standards for CO, reductions in CO beyond Phase 1 levels, due to improved technology, is also to be expected by year 2025.

6.2.4.1 Health and Welfare Effects of CO--The EPA has documented the detrimental health effects that CO can have on populations(11). Carbon monoxide is a colorless, odorless, tasteless and nonirritating gas and gives no signs of its presence. It is readily absorbed from the lungs into the bloodstream, there forming a slowly reversible complex with hemoglobin (Hb) known as carboxyhemoglobin (COHb).

Blood COHb levels do not often exceed 0.5 to 0.7% in normal individuals unless exogenous CO is breathed. Some individuals with high endogenous CO production can have COHb levels of 1.0 to 1.5% (e.g. anemics). The presence of COHb in the blood reduces the amount of oxygen available to vital tissues, affecting primarily the cardiovascular and nervous systems. Although the formation of COHb is reversible, the elimination half-time is quite long because of the right binding between CO and Hb. This can lead to accumulation of COHb, and extended exposures to even relatively low concentrations of CO may produce substantially increased blood levels of COHb.

Health effects associated with exposure to CO include cardiovascular system, central nervous system (CNS), and developmental toxicity effects, as well as effects of combined exposure to CO and other pollutants, drugs, and environmental factors. Concerns about the potential health effects of exposure to CO have been addressed in extensive studies with various animal species as subjects. Under varied experimental protocols, considerable information has been obtained on the toxicity of CO, its direct effects on the blood and other tissues, and the manifestations of these effects in the form of changes in organ function. Many of these studies, however have been conducted at extremely high levels of CO (i.e., levels not found in ambient air). Although severe effects from exposure to these high levels of CO are not directly germane to the problems from exposure to current ambient levels of CO, they can provide valuable information about potential effects of accidental exposure to CO, particularly those exposures occurring indoors.

All gasoline-powered engines produce carbon monoxide. According to the National Institute for Occupational Safety and Health (NIOSH), Americans who use gasoline-powered pressure washer indoors are risking their lives. This gas can rapidly build up in any indoor area, and individuals can be overcome without even realizing that they are being exposed. Confusion, headache, dizziness, fatigue, and weakness may set in too quickly for victims to save themselves. According to NIOSH director, Dr. J. Donald Millar, " Carbon monoxide strikes quickly, and it strikes without warning. Workers must be aware of the hazard and prevent exposure to this potentially fatal gas." Each of the victims interviewed by NIOSH expressed shock at how quickly they were overcome. Carbon monoxide poisoning can cause permanent brain damage , including changes in personality and memory. Once inhaled, carbon monoxide decreases the ability of the blood to carry oxygen to the brain and other vital organs. Even low levels of carbon monoxide can set off chest pains and heart attacks in people with coronary artery disease.

Although no studies measuring the human health effects of CO emanating from small SI engine exhaust have been conducted, ample research results are available concerning general health effects of exposure to CO . The effects of exposure to low concentrations-such as the levels found in ambient air - are far more subtle and considerably less threatening than those occurring in direct poisoning from high CO levels. Maximal exercise performance in healthy individuals has been shown to be affected at COHb levels of 2.3% and greater. Central nervous system effects, observed at peak COHb levels of 5% and greater, include reduction in visual perception, manual dexterity, learning, driving performance, and attention level. Of most concern, however, are adverse effects observed in individuals with chronic heart disease at COHb levels of 3 to 6%. At these levels, such individuals are likely to have reduced capacity for physical activity because they experience chest pain (angina) sooner. Exercise-related cardiac arrhythmias have also been observed in some people with chronic heart disease at COHb levels of 6% or higher and may result in an increased risk of sudden death from a heart attack .

The NAAQS set by EPA are intended to keep COHb levels below 2.1% in order to protect the most sensitive members of the general population (i.e., individuals with chronic heart disease). However, elderly people, pregnant women (due to possible fetal effects), small children, and people with anemia or with diagnosed or undiagnosed pulmonary or cardiovascular disease are also likely to be at increased risk for CO effects.

Since small SI engines are typically used in applications that require the operator to be near, and perhaps in the direct path of the exhaust, the effects of exhaust CO on the operator of the engine is a matter of concern. Although no studies measuring the human health effects of CO emanating from small SI engine exhaust have been conducted, laboratory animal studies reveal that CO can adversely affect the cardiovascular system, depending on the laboratory conditions utilized in these studies.

6.2.4.2 Developmental Toxicity and Other Systemic Effects of Carbon monoxide--Studies in laboratory animals of several species provide strong evidence that maternal CO exposures of 150 to 220 ppm, leading to approximately 15 to 25% COHb, produce reductions in birth weight, cardiomegaly, delays in behavioral development, and disruption in cognitive function (12). The current data (13) from human children suggesting a link between environmental CO exposures and sudden infant death syndrome are weak. Human data from cases of accidental high CO exposures (14) are difficult to use in identifying a low observed-effect level for CO because of the small numbers of cases reviewed and problems in documenting levels of exposure.

Behaviors that require sustained attention or sustained performance are most sensitive to disruption by COHb. The group of human studies (15) on hand-eye coordination (compensatory tracking), detection of infrequent events (vigilance), and continuous performance offer the most consistent and defensible evidence of COHb effects on behavior at levels as low as 5%. These effects at low CO-exposure concentrations, however, have been very small and somewhat controversial. Nevertheless, the potential consequences of a lapse of coordination, vigilance, and the continuous performance of critical tasks by operators of machinery could be serious.

At higher levels of exposure, where COHb concentrations exceed 15 to 20%, there may be direct inhibitory effects of CO resulting in decreases in xenobiotic metabolism , which might be important to individuals receiving treatment with drugs. Inhalation of high levels of CO, leading to COHb concentrations greater than 10 to 15%, have been reported to cause a number of other systemic effects in laboratory animals as well as humans suffering from acute CO poisoning. There are reports in the literature of effects on liver, kidney, bone, and immune capacity in the lung and spleen (16). It generally is agreed that these effects are caused by severe tissue damage occurring during acute CO poisoning.

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Chapter 7: Analysis of Aggregate Costs

This chapter develops the uniform annualized cost per class and the average cost per equipment per class for this rulemaking. This chapter also assesses the cost-effectiveness, in terms of dollars per ton of total emission reductions. This analysis relies on cost information from Chapters 4 and 5 and emissions information from the small engine model[35] presented in Chapter 6. Lastly, this chapter discusses possible economic effects of the regulation and compares the cost effectiveness of the new provisions with the cost-effectiveness of other HC+NOx control strategies from previous EPA rulemakings.

7.1 Aggregate Cost Analysis

The analysis examines total annual costs of the final standards for all applicable engines[36] from 2001-2027. The complete year-by-year stream of costs over time that are summarized in this section can be found in Appendix E. The uniform annualized cost per class and average cost per equipment per class are calculated. Costs of variable hardware, production, research and development,

35 The nonroad small engine emission model accounts for factors including various equipment types, consumer or professional usage, lifetime of the equipment, scrappage, etc., see Chapter 6.

36 The analysis covers all engines sold in the United States except those sold in California which are covered by rulemakings established by CARB.

and compliance programs are used and annualized where appropriate. Cost savings due to reduced fuel consumption are also addressed, including the valuation of the reduced fuel consumption to the consumer. Total costs to society are presented as the aggregate costs to consumers with and without fuel savings.

This analysis is based on cost estimates for variable and fixed costs from the 1996 ICF and EF&EE cost study, comments to the NPRM and confidential manufacturer data received in 1995. The 1995 and 1996 cost estimates are adjusted by the GDP Implicit Price Deflators per year to 1998 and the following analyses are all presented in 1998 dollars. The costs for the compliance program were based on costs estimated in 1997 and these are also adjusted to 1998 dollars.

This analysis also accounts for estimates of the increased profits to economic entities in the various levels of industry, including the engine manufacturer, equipment manufacturer, and mass merchandiser. As rationalized in Appendix E, full cost pass through and profitability on increased costs are assumed. Table 7-01 summarizes the assumed profitability factors, sometimes referred to as retail price equivalent factors, which were applied to specific costs in this analysis, to estimate the price increase to the consumer.

Table 7-01
Profitability Factors
(Retail Price Equivalent Factors)

Level	Factor
Engine Manufacturer	0.16
Equipment Manufacturer	0.05
Retail Merchandiser	0.05

These factors were applied to the specific variable engine and equipment manufacturer costs identified in this chapter. For example, EPA has estimated some variable hardware costs and production costs specific to engines and specific to equipment. From the consumer's point of view, the equipment specific costs were marked up the cost 10% and the engine specific costs were marked up 28%.

7.1.1 Uniform Annualized Costs

A uniform annualized cost is an expression of the equal annual payments that would be equivalent to a given cash flow schedule for a known interest rate. This expression of an annualized cost was chosen due to the variety of the programs that makeup this Phase 2 regulation. The methodology used for calculating the uniform annualized costs is as follows.

The EPA Phase 1 certification database was utilized to determine the number of engines, and related number of models, that would likely be improved during the course of the phase-in (see Tables E-01 to E-03). The costs per engine (variable and fixed costs) for emission improvements were estimated, as shown in Chapter 4. The variable costs per engine are then multiplied by the number of engines in that year[37] to incorporate that technology or set of technologies. The fixed costs are amortized for five years for engine manufacturers and ten years for equipment manufacturers starting in the phase-in years in which they are calculated to be recovered.

In order to determine the uniform annualized costs, the annual costs were discounted to the first year the Phase 2 standards are implemented for existing engine families, 2001 for Class II and 2007 for Class I engines, at a rate of seven

[37] The future sales growth estimates are based on the assumptions utilized in the nonroad model for the main types of equipment. The production estimates for the nonhandheld, Class I and II, categorized equipment are listed for each year from 2001 to 2027. A percentage increase from one year to the next is calculated and these factors are then utilized with the 1998 sales projections, as the base, and the resultant sales estimates for future years are developed. The resultant values for production of nonhandheld equipment are then further split into classes and engine technology types (such as SV and OHV). For the pre-Phase 2 split, the production was split by the proportions in the 1998 database. For the Phase 2 split, ABT calculations of each manufacturers situation and assumptions on technology were utilized.

percent (the consumption rate of interest). The uniform annualized cost was obtained by summing the discounted costs over the appropriate time period and dividing by the appropriate present worth factor (at an interest rate of 7% over the corresponding number of years). The sections below address each cost category separately. Section 7.3. contains the full 20 year analysis of total cost of the final standards.

7.1.1.1 Variable Costs -- Table 7-02 contains the uniform annualized variable costs per class with consumer markup (see Table E-08 for costs per year on which this table is based). The results are calculated to first year of implementation which is 2001 for Class II and 2007 for Class I or existing engine families.

Table 7-02
UNIFORM ANNUALIZED VARIABLE COST PER CLASS
WITH CONSUMER MARKUP
($Thousands, 1998$)

CLASS	ENGINE	EQUIPMENT	TOTAL
I	$138,398	$0	$138,398
II	$26,462	$175	$26,637

*Class I calculated to 2007, Class II calculated to 2001

7.1.1.2 Capital Costs -- Engine improvements, and thereby capital expenditures, are assumed to be phased-in over time for Class II and incurred in one year for Class I. The phase-in and number of models for each Class were determined in Chapter 4. Capital costs are estimated to be recovered over 5 years for engine manufacturers and equipment manufacturers, at a 7 percent interest rate. Costs incurred prior to the initial year of the Phase 2 rulemaking were moved to the first year of the rulemaking (i.e., the first year in which costs are recovered) using a 7 percent interest rate.

Potential capital cost increases include costs for development and application of engine designs with reduced emissions and costs for production facilities. EPA has accounted for some costs due to construction of production facilities for Class I OHV engines due to the fact one major Class I SV engine manufacturer has stated that it takes 4/3 of the time to make an OHV engine compared to a SV engine and thereby additional facilities will be needed to fulfill production quotas.

EPA has estimated the uniform annualized fixed costs as shown in Table 7-03. The results are calculated to first year of implementation which is 2001 for Class II and 2007 for Class I. Appendix E contains the tables on which this table is based.

Table 7-03
UNIFORM ANNUALIZED FIXED COST PER CLASS
($Thousands, 1998$)

CLASS	ENGINE	EQUIPMENT	TOTAL
I	$21,233	$6,946	$28,179
II	$6,648	$2,044	$8,692

*Class I calculated to 2007, Class II calculated to 2001

7.1.1.3 Compliance Costs -- This rulemaking accounts for those costs that are above and beyond those for the Phase 1 program. These costs are the compliance program costs presented in Chapter 5. Compliance costs include costs for certification and production line testing (PLT). Certification costs are treated as fixed costs and production line testing costs are treated as variable costs for this analysis. Appendix E and Chapter 5 contain details on the program costs assumed for the compliance programs. The estimates for the administrative burden for these programs are estimated in the supporting statements for the Information Collection Requests submitted to OMB. These supporting statements contain estimates of the testing, record keeping, and reporting burden on industry due to the final regulations. These costs are not included in this analysis for they were not yet available at the time of completion of this document.

Table 7-04 contains the uniform annualized compliance costs for all classes. The results are calculated to first year of implementation which is 2001 for Class II and 2007 for Class I.

Table 7-04
UNIFORM ANNUALIZED COMPLIANCE PROGRAMS
($Thousands, 1998$)

CLASS	COST
I	$233
II	$671

*Class I calculated to 2007, Class II calculated to 2001

The total uniform annualized costs for this rulemaking are presented in Table 7-05. The total value is calculated with all costs to 2001.

Table 7-05
TOTAL UNIFORM ANNUALIZED COSTS
INCLUDING CONSUMER MARKUPS
($Thousands, 1998$)

Class	Cost
I	$167,810
II	$40,186
TOTAL	$207,996

* All classes calculated to 2001

7.1.1.4 Fuel Savings -- As explained in Chapter 4, the technological changes necessary to bring these engines into compliance with the emission standards will cause a decrease in fuel consumption of approximately 15% for nonhandheld Class I and II SV engines. The tons/year savings per class (see Appendix E) are converted to gallons/year and then multiplied by $0.794/gallon to determine the fuel savings[38]. Table 7-06 contains the uniform annualized fuel savings for all equipment types in each class which have been discounted 7% to the first year of implementation for each class. Table E-07 contains the yearly fuel savings information on which this analysis is based.

Table 7-06
UNIFORM ANNUALIZED FUEL SAVINGS
and COMPARISON TO UNIFORM ANNUALIZED COST
($Thousands, 1998$)

CLASS	UNIFORM ANNUALIZED FUEL SAVINGS	UNIFORM ANNUALIZED COST	RESULTANT COSTS (SAVINGS)
I	$121,549	$167,810	$46,261
II	$177,191	$40,186	($137,005)

* Class II calculated to 2001, Class I calculated to 2007

7.1.2 Average Cost Per Equipment

The average cost per equipment changes over time due to the recovering of capital costs and the increased production over which costs can be spread. Therefore this analysis calculates a range of cost that is based on the uniform annualized cost. Since the production of these engines is assumed to increase over the years of this analysis, this section presents a range of cost per equipment estimates. The uniform annualized cost is divided by the production in the first

38 The value of gasoline used in this analysis is $0.794 per gallon. This is based on the average refinery price to enduser in 1995 from the Energy Information Administration multiplied by the GDP Implicit Price Deflators for 1996, 1997 and 1998.

full implementation year after use of flexibility provisions (2010) and the last year (2027) accounted for in this analysis. Results are shown in Table 7-07. An average of this range is also presented. Note that this table shows the costs and savings spread across all equipment within each engine class and not only those equipment whose engines will incorporate technology changes.

Table 7-07
AVERAGE COST PER EQUIPMENT PER ENGINE CLASS
BASED ON UNIFORM ANNUALIZED COST
(1998$)

	2010	2027	Average
I	$19.59	$19.68	$19.63
II	$12.61	$12.67	$12.64

*Class I calculated to 2007, Class II calculated to 2001

7.1.2.1 Fuel Savings -- The resultant fuel savings per engine per class is calculated in the same manner as the cost per equipment. The uniform annualized fuel savings is divided by the production in the years 2010 and 2027 to yield a range of costs for this analysis. The resultant cost per engine is then calculated by subtracting the fuel savings per engine from the total cost per equipment. Both results are listed in Table 7-08 below.

Table 7-08
FUEL SAVINGS AND
RESULTANT COST PER EQUIPMENT
Based on Uniform Annualized Analysis
(1998$)

Class	Average Cost Per Equipment	Average Savings Per Equipment	Average Resultant Cost Per Equipment
I	$19.63	$14.22	$5.41
II	$12.64	$55.72	($43.08)

NOTE: This table shows the costs and savings spread across all equipment within each engine class and not only those equipment whose engines will incorporate technology changes.

For Class I and II engines, EPA assumes that there will be fuel savings as SV engines are phased-out and replaced with more fuel efficient OHV engines. The high savings per equipment in Class II are influenced by the fact that the engines in this class are utilized for longer hours compared to the equipment in Class I.

The overall increase in price per equipment per engine in Class I is not insignificant compared to the selling price of the equipment in which small SI engines are used. For Class I engines, the major selling equipment type is the walk behind lawnmower. Some lawnmowers sell for as little as $150. The increased cost estimate of $19.63 is 13% of this price. For Class II, the overall increase in price per equipment is less significant for Class II equipment are much higher in price and the common equipment types include garden tractors and lawn tractors for both consumer and commercial use. These equipment sell for approximately $1,000-$5,000 to the residential and professional respectively. The increased cost estimate of $12.64 is 1% of the residential use price.

7.2 Cost Effectiveness

The following section describes the cost effectiveness of the final HC+NOx standards for Class I and II small SI engines. These cost effectiveness numbers are calculated by taking the net present value of the total costs per year (including amortized capital and variable costs) over the 27 year time line, discounted by 7%, and dividing it by the net present value of the HC+NOx emission benefits discounted by 7%. Table 7-09 presents the resulting cost effectiveness results.

Table 7-09
Cost Effectiveness of Phase 2 Rulemaking
(1998$)

	Cost Effectiveness ($/ton HC+NOx)
Without Fuel Savings	$852
With Fuel Savings	($507)

In an effort to evaluate the cost-effectiveness of the new standards, EPA has summarized the cost effectiveness results for several other recent EPA mobile source rulemakings. Table 7-10 summarizes the cost effectiveness results from the Small SI Engine Phase 1 rulemaking, the SI Marine OB/PWC Engine rulemaking(2) and the recently final standards for nonroad compression ignition (CI) engines (3).

Table 7-10
Cost Effectiveness of Other Like Rulemakings
With Fuel Savings

Rulemaking	Cost Effectiveness	Pollutants
Small SI Engine Phase 1	$217	HC+NOx
Marine	$1000	HC
Nonroad CI Standards	$410-$650	HC+NOx

7.3 20-Year Analysis

7.3.1. Costs

Table 7-11 contains the year by year fleet wide costs and emission benefits associated with the final small SI engine standards of the 20 year period from 2001-2020. Fuel savings are not included for they significantly dilute the costs to the manufacturers. (The numbers presented in Table 7-11 are not discounted).

Table 7-11
Costs and Emission Benefits of the Final Phase 2 Nonhandheld
Small SI Engine Standards
(Fuel Savings Not Included)
(1998$)

Calendar Year	Fleetwide Costs	Fleetwide Reductions (short tons) HC+NOx
2001	$493,873	17649
2002	$13,747,162	37,831
2003	$15,253,204	60,706
2004	$35,909,481	82,982
2005	$56,130,057	106,064
2006	$57,885,875	125,505
2007	$244,950,395	152,381
2008	$244,645,797	194,616
2009	$239,293,552	231,642
2010	$227,653,144	257,278
2011	$227,594,254	276,487
2012	$176,199,997	292,139
2013	$175,095,165	304,305
2014	$175,302,969	313,190
2015	$173,954,349	320,943
2016	$171,804,120	328,948
2017	$161,965,166	335,434
2018	$161,919,588	341,544
2019	$162,122,557	347,424
2020	$161,840,135	353,225

Table 7-12 contains the discounted year by year fleet wide costs and emission benefits associated with the final small SI engine standards for the 20 year period from 2001 to 2020. The year by year results were discounted to 2001 and a discount rate of seven percent was assumed for the analysis.

Table 7-12
Discounted Costs and Emission Benefits of the Final Phase 2 Nonhandheld Small SI Engine Standards
(Fuel Savings Not Included)
(1998$)

Calendar Year	Fleetwide Costs	Fleetwide Reductions (short tons) HC+NOx
2001	$493,873	17,649
2002	$12,847,815	35,356
2003	$13,322,739	53,023
2004	$29,312,833	67,738
2005	$42,821,352	80,916
2006	$41,271,829	89,483
2007	$163,220,791	101,538
2008	$152,353,107	121,197
2009	$139,271,026	134,818
2010	$123,828,227	139,942
2011	$115,697,378	140,552
2012	$83,711,349	138,793
2013	$77,744,347	135,115
2014	$72,744,500	129,963
2015	$67,462,496	124,467
2016	$62,269,719	119,226
2017	$54,863,205	113,623
2018	$51,259,595	108,124
2019	$47,966,215	102,790
2020	$44,750,146	97,670

Summing the discounted annual costs and discounted emission reductions over the twenty year period yields a 20-year fleet wide cost of $1.4 billion and 20-year emission reductions of 2.0 million tons of HC+NOx. The resulting 20 year annualized fleet wide costs and emission reductions are $132 million per year and 194,000 tons per year of HC+NOx. The spreadsheets prepared for this analysis are contained in Appendix E. The reader is directed to the spreadsheets for a complete version of the analysis.

7.3.2. Fuel Savings

Table 7-13 contains the year by year fleet wide gallon and monetary fuel savings associated with the final small SI engine standards of the 20 year period from 2001-2020. (The numbers presented in Table 7-11 are not discounted).

Table 7-13
Fuel Savings of the Final Phase 2 Nonhandheld
Small SI Engine Standards
(1998$)

Calendar Year	Fleetwide Savings	Fleetwide Savings (gallons)
2001	($26,802,859)	(33,756,749)
2002	($52,730,450)	(66,411,146)
2003	($80,308,880)	(101,144,685)
2004	($107,335,002)	(135,182,623)
2005	($135,128,973)	(170,187,624)
2006	($156,853,874)	(197,548,959)
2007	($181,605,469)	(217,267,808)
2008	($213,358,273)	(232,509,159)
2009	($237,225,474)	(244,793,317)
2010	($253,850,183)	(254,774,619)
2011	($266,821,935)	(263,377,096)
2012	($277,249,091)	(270,489,628)
2013	($285,760,487)	(276,926,307)
2014	($292,701,784)	(282,897,875)
2015	($299,061,284)	(288,525,768)
2016	($306,036,749)	(295,042,617)
2017	($311,788,945)	(300,448,566)
2018	($317,342,216)	(305,772,281)
2019	($322,774,260)	(311,040,878)
2020	($328,154,584)	(316,266,442)

Table 7-14 contains the discounted year by year fleet wide gallon and related monetary fuel savings associated with the final small SI engine standards for the 20 year period from 2001 to 2020. The year by year results were discounted to 2001 and a discount rate of seven percent was assumed for the analysis.

Table 7-14
Discounted Fuel Savings of the Final Phase 2 Nonhandheld
Small SI Engine Standards
(1998$)

Calendar Year	Fleetwide Savings	Fleetwide Savings (gallons)
2001	($26,802,859)	(33,756,749)
2002	($49,280,794)	(62,066,491)
2003	($70,144,886)	(88,343,685)
2004	($87,617,335)	(110,349,288)
2005	($103,089,247)	(129,835,323)
2006	($111,834,644)	(140,849,678)
2007	($121,011,392)	(144,774,714)
2008	($132,868,809)	(144,795,019)
2009	($138,067,385)	(142,471,939)
2010	($138,077,680)	(138,580,512)
2011	($135,638,742)	(133,887,560)
2012	($131,719,046)	(128,507,674)
2013	($126,881,074)	(122,958,592)
2014	($121,460,834)	(117,392,560)
2015	($115,981,122)	(111,895,267)
2016	($110,921,802)	(106,937,022)
2017	($105,613,703)	(101,772,324)
2018	($100,462,419)	(96,799,674)
2019	($95,497,257)	(92,025,772)
2020	($90,737,477)	(87,450,307)

Summing the discounted gallon and related monetary fuel savings over the twenty year period yields a 20-year fleet wide savings of $2.1 billion and 20-year fuel savings of 2.2 billion gallons. The resulting 20 year annualized fleet wide costs and emission reductions are $200 million per year and 2.1 million gallons per year. The spreadsheets prepared for this analysis are contained in Appendix E. The reader is directed to the spreadsheets for a complete version of the analysis.

Chapter 7 References

1. ICF and Engine, Fuel and Emissions Engineering, Incorporated; "Cost Study For Phase Two Small Engine Emission Regulations", Draft Final Report, October 25, 1996, EPA Air Docket A-93-29, Docket Item #II-A-04.

2. "Air Pollution Control; Gasoline Spark-Ignition Marine engines; New Nonroad Compression-Ignition and Spark-Ignition Engines, Exemptions; Rule", US EPA, Federal Register, vol 61, No. 194, Friday October 4, 1996, 40 CFR parts 89, 90 and 91, pg 52100

3. "Control of Emissions of Air Pollution from Nonroad Diesel Engines; Proposed Rule", US EPA, Federal Register, vol. 62, No 85, Wednesday, September 24, 1997, page 50152.

4. "Principles of Engineering Economics, Applying Financial Concepts for Effective Decision-Making", SAE Seminar Materials I.D.#95014, Kevin M. Zielinski

Chapter 8: Assessment of Impact on Small Entities

8.1 Introduction and Methodology

As part of the Notice of Proposed Rulemaking for Phase 2 emission standards for small spark-ignition (SI) engines, EPA prepared a Draft Regulatory Impact Analysis (RIA). The Draft RIA included an analysis of the types of entities, including small entities, that would be subject to the rule, a determination of the potential degree of impact on the small entities, and a determination as to whether a Regulatory Flexibility Analysis should be conducted, based on the significance of the impact and the number of small entities impacted. The Draft RIA focused primarily on the impact of the proposed rule on the manufacturers of nonhandheld Class II side-valve (SV) and Class III, IV, and V handheld engines and equipment, since the most stringent standards were proposed for these engine classes. Manufacturers producing only Class I engines or Class II overhead-valve (OHV) engines / equipment were excluded from the analysis, since they were expected to only need relatively minor internal modifications for compliance with the proposed standards; thus impacts on them were expected to be minimal.

However, as noted in Chapter 3, in response to comments on the proposal EPA has decided to increase the stringency of the emission standards for Class I engines, compared to the standard upon which the small entity analysis in the proposal was based. This increase in stringency was adopted in response to comments received which substantiated the technical and financial ability of the Class I manufacturers to meet such standards if given enough lead time under the time frame in which the Phase 2 rule will be implemented. These more stringent standards for Class I engines will also result in harmonized requirements with the similar California regulations for these engines.

EPA has also received comments containing information regarding advances in 2-stroke emission control technology that may ultimately enable handheld engines--Classes III, IV, and V--to meet emission standards that are also substantially more stringent than were proposed. Because this technology is new and manufacturers and other interested parties have not had an opportunity to comment on its application, the Agency has decided to issue a Supplementary Notice of Proposed Rulemaking for Class III, IV, and V engines. The emission standards for handheld engines and equipment will thus be considered in a separate rulemaking, and will not be included in this analysis.

Since the Draft RIA adequately addresses the impact on the Class II engine and equipment manufacturers, and since handheld engines are excluded from this rulemaking, this analysis will focus primarily on Class I engine and equipment manufacturers. These more stringent standards for Class I engines will require more effort on the part of the Class I engine manufacturers for compliance, and will also impact the equipment manufacturers using these engines.

8.1.1 RFA/SBREFA Requirements

Section 603 of the Regulatory Flexibility Act (RFA), 5 U.S.C. 601 *et seq.*, requires EPA to assess the economic impact of proposed rules on small entities. Sections 603 and 604 of the RFA generally require preparation of a Regulatory Flexibility Analysis for any rule subject to notice and comment rulemaking requirements, unless the agency certifies (pursuant to section 605(b)), that the rule "will not, if promulgated, have a significant economic impact on a substantial number of small entities." In 1996, the Regulatory Flexibility Act was amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA), P.L. 104-121, to strengthen the analytical and procedural requirements of the RFA and to ensure that the small entities are adequately considered during rule development. Small entities include small businesses, small not-for-profit organizations, and small governmental jurisdictions. Small not-for-profit organizations and small governmental jurisdictions are not expected to be impacted by this rulemaking, thus both the Draft RIA and this analysis place their primary focus on small businesses, specifically on the impact of this rule on small engine and equipment manufacturers.

8.1.2 Methodology

The Draft RIA relied on information from a cost study and a small business impact study, performed by ICF Incorporated under a contract with EPA, to determine the economic impact of the proposed regulations on small entities.(Ref. 1) (Ref. 2) The primary data sources for the small business impact analysis included the EPA Phase 1 Certification Database, the Power Systems Research (PSR) Database, and the Dun & Bradstreet (D&B) Market Identifiers Online Database.

The cost study also relied on the PSR database for engine and sales data, and incorporated the results of an engineering analysis that was performed to analyze the costs of compliance with the Phase 2 emission standards. The nonhandheld portion of this analysis was focused primarily on Class I engines, but was also adapted to Class II engines. EPA will also rely on this latter study and on the PSR and D&B databases for data on Class I engine and equipment manufacturers.

To evaluate the impacts of the final rule on small entities, EPA's Interim Guidance for Implementing SBREFA suggests a screening analysis using an economic measure known as a "sales test", which measures compliance costs as a function of sales revenue. After determining the costs of compliance to the manufacturers, these costs are annualized and expressed as a percentage of annual sales revenue. Then, based on the percentage of small entities that are affected by costs of compliance amounting to varying percentages of sales, the SBREFA guidelines suggest some criteria for evaluating whether the potential impacts represent a "significant economic impact on a substantial number of small entities". Although the guidelines suggest criteria for making the determination, each rule is unique so the criteria are just a starting point for an evaluation that must be made on a rule-by-rule basis

The RFA specifies that the Small Business Administration (SBA) definitions for small business should be used for the initial determination of a small entity, however, EPA may use an alternative definition of small business where appropriate, if it consults with SBA and follows certain procedures. The SBA defines small business by category of business using Standard Industrial Classification (SIC) codes, and in the case of manufacturing, generally defines small business as a business having 500 employees or less. However, for engine manufacturers (SIC code 3519) the cutoff is 1,000 employees and for construction equipment (SIC code 3531), it is 750 employees. Table 8-1 shows the range of primary SIC codes listed for the engine and equipment manufacturers identified, and the corresponding SBA small business cutoff, based on number of employees.

Table 8-1

Small Business Engine and Equipment Manufacturer Definitions

SIC Code	Applicable	Title	Employees
3519	Engine	Internal Combustion Engines	1000
3523	Equipment	Farm Machinery & Equipment	500
3524	Equipment	Lawn & Garden Equipment	500
3531	Equipment	Construction Machinery	750
3561	Equipment	Pumps and Pumping Equipment	500
3621	Equipment	Motors and Generators	500

8.2 Impact on Engine Manufacturers

8.2.1 Identification of Manufacturers

The PSR database shows that there are 13 primary manufacturers of Class I engines. The majority of these (9) are large businesses; the other four are small entities as defined by the SBA. All but two of the 13 also manufacture Class II engines. Both of the two Class I-only manufacturers are large-volume concerns, one of which also manufactures the associated equipment in which these engines are used. All four of the small business engine manufacturers were included in the ICF study.

8.2.2 Expected Technologies/Costs

The cost of compliance for nonhandheld engines depends on the technology employed by engine manufacturer to meet the emission standards. EPA has become aware of potential advances in engine technology which may allow Class I and II SV engines to achieve the Phase II standards with minimal additional cost. However, because this technology is still undergoing development, it will not be considered in this analysis. The Agency will conservatively assume that the standards will require conversion to OHV technology for attainment. Based on the cost study and other information made available to EPA, this could increase the average cost per engine by $31.67 for Class I engines and $18.42 for Class II engines. As noted in Chapter 3, a substantial number of manufacturers of Class II SV engines have already converted all or portions of their product lines to OHV technology for other reasons (desire of customers to have premium engines, increased efficiency of OHV engines, etc.). Some Class I manufacturers have also begun this transition, although the numbers of engines are less than for the Class II firms.

8.2.3 Expected Impact on Small Business Entities

To estimate impacts on engine manufacturers, specific compliance costs were developed for each engine manufacturer based on the type of engine modification needed and the level of engine production. The individualized annualized compliance costs were then estimated for each small ultimate parent company identified. Table 8-2 summarizes these costs. A more detailed technology analysis is available Chapter 3 and in the ICF cost report.

Table 8-2

Engine Modifications and Associated Costs

Engine Class	Engine Modification	Fixed Cost (Annualized)	Variable Cost Per Engine	Average Master Die Retirement Costs
I	Conversion to OHV technology	$2,613,103	$13.68	Not determined
	Improve OHV - modified combustion and intake	$84,850	$3.05	$59,602
	Improve OHV - piston / rings	$74,500	$4.60	$10,518
II	Conversion to OHV technology	$2,873,322	$22.00	Not determined
	Improve OHV - modified combustion and intake	$84,850	$3.05	$59,602
	Improve OHV - piston / rings	$74,500	$4.60	$10,518

Source: U.S. Environmental Protection Agency, *Cost Study for Phase Two Small Engine Emission Regulations*, prepared by ICF/Engine Fuel Emissions, October 1996

8.2.4 Sales Test for Engine Manufacturers

A compliance cost to sales ratio was calculated for each small ultimate parent company for which D&B data were available. The Draft RIA concluded that not more than one of the Class II small engine makers would be impacted more than 1 percent of sales by the annualized costs of compliance. Of the four small-volume Class I manufacturers, D&B data are available for two of the four. One of these is also an equipment manufacturer which, if it has not already converted to OHV technology, at least currently manufactures significant numbers of OHV engines for use in its present product line. The other also produces Class II engines which would be impacted considerably less than one percent by the Class II standards. For these two manufacturers, the need to convert 2 Class I families to OHV designs should not significantly increase the economic impact of the regulations, certainly impacting less than amount equal to 1 percent of sales income. Data on the other two small volume Class I engine manufacturers were insufficient to determine the impact of these rules. Thus, in the worst case, the more stringent requirements for Class I engines could add at most 2 additional small business entities to this total. EPA believes that even if the two remaining engine manufacturers where impacted by more than one percent, this does not constitute a "significant number" of small entities .

8.3 Impact on Equipment Manufacturers

8.3.1 Number of Small Manufacturers

Data for this analysis were taken from the PSR Database (for models and sales), and from the D&B database for number of employees and for dollar value of sales. The PSR data show that there are 220 Class I manufacturers with 1,036 total equipment lines. They produce approximately 7 million units per year. D&B data are available for 150 manufacturers with a total production of about 3.8 million units. In addition, there were 70 manufacturers for which no D&B data are available, with annual production of about 3.1 million units.

Of the firms for which financial data are available, 27 are large manufacturers. These manufacturers produce approximately 3.4 million units per year, or 89 percent of the total production for which D&B data are available. The remaining 123 manufacturers are small businesses, producing approximately 460,000 units per year in 437 equipment lines.

No D&B data are available for 70 of the manufacturers. However PSR production figures indicate that two of these firms account for 90 percent of the 3.1 million total production involved, and must be assumed to be large. Although two other manufacturers account for 204,000 of the remaining 319,000 production units, EPA cannot assume with any certainty that these are large firms. Therefore, all of the remaining 68 manufacturers are assumed to be small business entities. In the absence of better information, EPA will assume that these entities are affected in the same proportion as the small business entities for which financial data are available.

Of the 123 small manufacturers with financial sales data, some 66 of these companies only manufacture Class I equipment, 40 produce both Class I and Class II equipment, and nine also make handheld equipment. The PSR data show that 10 of the 123 are California firms, which will presumably continue to market in California, and will therefore be required to meet the identical California standards well in advance of the Federal requirement. The California manufacturers produce roughly 47,000 units per year. They will not be included in this analysis, since they will already be meeting equivalent California standards when the Federal requirements take effect.

8.3.2 Impact on Equipment Manufacturers

Conversion to OHV technology may require equipment modifications to accommodate new engines. The ICF cost study provided estimates for Class II manufacturers which should be similar to the ones required for Class I equipment. Input from equipment manufacturers and other sources indicate that the longer OHV engines may necessitate some changes in cowling, hoods, or other components due to interference with some portion of the engine. Modifying existing equipment lines could require significant investment for tooling changes. Such costs are expected to vary, according to the type of equipment in question. Some pieces of equipment, due to their open configuration, could require little or no capital investment to make the changeover to OHV technology. Some applications already use OHV engines, or offer them as an option. The ICF cost study and the small business analysis took these differences into consideration in providing general estimates for the costs of modifying various types of equipment to accommodate OHV engines. EPA has subsequently modified some of these estimates to reflect information received from manufacturers and other sources. Table 8-3 summarizes the current estimates for these costs.

Table 8-3

Cost Estimates for Nonhandheld Equipment Manufacturers

Application	Fixed Costs (per line)	Variable Costs (per unit)
Lawn Mowers	$70,000	$0
Commercial Turf		
12 hp	$1,000	$0
>12 and <16 hp	$600,000	$0
> 16 to 25 hp	$100,000	$12
Leaf Blower/Vacuum	$50,000	$0
Snow Blowers/Tillers	$50,000	$0
Generator Sets	$100,000	$0
Pumps	$50,000	$0
Roller, Concrete Saw	$50,000	$0
Other	$50,000	$0

8.3.3 Possibility of Cost Passthrough

Small equipment manufacturers have expressed concern that the cost increases resulting from implementing the final standards could affect their sales. Two types of cost increases are involved: (1) the increased cost of engines to the equipment manufacturers and (2) costs involved in modifying equipment lines to utilize the new engines. EPA has concurred with the assumption found in both the ICF cost study and the small business analysis that the costs for new engines would be passed along to the consumer, since this would be an industry-wide impact. Costs for modifying equipment lines, on the other hand, could vary considerably from manufacturer to manufacturer according to variations in types of equipment made and existing equipment configurations. Such cost increases could potentially affect product demand.

Cost increases for equipment could potentially decrease the demand for new units in a number of ways: Customers might switch to another manufacturer, although ultimately they would likely find little advantage in doing so, due to the industry-wide scope of the regulations. Customers might also try to extend service life of older existing equipment. However, this strategy soon reaches the point of diminishing returns due to decreased reliability and increased maintenance costs, particularly for commercial applications with their higher usage. Alternatively, consumers might switch to electric equipment. However, this choice is limited by relatively low power and the inconvenience of dealing with power cords or by the higher cost of cordless equipment. This choice would likely be limited to less demanding applications, and again would be unlikely to apply to commercial operators. Finally, increased costs to engine manufacturers could lead them to drop low-production engine lines, which could affect some small-volume equipment lines that depend on others for their engines. The possible lack of availability of suitable engines could then force some small manufacturers with limited product lines out of business. However, again, EPA is providing flexibilities that should address these concerns and allow these relatively few small entities to continue production of their equipment.

EPA does not believe that any price increases that may result from this final rule will necessarily diminish the demand for these manufacturers' products. The Agency believes that the need for the products will likely remain even in the event of the cost increases contemplated by this rule--lawns will need to be mowed, water pumped, construction will need to go on, etc. Then too, the across-the-board nature of the increases for SI engines will ultimately impact all equipment manufacturers equally so that no manufacturer should gain a substantial competitive advantage. Individual small business equipment manufacturers have also informed EPA of the likelihood they would pass most, if not all, additional costs on to consumers. Many of these small business equipment manufacturers also appear to cater to niche markets, which provides a better opportunity for partial or even full cost passthrough. Finally, the ample lead time being provided allows transition costs to be spread over a longer period of time and for the necessary changes to be incorporated when other engine or equipment changes are made.

8.3.4 Other Considerations

Some existing OHV engines are manufactured with the same bolt pattern as the SV engines they replace--no retooling would be required, provided the equipment configuration presents no other clearance problems. Some manufacturers in fact offer a choice of SV or OHV engines on otherwise identical models. Then too, many product lines, particularly toward the high end of the price scale, seem to be open configurations which will require minimal changes to accommodate OHV engines. This could be due at least in part to purchase by commercial operators who are less concerned with styling considerations and more concerned with performance and reliability. The same could also be said for many generators, pumps and pressure washers. The timing of the California standards could also affect costs to equipment manufacturers. The California standards become effective the 2000 model year (MY). Many manufacturers will use the technology developed for their California engines to meet the Federal standards. Such usage would decrease or eliminate costs for meeting the Federal standards, at least for the 50 state equipment lines. Some manufacturers do not market in California, however, or maintain only a limited market presence there, and would thus not benefit from the development of California technology. EPA has no way of knowing the exact percentages involved, and so will conservatively assume that equipment models not produced in California will not be marketed there.

8.4 Estimation of Impacts on Small-Volume Equipment Manufacturers:

8.4.1 Base Case--No Flexibilities

Cost estimates were calculated per equipment model for each manufacturer. Each equipment model is assumed to correspond to an application with a specific horsepower rating. The fixed costs for each model were calculated and then annualized, using a nine percent annual cost of capital over a ten year period. The variable costs per unit were multiplied by the number of units produced annually, yielding total annual variable costs. These costs were then added to the annualized fixed costs to calculate the total annualized cost per model. An annualized cost of compliance for each manufacturer was calculated by summing the annualized costs per model for the number of equipment models produced by that manufacturer. The results were then compared to total value of sales for the manufacturer to determine the costs as a percentage of sales. The base case presented here depicts a worst-case scenario, in which none of the small-business equipment manufacturers take advantage of the flexibilities provided for small volume manufacturers or small volume equipment lines under the regulations.

Without the flexibilities, EPA estimates that the 113 small businesses for which D&B data are available would be impacted as shown in Table 8-5.

Table 8-5
Base Case

Percent of Sales Affected	Companies With D&B Data	Companies With No D&B Data	Total Businesses Affected	Percentage of Total
<1 percent:	66	39	105	(58 percent)
1-2 percent:	13	8	21	(12 percent)
2-3 percent:	13	8	21	(12 percent)
> 3 percent:	21	13	34	(18 percent)

The 68 small entities for which D&B information is not available must also be factored into the analysis. Applying equivalent percentages, Table 8-5 shows that 39 of these would be affected by less than one percent, 8 entities by one to two percent, 8 by two to three percent, and 13 by more than three percent. Adding these to the entities for which D&B data are available yields a total of 76 small entities that would be affected by more than one percent of sales by this rule. Although the number is noteworthy, this figure will be greatly reduced if equipment manufacturers take advantage of the regulatory small volume flexibilities described below.

8.4.2. Flexibilities Case

As noted above, EPA is finalizing a number of small-volume flexibilities which ease the burden of regulatory compliance on the smallest entities. There are two major small-volume flexibilities operating to benefit small equipment manufacturers:

(1) Small volume equipment manufacturers are defined as those manufacturers which produce less than 5,000 units per year for nonhandheld applications. Small volume equipment manufacturers will be allowed to use Phase 1 engines for three years beyond last date of standards phase in if they can demonstrate to EPA that no suitable Phase 2 engine is available. Engine manufacturers are allowed to continue production of the necessary engines to satisfy this demand.

(2) Small volume equipment models are defined as model lines consisting of less than 500 units for nonhandheld equipment model lines. These small volume models can use Phase 1 engines throughout the entire Phase 2 period if no suitable Phase 2 engine is available. Again, engine manufacturers will be allowed to continue production of the engines necessary to satisfy the demand.

These flexibilities would greatly decrease the impact of the Phase 2 standards as shown in Table 8-6.

Table 8-6

Flexibilities Case

Percent of Sales Affected	Companies With D&B Data	Companies With No D&B Data	Total Businesses Affected	Percentage of Total
<1 percent:	113	66	179	(99+ percent)
1-2 percent:	0	2	2	(<1 percent)

All but one of the companies for which D&B data are available would be impacted by less than one percent. The affected company makes both handheld and nonhandheld equipment, and if only the nonhandheld portion of its production is considered, it too is affected by less than one percent of sales. Applying a comparable percentage to the manufacturers with no D&B data would also result in none of the firms being affected by more than one percent of sales. However, as a worst-case analysis, an alternative way of looking at the effect on the manufacturers with no D&B data would be to see how many of their product lines would benefit from the flexibilities. Some 56 of the 68 manufacturers with no D&B data, but who are likely to be small business entities, would benefit from the small volume manufacturer and small volume equipment model flexibilities for all of their product lines, and an additional six manufacturers would gain partial benefit for about 70 percent of their total product lines. This would leave a total of not more than six manufacturers which could likely be impacted by more than one percent of sales. From sales data and other information, EPA believes that not more than one or two of these would actually be impacted by more than one percent of sales. In any event, the total number impacted would not amount to a "substantial number of small entities."

8.5 Conclusions

Analysis of the current data shows that, in the worst case, the majority of small Class I equipment manufacturing firms (58 percent) could be impacted by less than 1 percent of sales, given the flexibilities provided. Some 24 percent could be impacted between 1 and 3 percent of sales, and only 18 percent could be impacted by more than 3 percent. If the small manufacturers take advantage of the flexibilities offered, only a handful of firms would likely be affected by more than 1 percent of sales and none would be impacted by more than three percent of sales. Moreover, there are a number of mitigating factors which enter into the cost equation. For example, manufacturers with significant California sales would only incur costs on the portions of their product lines not originally sold in California. Also, many small manufacturers appear to be in niche markets, e.g, catering to commercial lawn operators who are not as sensitive to price as residential consumers. Many small manufacturers also produce high-end consumer products which are also less sensitive to price increases than mass-market products, and could thus pass much or all of any necessary cost increases on to the ultimate customers. Some of these products also appear to be less costly to convert to OHV technology because they are more open configurations , and not as highly styled as mass-market products. Many of these manufacturers also currently offer OHV engines as options or on major product lines for other reasons.

The ABT provisions also provide opportunity to reduce the impact on small entities. Under the ABT provisions, an engine manufacturer may be able to continue producing SV engine designs and not have to undergo the cost of converting to OHV technology if it can average the emission performance of the SV design with emission credits either earned from sale of low emitting OHV designs or purchase from other manufacturers. While it is presumed that a manufacturer would do so if this would lower its cost of compliance (indeed we expect such averaging will occur within a major manufacturer's product line), it is unknown to what extent small entities will be able to benefit from these ABT provisions. Therefore, no benefit is assumed in this analysis although EPA fully expects at least some niche market engine families whose sales are targeted at small equipment manufacturers will remain SV designs, thus causing no adverse impact on the equipment manufacturer.

Finally, the inclusion of additional flexibilities, which will benefit both small engine and equipment businesses, will further reduce impacts. For example, EPA is finalizing a hardship provision, which will provide additional relief to companies undergoing severe financial distress. Although this provision was not considered in determining the number of small entities that would be affected for compliance with SBREFA guidelines, it would serve as a safety valve to provide relief to a company in a state of poor financial health and facing further cost impacts of compliance with the final rule.

8.6 Outreach Activities

In addition to the comments received on the NPRM, EPA has made other outreach efforts. A number of small businesses were contacted to determine the impact of the more stringent standards for Class I engines. In addition, the Agency has been in contact with other small entities at their own request or at the request of trade associations. Numerous meetings have been held with industry and/or trade association representatives. Many of those who have provided input believe that sufficient lead time can alleviate some of the problems associated with a transition to OHV technology. Additional lead time allows for a more orderly transition to OHV engines when other engine or equipment changes are made. Many firms also expressed the belief that harmonization with California regulations will greatly ease the transition. EPA believes that this is a valid point, and has in fact increased the stringency of the Class I standards in part to facilitate harmonization with the California requirements.

Chapter 8: References

1. "Small Business Impact Analysis of New Emission Standards for Small Spark-Ignition Nonroad Engines and Equipment," prepared for EPA by ICF Incorporated under EPA Contract 68-C.-0010, August 1998, available in Docket A-96-55, Docket Item II-A-01.

2. "Cost Study for Small Engine Emission Regulations," prepared for EPA by ICF Incorporated under EPA Contract 68-C.-0010, October, 1996, Docket A-96-55, Docket Item II-A-04.

Chapter 9: Useful Life and Flexibility Supporting Data

9.1 Information on Useful Life

This Chapter contains information used by the Agency in the development of the final useful life categories for Phase 2 nonhandheld small engines.

During the development of the Phase 2 program, and during the development of the Phase 1 regulation, EPA was aware that the nonroad SI category of engines and equipment was comprised of a wide variety of equipment with a wide range of usage patterns. Nonhandheld engines are designed for many different types of applications, with each application having specific design criteria, resulting in different expected lifetimes. The most obvious example of these differences is the distinction between commercial (or professional) operators and residential (or home) operators. In general, commercial operators expect to accumulate high number of hours on equipment on an annual basis, such as commercial lawn-care companies or rental companies, while a residential operator expects to accumulate a relatively low number of hours on an annual basis, such as a residential chain saw owner. Several organizations have investigated the issues related to average life and annual use of equipment powered by small SI engines, including industry organizations, CARB, and the EPA. A brief summary of several of these reports is presented in the remainder of this Chapter.

9.1.1 Nonhandheld Useful Life Estimates from CARB

In 1990, the California Air Resources Board (CARB) contracted for a report from Booz, Allen and Hamilton which included estimates of usage rates and life spans for several categories of nonroad equipment powered by small engines.(Ref. 1) A summary of the information contained in the report is presented in Table 9-02.

Table 9-02
Summary of Information on Useful Life
Available from Booz, Allen & Hamilton Report, Nov. 1990
(Res. = residential user, Com. = commercial user)

Product Category	% of Total Sales, Home Use	% of Total Sales, Commercial Use	Res. Implied Avg. Lifespan (years)	Com. Implied Avg. Lifespan (years)	Res. Annual Hrs Use per Year	Com. Annual Hrs Use per Year	Res. Implied Avg. Lifespan (hours)	Com. Implied Avg. Lifespan (hours)
Walk Behind Mowers	88%	12%	7.04	2.68	20	320	141	858
Riding Mower (Frt. Eng.)	95%	5%	7.04	3.78	38	380	268	1,436
Riding Mower (Rear Eng.)	95%	5%	7.04	3.78	38	380	268	1,436
Garden Tractor	95%	5%	7.04	3.78	56	180	394	680
Tillers	60%	40%	7.04	5.41	18	72	127	390
Snowthrowers	90%	10%	5.41	5.41	10	60	54	325
General Utility	25%	75%	7.04	2.85	5	96	35	274
Shredders/ Grinders	60%	40%	7.04	5.41	17	190	120	1,028
Specialized Turf Care	0%	100%	N/A	3.78	N/A	800	N/A	3,024
4-cyc. blowers/ vacuums	60%	40%	7.04	2.68	10	190	70	509
4-cyc. edgers/ trimmers	60%	40%	7.04	2.68	10	190	70	509

This report also indicates there is a large disparity in average life-span between equipment used by residential and commercial applications. Residential equipment implied average lifespan estimates range from 35 to 394 hours, and commercial equipment implied average lifespan estimates range from 274 to 3024 hours.

9.1.2 Nonhandheld Useful Life Estimates from OPEI

A 1992 report from the Outdoor Power Equipment Institute (OPEI) report studied the issue of usage rates for two types of nonhandheld equipment, a summary of the report was provided in a subsequent memo from OPEI to EPA. (Ref. 2) The OPEI report included a nationwide phone survey of over 6,000 households. A summary of the information on usage rates for consumer owned walk-behind and ride-on mowers is presented in Table 9-03.

Table 9-03
Summary of OPEI 1992 Report on Residential Phone Survey

Equipment Type	B-50 value (years)	Median Annual Use (hours)	Median Hours Accumulated at B-50 value (hours)
Consumer Walk-behind Mower	5	20.0	100
Consumer Ride-on Mower	6	34.5	207

The term B-50 is used to denote the number of years at which 50 percent of the equipment from a particular model year are no longer in service, i.e., for consumer walk-behind mowers, after 5 years one-half of the mowers are no longer in-use.

9.1.3 Small Engine Equipment Usage Estimates used by EPA

The Agency has also developed estimates related to average annual use and equipment survival, many of these estimates are based on the usage information in the previously cited reports. These estimates are presented in Appendix F to this RIA which include Agency estimates of: average annual sales by equipment type, splits between residential and consumer equipment, average annual use by equipment, B-50 (number of years after which 50 percent of the equipment have failed). Figures 9-01 through 9-02 are a series of bar graphs summarizing the Agency's information regarding engine Classes and hours of

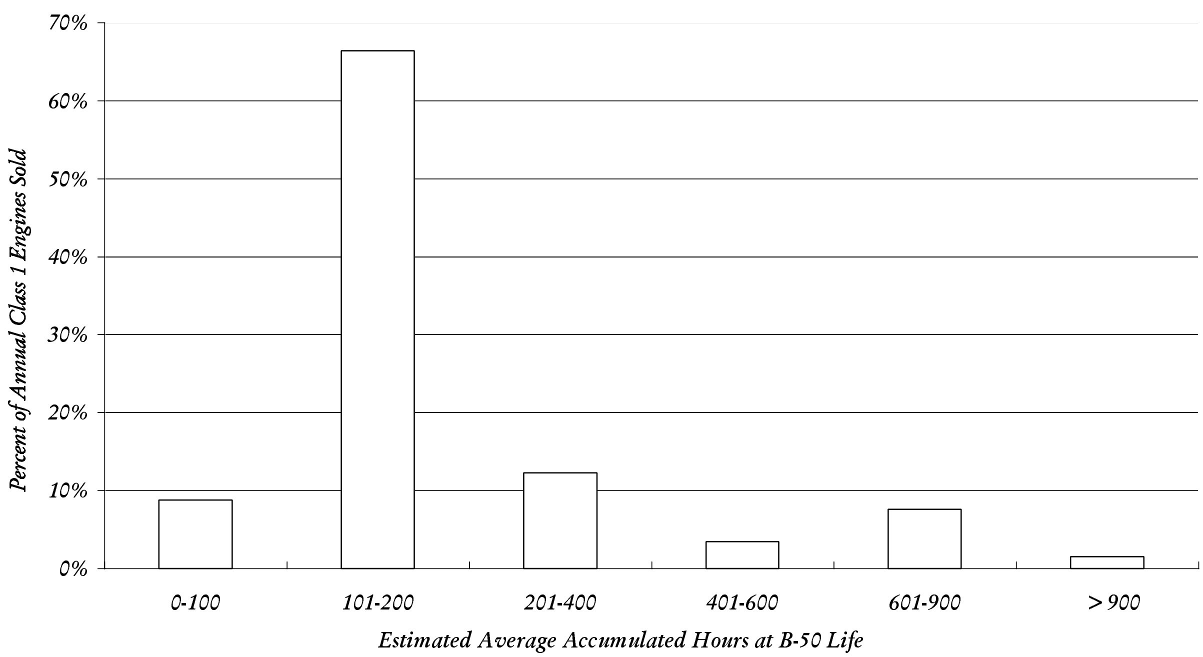

Figure 9-01: Summary of EPA Class 1 Engines Useful Life Estimates

use.

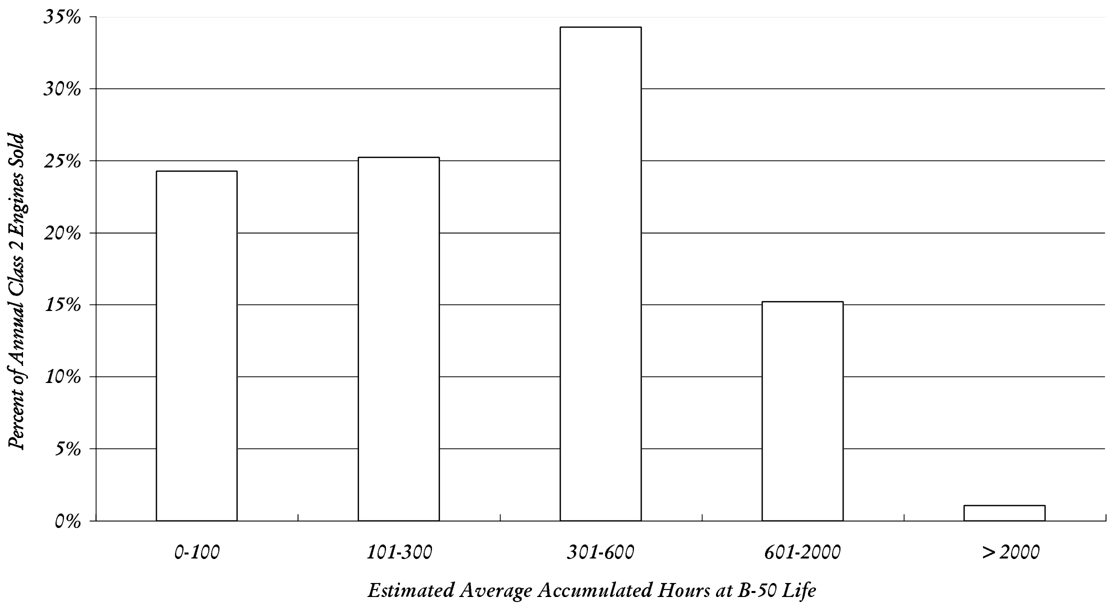

Figure 9-02: Summary of EPA Class 2 Engines Useful Life Estimates

Figures 9-01 thru 9-02 make it clear that small engines can accumulate vastly different hours of use over the life of the equipment. Manufacturers are able to design and build engines for various design lives which fit the type of equipment the engine is likely to be produced for.

9.1.4 Final Phase 2 Nonhandheld Useful Life Categories

EPA is adopting several useful life categories for nonhandheld engines. The final useful life categories are presented in Table 9-04. Based on the data presented in Sections 9.1.1 through 9.1.4 the Agency believes these useful lives are appropriate for regulatory purposes.

Table 9-04: Final Regulatory Useful Life Values for Phase 2 NHH Small SI Engines

Engine Class	I			II		
Category	C	B	A	C	B	A
Useful Life (hours)	125	250	500	250	500	1000

The Agency believes multiple useful life categories are appropriate considering the wide range of useful life values for small SI engines. At the same time, the Agency would like to keep the number of useful life categories small to avoid confusion among consumers. The Agency believes the three categories for nonhandheld engines and andheld engines fulfils the goal of having a small number of useful life categories, and at the same time, adequately covering the useful lives experienced by engines in actual use.

9.2 Background for Choice of Small Volume and Small Family Cutoffs

The Preamble for this rulemaking discusses a number of flexibilities the regulation provides for small volume engine and equipment manufacturers as well as small volume engine families and equipment models, (see Table 9-04 at the end of this section). This section describes the methodology utilized to develop these estimates. The main sources for this analysis include the EPA Phase 1 certification database (engine manufacturers) and Power Systems Research 1996 OE LINK database (equipment manufacturers) along with the results from EPA's work to analyze the impact on small businesses which can be found in Chapter 8.

9.2.1. Small Volume Engine Manufacturers

The work performed to determine the impacts on small businesses, as described in Chapter 8 of this RIA, utilized the SBA definition of 1000 employees as a cutoff for small volume engine manufacturers. An overview of the companies that fall under this definition, for which all information was available, showed that the companies varied in income and production volumes. Several companies were clearly small with low number of employees and annual revenue. However, several other companies produced 75,000 to 700,000 engines and had very high annual income. The high annual income and the high volume of engine production of some companies raised doubt about the use of the SBA definition in this rulemaking. EPA consulted the September 1998 Phase 1 certification database for its basis of a new definition of small volume engine manufacturer.

EPA reviewed the September 1998 Phase 1 certification database for the range of engine manufacturers and their estimated annual production in Classes I and II. EPA observed that there is a relatively clear break between large and small volumes among the engine manufactures. The database shows that thirteen manufacturers have sales under 10k, four have sales between 10k and 50k, three have sales between 50k and a half million and five have sales over a half million. Based on this, the production cutoff selected is listed in Table 9-05.

Table 9-05

Production Cutoffs for Small Volume Engine Manufacturer

# Engines	10,000

Application of these cutoffs to the September 1998 EPA Phase 1 database show that the nonhandheld definition will include 52% of the companies and 0.15% of the engine production.

9.2.2 Small Volume Engine Family

Data utilized to determine small engine families for the nonhandheld sections of this industry were from the EPA Phase I certification database. The number of engine families and family estimated production were utilized.

A value of 5000 is set for nonhandheld engine families as requested by EMA in comments to the NPRM. Refer to the Summary and Analysis document to this rulemaking for a discussion of the comments and EPA's response on this issue.

Table 9-06
Small Engine Family Definition

# Engines	5,000

The result is that approximately 57% of the engine families will be considered small engine families. While this may seem like a large number of families, when one compares the number of engines represented by these families and the total number of engines, only 1.16% of the annual production of small engines will be included in this definition.

9.2.3 Small Volume Equipment Manufacturer

The 1996 Power Systems Research EO LINK database and information from various equipment manufacturer associations were utilized to determine the cutoffs for small volume equipment manufacturers.

For nonhandheld equipment manufacturers, it is estimated that there will be an impact on equipment manufacturers currently using Class I and II SV engines. It is also estimated that there will be no equipment impact for engines using Class I or II OHV engines. The nonhandheld equipment industry is made of a large number of small companies and some larger well established companies. The basis for the cutoff is that this is the general point at which production per equipment manufacturer increases exponentially. As shown in Table 9-07, the cutoff for small volume equipment manufacturer is selected at

5,000 units. Based on PSR, this would affect only 1.61% of the equipment production and 82% of the equipment manufacturers. However, this impact is very likely to be less than that calculated with the data in the PSR database based on the results from the work done to analyze the impacts of this rulemaking on small businesses using Class II engines (see Chapter 8 of the RIA). The results showed that many of the small[39] volume equipment manufacturers have already converted their products to utilize OHV engines. This is mainly due to market competition or engine manufacturers already beginning to phase out Class II SV engines.

Table 9-07
Small Volume Equipment Manufacturer

# Units	5,000

9.2.4 Small Volume Equipment Model

The analysis to determine the cutoff for small volume equipment models, see Table 9-08, was based on the need by some equipment manufacturers to be able to use Phase 1 engines for niche market applications. In addition, the cost of adapting low volume equipment with new engines may result in the elimination of that product from the marketplace. In order to set a reasonable cutoff for small volume equipment models, the sales estimate data in the PSR 1996 OE LINK database and the 1998 Phase 1 certification database were used. Based on review of the Phase 1 engine certification database, it is clear that there are some manufacturers with engine families under 500 in sales. A number of these are companies utilize clean OHV engines, but that must also meet the CO

[39] The definition of small in the study was determined by the Small Business Administration for the corresponding SIC codes. The definition was based on employment of the ultimate parent. For this industry it was set at 500 employees or less.

standard for OSHA indoor air quality that these are affected companies by EPA's Phase 2 rulemaking for small SI engines in that the enleanment of the engine raises them above the HC+NOx limit. The use of ABT will aid most manufacturers, however there are a few which cannot use ABT effectively due to the limited number of engine classes.

Based on the PSR 1996 OELINK database, a cutoff of 500 units will result in approximately 1.14% of the equipment being allowed to utilize the flexibility of using a Phase 1 engine throughout Phase 2. The result may be less for the database for this analysis does not consider whether the equipment manufacturer or engine manufacturer has or will have already converted the line to be in compliance with California ARB standards.

There are a number of factors that will influence whether this definition is put to use by equipment manufacturers. These include 1) the distribution system for engines and equipment is complex and all engine fmailies may meet the standards in order to have a nationwide engine program, 2) the inability for engine manufacturers to pick who gets a "lower price enigne" over others, 3) market pressure for a Phase 2 certified engine may result in less use of this flexibility, 4) some technologies require little changes to the engine and therefore the equipment changes are minor.

Table 9-08
Small Volume Equipment Model

# Units	500

Table 9-04

SUMMARY OF RULEMAKING FLEXIBILITIES

The table below lists the flexibilities adopted in the final rule.

SECTOR	CUTOFF	FLEXIBILITY
Small Volume Engine Manufacturer / Small Volume Engine Family	NHH: 10,000 / 5,000	1. Allowed to be "Phase 1" engines until 2010 model year. Excluded from ABT until model year 2010 2. Can opt out of PLT; SEA still applicable. 3. Can certify using assigned deterioration factors.
Class II SV Engine Family	1000 and less	24 g / kW-hr HC+NOx standard throughout Phase 2
Small Volume Equipment Manufacturer	NHH:5,000	Can use a Phase 1 engine, and manufacturer can supply this engine if no Phase 2 engine is available for existing equipment, for up to three years beyond last date of phase-in of standard. These dates are: Class I: Aug 1, 2010 Class II: 2008 MY
Small Volume Equipment Model	NHH: 500	Can use Phase 1 engines throughout Phase 2 if they demonstrate no Phase 2 compliant engine is available for existing model (if the equipment is "significantly modified" then this exemption ends)
Any Equipment Manufacturer	ALL	Any equipment manufacturer which demonstrates substantial economic impact if required to use a Phase 2 engine may use a Phase 1 engine for 1 year beyond last implementation date of the applicable Phase 2 standard. These dates are: Class I: Aug 1, 2008 Class II: 2006 MY

Chapter 9: References

1. "Utility Engine Emission Report", prepared by Booz, Allen & Hamilton Inc., for the California Air Resources Board, November 20, 1990. This report is available in EPA Air Docket A-93-25, Docket Item # II-I-02.

2. "Useful Life, Annual usage, and In-use Emissions of Consumer Utility Engines", memo from the OPEI CAAC In-Use Working Group to Ms. Gay MacGregor, US EPA, EPA Air Docket A-96-55, Docket Item # II-D-13.

APPENDIX A

Appendix A: Industry Characterization

This Appendix discusses the structure of the industries producing engines and equipment affected by this FRM.   The industry characterization presented here is taken from a report prepared under a contract work assignment for EPA by Jack Faucett Associates.(1) The purpose of the work assignment was to prepare a report describing and analyzing the market structure, conduct, and performance of the small nonroad engine and equipment industry and to assess the technologies represented by the most common engines and equipment. The following descriptions are excerpted from that report. Some sections which are excerpted are specific to the Lawn and Garden Equipment Standard Industrial Code (SIC) 3524, although 11 SIC code categories were analyzed in the report. The reason this section is focusing on the lawn and garden equipment category is that most of the engines and equipment covered by this regulation are in that category.

> [T]he small nonroad engine market is best described as a chain of industries that: convert raw materials into components, engines, and equipment; distribute the final product to end users; and, provide service and parts as required. The establishment of regulation or alternative-market based regulatory approaches will impact this chain of industries in a variety of ways. The structure of this chain, and the characteristics of the industries that comprise it, will influence how successful alternative control strategies will be in practice.
>
> ...
>
> [The relationships and flow of goods for engine manufacturers are as follows: 1) raw materials and components are purchased from suppliers. Necessary raw materials include the steel and aluminum required to manufacture engine parts. 2) The amounts and types of purchased components will vary from one manufacturer to another. Some engine manufacturers make their own parts, others purchase components. Die-cast molds are used to forge parts. 3) The finished parts and components are assembled into engines on an assembly line.
>
> Complete engines are sent to one of three places: equipment manufacturers, distributors, or export markets. A great deal of engines are sold directly to equipment manufacturers. In cases where engine manufacturers are vertically integrated, these sales would be recorded as intra-company transfers. Direct sales to equipment manufacturers is particularly common for high volume consumer equipment and for technically demanding equipment for the commercial market. The large volume engine manufacturers such as Briggs & Stratton and Tecumseh sell directly to mass merchandiser equipment manufacturers such as Murray Ohio Manufacturing and American Yard

Products. Price and economies of scale[40] are the primary factors of competition for engine sales to mass merchandisers. For direct sales to equipment manufacturers producing mid-range and premium priced equipment, engineering and design cooperation is essential. In these cases, the engine manufacturers also work closely with the equipment manufacturers to develop superior products.

For smaller equipment manufacturers, or for some of the cases where there is no need for technical cooperation, it is usually not cost-effective for the engine manufacturer to sell engines directly to the equipment manufacturer. In those cases, engine manufacturers often ship engines to independent wholesale distributors. As independent businesses, these distributors carry engines from multiple manufacturers. The distributors then sell the engines to original equipment manufacturers (OEM's) to be installed as product components. Distributors also sell "loose" engines as replacement parts. Large-scale end-users and dealers/retailers who provide service on used equipment are the most frequent purchasers of replacement engines. Engines not sold to equipment manufacturers or domestic distributors are shipped as exports.

In every segment of the utility industry, equipment manufacturers must decide whether to use "two-tiered" distribution channels or to interface directly with their dealer network. In a two-tiered distribution system, an independent wholesale distributor acts as an interface between the equipment manufacturers and the dealer network. Distributors add value by providing service to both the equipment manufacturers and the dealer network. Distributors remove a great deal of the inventory burden from dealers. Because dealers generally do not have the facilities or financial strength to maintain large inventories, they must frequently order parts for repair. Successful distributors can usually provide parts within 24 hours. In the absence of a distributor, parts must be shipped from the equipment manufacturers by package delivery services (such as UPS). This can take several days or more, depending on manufacturer location and the availability of the part. Furthermore, because many dealerships are small businesses, they often rely on their distributors for bookkeeping and general business support. Enhanced service provided by the distributors improves the reputation of the equipment manufacturers. Also, distributors provide market information to manufacturers because they are closer to the consumers and are often able to identify emerging trends faster than the manufacturers themselves.

Despite the added value that distributors provide for both dealers and manufacturers, they are declining in numbers and importance. This shift is generally attributed to the ever increasing price competition in the consumer marketplace. The value added by distributors must be offset by the profit margin required by the additional tier in the distribution chain. Although distributors will remain important, particularly for premium line equipment, their impact on the market is projected to decline.

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[40] An economy of scale is said to exist when larger output is associated with lower average cost.

The distribution system for lawn and garden equipment manufacturers is probably the most diverse and complex in the utility market. This is primarily due to the different needs of the commercial and consumer markets. The bulk of all lawn and garden unit sales go to consumer end-users.[41] However, commercial customers represent too large a market to ignore, and some equipment manufacturers and members of the distribution chain focus strictly on the commercial business. Balancing the commercial customers need for performance and service with the consumer customers need for a low price is the challenge facing manufacturers and the distribution channels they have developed.

[The relationships and flow of goods from the viewpoint of the lawn and garden equipment manufacturers are as follows: 1) the manufacturers design and manufacture their own parts and/or purchase components, 2) the finished parts and components are assembled into end-user equipment, 3) finished goods are sent to one of three places: wholesale distribution dealers or other retail establishments, or shipped for export.]

Some manufacturers use a direct (i.e., one-tier rather than two-tier) distribution system, dealing directly with dealers or other retail establishments. The larger the manufacturers and the larger the retail unit, the more likely that this link will be direct. Mass merchandiser manufacturers deal directly with mass merchant and discount retail outlets. Some manufacturers deal directly with all types of retail outlets. The trend towards direct distribution is expected to continue, as is the trend towards the mass merchandisers. These trends serve to keep prices low, foster price based competition, and put a squeeze on distributors and local dealers. The average service dealer makes $100,000 to $250,000 in sales per year. There are 300 dealers that bring in over $1,000,000 in revenues annually. There are also a great many dealers that have less than $100,000 annual revenues. Dealers are extremely dependent on service revenue to stay in business. Approximately 50 percent of the average dealers revenues are realized through parts and repair work.[42]

As emission requirements force small nonroad engines to be more complex, more will be expected of small engine technicians. The situation is similar to automobile dealers who must perform vehicle emission compliance work. Jeff Voelz, Marketing Director at Onan Corporation, noted that, "dealers will have to get savvy and understand that this is their future."[43] As in the automotive industry, emission control advances are likely to reduce the user's maintenance abilities and require an increase in small engine technician skills.

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41 For example, OPEI estimates that 90% of walk behind lawnmower sales go to the residential market.

42 North American Equipment Dealers Association.

43 Phone conversation on June 8, 1992.

Although two-tier distribution is declining, it is still an important feature of the distribution network. According to a survey of its members, OPEI found that 41.4 percent of shipments were distributed through wholesale distributors in 1988. Many manufacturers use two-tier distribution for virtually every type of retail establishment, although distributors are generally bypassed when shipments go to mass merchandisers and discounters. Because of fierce price based competition, the pressure is on distributors to prove their ability to add value in order to maintain their volumes of business in the future.

Most manufacturers choose to focus on either the consumer or commercial market. These factors, in turn, influence their choice of distribution channels. Manufacturers that focus strictly on the consumer market, especially at lower end prices, generally retail exclusively through mass merchandisers. Manufacturers that focus strictly on the commercial market, generally rely exclusively on dealers. Mid-range manufacturers and other manufacturers that wish to compete at the commercial or top-end consumer market and the low-end consumer market face a difficult choice. It is tempting to use both mass merchandisers (for sales volume) and dealers (for value added service). However, this creates tremendous conflict within the channels, particularly for the dealers. The dealers cannot match mass merchandisers on price, and frequently end up as repair shops, merely servicing the equipment that they can no longer sell. The solution to this situation that has been most successful is to sell separate lines of products, restricting the mass merchandisers from selling the higher quality product lines. McCullough has been able to do this successfully. Toro tried to do this, but eventually withdrew from mass merchandiser outlets. Toro is now trying the mass merchandisers again with its Lawnboy subsidiary.

This discussion of lawn and garden manufacturer distribution channels primarily addresses nonhandheld equipment manufacturers, although, in general, it applies to handheld equipment manufacturers as well. There are, however, some unique facets of the handheld manufacturers distribution networks that have not been previously addressed. The major difference is that the handheld manufacturers all make their own engines. This changes the mixture of raw materials and components they purchase as well as their manufacturing and design processes. A separate engine market would not suffice for handheld manufacturers because of the size, performance, and design restrictions placed on their products by the unique end-user requirements for handheld equipment.

There are only a handful of nonhandheld equipment manufacturers that are vertically integrated. ? of these, producing a broad line of premium engines and products from its North Carolina plant. Kubota is also another example of a major manufacturer of both engines and equipment.(2)

...

The Lawn and Garden Equipment Industry (SIC 3524) accounted for 0.11 percent of GDP in 1990. ... Constant dollar shipments have increased sharply, with a 33.1 percent increase from 1984 to 1990. ... [R]oughly the same number of companies were responsible for the increased out, indicating that new firms entering the industry may not have been responsible for higher output. Value added as a percent of output for the industry in 1990 was 40.9 percent, roughly the same as the internal combustion engine industry.

This industry does not seem to be capital intensive, as assets were only 18.8 percent of output in 1990, less than the corresponding percentage for All Manufacturing Industries. ... In addition, capital turnover rates are 15.6 years, slightly above the average for All Manufacturing Industries. As a result, should regulation result in new purchases of capital, the industry may not have as much difficulty as other industries in adapting to regulatory actions.

Concentration in this industry is high, as the 8 largest companies control 71 percent of the market. These companies may have the ability to influence the price of their products. Yet the industry does not seem to have excess capacity, with a capacity utilization rate of 73 percent. This figure is slightly less than the 76 percent rate for All Manufacturing Industries. ...

...

Because the Statistics of Income Classification code relevant to the Farm Machinery and Equipment industry includes both 4-digit SIC codes 3523 and 3524, the profitability analysis for the Farm Machinery and Equipment industry also applies to the Lawn and Garden Equipment industry. For 1988, profitability for this industry seemed quite good, with the average return on equity up to 17.9 percent, a 14.1 percent increase from 1990. The average debt to asset ratio, however, is among the higher of the seven minor industries considered ... at 42 percent.

...

Constant dollar shipments are expected to grow at an annual rate of 2 percent over the next 5 years for the Lawn and Garden Equipment industry. The U.S. Industrial Outlook attributes this increase to several factors, first among them are demographic changes in the U.S. population. In particular, the fastest growing age group, 44-54, will be near their maximum earning potential, which should result in larger expenditures on lawn and garden equipment. The report also notes that many of these consumers will be more inclined to upgrade their current properties, which may entail landscaping. The removal of trade barriers in Mexico and Canada as a result of the North American Free Trade Agreement (NAFTA) should give companies in the three North American countries the opportunity to expand their exports. In addition, the report mentions that possible environmental standards may have an impact on sales, but the report does not give a clear indication of whether or not these regulations will cause sales to increase or decrease.(3)

...

[M]any of the eleven 4-digit SIC industries encompassing the small nonroad engine and equipment industry are characterized by significant value added, fairly high concentration, growth in the value of shipments, capital intense production processes, high capital turnover, and relatively efficient capacity utilization. These basic industry trends determine the competitive nature of the industry and condition the interactions of the firms that form these industries with suppliers, consumers and each other.(4)

[T]he competitive features of the small nonroad engine and equipment industry have been reviewed. These features include: channels of product distribution, the levels of vertical and horizontal integration across engine and equipment manufacturers supplying the nonroad engine and equipment industry, the types and extent of barriers to entry that may exist in this industry, the degree of market power inherent in the nonroad engine and equipment industry at various levels of producer interactions, the availability and importance of substitute power sources for ? engines, the global competitive position of U.S. firms in this industry, and characteristics of end-users which drive the demand for the various products that are sold in the small nonroad equipment industry. Such a comprehensive description of this industry's competitive features has revealed various interesting results which should be summarized.

First, the level of vertical integration in the small nonroad engine and equipment industry appears to be rather small. Where present, vertical integration is concentrated in three areas of the industry: foreign lawn and garden engine and equipment manufacturers, foreign recreational engine and equipment manufacturers, and handheld lawn and garden engine and equipment manufacturers. For example, Honda produces both the engine and equipment components of their lawn and garden products... In fact, most of the vertically integrated companies are foreign companies.

Horizontal integration, on the other hand, is common among engine manufacturers in the small nonroad engine and equipment industry. This follows directly from the fact that a single engine design is often used in many small nonroad equipment applications. ...[T]ecumseh and Briggs & Stratton engines, for example, are employed by various types of equipment including lawn and garden equipment, light commercial and industrial equipment, light agricultural equipment, and others.

Second, advertising and product differentiation, economies of scale, and large capital requirements appear to be the only forms of barriers to entry that <u>may</u> characterize the small nonroad engine and equipment industry. However, the effectiveness of these phenomena is difficult to assess. Nevertheless, advertising plays an important role in the lawn and garden equipment industry, as shown by its relatively high advertising intensity ratio. Similarly, product differentiation is important in this market as evidenced by the large number of brands and product models that are offered for different equipment types, such as lawnmowers or chainsaws...

Economies of scale and large capital requirements, on the other hand, are likely to be more important at the engine manufacturing level of the industry, since this level is capital intensive and characterized by few dominant sellers. It should also be noted that patents may play an important role in deterring new entry as a result of Section 308 of the Clean Air Act. Ryobi, for example, may clearly have a competitive advantage if its new 4-stroke CleanAir Engine is protected through patent.

...[O]ne general characteristic of the industries that comprise the small nonroad engine and equipment industry is high levels of seller concentration. Empirically, high seller concentration has been shown to perpetuate product pricing that is above the marginal cost of the products production.(5) ...[R]esults that are characterized by this pricing outcome are economically inefficient, and display the market power, of at least the market leaders, in the industry. However, although the small nonroad engine and equipment industry is generally characterized by seller concentration, ...the various relationships between the economic agents operating in this industry are not characterized by significant levels of market power. Much of the reasoning behind this conclusion centers on the concept of contestable markets... The fact that the small nonroad engine and equipment industry is not characterized by market power implies that if regulatory actions increase the production costs of the firms producing in this industry, then these incremental costs will likely be passed on to consumers, or end-users, in the form of higher prices. Moreover, the likelihood that market power is not prevalent in the small nonroad engine and equipment industry implies that economic profits are not being accrued in the long run. This in turn suggests that entry into the market is relatively free. Although some aspects of barriers to entry may exist (such as product differentiation, advertising, and economies of scale), their effectiveness at deterring entry is not necessarily evident.

Fourth, the prevalence of substitute power sources and equipment that displace equipment powered by internal combustion engines is most evident in the lawn and garden equipment market where electrically powered machines have been common for many years. However, the sale of electrified lawn and garden equipment is hampered by various factors. For example, the long extension cords necessary for the operation of electrified equipment are cumbersome, while electrified lawn and garden equipment are generally not a viable option for commercial users. However, use of battery packs could potentially resolve some of the detrimental user oriented externalities associated

Appendix References

1. Jack Faucett Associates, *Small Nonraod Engine and Equipment Industry Study*, JACKFAU-92-413-14, December 1992

2. ibid, pages 68-76

3. ibid, pages 57-58

4. ibid, p. 67

NOTE: Graphs not included in this electronic version

APPENDIX B

Appendix B: Manufacturer and Product Summary

B.1 Introduction

This appendix summarizes information on the equipment related to the category of engines regulated, nonroad 0-19 kilowatt spark-ignited engines. This appendix summarizes the engine manufacturers and their products, the technology used on these engines, and estimates the amount of these engines consumed in the United States.

B.2 Engine Manufacturer Summary

There are a wide variety of engine manufacturers producing engine products which will be regulated. Data on the manufacturers and their products is provided from EPA's Phase 1 certification database[44].

B.2.1. Listing of Known Engine Manufacturers

EPA has generated a listing of engine manufacturers from EPA database. It appears that there are approximately 26 engine manufacturers selling nonhandheld gasoline engines under 25 horsepower. Please refer to Table B-01, which summarizes the manufacturers who produce nonhandheld engines.

B.2.2. Listing of Known Engine Models per Manufacturer

The EPA Phase 1 database contains the most extensive listing of information at the engine model level. The data in this section is excerpted from this database. Presented in Table B-01 are the number of engine models per manufacturer and the estimated number of engine models in each standard

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44 All engine models for production in the 1997 model year were to be certified by September 1, 1997. The only exception are those models that are exempt from CARB's Tier 1 program (Class V engines) which have until January 1, 1998. **CHECK!**

category.

B.2.2.1. Number of Engine Models- Table B-01 shows that there are 151 engine models in Classes I and II (nonhandheld). There are five nonhandheld engine manufacturers of moderate diversity producing between 15 and 25 engine models for approximately 64%of the number of 4-stroke engine models. The two most diverse engine manufacturers produce 32% of the engine models, while the most diverse engine manufacturer produces 16.5% of the product models. The data these conclusions are based on are summarized in Table B-01.

B.2.2.2. Engine Family and Emissions Per Engine Family Per Class -- Table B-02 through B-06 contain information per engine family per manufacturer on engine family, new engine emissions (HC, NOx, CO), emission control technology, major applications and displacement.

Since the final Phase 2 regulation is an in-use set of standards, the new engine values from the Phase 1 certification database have been deteriorated to compare to the new engine standard. Deterioration factors were taken from data submitted by industry and EPA's own analysis. Table B-07 lists the deterioration factors applied to the corresponding engine families. EPA requests comment on the accuracy of the information presented in all tables in this Appendix.

Table B-07
Deterioration Factors

CLASS	I	II
	HC+NOx	HC+NOx
SV	2.1	1.6
OHV	1.5	1.4
2-STROKE	1.1	--

B.3 Estimate of Historical and Future Equipment Consumption (Population)

EPA's NONROAD model was utilized to calculate HC, NOx and CO inventories and fuel consumption by Class. The calculations in the NONROAD model are based on the population of each equipment. The NONROAD model uses national equipment population data from Power systems Research (PSR), a company that tracks the sales and populations of all types of nonroad equipment sold in the U.S. Nonroad engines were separated based on market sector and fuel type. Individual applications in the PSR database were assigned to broad market sectors. Eight market sector populations, segregated by fuel type, were calculated for each year from 1989 through 1996. For future populations, EPA extrapolates using a simple linear regression of the historical populations for estimates of future populations.

The results from this work were reviewed by the small engine team prior to inclusion in this FRM. The NPRM inventory and fuel consumption estimates were based on the NSEEM model and the team compared the outputs from the NONROAD model to those from the NSEEM model. Differences in the inventories were identified and it was determined that the population of each Class was the main source of the difference. The team then calculated expected populations utilizing a reliable base for sales information, the Phase 1 certification database, to which all engine manufacturers had certified their engine families and supplied confidential estimated sales for 1998. The certification database allowed identification of sales for only four major equipment types (lawnmowers, chainsaws, trimmers and blowers) for the majority of engine families were identified to be used in several applications. The sales values were converted to populations for using the NSEEM model[45].

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[45] The 1998 sales for the noted applications were updated in the NSEEM model, and sales were extrapolated from the last date of the industry

The 1996 populations for the four applications were then compared with those in NONROAD and the updated populations were passed onto the NONROAD modeling group who then updated the base population estimate for the major applications. The outputs from the NONROAD model were then agreed upon and used by the team in this rulemaking.

known sales data for each application (see the Phase 1 RSD), and a 1996 population for each application was calculated.

Table B-01
Engine Manufacturers and Engine Families Per Class and Engine Type
EPA Phase 1 Certification Database

Manufacturer	Number of Engine Families for Each Standard Category					TOTAL
	I SV	I OHV	I 2-S	II SV	II OHV	
A.L. Cook					3	3
Briggs & Stratton	6	5		6	11	28
Daihatsu Motors					3	3
Flex Systems					1	1
Fuji Heavy Industries, Ltd.	2	3		2	6	13
Generac		3			8	11
Honda	2	8			10	20
Hydramaster					1	1
Kawasaki		4		1	11	16
Kohler Company		1		3	17	21
Kohler Company Generator Division					9	9
Kubota		3			5	8
Lister- Petter					3	3
Mayville Engineering					1	1
Minute man					3	3
Mitsubishi Engine North America, Inc		2			3	5
Onan				5	3	8
Pioneer/Eclipse Corp.					4	4
Spectrum Industrial Products Inc.		1			3	4
Suzuki		1	3		2	6
Swiss Clean					2	2
Tecumseh	8	6		7	6	27
Toro					1	1
Westerbeke					6	6
Wis-con Total Power Corp.				3		3

Yamaha Motor Company, Ltd.		3			3	6
TOTALS	18	40	3	27	125	213

APPENDIX C

Table C-03

TOTAL COSTS

NOTES:
All costs are as incurred.

	2001	2002	2003	2004	2005	2006	2007	2008
CERTIFICATION COSTS	$1,354,950	$4,354	$24,243	$52,841	$118,258	$0	$269,175	$0
PLT COSTS	$498,960	$498,960	$498,960	$498,960	$498,960	$574,560	$785,680	$785,680
TOTAL COSTS	$1,853,910	$503,314	$523,203	$551,801	$617,218	$574,560	$1,054,855	$785,680

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
CERTIFICATION COSTS	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
PLT COSTS	$785,680	$785,680	$785,680	$785,680	$785,680	$785,680	$785,680	$785,680	$785,680	$785,680
TOTAL COSTS	$785,680	$785,680	$785,680	$785,680	$785,680	$785,680	$785,680	$785,680	$785,680	$785,680

	2019	2020	2021	2022	2023	2024	2025	2026	2027
CERTIFICATION COSTS	$0	$0	$0	$0	$0	$0	$0	$0	$0
PLT COSTS	$785,680	$785,680	$785,680	$785,680	$785,680	$785,680	$785,680	$785,680	$785,680
TOTAL COSTS	$785,680	$785,680	$785,680	$785,680	$785,680	$785,680	$785,680	$785,680	$785,680

APPENDIX D
(Reserved)

APPENDIX E

Table E-05
Fuel Consumption

Price /gallon from Energy Information Administration

Average refinery price to enduser in 1995$ = $0.765

1998$ = 0.794

1998$ obtained by multiplying $0.765 by the GDP Implicit Price Deflators for 1996, 1997, 1998 of 1.9%, 1.9%, 1.0% respectively

ALL CLASSES

	CLASS I tons/yr	CLASS II tons/yr	Total tons/yr	difference $/yr
2001	0	(114,528)	(114,528)	($26,802,859)
2002	0	(225,316)	(225,316)	($52,730,450)
2003	0	(343,158)	(343,158)	($80,308,880)
2004	0	(458,640)	(458,640)	($107,335,002)
2005	0	(577,403)	(577,403)	($135,128,973)
2006	0	(670,233)	(670,233)	($156,853,874)
2007	(38,862)	(737,134)	(775,996)	($181,605,469)
2008	(122,831)	(788,844)	(911,675)	($213,358,273)
2009	(183,138)	(830,521)	(1,013,659)	($237,225,474)
2010	(220,311)	(864,385)	(1,084,696)	($253,850,183)
2011	(246,553)	(893,571)	(1,140,124)	($266,821,935)
2012	(266,977)	(917,702)	(1,184,679)	($277,249,091)
2013	(281,508)	(939,540)	(1,221,048)	($285,760,487)
2014	(290,908)	(959,800)	(1,250,708)	($292,701,784)
2015	(298,988)	(978,894)	(1,277,882)	($299,061,284)
2016	(306,684)	(1,001,004)	(1,307,688)	($306,036,749)
2017	(312,922)	(1,019,345)	(1,332,267)	($311,788,945)
2018	(318,589)	(1,037,407)	(1,355,996)	($317,342,216)
2019	(323,925)	(1,055,282)	(1,379,207)	($322,774,260)
2020	(329,186)	(1,073,011)	(1,402,197)	($328,154,584)
2021	(334,446)	(1,090,598)	(1,425,044)	($333,501,442)
2022	(339,702)	(1,108,138)	(1,447,840)	($338,836,364)
2023	(344,965)	(1,125,619)	(1,470,584)	($344,159,116)
2024	(350,219)	(1,143,095)	(1,493,314)	($349,478,593)
2025	(355,482)	(1,160,559)	(1,516,041)	($354,797,367)
2026	(361,512)	(1,181,948)	(1,543,460)	($361,214,205)
2027	(366,804)	(1,199,816)	(1,566,620)	($366,634,313)

P/A Factor for 7% discount rate

discount rate	0.07	
21 years	10.8355	Class I
27 years	11.9867	Class II

APPENDIX F

Table F-01

Average Power Rating (hp) of Nonhandheld Equipment by Engine Type*

Equipment Description	G2N1	G2N2	G4N1O	G4N1S	G4N2O	G4N2S
LAWN AND GARDEN EQUIP.(RES)						
Leafblowers/Vacuums	NA	NA	8.35	3.42	14.20	14.20
Lawn & Garden Tractors	NA	NA	9.59	5.50	18.40	18.40
Lawn Mowers	NA	NA	4.10	2.55	6.24	6.24
Other Lawn &garden Equipment	NA	NA	8.26	4.81	20.00	15.60
Rotary Tillers < 6HP	NA	NA	4.68	4.68	4.68	4.68
Rear Engine Riding Mowers	NA	NA	6.24	4.10	20.42	20.42
Snowblowers	NA	NA	4.59	4.59	12.41	8.48
Shredders < 6 HP	NA	NA	3.00	3.00	5.01	5.01
Trimmers/Edgers/Brush Cutters	NA	NA	7.86	3.30	18.00	18.00
LAWN AND GARDEN EQUIP.(COM)						
Commercial Turf Equip. (2&4-stroke)	5.00	NA	8.76	5.17	16.93	16.93
Front Mowers	NA	NA	11.25	11.25	20.42	20.42
Leafblowers/Vacuums	NA	NA	8.35	3.42	14.20	14.20
Lawn & Garden Tractors	NA	NA	9.59	5.50	18.40	18.40
Lawn Mowers	NA	NA	4.10	2.55	6.24	6.24
Other Lawn &garden Equipment	NA	NA	8.26	4.81	20.00	15.60
Rotary Tillers < 6HP	NA	NA	4.68	4.68	4.68	4.68
Rear Engine Riding Mowers	NA	NA	6.24	4.10	20.42	20.42
Snowblowers	NA	NA	4.59	4.59	12.41	8.48
Shredders < 6 HP	NA	NA	3.00	3.00	5.01	5.01
Trimmers/Edgers/Brush Cutters	NA	NA	7.86	3.30	18.00	18.00
COMMERCIAL EQUIP.						
Air Compressors	NA	NA	9.51	5.00	18.50	13.90
Generator Sets	1.78	NA	8.82	4.59	20.80	14.30
Pumps	1.00	2.29	8.40	4.69	18.30	14.90
Pressure Washers	NA	NA	9.73	4.78	18.60	14.20
Welders (2 and 4-strokes)	5.98	NA	9.72	9.41	16.20	16.20
LOGGING EQUIP						
Shredders >6hp (4-stroke)	NA	NA	NA	NA	8.16	8.16

*These power ratings were calculated from the Nonroad Model inputs by weighting power categories within each equipment type by the equipment population values at baseline.