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Regulatory Impact Analysis and Regulatory Support Document

Control of Air Pollution; Emission Standards for New Nonroad Spark-Ignition Engines At or Below 19 Kilowatts

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

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Introduction

This document presents the Regulatory Impact Analysis (RIA) for the Final Rulemaking (FRM) for the establishment of Emission Standards for New Nonroad Spark-ignition Engines At and Below 19 Kilowatts, herein after referred to as the Smallgas FRM.

This RIA is organized into chapters and appendices. Chapter 1 presents the engineering evaluation EPA has undertaken to determine the possible technical solutions for emission reductions from these engines. In Chapter 2, the specific technology and the related cost of such solutions are discussed. Chapter 3 considers the aggregate costs of the Proposal and analyzes economic impacts. Chapter 4 quantifies the emission reduction benefits of the Proposal and assesses impacts on environmental and health effects of these emissions. Chapter 5 presents the schedule of emission reductions and costs of the Proposal and relates them to one another in terms of cost-effectiveness. Several appendices are provided which contain analyses and data upon which data in the chapters are based.

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Chapter 1: Technology Assessment

The Clean Air Act Amendments of 1990 Section 213(a)(3) present statutory criteria that EPA must evaluate in determining standards which achieve the greatest degree of emission reduction. These criteria include technical feasibility, cost, time line constraints, safety, noise and energy. This chapter presents the technical analyses and information that form the basis of EPA's determination that the proposed emission standards are technically achievable accounting for all the above constraints except cost. Specific areas of discussion are: adequacy of the test procedures; emission control technologies; achievable emission reduction; impacts on performance (i.e., energy, noise and safety); and impacts on equipment. Cost information is presented in Chapter 2.

1.1. Adequacy of Proposed Test Procedures

1.1.1. Emission Test Procedures

In order for EPA to successfully regulate tailpipe emissions, the Agency strives to establish test procedures that ensure use of technologies that not only meet the emission standards when tested over the required test procedures, but also result in a predictable emission reduction in actual use. In the nonroad environment, one engine model is likely to be used in a large number of equipment applications. It will

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take a substantial amount of EPA time to develop test procedures that give the best approximation of average use of a nonroad engine in actual use. EPA and industry are currently studying test procedure options with a goal to choose emission test procedures that ensure emission reductions from engines that use future technologies capable of meeting the second phase emission standards. However, considering the first phase emission standards levels and the tight time constraints proposed in this Smallgas FRM, EPA has decided that a meaningful first step in HC, CO, and NO_x emission reduction can be realized in the near future from small SI engines using available test procedures. The test procedures available at this time are the SAE J1088 engine test procedures for nonroad engines developed by the Society of Automotive Engineers (SAE) and currently being coordinated with the ISO 8178 test procedures developed by the International Standards Organization (ISO).

The SAE procedures were first published in 1974 with a push to finalize the test procedures coming as a result of the regulatory actions of the California Air Resources Board (CARB) in 1990. The 1974 SAE procedures were the result of work from the SAE Small Engine Emissions Subcommittee which submitted a proposal for spark ignited engines. The Small Engine Emissions Subcommittee was formed which consisted of individuals from industry, the academic community, and the federal government. The J1088 test procedures document that resulted from this group's work is a draft recommended practice. As such it allows as much flexibility as possible in the physical construction of the experimental apparatus. As a result of the flexibilities afforded by the recommended practice, there is currently much variation in test equipment in the laboratories of small engine manufacturers.

The finalized version of the J1088 recommended practice accounts for the evaluation of gaseous exhaust emissions from small utility

engines typically less than 20 kW. The SAE procedures include a steady state test cycle comprised of a specified number of different load and speed conditions called "modes". Emission measurements are taken three times per mode only after the engine reaches equilibrium temperatures in that mode. Three different cycles (sets of modes) are available for the range of small engines: (1) those used in non-handheld intermediate speed applications; (2) those in non-handheld rated speed applications; and, (3) those used in handheld rated speed applications. The cycle for non-handheld intermediate speed applications 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 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 modes are then weighted to estimate the relative percentage of time a non-handheld engine spends in each mode of operation in actual use. The cycle for handheld applications consist of 2 modes, one full load condition at rated speed and one no load condition at idle speed. For handheld applications, weightings of the two modes are based on the relative percentage of operation time in each mode expected in actual use. The weightings utilized by CARB(1) are also used in this rulemaking.

Test procedures for this rule are detailed in Subpart E, Sections 90.401- 90.426. The procedures are compatible with J1088, however a number of specific modifications have been made to limit the flexibilities of the recommended practice. This allows the certification test procedures to be more repeatable between laboratories performing the testing. This is important to ensure that in-use testing can be compared to the emission standards without realizing a wide tolerance band to accommodate technical differences in how the test procedures are performed at different laboratories.

1.1.2. Durability Test Procedures

1.1.2.1. General Emission Control System Durability--EPA expects the emission control technologies used to meet the exhaust emission standards specified in this rulemaking will be sufficiently durable that post control emission performance deterioration rates will not increase over pre-control deterioration rates. In Chapter 5, EPA provides its rationale behind this expectation.

Although EPA is not adopting full emission control system durability demonstration requirements in this notice, manufactures are fully expected to design such systems to be effective under normal in-use operating conditions over time. Full emission control system durability demonstration requirements are expected to be included in the second phase regulations for small engines.

1.1.2.2. Catalytic Converter System Durability--EPA is adopting durability demonstration requirements for catalysts in this notice. Relative to all other types of emission-related engine components, catalysts are unique in the following respects.

- A catalytic converter represents an emission control system that can realize substantial emission control deterioration without causing an engine performance change detectable by the equipment operator.
- Since it is the last component in the emission control system, a catalyst can compensate for sub-standard performances by other emission control components, but it is not itself supported by any other back-up component that would be able to compensate for a reduction in catalyst performance capability.
- The addition of a catalyst can allow compliance with the emission standards without any improvements in the performance of other emission-related engine components and without any reduction in engine-out emissions.

- Substantial reductions in conversion efficiency can result from abrasion or fracturing as a result of relative motion between the catalyst and its protective outer metal jacket, poisoning as a result of fuel contaminants (e.g., lead), glazing as a result of excessive quantities of lubricating oil in the exhaust, and/or thermal degradation as a result of exposure to excessively high temperatures for prolonged periods.

EPA is concerned that these unique conditions that are inherent in catalyst usage warrant the need for some means for validating the adequacy of catalysts that are added to engines to provide compliance with the emission standards during in-use operation. Various approaches can be used for ensuring that the "long term" conversion capabilities of catalyst will be adequate. For example, certification engines can be tested with catalysts which have been subjected to some type of "aging" process which substantiates that the catalysts are adequately designed and fabricated. Alternatively, certification engines can be tested with new catalysts that have been proven to be satisfactory by meeting the requirements of a catalyst certification procedure that is separate from the engine emission certification test. These two alternatives are discussed in more detail below.

The main advantage of a validation approach that would involve the use of "aged" catalysts on certification engines would be its simplicity. The aging process could be carried out by either the engine manufacturers or the catalyst vendors. In either case, there would be no requirement for special catalyst performance testing, and hence, no need for the establishment of performance standards that would be needed for evaluating the test results.

The main disadvantage of this approach is the possible negative impact on catalyst usage that might result from a Phase I certification process which imposes durability testing requirements on catalysts but

not on certification engines or any other engine components involved in their construction. The dependence of successful certification of engine families on the performance capabilities of aged catalysts might result in engine manufacturers being reluctant to use catalysts to meet the applicable emission standards. Also, given that there are no field data on small engine catalysts, it would be extremely difficult to design a fair aging procedure that could be evaluated by the certification engine test and accompanying emission standards.

The adverse results of using an aged catalyst on a certification engine would be avoided by the engine manufacturer's use of a new catalyst that is "certified" by the supplier or the engine manufacturer as having design and fabrications details that result in specific long term conversion performance capabilities. The main advantage of this approach is that it addresses the reluctance of engine manufacturers to use catalyst technology because it makes the demonstration process transparent to the engine manufacturer. The catalyst manufacturer may provide a statement of compliance to the engine manufacturer to be submitted as part of the certification application. This approach has the disadvantage of being more complicated in that it would additionally involve the establishment of limits on the amount of efficiency loss that is acceptable and a test procedure for determining compliance with such limits.

As a consequence of concerns regarding possible negative impacts on catalyst development for small engines that might result from a provision requiring the certification of engines with aged catalysts, EPA is not adopting such a requirement in this Small Gas FRM. Instead, EPA is requiring that for systems utilizing catalysts, certification engines must be equipped with a new "certified" catalyst during emission certification testing. A "certified" catalyst is one which has been demonstrated to be capable of successfully meeting the requirements of

a separate catalyst durability demonstration procedure which is described in more detail in the following text section. This approach will ensure that durable catalysts are used on small engines while avoiding excessive requirements that could discourage the development of very promising catalyst technology.

1.1.2.2.1. Certification of Catalysts by Thermal Aging-- Exhaust emission control systems which utilize catalytic converters have been used extensively in on-highway applications for a number of years. Such usage has resulted in improvements that greatly minimize the likelihood of the previously discussed degradations in catalyst conversion efficiency. For example, abrasion and fracturing has been essentially eliminated by the use of intumescent protective wrapping which permanently expand when initially heated and, as a result, hold the catalysts securely in position with very little possibility of destructive contact with the outer metal jackets. Poisoning by lead in the fuel has been eliminated by the use of "lead-free" fuel. Oil glazing has been minimized by improvements in engine design and build practices which reduce the various adverse effects of engine wear, such as excessive oil consumption. Thermal degradation effects have been reduced by: (a) improvements in engine design and manufacture which reduce the possibility of operation that can result in excessive catalyst temperatures, such as ignition misfire; and (b) improvements in catalyst design and fabrication which raise thermal thresholds so that brief exposure times to temperatures well in excess of normal operating temperatures can be tolerated without significant loss of conversion efficiency. Exposure to temperatures as high as 1000°C for several hours without an excessive loss of conversion capability is possible when a catalyst is designed and fabricated in accordance with currently used good engineering practice.

EPA anticipates that the use of catalysts for nonroad applications

will be based on on-highway experience concerning means for minimizing catalyst performance degradation. However, the design and operating conditions of small engines may be even more conducive to high catalyst temperatures than on-highway applications. Catalysts used for small engines will be located very near the exhaust port. Also, the exhaust of small engines is likely to contain a higher fraction of unburned fuel, which in the presence of oxygen, can provide a greater potential for excess catalyst temperatures from exothermic oxidation reactions. For these reasons, EPA is focusing on resistance to thermal stress for evaluation in the catalyst certification procedure. The purpose of the certification procedure is to ensure that the catalysts are designed and fabricated in accordance with principles that have been proven to provide adequate resistance to thermal degradation.

1.1.2.2.2. Generation of Elevated Catalyst Temperatures-- With respect to evaluating a catalyst's resistance to thermal degradation, two basically different approaches can be used for generating the desired elevated exposure temperatures. In one approach, the catalyst is heated as a consequence of being exposed to a high temperature environment. In the other approach, the catalyst is heated as a result of two effects, the temperature of a hot gas mixture that enters the catalyst and the exothermic conversion reactions that occur as the mixture flows through the catalyst. These are described in more detail later.

1.1.2.2.3. Exposure to Hot Air in an Oven--A test catalyst can be exposed to a high temperature environment by placing it in an oven that is at the desired air temperature and maintaining the oven at that temperature for a specific time interval. This is one of the simplest methods for thermally stressing the catalyst since a relatively few number of test parameters are involved. Also, this technique has been used for many years in catalyst design development work. The two

essential parameters are the oven temperature and the duration of the exposure. Other possible variables of importance include the chemical composition and volumetric flow rate of a gas or gaseous mixture that flows through the internal passages in the catalyst during oven exposure.

1.1.2.2.4. Exposure to Synthetic Exhaust Gas Mixtures-- The heating of a catalyst as a consequence of exposure to a hot gas mixture which undergoes catalytic reaction can be accomplished by means of a heated synthetic exhaust gas mixture. This approach to catalyst thermal stressing is more representative of in-use conditions than oven exposure but it involves considerably more test variables. These variables include the means that is used to generate the gas mixture, the composition and temperature of the mixture, and time that it flows through the test catalyst. All of these variables, with the exception of the duration of the exposure, can be based on the conditions that will exist when the in-use engine for which the catalyst is intended is in normal operation. Exposure duration involves one additional parameter, the anticipated life of the engine. The degree to which the exposure testing represents the conditions that the catalyst will experience in the field will be directly related to how closely the duration of the exposure correlates with the anticipated engine life. With respect to such correlation, variations in the exposure procedure are possible. Regardless of the duration of the correlated exposure time, variations in the exposure testing procedure are possible. For example, the duration of the exposure test may be set equal to the correlated exposure time. On the other hand, the duration of the test may be shortened, with some technique, such as linear regression, being used to extrapolate test results to the full correlated exposure time.

1.1.2.2.5. Exposure to Actual Exhaust Gas Mixture-As is the case with exposure to synthetic exhaust gas mixtures, exposure to

real exhaust gas mixtures is more representative of in-use conditions than oven exposure but it involves even more test variables than is the case with exposure to synthetic exhaust gas mixtures. The variables that are involved in addition to temperature and time include engine type, engine operating conditions, the duration of each different type of engine operation and the chemical composition and volumetric flow rate of the exhaust gas mixture during each type of engine operation. As is the case with exposure to synthetic exhaust gas mixtures, other variables must be considered, such as the representivity of the duration of the exposure and the use of an abbreviated exposure period with some means for extrapolating the test results.

1.1.2.2.6. Adopted Methodology--The use of an oven exposure procedure for the evaluating catalyst resistance to thermal degradation is adopted in this Small Gas FRM. This procedure involves the heating of the test catalyst in air to an initial temperature 500°C for 2 hours, and a final temperature 1000°C for six hours. This procedure is adopted in lieu of procedures which involve exposure to synthetic or actual exhaust gas mixtures for a number of reasons. One of the main reasons is that EPA believes that the oven aging procedure aggressively and directly stresses the catalyst and is the best method for assessing the most major catalyst durability concern: thermal stability. Also this method is much less complex than the other exposure procedures.

Another reason is the present lack of the information that is essential for the effective implementation of the other two alternative procedures. For example, in the case of the procedure which involves exposure to synthetic exhaust gas mixtures, information is lacking regarding the most appropriate test parameters, such as the temperature of the mixtures and the duration of the exposure. Similarly, with respect to the procedure which involves exposure to actual exhaust gas mixtures, information is needed regarding a number

of test variables that are related to the engine that is used to generate the exhaust gas mixture, such as its combustion cycle and power output, the manner in which it is operated and the operating times that are involved in each phase of the operating cycle.

1.1.2.3. Evaluation of Aging Effects--

1.1.2.3.1. Basic Evaluation Approach--Catalytic converter evaluation would involve the determination of the extent to which the performance characteristics of the test catalyst had been adversely affected. Of particular significance would be the adverse effects on the catalysts conversion capabilities with respect to the oxidation of hydrocarbons and/or carbon monoxide and/or the reduction of oxides of nitrogen.

1.1.2.3.2. Conversion of Synthetic Exhaust Gas Mixture-- The effect of the aging process on catalyst conversion effectiveness could be determined by flowing a synthetic exhaust mixture through the catalyst under representative conditions and determining the reduction in efficiency that occurs. One advantages of such an approach is its simplicity. Engine operation is not involved, also there are relatively few variables, such as the composition, temperature, and flow rate of the gas mixture. One of the disadvantages is the requirement for some means for generating the mixture.

1.1.2.3.3. Conversion of Actual Exhaust Gas Mixture--In lieu of a synthetic exhaust gas mixture, an exhaust gas mixture could be used that is obtained by the operation of an engine that is representative of the in-use engines that will be equipped with the production catalysts. However, a number of variables that are related to the engine, such as the components involved in its construction, its age and condition, and its horsepower rating, and a number of variables that are involved in its operation, such as speed and load complicate this procedure.

1.1.2.3.4. Adopted Methodology--The use of a procedure which uses a synthetic exhaust gas mixture for evaluating the effects of thermal stressing is adopted for several reasons. One of the main reasons is the relative simplicity of such a procedure. For example, it does not involve the questions regarding the in-use representivity of test parameters, such as the temperature of the mixture and the duration of the test, that arise when a synthetic exhaust gas mixture is used for actually thermal stressing a catalyst. For evaluation purposes, any fixed temperature which allows the conversion reactions of interest to occur can be specified. The specification of a particular exposure time is not required since the conversion efficiency existing as a result of the previous thermally stressing is involved rather than a time-related change in efficiency. Furthermore, a procedure which uses synthetic exhaust gas is simpler than a procedure that uses actual exhaust gas in that it does not involve detailed information that is not readily available at this time regarding the operating conditions of the various types of engines that are utilized in the various applications covered by this Small Gas FRM. Another reason supporting use of synthetic exhaust gas mixture is the standardization that would result; all catalysts would be aged under the specific conditions that are specified in Subpart E of this Part.

1.1.2.4. Allowable Degradation Limits--Durability testing of on-highway engines results in emission control system deterioration that is typically in the range of 10 to 20%. As a consequence of the improvements that have been made in engine design and fabrication, most of this deterioration is the result of reductions in the performance of catalysts which have an initial conversion efficiency on the order of 90%. On-highway experience suggests that a limit of 15% on the deterioration of catalysts that are used on the engines that are covered by this notice might be appropriate.

The limited information that has been obtained by EPA regarding small engine catalysts suggests the possible use of very wide variations in initial conversion efficiency, with values as low as 30% in some applications. Such a development might make the use of several different deterioration limits that are proportional to ranges of initial conversion efficiencies appropriate. EPA thereby establishes a fixed deterioration limit of 20% on the basis of on-highway experience and the absence of information at this time regarding the conversion efficiencies that will be used with small engines.

In addition, the Agency does not hold catalyst manufacturers accountable for pollutants which they were not designed to reduce (i.e., NO_x) or oxidize (i.e., HC or CO). Therefore, the engine manufacturer must specify the pollutants that the catalyst will be converting and submit data on only that pollutant. For catalysts that convert CO on an already low CO emitting engine (i.e., CO levels are below the standards enough such that if the catalyst is removed or deteriorates to 0% efficiency on conversion of CO, then the engine will still emit CO emissions below the CO standards), the catalyst manufacturer of the two-way catalyst will not have to meet the CO conversion deterioration limit.

1.1.3 Certification Fuels

1.1.3.1. Representation of Available Fuel--Manufacturers will have two options for certification fuel used for gasoline fueled engines for this rule. The first option is an industry average fuel which has the composition of a typical summertime fuel sold in 1990. The second option is to use a certification grade fuel commonly known as Indolene. The specifications for each fuel are detailed in Section 90.308 and Table 3 in Appendix A to Subpart D of the regulation language. Table 1-07 shows how the specifications of Clean Air Act Baseline (CAAB) relates

to certification fuels including Indolene, California certification Phase I fuel and European test fuels(2)(3)(4)(5)(6).

1.1.3.2. Differential Impacts on Emissions of Various Blends-- Preliminary testing has been performed with shows the emission results of regulated and unregulated emissions on several fuels. The testing was performed on a 4-stroke OHV 2.6kW Tecumseh engine which can be considered an advanced engine for it was OHV and contained pump lubrication, electronic ignition and aluminum, cylinder with iron sleeve which is not presently representative of the majority of lawn mower engines in the field. Table 1-08 presents information on changes in emissions results due to different test fuels(7). Slight variations between emission test results are observed. A maximum difference of 20% is seen in the results on Reformulated fuel with Ethanol compared to the industry average.

1.2. Achievability of Emission Standards

The following emission information on available technologies and data on prototypes using the technologies were collected from industry, SAE papers and EPA analysis of information on technologies. EPA has determined that, to set equitable standards for the vast range of engines covered by this proposal, it is necessary to set up five engine classes that are capable of achieving different standards. The need for these classes is discussed in the section 1.2.1, and the classes will be integral to each discussion of achievability.

1.2.1. Engine Class Determinations

EPA is proposing, based on input from industry and the California Air Resources Board, to group engines in five classes each assigned a unique set of emission standards based on technical feasibility. The first two classes are for non-handheld equipment engines. The remaining three classes are for handheld equipment

engines. All classes are distinguished by engine displacement with Class I consisting of engines less than 225 cubic centimeters(cc) and Class II includes engines greater than 225cc. Handheld classes consist of Class III including engines less than 20cc, Class IV including engines 20cc-50cc and Class V consisting of engines greater than 50cc.

EPA has decided to divide the regulated engines into five classes because there are unique constraints that make five sets of proposed emission standards necessary in the first phase of regulation. First, it is necessary to adopt different emission standards for the classes of engines used in handheld equipment than for classes of engines used in non-handheld equipment. Second, within the combustion process type, there is still a need to adopt different levels of emission standards based on engine displacement size. California is also regulating these engines within the same five classes for much the same reasons as EPA. This will ensure harmonization between the Federal and California programs.

Current 2-stroke engines cannot be modified in the short timeline of this rule (within a reasonable cost) to achieve the low level of HC and CO emission achievable by modifying current 4-stroke engines. Handheld equipment engines have unique performance needs, such as high power to weight ratio, high speed, and multi-position use, that are currently most often achieved through the use of 2-stroke engine technology. Non-handheld equipment are generally not as constrained and can use either 2- or 4-stroke engines. Furthermore, by the implementation date in this phase 1 rule, there are inadequate technological substitutes to replace all 2-stroke engines and still meet the unique needs of handheld applications. Therefore, the emission standards achievable for Classes III-V on the phase 1 timeline must be the levels achievable through modification of current 2-stroke handheld engines. Since 4-stroke engines are generally available for use in non-handheld equipment, the emission standards for the Classes of non-

handheld engines will be based on modification of 4-stroke engines.

EPA will further divide engine classes on the basis of engine displacement. Divisions are adopted because there are two distinct technical hurdles faced by engines with smaller displacement. Smaller displacement engines experience: (1) Higher level of flame quenching in the combustion chamber; and, (2) Lower average horsepower output than larger displacement engines.

First, smaller engines produce higher levels of HC emissions due to wall induced flame quenching. As combustion chamber displacement decreases the resulting surface to volume ratio becomes greater. The fuel ignites at the same rate as a larger engine, but the fuel/air mixture propagates to the cylinder wall more quickly, resulting in a higher percentage of fuel remaining unburnt in the quench area and being expelled from the cylinder in the unburnt state.

Flame quenching can occur at any time during operation. When an engine is first started, flame quenching occurs when the fuel condenses or deposits on the surfaces of the combustion chamber and is not ignited during flame propagation. This often results in higher HC and CO emissions during cold start up. After the engine is up to operating temperature, the likelihood of such condensation or deposition is reduced, however flame quenching continues. As the spark initiated flame expands within the air/fuel mixture, it is extinguished or "quenched" when it contacts the relatively cooler surfaces within the chamber or small crevices into which the flame does not propagate. Smaller cylinder diameter engines have less time for the flame to expand within the charge before it contacts the combustion chamber surfaces and is quenched or extinguished. The rapidity with which the flame expands is such that changes in the time available as a result of small changes in cylinder design are not usually significant.

Larger displacements engines inherently experience less emissions

from flame quenching. The portion of the total HC emissions that result from flame quenching changes whenever the surface to volume ratio of the combustion chamber changes. When the volume of a combustion chamber is fixed, only relatively small changes can be made to the surface to volume ratio by modifying the relative dimension of the combustion chamber, or the shape of the cavities within it. When the volume of a combustion chamber increases as a result of proportional increases in its dimensions (i.e., the manufacturer increases engine displacement), the surface to volume ratio decreases because the surface area increases as the square of the diameter, whereas the volume increases as the cube of the diameter.

Second, as the displacement decreases, emissions generated per unit of work accomplished increases because the power output decreases more rapidly than the HC emissions. Due to this technical reality, using the same standard for all engines, regardless of displacement, may be inequitable and unfair to the smallest displacement engines.

Smaller displacement engines have been shown to produce higher mass emission levels for the same work output than a larger displacement engine. This is due to the fact that reducing displacement has less of an impact on mass emissions (g/hr) than it has on loss in work output (kW-hr). Therefore, the emission produced relative to the amount of work done (g/kW-hr) by a smaller engine is greater than the emission produced by a larger engine doing the same amount of work. Again, given the same range of feasible technologies, the smaller displacement engine will be unable to achieve as low an emission standard as a larger displacement engine.

Finally, dividing engine classes on the basis of engine displacement within either the non-handheld or handheld engine categories allows some differentiation of standards for consumer and

commercial engines. For example, in the handheld engine categories, engines under 20cc are low cost consumer market focused, 20-50cc engines are a mixture of both low cost consumer and commercial markets, and greater than 50cc engines are more expensive commercial market focused. Technology solutions available to lower cost consumer engines are more constrained by cost than solutions for larger commercial engines, since the consumer user market is very sensitive to price increase. At the same time, larger commercial engines will be capable of meeting lower emission standards because these engines are on average higher horsepower and are built with a longer expected useful life, and therefore are built to a higher precision. These features will generally result in lower baseline emissions and thus require less modification to comply with the emission standards than comparable consumer quality engines.

1.2.2. Class I and II (non-handheld) Engine Concepts Proven with Prototype Engines

The majority of engines in Class I are produced for the low cost consumer market and are of 4-stroke side valve design. In the past, cost has been the major design consideration for these engines, with some attention to maintaining adequate performance and durability. As a result, many internal engine modifications that have already been applied to higher cost commercial engines, to optimize durability and performance, have not yet been applied to these low cost consumer engines. Therefore, a range of internal engine modifications will have to be made to these engines to help them comply with proposed Phase 1 emission standards. This will require substantial attention to fuel system modifications and changes to the design of existing engine components. Achievable technologies for this rulemaking include enleanment of the operating air to fuel ratio with major and minor

modifications to the carburetor and fuel distribution system, changes in ignition timing, combustion chamber redesign, valve system and improvements including valve timing, improved cooling, conversion from side valve to overhead valve engine design, and conversion from 2-stroke to 4-stroke engine designs.

A portion of the engines in Class II will also realize design changes to existing components. Because Class II engines are generally higher power and of higher quality than Class I engines, their baseline emissions are lower on average and less modifications are required to bring Class II engines into compliance. Achievable technologies for this rulemaking include enleanment with minor carburetor modifications, combustion chamber redesign, improved cooling, changes in ignition timing, and conversion of 2-stroke to 4-stroke engine designs.

The use of catalytic converters, exhaust gas recirculation, and air injection technology may occur on a limited basis or not at all in the 1997 model year. While EPA recognizes that these technologies have the potential to provide substantial emission reductions in the future, the safety and durability concerns with these technologies may not be fully resolved by the 1997 model year. Limited catalyst system designs have been developed that generate low conversion efficiencies. These catalyst designs present a reduced safety concern because they do not generate the high exotherms that can translate into excessive exhaust system temperatures. These low efficiency catalysts can only bring engines into compliance that has been modified sufficiently to generate emissions close to the standards without a catalyst. Therefore, durability is less of a concern, since failure of the catalyst will not cause a gross increase in emissions. Currently EPA has not seen an adequate EGR design or stand alone air injection system that would be available by the 1997 model year that addresses durability concerns.

Table 1-09 shows the available data on non-handheld prototype

engines in this category(8)(9) with pre-control numbers presented in Table 1-15. All of the prototype engines meet their respective emission standards. For Class I engines, the actual percentage reductions in emissions range from 51% to 98% for HC and 43% to 89% for CO. As expected in the prototypes available, NO_x emission increased in some cases from 71% to 281%. For Class II engines, EPA had results from only one engine with shop air delivered to the muffler, thereby acting as a thermal reactor. Results showed percentage reductions of 33% for HC and 13% for CO. For this engine, NO_x emissions were also reduced by .39%. Class I and II prototype engines show the composite HC +NO_x and CO emission levels below the standard. These prototypes represent the greatest degree of emission control technology achievable given the aggressive timeline for earliest possible introduction of these engines into commence at reasonable cost, one of the parameters for achievability listed in CAA section 213(a)(3).

1.2.3. Class III-V (handheld) Engine Concepts Proven with Prototype Engines

A large portion of engines in Classes III-V are produced for the low cost consumer market. In the past, cost has been the major design consideration for these engines, with some attention to maintaining adequate performance and durability. As with the low-cost non-handheld engines, many internal engine modifications that have already been applied to higher cost commercial engines, to optimize durability and performance, have not yet been applied to these low cost handheld engines. Therefore, a range of internal engine modifications will have to be made to these engines to help them comply with emission standards. This will require substantial attention to changes in the fuel system modifications and design of existing engine components. Achievable technologies for this rulemaking include enleanment with minor and

major changes to the carburetor, carburetor limiter caps, combustion chamber/scavenging/port timing modifications, cooling improvements and conversion of a limited number of engine designs to 4-stroke engine design.

The use of catalytic converters, exhaust gas recirculation, fuel injection, and air injection technology may occur on a limited basis or not at all on handheld engines in the 1997 model year. While EPA recognizes that these technologies have the potential to provide substantial emission reductions in the future, the safety and durability concerns with these technologies may not be fully resolved by the 1997 model year. Limited catalyst system designs have been developed that generate low conversion efficiencies. For the same reasons discussed in the previous section, these low efficiency catalyst designs provide a reduced safety and durability concern. Currently EPA has not seen an adequate EGR design or stand alone air injection system that would be available by the 1997 model year that addresses durability concerns.

Industry and research labs have collected emission data on a number of engines used in the three handheld equipment classes (Tables 1-16 to 1-20). Table 1-10 lists the emission results of three prototype engine designs compared with a number of current 2-stroke engines and 2-stroke engines enleaned to 6% CO(10)(11)(12)(13)(14)(15). One engine is a 4-stroke handheld engine which can be used in a limited number of handheld applications(16).

All of the prototype engines meet their respective standards. The actual percentage reductions in emissions ranged from 1 to 94 % for HC and 10 to 82 % for CO. The typically low NO_x emission generated by these engines increased from 15 to 325 %. In one case CO increased by 38 % and in the same case NO_x decreased by 21 %.

In the case of Class III and Class IV engines, it is clear that the HC standard is the one that is driving the technology for the CO and

NO_x levels are as much as two to three times lower than the standard and do not appear to be driving the design process. For Class V, CO and HC are the driving standards. The NO_x levels on one engine are seen to be four times lower than the standard.

1.2.4. Lowest Feasible Emission Standards

EPA has determined that there are some new technologies being developed that are capable of meeting lower standards than adopted in this FRM, but cannot be developed within the timeline of this rule, nor at reasonable cost.

Technologies such as high efficiency catalytic converters, low cost fuel injection systems, 4-stroke engine designs in place of 2-stroke engine designs, and overhead valve in place of side valve, are currently available on a limited basis to be used on engines covered by this FRM. These technologies have the potential to develop much greater emission reductions than those technologies determined to be feasible for this rule. However, there are a number of technical barriers and safety issues that must still be overcome before standards can be set that would reflect general or blanket use of these technologies. EPA has determined that extensive use of these three technologies will not be feasible within the time allocated to complete this Smallgas FRM.

EPA expects no use of low efficiency catalytic converter technology as a result of the adopted standards. However, the option does exist that some engine manufacturers may choose to utilize the technology in a limited number of cases as explained in Chapter 2, and there is a less likelihood that catalytic converters designed with high efficiencies will be utilized on small SI engines. High efficiency catalysts generate a large exotherm which can increase exhaust temperatures and can ignite unburnt fuel in the exhaust. This presents safety concerns for handheld equipment where the engine is in close proximity to the

operator or may be used around flammable objects. For other engines there is a lesser proximity concern, yet there is a need to accommodate the existence of higher temperatures around the fuel system presenting both safety concerns and vapor lock concerns, as well as safety concerns when the equipment operates around yard waste.

As has been the case for other mobile sources that currently utilize aftertreatment technologies, EPA believes that, given sufficient development time, creative solutions will be developed to overcome these concerns. However, the Agency has determined that there is insufficient time available to address these safety concerns adequately to propose tighter standards that might require high efficiency catalytic converters within the court-mandated timeline.

Fuel injection systems that inject fuel directly into the combustion chamber of an engine have the potential to greatly reduce HC emissions over the current production 2-stroke engine, and the potential to reduce emissions to a lesser extent on 4-stroke engines. To ensure that all exhaust gases have been purged from the cylinder and that a new air/fuel charge has been introduced for the next power stroke, current 2-stroke engines are designed to expel some of the uncombusted air/fuel mixture into the exhaust before the exhaust valve closes and the power stroke takes place. Introducing this raw fuel directly into the exhaust stream results in very high HC emission from these engines. With direct cylinder fuel injection systems, fuel is not introduced until after the cylinder has been purged and the exhaust valve has closed. As a result, no raw fuel escapes into the exhaust and the resulting HC emission is reduced substantially.

High pressure, direct cylinder fuel injection systems have been successfully developed for 2-stroke applications for the automotive industry and will be introduced in the future in passenger cars in Europe and possibly the U.S. EPA is aware of fuel injection system

designs that are currently being explored for both nonroad small spark-ignited engine applications as well as for outboard marine applications (that also use 2-stroke engines). These designs are well behind the development curve of automotive engine systems and face unique hurdles with respect to size, simplicity, and cost. EPA is not currently aware of any fuel injection system that has been developed to the point that it would be available within the timeline constraints of this rule.

Fuel injection systems have less benefit for 4-stroke engines. There are lower cost options to keep raw fuel from entering the exhaust, thus there is less justification for manufacturers to assume the cost of such systems for the minimal emission benefit.

Using 4-stroke engines in current 2-stroke applications can substantially reduce the HC emission over current 2-stroke engine designs. However, 2-strokes currently enjoy a number of performance advantages over typical 4-strokes. The 2-strokes typically operate at higher speeds, have a higher power to weight ratio (especially important in handheld applications), and can operate in any position. While development is underway to design small 4-strokes with acceptable performance features, to date, only one manufacturer is planning to produce a 4-stroke engine whether this rule is promulgated or not. That engine currently has limited application within the handheld category and currently is more expensive than comparable 2-stroke engines in its class. While EPA believes this technology has great promise for the future to reduce emissions further than the levels adopted in this rule, the Agency has determined that this technology will not be available within the time constraints of this rule.

Using overhead valve engines in place of side valve engines would require a major retooling of the engine manufacturing industry. While this might occur over time, a sudden changeover within the timeline constraints of this rule would be extremely costly and might

not be physically possible. The side valve engine makes up the majority of the low cost consumer market. This represents tens of millions of engines sold per year. Not only would the industry be required to divest facilities and tooling geared toward such enormous production volumes, but at the same time, it would have to invest in redesigning OHV engine lines that were designed to be flexible and lower volume. Current manufacturing facilities are at different stages in their life cycle. As Phase 1 emission standards take effect, and as EPA works toward the Phase 2 requirements for these engines, the industry may evolve toward overhead valve designs in a more orderly fashion. Adopting standards today that would require overhead valve technology would result in an extremely costly rule.

1.3. Impacts on Performance

Section 213 (a)(3) of the Clean Air Act Amendment requires that EPA give appropriate consideration to factors including energy, noise and safety associated with the application of technologies. EPA has chosen the THC, NO_x and CO standards such that the effects on performance will be minimal. This section discusses EPA's assessment of the effects of this Small Gas FRM on energy (i.e., fuel economy), power, noise, safety, and maintenance. The analysis is based on information presented in Table 1-11(17)(18)(19)(20)(21)(22)(23). Detailed calculations are included in Appendix B.

1.3.1. Fuel Consumption

Data showing the impact of the application of engine technologies on fuel consumption by nonoptimized prototype engines are listed in Table 1-11. Fuel consumption will decrease slightly based on the application of technologies of enleanment, increased combustion efficiency, and reduction of scavenging losses.

The early nonoptimized 4-stroke side valve and handheld 2-stroke prototype engines using enleanment demonstrated a brake specific fuel consumption reduction of between 6% to 22% (see Table 1-11). However, this reduction is expected to decrease slightly as these engines are optimized to achieve best performance within the proposed requirements. This occurs as the level of enleanment on many of these engines is customized across the engine performance band and the average enleanment during all operation is reduced. Table 1-11 also shows data on one overhead valve engine (OHV) and one 2-stroke handheld engine which suggests that some engines will experience no fuel consumption reduction or a small fuel consumption increase. The Class II OHV engine prototype and Class IV 2-stroke prototype showed fuel consumption increases of between 1% and 3%, respectively.

EPA has analyzed the likely average fuel consumption change considering all factors that would impact the final figure in actual use. EPA estimates that the actual fuel consumption will be an average of 25% reduction in nonhandheld engines, i.e., Class I and II engines, and 13% reduction in handheld engines, Classes III-V, per engine basis sales weighted. Since this is a desirable impact, little additional design effort will be expended to optimize fuel consumption effects. The main influence on the decrease in fuel consumption for nonhandheld engines is the conversion of 2-stroke Class I engines to 4-stroke Class I engine designs. The reduction for handheld engines is influenced by the use of enleanment and the reduction of scavenging losses. The following explains the methodology utilized to calculate fuel consumption changes. Details can be found in Appendix B.

Fuel consumption changes are expressed in percentage reduction with respect to nonhandheld (Classes I and II) and handheld (Classes III-V). Each fuel consumption change is calculated by first estimating fuel consumption for each engine design in each class for pre-control

and post-control engines (summarized in Tables 1-01 and 1-02 from Table 1-11). These estimates are then sales weighted by multiplying the fuel consumption by the resultant of the division of the 1996[1] total sales in each engine design and class by the 1996 total sales in the appropriate handheld or nonhandheld group as defined previously.

TABLE 1-01
Pre-Control Fuel Consumption Estimates Per Engine Per Class (g/kW-hr)

CLASS	SV	OHV	OTHER	2-STROKE
I	830	60[illegible]	603	854
II	570	510	510	570
III	--	--	--	830
IV	--	--	--	830
V	--	--	--	560

Table 1-02
Post-Control Fuel Consumption Estimates Per Engine per Class(g/kW-hr)

CLASS	SV	OHV	OTHER	2 STROKE
I	600	430	430	0
II	520	520	520	0
III	--	--	720	
IV	--	253	720	437.76
V	--	--	529	321.632

EPA's 1996 sales estimates were utilized to sales weight power estimates for pre-control and post-control engines. Pre-control sales estimates were taken directly from 1996 sales estimates. Detailed

[1] Sales estimates for 1996 are used as the basis for calculations in this RIA/RSD. The year 1996 is included in the definition of the 1997 model year. See the Final Rulemaking for a complete explanation.

discussion on the determination of 1996 sales estimates per class and engine design is discussed in Chapter 3 with detailed calculations shown in Appendix B. Post-control sales estimates were calculated by applying technology change estimates that would affect sales in each class and technology to the base 1996 sales estimates. The technology changes that were applied to the pre-control sales estimate were: (1) apply 2-stroke engine sales Class I to a 50/50 split between side valve and overhead valve engine designs, (2) apply 2-stroke engine sales in Class II to 100% side valve engines, (3) 1% of side valve engines in Class I are sold as overhead valve designs in Class I, and, (4) 1% of Class IV handheld engines convert to a new Class IV 4-stroke engine design (a new design by an engine manufacturer).

Table 1-12 shows the fuel consumption numbers for pre-control, post-control and calculated percent fuel consumption change per engine design per class and summarized in nonhandheld and handheld designations. Additional calculations for number of barrels reduced and resultant cost savings is presented in Chapter 3 on Aggregate Costs. For that analysis, EPA calculated sales weighted averages for the handheld and nonhandheld variables of kilowatt rating, usage and load factor, fuel consumption rates and useful life. The equipment categories were differentiated by residential and professional usages. Fuel consumption changes over time was not accounted for in the fuel consumption estimates.

1.3.2. Power

The test results of seven non-optimized prototype engines demonstrate a maximum rated power loss of between 0% to 13% (see Table 1-11). In one case, the prototypes experienced a power gain of 14%. The power gain was associated with the use of enleanment and a catalyst. Manufacturers will optimize final designs such that the expected power loss on resulting production engines will be minimized.

EPA estimates that the resulting average power change in actual use will be a gain of approximately 5% for non-handheld engines and a reduction of 3% for handheld engines (Table 1-13). The major contributor to the gain for non-handheld engines is enleanment and combustion chamber redesign for more efficient combustion for Class I side valve engines which make up a large majority of engines in this rulemaking. For handheld engines, a majority of the engines are estimated to utilize enleanment technology which is estimated to result in an increase or decrease in power, depending on each engine design.

Power changes are expressed in percentage reduction by class. The power change is calculated by first estimating the power for each engine design in each class for pre-control and post-control engines (summarized in Tables 1-03 and 1-04 from Table 1-11). These estimates are then sales weighted by multiplying the power by the resultant of the division of the 1996 total sales in each engine design and class by the 1996 total sales in the appropriate handheld or nonhandheld group as defined previously. Discussion of the calculation of 1996 sales is found in the previous section 1.3.1 Fuel Consumption.

Table 1-03
Pre-Control Power Estimates Per Engine Per Class in kW

CLASS	SV	OHV	OTHER	2-STROKE
I	0.9	0.9	0.9	1
II	3.25	3.06	3.06	3.25
III	--	--	--	0.86
IV	--	--	--	0.86
V	--	--	--	2.28

Table 1-04
Post Control Power Estimates Per Engine per Class in kW

CLASS	SV	OHV	OTHER	2-STROKE
I	1.08	0.87	0.87	1
II	3.06	3.01	3.01	3.25
III	--	--	--	0.83
IV	--	1	--	0.83
V	--	--	--	2.27

Table 1-13 shows the results from pre-control, post-control, and calculated percentage power change per engine design per engine class and summarized in non-handheld and handheld designations. Although overall power may increase, some engines may experience a decrease in power availability. However, real time data collected on equipment in actual use (26) demonstrate that many engines require only a portion of their maximum rated horsepower (sometimes as little as 30%), to operate most applications. The remaining power available prevents engine stalling when extreme torque fluctuations are experienced. This is especially true in the case of nonhandheld engines. The operators of these engines will likely experience no performance impact as a result of this rule. Even in those cases where the power loss does carry through to actual use, the small performance loss projected will not substantially compromise the ability of an engine to perform its work adequately.

1.3.3. Noise

Regulations exist in Europe on the noise level acceptable from lawnmowers. Additional voluntary standards exist in the United States through the American National Standard Institute (ANSI). The noise standards for the EEC regulation for lawnmowers is presented in Table

1-05(24). A more general list of regulations and voluntary standards is listed in Table 1-14.

The objective of the European regulation is to ensure protection against nuisances due to noise by reducing the inconvenience caused by the noise emitted by lawnmowers. Small engine manufacturers export product from the United States to the countries in which this law is in effect. As a result, EPA does consider the influence of emission reduction technologies on the noise.

Although noise data on engines with emission reduction technologies has not been collected, it is the Agency's technical judgment, based on years of emission control system experience with on-highway vehicles and engines, that there will be no negative impact on noise due to the emission control technologies being considered for this Phase 1 rule.

Table 1-05

Cutting Width of Lawnmower (L)	Permissible sound power level dB(A)/1 pW
L≤50cm	96
50cm≤L≤120cm	100
L≥120cm	105

1.3.4. Safety

Many safety regulations and recommendations have been established for small engines and their related use in equipment. These regulations will affect the feasibility of using some technologies on handheld engines. One example is regulations requiring spark arresters on equipment used on certain federal lands. The regulation results in a temperature limit on exhaust and exhaust surfaces which, to date, has resulted in a limitation on the feasibility of the use of catalysts for

handheld engines due to the high heat levels emitted during conversion of pollutants as seen when applied to these engines.

Safety recommendations and regulations also have an impact on the end use of the engines. Some small SI equipment have operating restrictions of certain speeds and loads. One example is ANSI standard B71.1 which contains information for measuring mower blade tip speed and a description of the use of safety brake systems. A summary of such regulations and recommendations is presented in Table 1-14.

EPA estimates that the impact of engine changes to be made by engine manufacturers will not affect these safety recommendations and regulations. EPA projects very little change to exhaust system surface and gas temperatures due to this rule. Thus, there will be no impact on manufacturers' ability to comply with exhaust temperature safety limits. Even if catalysts are used on a small percentage of non-handheld engines, the low conversion efficiencies generated will generate easily manageable levels of additional exhaust system heat.

1.3.5. Maintenance

Small SI engines are used in equipment from handheld trimmers to industrial generator sets and by a wide variety of users including consumers and professionals. EPA has received a number of survey results from industry, cooperative agreements and contract work. EPA has received a study from OPEI which surveyed a number of lawnmower and lawn/garden tractor owners to investigate maintenance habits. A survey of over 1000 lawnmower users was also conducted through a Cooperative Research and Development Agreement with Electric Powers Systems Research which included a number of electric utilities around the United States of America. EPA also received survey data from 20 to 30 handheld equipment owners in the San Antonio, Texas area as part of a contracted work assignment. Results from the

surveys ranged from no maintenance over the owners experience with the equipment to regular maintenance practices. As a result, there were no maintenance patterns in relation to small SI engines. Therefore, EPA cannot conclude what the impacts of maintenance will be based on applying emission reduction technologies to these engines.

1.4. Impacts on Equipment

EPA estimates that the HC, NO_x, and CO emission standards can be met within the adopted timeline with a range of engine emission control technologies that will have minimal impact on engine and equipment design. However, EPA has also estimated that to adopt more stringent HC, NO_x, and CO standards than those finalized in today's rule, would necessitate equipment redesign to accommodate more sophisticated technologies, such as high efficiency catalysts.

Generally, additional attention to engine design to minimize impact on equipment will be the most efficient approach. The market for equipment used in nonhandheld applications is governed by horizontally integrated engine manufacturers (i.e., engine manufacturers do not make the equipment). As a result, equipment manufacturers will consider minimal equipment impacts as one of their purchasing criteria. In this highly competitive market, engine manufacturers have strong incentive to build complying engines that will not impact equipment design. By contrast, the market for handheld engine applications consists of a majority of vertically integrated companies (i.e., the engine and equipment are built by the same manufacturer). These manufacturers have more latitude to effectively plan changes to equipment and/or engines to minimize costs. Given that latitude, EPA's past experience strongly suggests that most changes will be applied to the engines of handheld equipment as well.

EPA estimates that most engine models will require only internal

modifications (such as tighter tolerances, and fuel mixture enleanment strategies) to meet the emission standards. These modifications will have little, if any, effect on equipment design. This is based on the assumption that a majority of equipment designs are more sensitive to changes on external dimensions of an engine rather than any slight change in power that may occur due to change in combustion efficiency. Such equipment includes generator sets and chainsaws which have equipment panels and other components designed tightly around the external dimensions of the engine.

EPA expects that some engine models will require external engine changes occurring as a result of improved engine cooling and carburetor limiter caps to meet the emission standards. These modifications will affect the design of equipment panels and components. The largest impact of this change on a manufacturer is in designing the equipment component dies. However, since equipment component dies wear out and are repaired or replaced several times a year, the major cost to change the die will be inherent to doing business, and only a marginal cost will be due to the die modifications caused by this rule. As discussed in detail in this RSD, handheld engines have unique technical constraints that require higher standards than all other engines covered by this FRM. For engines that qualify as handheld, EPA set standards based on a separate feasibility determination. Since the emission standards for handheld engines are less stringent, EPA will not preclude handheld engines from certifying to the tighter standards adopted for non-handheld engines.

EPA estimates that few engine models will be discontinued as a result of this FRM. Models that may be discontinued represent older engine designs and low volume sales. Since this market generally has a large number of engine models, substitutions should be readily available for these few incidences of model discontinuation.

Catalytic converter use is not predicted for the Phase 1 rule. However, as a back-up, catalytic converters may be used on a limited number of engine families that cannot be made to comply by the 1997 model year. Should catalyst use occur, a small percentage of equipment using engines equipped with catalysts may require additional shielding as a result of higher exhaust skin temperatures.

Table 1-06 summarizes EPA's estimates of equipment impacts as a result of this rulemaking. Percentages for the table were calculated from equipment estimates as utilized for first year of implementation.

Table 1-06
Equipment Design Change Estimates

EQUIPMENT CATEGORY	EQUIPMENT DESIGN CHANGES
Equipment with Class I Engines	NONE OPTION: 3% Alterations for Catalyst use
Equipment with Class II Engines	NONE
Handheld Equipment Engines	40% Alterations for Additional Cooling OPTION: .05% Alterations for Catalyst Use

45

Table 1-07
Certification Fuel (CAAB) and Other Test Fuels

Property	CAAB	40CFR 86.113-90(a)	California Phase I	CEC Legislative Fuel RF-05-A-85	CEC Legislative Fuel RF-05-A-83 (* need specs - # from 1 bottle)
Sulfur, ppm, max.	339+/- 94				
Sulfur, wt. pct., max. (ASTM D1266,D2622, D2785)		0.10	0.03	.04	36 mg/kg
Phosphorus, g./liter, max. (ASTM D 3231)	0.02	0.00132	0.00132	0.0013	<0.1 mg/l
Manganese, g/liter, max	0.004				
Benzene, % (ASTM D3606)	1.5			5% vol max (oxygenates prohibited)	
Lead (organic) gr/liter, max. (ASTM D3237)	0.02	0.0132	0.0132	0.005	<0.0025 g/l
RVP, psi	8.7 +/-0.2% ASTM D5191	8.7-9.2	7.5-8.0	.56-.64 bar (8.1-9.3 psi)	.61 bar (8.85 psi)
Sensitivity, minimum (ASTM D 2699/2700)		7.5	7.5		7.5
Octane, Research, minimum (ASTM D2699)		93	93	95.0 min	91.9
Motor Octane Number (ASTM D2700)				85.0 min	
Octane, R+M/2 (ASTM D 2700)	87.3 +/- 0.5%			(137.5 min - calc)	84.4
Distillation (ASTM D 85)					
IBP,C	32.8 +/- 11	24-36	24-38	24-40	34
10% point, C	53.3 +/- 5.5	49-57	49-60	42-58	54
50% point, C	103.3 +/- 5.5	93-110	93-110	90-110	100
90% point, C	165.6 +/- 5.5	149-163	149-163	155-180	161
End Point, C, max	212.8	212.8	212.8	190-215	206
Aromatics, % (ASTM D2267/D1319)	32 +/- 4.0				21.6 %v/v
Aromatics, max. %		35	35	45 vol.	
Olefins, % (ASTM D1319)	9.2 +/- 4.0				9.0 %v/v
Olefins, max. %		10	10	20 vol.	

Saturates, % (ASTM D1319)	remainder			remainder	59.5 %v/v
Saturates, max. %		remainder	remainder		
Oxidation stability induction period (ASTM D525)				480 min	>1000 min
Carbon/hydrogen ratio (Ultimate analysis)					6.41:1
Residue (ASTM D86)				2% max	
Existent gum (ASTM D381)				4mg/100ml max	
Copper [illegible] at 50C (ASTM D[illegible])				1 max	
Density at 15C (DIN 51 757-D)					0.7257 kg/[illegible]

Table 1-08
Average (3 tests) 1-Bag J1088 6-Mode Test Results by Fuel
Tecumseh 4-Stroke 2.6kw WBM Engine

Fuel Type	Industry Average	Reformulated with MTBE	Reformulated with Ethanol	Alihatic
Regulated Emissions (note: THC = Methane + NMHC, Particulates not regulated)				
	g/kw-hr	g/kw-hr	g/kw-hr	g/kw-hr
Methane	2.68	3.27	3.15	4.73
NMHC	21.5	18.8	17.2	20.3
CO	480	447	433	464
NOx	1.73	1.61	1.7	1.6
Particulate	0.76	0.43	0.48	0.28
Individual Toxic Species and Oxygenates				
	mg/kw-h	mg/kw-h	mg/kw-h	mg/kw-h
1,3-Butadiene	209	178	164	178
Ethanol	--	--	719	--
MTBE	--	508	--	--
Benzene	925	713	801	217
Formaldehyde*	145	139	142	157
Acetaldehyde*	25	27	78	34
Distribution of Nonmethane Exhaust Organics using Speciation Procedures				
	g/kw-hr	g/kw-hr	g/kw-hr	g/kw-hr
Other Saturates	5.86	5.48	6.38	9.2
Olefins	7.25	8.48	7.4	11
Aromatics	5.7	3.77	3.27	0.43
Oxygenates	--	0.51	0.72	--
Carbonyls	0.21	0.23	0.27	0.24
Unidentified	2.92	1.57	1.15	1.23
TOTAL (NMOG)	21.9	20	19.2	22.1
Ozone Formation Potential of Exhaust Organics				

	g/kw-hr	g/kw-hr	g/kw-hr	g/kw-hr
Methane	0.031	0.035	0.032	0.055
Other saturates	4.24	3.9	4.39	6.05
Olefins	28.7	32.1	29.1	42.4
Aromatics	19.6	11.1	9.51	1.17
Oxygenates	--	0.24	1.62	--
Carbonyls*	1.11	1.09	1.29	1.22
Unidentified	7.86	4.24	3.1	3.34
TOTAL	61.5	52.7	49	54.2
* Each value represents a single determination Ref: SAE# 911222				

Table 1-09
Technologies to Reduce Emissions from Current Production Small Nonroad SI Engines in Classes I and II

ENGINE DESCRIPTION	CURRENT EMISSIONS (g/kW-hr)			AFTER STANDARD (g/kW-hr)			% Change From Present			Technology
	HC	NO_x	CO	HC	NO_x	CO	HC	NO_x	CO	
Class I (<225cc)										
4-Stroke, SV 2.98kW (190cc)	66	1.55	638	5.76	5.91	75	-91	+281	-88	4-stroke OHV Lean & EGR
4-Stroke, SV 3.73kW (190cc)	24.5	1.61	680	11.9	2.75	385	-51	+71	-43	Lean & Catalyst
4-Stroke, OHV 2.98kW (148cc)	13.4	3.3	499	5.76	5.91	75	-57	+79	-85	Lean & EGR
	13.4	3.3	499	2.83	8	54	-79	+142	-89	Lean & Catalyst
2-stroke 3.73kW(145cc)	255	0.416	595	5.76	5.91	75	-98	+132	-87	4-stroke OHV Lean & EGR
Class II (>225cc)										
4-Stroke, SV 8.95kW (465cc)	8.7	6.72	367	7.4	6.0	469	--	--	--	Class II Standards
4-stroke OHV 8.21kW(338cc)	10.9	2.57	340	7.25	2.56	295	-33	-0.39	-13	Air Injected Into Muffler

Additional Current Emission Level data are presented in Table 1-15.

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Table 1-10
Technologies to Reduce Emissions from Current Production Small Nonroad SI Engines in Classes III, IV and V

ENGINE DESCRIPTION	CURRENT EMISSIONS (g/kw-hr)			AFTER STANDARD (g/kw-hr)			% CHANGE FROM PRESENT			TECHNOLOGY
	HC	NO_x	CO	HC	NO_x	CO	HC	NO_x	CO	
Class III (<20cc)										
16.3cc Trimmer	384	0.5	499	295	0.9	499	--	--	--	HC - Standard, Est for NOx & CO
Class IV (20-50cc)										
25cc Trimmer	197	1.0	449	176	1.0	404.5	-10	-2.3	-10	Enleanment (4.5%)
30.1cc Chainsaw	178	0.4	384	179	0.5	333	-1	21	-13	Enleanment?
Average of 27 2-Stroke Engines	350	N/A	964	228	N/A	596	-35	N/A	38	Avg of 27 2-Stroke Engines with 6% CO Enleanment
Average of 27 2-Stroke Engines	350	N/A	964	20	5.4	170	-94	+325	-82	4-stroke
Class V (>50cc)										
53cc Chainsaw	120	0.7	427	110	0.8	357	-8	15	-16	Enleanment (6%)
Average of Eighteen 2-Stroke Engines	214	N/A	696	108	N/A	368	-50	N/A	-47	Avg of four 2-Stroke Engines with 6% CO Enleanment

Indicated Average numbers were taken from data presented in Tables 1-16 through 1-20.

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Table 1-11
Fuel Consumption and Power on Prototype Engines

ENGINE DESCRIPTION	CURRENT BSFC (kg/kw-hr)	AFTER STANDARD (kg/kw-hr)	% CHANGE IN BSFC	CURRENT POWER (kw)	AFTER STANDARD (kw)	% CHANGE IN POWER	TECHNOLOGY
Class I (<225cc)							
4-Stroke, SV 2.98kW (190cc)	0.83	0.43	-48	0.9	0.87	-3	4 Stroke OHV Lean & EGR
4-Stroke, SV 3.73kW (190cc)	0.75	0.60	-20	1.0	1.08	+14	Lean & Catalyst
4-Stroke OHV	0.603	0.43	-29	0.9	0.87	-3	Lean & EGR
2.98kw (148cc)	0.603	0.47	-22	0.9	0.82	-9	Lean & Cat
2-Stroke 3.73kW(145cc)	0.854	0.43	-50	1.0	0.87	-13	4 Stroke OHV Lean & EGR
Class II (>225cc)							
4-Stroke, SV 8.95kW (465cc)	0.57	0.52	-9	3.25	3.06	-6	4-Stroke OHV Air Injected
4-Stroke OHV 8.21kw (338cc)	0.51	0.52	+1	3.06	3.01	-2	Air Injected (Muffler)
Class III (<20cc)							
N/A							
Class IV (20-50cc)							
25cc Trimmer	1.04	0.8	-22	0.56	0.55	-2	Enleanment
30.1cc Chainsaw	0.62	0.64	+3	1.15	1.11	-4	Enleanment?
4-Stroke	0	0.25	--	0	.746	--	New Technology
Class V (>50cc)							
53cc Chainsaw	0.56	0.53	-6	2.28	2.27	-0.5	Enleanment (6%)

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Table 1-12
Estimated Change of Fuel Consumption Per Class and Technology
Based on 1996 Sales Weighting

CLASS	PRE-CONTROL (g/kW-hr)	POST-CONTROL (g/kW-hr)	% CHANGE FROM PRE-CONTROL
CLASS I			
SV	528	402	-24
OHV	32	43	+35
Other	0	0	-29
2-Stroke	69	0	-100
CLASS II			
SV	106	97	9
OHV	21	21	+2
Other	1	1	+2
2-Stroke	0	0	-100
TOTAL NHH	**758**	**565**	**-26**
CLASS III			
2-Stroke	60	52	-13
CLASS IV			
2-Stroke	725	623	-14
4-Stroke	0	2	
CLASS V			
2-Stroke	30	29	-6
TOTAL HH	**815**	**706**	**-13**

Note: See Appendix B for calculation details.

Table 1-13
Estimated Change of Power Per Class and Technology
Based on 1996 Sales Weighting

CLASS	PRE-CONTROL (kW)	POST-CONTROL (kW)	% CHANGE FROM PRE-CONTROL
CLASS I			
SV	0.57	0.72	26
OHV	0.047	0.09	83
Other	0	0	-3
2-Stroke	0.081	0	-100
CLASS II			
SV	0.60	0.57	-6
OHV	0.12	0.12	-2
Other	0.01	0	-2
2-Stroke	0	0	-100
TOTAL NHH	**1.44**	**1.51**	**+5**
CLASS III			
2-Stroke	0.062	0.06	-3
CLASS IV			
2-Stroke	0.75	0.72	-4
4-Stroke	0	0.01	--
CLASS V			
2-Stroke	0.12	0.12	0
TOTAL HH	**0.94**	**0.91**	**-3**

Note: See Appendix B for calculation details.

Table 1-14
Sample of Noise and Safety Regulations and Voluntary Standards for Small Engines

CLASSES OF ENGINES	SAFETY REGULATION OR RECOMMENDATION	DESCRIPTION
REGULATIONS		
All Classes	Title 36 CFR Part 261.1	Spark arresting device on equipment in lands overseen by the US Forest Service
All Classes	Title 43 CFR 420.11	Spark arresting device on equipment on Reclamation Lands
Class I and II	EEC Council Directive of 19 Dec 1978	Noise emission of construction plant and equipment
Class I	EEC Council Directive 84/538/EEC 17 Sept 1984 & 7 April 1987	Council Di rective of the approximation of the laws of the Member States relating to the permissible sound power levels of lawnmowers
As Applicable	EEC Council Directive 84/533/EEC	Compressors
As Applicable	EEC Council Directive 84/536/EEC	Power Generators
As Applicable	EEC Commission Directive of 7 April 1987 for Heat Protection (USO 5395: 1990(E))	Temperature for surfaces and protection from exposure to exhaust components > $10cm^3$
As Applicable	ISO 11094 (International Standard specific to mowing equipment)	Acoustics – test code for the measurement of airborne noise emitted by power lawnmowers, lawn tractors, lawn and garden tractors, professional mowers and lawn and garden tractors with mowing attachments.
VOLUNTARY STANDARDS/TEST PROCEDURES		
As Applicable	NIOSH Lifting Limits for Individuals	Guidelines for allowable weight of equipment based on ergonomics of the human body.
Classes III-V	ANSI B175.1 - Gasoline Powered Chain Saws - Safety Requirements	Includes safety requirements for topics including throttle control linkage, spark arresting mufflers, chain guards, etc.
Classes III-V	ANSI B175.2 Handheld and Backpack, Gasoline Engine Powered Blowers	Sound-Level Labeling Requirements and Test Procedures
Classes I and II	ANSI B71.1 (1990)	Blade tip speed for WBM and Riding Mowers, Safety Brake
As Applicable	ANSI B71.3 (1984)	Snowthrowers
As Applicable	ANSI B71.4 (1990)	Commercial Turf Equipment
As Applicable	ANSI B71.5	American National Standard for Powered Lawn, Garden and Snow Removal Equipment - Operator-Ear Sound Pressure Level – measurement and Rating Procedure
As Applicable	ANSI B71.6 (1990)	Shredders and Grinders
As Applicable	ANSI B71.8 (1986)	Tillers

Table 1-15
Individual Tests of Current Production Small Engines Used In Class I and Class II Small SI Engines, Weighted J1088, g/kW-hr

ENGINE	HC g/kw-hr	NOx g/kw-hr	CO g/kw-hr	Wtd A/F	Wtd. Power kW	BSFC kg/kw-hr	Meet Standard
4-Stroke <225cc							
135cc, 4.5hp OHV	14.2	3.04	512	11.4	0.895	0.608	N
	12.6	3.55	511	11.5	0.903	0.598	N
140cc, 4.5 hp OHV	14.2	3.12	512	11.4	0.895	0.608	N
	12.6	3.67	484	11.5	0.903	0.596	N
148cc, 4 hp SV	66.0	1.55	649	11.6	0.88	0.839	N
	65.4	1.55	630	11.6	0.91	0.821	N
148cc, 4 hp OHV	24.5	2.57	485	11.7	1.07	0.614	N
	25.1	2.76	480	11.8	1.02	0.62	N
148cc, 3.5hp (WMB) with Liner	22.5	2.14	529	N/A	N/A	N/A	N
	21.4	2.01	516	N/A	N/A	N/A	N
	27.5	1.58	540	N/A	N/A	N/A	N
190cc, 5 hp SV (WBM)	25.2	1.77	666	10.5	0.955	0.874	N
	23.9	1.45	692	10.9	0.985	0.838	N
2-Stroke <225cc							
145cc, 5 hp	267	0.42	599	10.5	0.955	0.869	N
	243	0.40	591	10.9	0.985	0.839	N
4-stroke >255cc							
338cc, 11 hp OHV	7.33	2.80	342	11.9	0.955	0.492	Y
	8.70	2.99	340	12	0.985	0.492	Y
338cc, 11 hp OHV	10.88	2.57	340	11.3	3.06	0.512	N
400cc, 12 hp SV	9.64	7.24	347	12.7	3.245	0.565	N
	7.86	6.19	387	12.5	3.253	0.578	N
400cc, OHV	9.26	1.78	408	difficult to decipher			Y
782cc, 18 hp SV	9.28	3.59	484	12	5.33	0.632	N
	8.58	3.90	479	12	5.237	0.644	N
5.88 kw/7.88 hp OHV	6.97	5.42	260	12.7	2.19 (2.93)	0.442 (0.727)	Y
	7.1	5.03	260	12.9	2.10 (2.82)	0.449 (0.738)	Y

(References: SAE#910560, SAE#911807,SAE#911805,SAE#911222)

Table 1-16
Individual Emissions of Current Production Handheld Equipment Engines
20cc-50cc, WOT Mode J1088, kg/kw-hr

ENGINE CC	HC g/kw-hr	NO_x g/kw-hr	CO g/kw-hr	Wtd A/F	Wtd Power kw	BSFC kg/kw-hr	Meet Emission Std?*
21	434.32		1202.4	N/A	N/A	N/A	N
24	229.22	1.50	328.42	12.3	0.54	0.75	Y
24	219.84	1.29	395.44	11.9	0.54	0.75	Y
24	217.16	1.06	378.02	11.1	0.53	0.72	Y
24	241.29	1.21	418.23	11.4	0.51	0.81	N
25	281.50		804.29	N/A	N/A	N/A	N
26	360.59		1139.41	N/A	0.41	N/A	N
26	360.59		1142.09	N/A	N/A	N/A	N
28	268.10		938.34	N/A	N/A	N/A	N
30	281.50		804.29	N/A	N/A	N/A	N
30	294.91		804.29	N/A	N/A	N/A	N
32	402.14		938.34	N/A	N/A	N/A	N
32	563.00	<.27	1313.67	N/A	0.41	N/A	N
32	268.10		1005.36	N/A	N/A	N/A	N
32	670.24		1340.48	N/A	N/A	N/A	N
32	569.71		1313.67	N/A	N/A	N/A	N
34	268.10		804.29	N/A	1.12	N/A	N
34.41	264.08		694.37	N/A	1.19	N/A	N
35	435.66		871.31	N/A	N/A	N/A	N
35.2	268.10		737.27	N/A	1.08	N/A	N
38	201.07		871.31	N/A	N/A	N/A	N
38	268.10		804.29	N/A	N/A	N/A	N
38	308.31		831.10	N/A	N/A	N/A	N
40	294.91		890.08	N/A	N/A	N/A	N
40	167.56	~.27	670.24	N/A	1.64	N/A	Y
40	268.10		804.29	N/A	N/A	N/A	N

42	160.86	~.27	670.24	N/A	1.87	N/A	Y
42	113.94	~.27	589.81	N/A	2.16	N/A	Y
44	115.28		671.58	N/A	N/A	N/A	Y
45	294.91		871.31	N/A	N/A	N/A	N

*Note that these emission numbers are from the WOT mode of J1088 which is weighted 90% of the J1088 two mode test, except the four test results of the 24cc engine which is from SAE#910560 (Sources: Heiden Report, McCullough Corporation,SAE#910560)

Table 1-17
Emissions of Current Production Handheld Equipment Engines >50cc
WOT Mode J1088, g/kW-hr

ENGINE CC	HC (g/kW-hr)	Nox (g/kW-hr)	CO (g/kW-hr)
50	308.31		871
51	335.12		806
51	160.86		684
51	160.86	0.20	684
51	127.35	~.27	590
54	191.69		696
54	202.28		696
54	195.71		697
54	127.35	0.16	590
54.1	123.32		603
55	227.88		804
57	502.68		603
57	481.23		1005
60	335.12		804
61	214.48		804
61	214.48		737
61	160.86	~.27	657
61	160.86	~.27	657
67	154.16	~.27	643
67	116.62		590
67	120.64	~.27	576
67	120.64	~.27	576
70	428.95		871
70.46	201.07		745
81	127.35	~.27	576
83	164.88		718
87	127.35	~.27	576
87	107.24		575
92	308.31		737

*Note that these emission numbers are from the WOT mode of J1088 which is weighted 90% of the J1088 two mode test
(Sources: Heiden Report, McCullough Corporation)

Table 1-18
Small SI Engines 20-50CC With Emission Reduction Technology
Handheld ApplicationsTable, WOT Mode of J1088

ENGINE CC	Technology	HC g/kw-hr	NO_x g/kw-hr	CO g/kw-hr	Met Emission Standard?*
28-30?	4 Stroke	20	5	170	Y
21	6% CO	291		643	Y
21	6% CO	670		1206	N
25	6% CO	416		938	N
25	6% CO	147		536	Y
26	6% CO	189		592	Y
28	6% CO	181		536	Y
30	6% CO	201		536	Y
30	6% CO	201		550	Y
31	6% CO	201		603	Y
32	6% CO	147		503	Y
32	6% CO	107		469	Y
32	6% CO	322		670	N
32	6% CO	268		737	N
35	6% CO	302		570	N
35	6% CO	235		737	Y
38	6% CO	161		469	Y
38	6% CO	134		469	Y
38	6% CO	174		496	Y
40	6% CO	201		469	Y
40	6% CO	184		453	Y
44	6% CO	101		393	Y
45	6% CO	194		536	Y
21	?	206	0.64	299	Y
21	?	201	0.58	328	Y
24	?	443	0.17	927	N
24	?	345	0.64	332	N
25	?	168	1.15	441	Y
25	?	168	0.88	353	Y
30.1	?	176	0.56	294	Y

30.1	?	182	0.50	371	Y
38	?	211	0.86	531	Y
38	?	213	0.67	467	Y

*Note that these emission numbers are from the WOT mode of J1088 which is weighted 90% of the J1088 two mode test (Sources: Heiden Report, McCullough Corporation).

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Table 1-19
Small SI Engines >50CC With Emission Reduction Technologies
Handheld Applications, WOT Mode of J1088

ENGINE CC	Technology	HC g/kw-hr	NO_x g/kw-hr	CO g/kw-hr
50	6% CO	208	NA	469
51	6% CO	201	NA	469
51	6% CO	122	NA	402
51	6% CO	174	NA	496
54	6% CO	157	NA	406
54.1	6% CO	107	NA	369
55	6% CO	194	NA	469
57	6% CO	174	NA	429
57	6% CO	235	NA	536
60	6% CO	268	NA	536
61	6% CO	147	NA	489
61	6% CO	161	NA	456
67	6% CO	91	NA	362
70	6% CO	322	NA	536
83	6% CO	129	NA	405
87	6% CO	97	NA	374
92	6% CO	214	NA	469
The following are repeat tests of the same engine design - four different engines.				
53	?	105	0.74	357
53	?	115	0.84	356
53	?	114	0.80	358
53	?	114	0.78	363
*Note that these emission numbers are from the WOT mode of J1088 which is weighted 90% of the J1088 two mode test (Sources: Heiden Report, McCullough Corporation).				

Chapter 1 References

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2. Section 211(k)(10)(B)(i) of the CAA

3. CFR, Title 40, Part 86, Section 113-90(a)

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5. CEC Legislative Fuel, RF-05-A-85

6. Husqvarna AB, Letter to Cheryl Caffrey, EPA from Dan Ericsson, Specification of Certification Fuels (Analysis Certificate No 23586 for CEC Legislative Fuel RF-05-A-83) (EPA requests information on the general specifications)

7. Hare, Charles T, et al, *Toward the Environmentally-Friendly Small Engine: Fuel, Lubricant, and Emission Measurement Issues*, SAE #911222, 1991.

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11. PPEMA/AQC, *In-Use Emissions Test Report* (25cc String Trimmer), February 5, 1993

12. PPEMA/AQC, *EPA/PPEMA In-Use Emissions Test Report* (30.1cc Chainsaw), February 8, 1993

13. Heiden Associates Report, *A 1989 California Baseline Emissions Inventory for Total Hydrocarbon and Carbon Monoxide Emissions from Portable Two-Stroke Power Equipment*, 24 July 1990.

14. McCulloch Corporation, *Small Engine Test Data* to Cheryl Caffrey, EPA from Rod Harms, May 11, 1993 & May 13, 1993.

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16. Popular Science, *New Environmental Technology Developed for Portable Lawn and Garden Engines* by Ryobi America Corporation, March, 1993, pp 90-96.

17. White, supra note 8

18. White, supra note 8

19. PPEMA/AQC, supra note 11

20.

21. PPEMA/AQC, supra note 12
Phone Conversation with Dee North of EPA and Bela Csonka of Ryobi on November 15, 1993.

22.
Ryobi, supra note 16

23.
PPEMA/AQC, supra note 15

24.
Official Journal of the European Communities, *Council Directive of 17 September 1984 on the approximation of the laws of the Member States relating to the permissible sound power level of lawnmowers (84/538/EEC)*, 19.11.84.

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Chapter 2: Technology Market Mix and Cost Estimates for Small SI Engines and Related Equipment

The Clean Air Act Amendments of 1990 section 213(a)(3) present statutory criteria that EPA must consider cost in determining whether proposed standards achieve the greatest degree of emission reduction. This chapter presents the Agency's estimation of costs for expected technologies including associated variable hardware, production, research and development and related equipment costs.

To calculate estimated costs incurred by engine manufacturers, market mix percentage estimates for pre and post control engines must first be assessed. This is done by determining the pre-control engine market percentage makeup from available sales data. Then estimates on the amount of use of emission reduction technologies are made and applied to the pre-control sales mix in order to estimate post-control market mix percentages. Resources and description of the methodologies for these estimates are described in 2.1 Technology Market Mix Estimates.

Variable hardware and production costs are determined by estimating variable hardware and production costs for each emission reduction technology to a calculated post-control technology sales mix estimate. The methodology for estimating emission reduction

technology costs, post-control technology sales mix, and variable hardware and production costs are presented in 2.2 Variable Hardware and Production Cost Estimates per Engine Class.

Research and development costs are determined by estimating costs to research and development activities required of each emission reduction technology. These costs are amortized and therefore do not apply on a per engine basis as do variable hardware and production cost estimates. Discussion of the methodology utilized to estimate research and development costs are presented in 2.3. Research and Development Cost Estimates per Engine Class. Detailed discussion on amortized research and development costs is presented in Chapter 3.

Engines are utilized in equipment which may require alterations due to changes in the reduced emission engines. One example is the requirement of carburetor limiter caps on engines which contain an adjustable carburetor. Handheld equipment has a shroud around the engine. The shroud near the adjustable jet must be widened to allow for the carburetor limiter cap. A discussion of equipment impacts is presented in 2.4 Equipment Variable Hardware and Production Cost Estimates. A summary of all resultant cost estimates are listed in Table 2-01.

Table 2-01
Estimated Costs Per Engine Per Class and Equipment for Small SI Engines

ENGINE CLASS	Variable Hardware (Engine)	Production (Engine)	Research and Development (Total per Engine Class)	Equip-ment Impacts	Additional Catalyst Variable Hardware	Additional Catalyst Research & Development	Additional Equipment Impacts due to Catalyst
I	$1.89	$0.74	$10,803,000	$0.10	$1.32	$100,483	$0.06
II	$0.65	$0.31	$10,000,000	$1.00	NA	NA	NA
III	$1.69	$0.49	$72,500	$1.24	$0.03	$20,000	$0.20
IV	$1.92	$0.34	$2,115,000	$1.24	$0.03	$20,000	$0.20
V	$2.37	$0.48	$2,812,500	$1.24	$0.03	$20,000	$0.20

2.1 Market Mix and Emission Reduction Technology Estimates

Market mix estimates are calculated percentage sales estimates of engine designs (ie: side valve, overhead valve, 2-stroke, etc.) per class (i.e., Classes I-V) of the year prior to and the first year of emissions regulation. Additional changes for the later 2-stroke phase-in are also included. Emission reduction technology estimates are percentage estimates of individual emission reduction technologies that will be applied to engine designs as a result of emission regulation. The following describes the methodology used to calculate market mix estimates and emission reduction technology estimates for small SI engines. A summary of results are in Tables 2-05 and 2-06 with detailed calculations in Appendix B Manufacturer and Product Summary.

The pre-control small SI engine market mix estimate is based on the Power System's Research (PSR) "Engindata" database. The database contains information such as engine models, engine manufacturers, bore and stroke measurements, valve orientations, equipment usages and sales data. The engines and corresponding engine sales are separated into engine displacement classes (i.e., Class I (<225cc), Class II (>225cc), and handheld engine classes (Class III (<20cc), Class IV (20-50cc), and Class V (>50cc))), 4-stroke side valve, overhead valve, 2-stroke engine designs, and an "other" category of alternative fuel, fuel injected, and water-cooled engines (see Appendix B). PSR sales numbers for 1992 are utilized for estimating pre-control market mix. Although this should be based on sales estimates for the year prior to engine regulation, i.e., 1995, EPA has determined that the technology mix will not change significantly between 1992 and 1995 sales years.

EPA has estimated percentage usages of emission reduction technologies for engine designs in Classes I-V and calculated resulting post-control percentage engine design sales mix for the first full year of regulation implementation. Emission reduction technology estimates are

based on emission data provided in SAE technical papers(1)(2)(3)(4)(5)(6), confidential discussions with manufacturers and internai analyses.

2.2 Variable Hardware and Production Cost Estimates per Engine Class

Many of the emission reduction technologies assumed feasible for this rule consist of engine design changes with a minor number of technologies requiring the addition of extra hardware, such as catalysts. As a result, many technologies require changes in manufacturer production including tooling and die design. The following definitions were utilized to separate costs for emission reduction technologies into variable hardware, production, research and development costs. Variable hardware costs are those costs which are associated with pieces of hardware added to an engine. Examples include carburetor limiter caps, additional metal to the engine block, and valve guides. Production costs are those costs which relate to inputs in production. These costs consist of additional production tasks related to the addition of carburetor limiter caps and increased maintenance on tooling due to tighter component tolerances. Research and development costs are those costs associated with development of engine and engine component designs. Changes to production such as tooling and die design changes are included in research and development costs due to their one-time effect on the production process. Examples include engine block die design and retooling for tighter production tolerances.

EPA developed cost estimates for variable hardware and production costs for post-control engine sales, in the following manner (detailed calculations are in Appendix B). First, engine sales numbers for the first year of implementation were taken from EPA's estimated sales of small SI engine equipment for the first year of implementation as presented in Chapter 4 of this document. Second, the equipment sales estimates

were separated into engine classes and engine designs based on the PSR "Engindata" database equipment/engine design splits for the 1992 sales year. Third, the number of engines in each class and engine design were adjusted by applying the percentage use estimates for each emission reduction technology which were determined in 2.1 Market Mix and Emission Reduction Technology Estimates. Fourth, estimates were made for the variable hardware cost and production cost for each emission reduction technology. Fifth, cost estimates for each emission reduction technology were multiplied by the corresponding number of engines within each class. Lastly, all costs associated for each emission reduction technology within each class were summed and divided by the number of engines in the class, thereby yielding a sales weighted cost per engine in the class. Tables 2-07 to 2-11 show the cost estimates for each emission reduction technology per class and engine design.

Tables 2-07 and 2-08 show that costs are estimated to be slightly higher for Class I engines than Class II engines. This result is due to the number and extent of emission reduction technologies required per engine to meet the respective emission standards in each class. Many of the Class II engines have the advantage of lower surface to volume ratios and higher power than Class I engines which allows them to have lower brake specific emissions. In addition, Class II engines are comprised of a larger number of higher quality engines in relation to Class I which require less alterations to meet emission standards. EPA estimates that many of the internal engine modifications that will be made to low cost engines to help them comply with the adopted standards have already been applied to commercial engines to optimize durability and performance.

For Classes III-V, shown in Tables 2-09 to 2-11, EPA estimates that the technology costs will be evenly spread due to the similar levels of modification required in engines throughout these classes with some

differences in Class IV where there is a mixture of professional and residential designed engines.

2.2.1 Class I

The majority of engines in Class I are made for the low cost consumer market and are of 4-stroke side valve design. Cost is the major design consideration for these engines, with some attention to maintenance of adequate performance and durability. As a result, major changes are required on a large portion of these engines in order to meet emission regulations. The major feasibility barriers for these engines include exhaust valve seat temperature and high surface to volume ratio as described in Section 1.2. Table 2-07 summarizes the technologies EPA is estimating will be available to meet emission standards for Class I engines on the implementation time line specified in this rule. In summary, EPA estimates that increased variable hardware and production costs for Class I engines will be $1.82 and $0.50 per engine respectively. These estimates apply to the sales and annual consumption of Class I small engines in the United States. The percentages apply to the change in annual sales as a result of first full year of regulation implementation. Cost estimates are based on confidential conversations with manufacturers of engines and engine components.

EPA estimates that 78% of the present 4-stroke side valve engines will utilize enleanment with major redesigns occurring to the carburetor and fuel distribution systems. A large majority of current engines have very simplistic carburetor systems which run very rich in order to provide stable operation under a variety of speed, load and altitude conditions. Carburetors will be required to provide more precise fuel distribution to the engine as the engines are enleaned. Major redesigns consist of replacing the fuel system and carburetor with new designs

which includes changes from adjustable to fixed jet and changing the jet size to enlean the air/fuel mixture entering the engine. EPA estimates that no engines will utilize adjustable carburetors thereby virtually eliminating the need for limiter caps and refined adjustment and idle needles.

EPA estimates that 80% of the carburetors presently used in Class I are manufactured by the engine manufacturer while 20% are purchased from an outside source. The variable hardware and production costs will vary for this Small Gas FRM based on who bears the additional cost of redesigning the carburetor. EPA requests further information on the in-house and outside sourced carburetors. The variable hardware cost for purchased carburetors is estimated at $1.50 per engine. EPA estimates that the variable hardware costs of manufactured carburetors is $0.00 per engine. In making this determination, EPA assumed that there will be no increase in parts or materials for the newly designed carburetors. Production costs estimates are also contingent on whether the engine manufacturer produces its own carburetors or purchases them from an outside source. For an engine manufacturer producing its own carburetor, two things will increase, (1) the frequency of production machine maintenance frequency of production machinery due to tighter production tolerances on carburetor components, and (2) the number of carburetor pieces not meeting production specifications. Production costs also include the costs of increasing production of a higher quality but smaller volume carburetor and fuel system or providing alterations to a production system in order to account for carburetor and fuel system changes. EPA estimates production costs at $0.20 per engine.

EPA estimates that 21% of the 4-stroke side valve engines will utilize enleanment with minor adjustments to the existing carburetors. It is estimated that a large number of these engines will be horizontal shaft

orientated engines. This estimate is based on discussions with engine manufacturers who have indicated that the emissions from horizontally crankshaft orientated engines have been found to be less than those from comparable vertically crankshaft orientated engines. Minor carburetor changes include conversion from adjustable to fixed jet and jet size changes to enlean the air/fuel mixture entering the engine. EPA assumes that 80% of carburetors in this category are made by engine manufacturers and that 20% of carburetors are purchased from an outside source. The cost for outside purchased carburetors is estimated to increase the cost of each engine by $0.50 with no cost increase for the in-house manufactured carburetors. Production cost increases for in-house manufactured carburetors are estimated to be $0.20 per engine based on the same items for major carburetor and fuel system changes which include increase in production machinery maintenance and increased components not meeting production specifications.

EPA estimates that improved ignition systems, such as solid state ignition systems, are already used on all small engines for improved reliability and spark control and therefore will not be a technology change. However, EPA does estimate that 50% of the side valve engines will utilize changes in ignition timing. Since spark timing has been optimized for power rather than fuel economy or emissions, it is likely that changes in ignition timing will be utilized. Changes in base ignition timing may affect power and, therefore, further compensations will have to be made in order to improve engine power. Base ignition timing changes require modification to change the relative position between the two halves of the magnetic pick-up. For example, on most engines, the ignition breaker is part of the engine flywheel. For these systems a modified flywheel key would be used to index the flywheel the desired number of degrees relative to the engine crankshaft. This modification will require research and development time to determine

the level of timing modification required. EPA estimates the necessary changes are limited to either one machining operation to index the crankshaft keyway, or a redesigned key. This results in a small adjustment to the mill cutting key or a one-time die change for the offset key.

EPA estimates that 95% of 4-stroke side valve engines will utilize combustion chamber redesigns. Combustion chamber redesigns include maximization of the surface to volume ratio and stiffening of the engine block. As described in Chapter 1, side valve 4-stroke small engines have large surface to volume ratios, in relation to overhead valve engines, and crevices to which the flame front does not reach. Decreasing the surface to volume ratio will improve combustion efficiency as the time to flame quenching is lengthened and less of the fuel is left unburned. Stiffening of the engine block will allow for more even heat distribution which will result in less affects of warping of the cylinder on the piston and valve openings, resulting in improved combustion efficiency. Combustion chamber redesign is estimated to require $0.10 in additional variable hardware costs based on the increased amount of material used in the die. Production costs are estimated to increase $0.20 based on increased maintenance and die replacement due to tighter tolerances and increased number of rejects.

EPA estimates that 80% of 4-stroke side valve engines will utilize valve system improvements including valve timing. In a large number of side valve engines, valve seating and timing characteristics have not been optimized. As a result, scavenging can occur as the air/fuel mixture enters the combustion chamber and leaves (before it is ignited) through an exhaust valve that is either not seating properly or has not yet closed. Combustion may even occur with the valves still partially open for the same reason stated above, thereby leading to low compression and raw exhaust escaping through the exhaust port. Valve

timing changes will not be substantial and represent minimal cost. However, valve guides will be added to the valve system to improve durability into the valve/mating surface fit regardless of engine block warpage and thereby reduce the oil and/or exhaust gases that may escape. The variable hardware cost estimate for valve system improvements is $0.40 per engine. Production costs include the additional step of inserting the valve guides in each engine. Production costs are estimated at $0.20 per engine.

EPA estimates that 1% of 4-stroke side valve design engines, i.e., larger low production engines, will be exchanged for 4-stroke overhead valve (OHV) designs. OHV engines are readily available in similar side valve horsepower size and there will likely be excess capacity available in OHV engine production facilities to accommodate the small increase in production necessary to replace these low volume side valve models. Therefore, to obviate the need to perform any development work on the low production side valve engine, the manufacturers will find it more cost effective to replace them with OHV engine designs. There will be no increase in variable hardware cost estimates per engine or increase in production costs for engine manufacturers already making both engine designs and therefore capable of covering this increased demand with existing production facilities.

EPA estimates that 50% of the 4-stroke side valve, overhead valve and other engines will require improved cooling in addition to changes made by carburetor enleanment and combustion chamber redesigns. Improved cooling changes are required to prevent premature wear of the valves, valve seats and piston rings. Improved cooling changes can consist of additional surface area, on the cylinder head and engine block, and increased fan area. Improved oil splash and oil circulation systems as well as improved materials for the valve train and piston components will help to remove heat from the valve train and piston

areas. Variable hardware costs consist of increased material for components such as cylinder head, engine block and fan moldings. Variable hardware costs are estimated at $0.10 per engine. EPA estimates that no new production-related costs will be incurred. One time die design changes are expected to occur simultaneously with combustion chamber redesign costs and are included in research and development costs.

EPA estimates that 100% of the 4-stroke OHV engines will utilize enleanment through minor modifications to the carburetor. This estimate is based on confidential information from engine manufacturers and emission data published in SAE papers as listed in Appendix B. Most of the OHV design engines are newer engine designs and are used in more expensive and durable equipment. Therefore, these engines tend to be of higher quality in terms of machining tolerance and durability. Such features allow these engines to produce lower baseline emissions, thus requiring less modification to meet the adopted standards. Modifications include fuel metering needle resensitizing and conversion to fixed jet systems. EPA estimates that engine manufacturers produce 80% of the carburetors for these engines while purchasing 20% from outside sources. As a result, the variable hardware cost is estimated to apply only to the outside sourced carburetors for an additional $0.50 per engine. Variable hardware costs for in-house manufactured engines are estimated at no cost to the engine manufacturer based on the same reasons discussed earlier for side valve engines. Production costs for in-house manufactured carburetors are estimated to increase $0.20, again for the same reasons stated for side valve engines including more precise production tolerances.

Special sales cap provisions are included in this regulation for Class I 2-stroke engines. In the initial implementation year, the sales cap will

be the number of 2-stroke engines in lawnmowers and snowblowers sold in 1994 and must meet the handheld Class V emission levels. The technologies to meet this level include enleanment with major carburetor and fuel districution changes (estimated $0.20 production cost per engine), carburetor limiter caps ($1.00 HVC and $0.20 production costs per engine), combustion chamber redesigns ($0.10 HVC and $0.20 production costs per engine) and improved cooling ($0.10 HVC per engine). In the year 2003, the 2-stroke engines must meet the same non-handheld Class I emission levels. At this time, EPA expects that either technologies, such as fuel injection and catalysts, will be available and applicable for 2-stroke Class I engines. Costs are estimated at $20.00 Hardware Variable Cost and $1.00 Production Cost per engine to meet Class I emission levels with a 2-stroke engine.

EPA also estimates that technology changes will be necessary for 50% of "other" Class I engines. For example, fuel injected engine designs, 50% will require enleanment with fuel injector optimization. This estimation is based on the assumption that these engines are of high quality and thus will need less technology changes to meet the emission standards. These engines are a very small percentage of the market. They are too expensive to be considered direct substitutes, but meet high durability needs of a very small segment of the market (i.e., less than .01%). These engines are not driving the feasibility determination of this rule. EPA estimates that there is a $0.20 increase in variable hardware costs for these engines based on the more complex fuel injector components. To simplify the cost estimate, EPA assumed that all fuel injector components are outside sourced.[2] Therefore, EPA

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[2] This is not a totally valid assumption. However, the population of these engines is so small that a more rigorous analysis would not impact cost ofthe rule. PSR database showed B&S as manufacturer of FI engine. B&S was contacted and they said they did not produce an FI engine, however, Kohler does produce an FI engine in Class II.

estimates no change in production costs.

EPA estimates that there will be no use of catalysts to meet the requirements of this regulation. This is based on confidential discussions with manufacturers and consideration of lead time available until implementation of the regulation. However, the use of catalysts is an option to engine manufacturers and if used, EPA estimates that 33% of 4-stroke side valve engines could utilize minimally loaded catalysts, mainly to reduce emission variances due to production variability. The variable hardware cost estimate for minimally loaded catalysts is $1.32 per Class I engine in addition to the per Class I engine variable hardware estimate previously discussed. The cost estimate is based on a catalyst cost of $4.00. EPA estimates no production costs since the catalyst is purchased from an outside source.

Each engine will require a label which indicates engine certification. The estimated hardware variable cost of the label per engine is $0.04. The production/administration cost to apply the label is estimated at $500 per engine family. This cost is included under administrative costs.

2.2.2. Class II

The majority of Class II engines are of 4-stroke overhead valve and side valve designs. This class, according to PSR data, contains only one-half of 1% 2-stroke engines. The engines are of higher horsepower and are also larger displacement than Class I engines. As a result, the effects of flame quenching are less and therefore the emissions are lower on a brake specific basis. EPA estimates that a majority of the side valve engines will require minor improvements, such as carburetor adjustments and combustion chamber redesign, while the overhead valve engines will need little to no improvements. These estimates are based on examination of emission data. EPA also estimates that the 2-stroke engines will convert to 4-stroke engine design.

Table 2-08 summarizes the technologies EPA is estimating will be available to meet the emission standards for Class II engines. In summary, EPA estimates that the sales-weighted average increase in variable hardware and production costs for Class II engines will be $0.65 and $0.16 per engine, respectively. The estimates apply to the sales and annual consumption of Class II small engines in the United States. The percentages apply to the change in annual sales as a result of first full year of regulation implementation. Cost estimates are based on confidential conversations with manufacturers of engines and engine components.

EPA estimates that 100% of the 4-stroke side valve engines in Class II will utilize enleanment with minor redesigns to the existing carburetors. Minor carburetor changes consist of jet size changes to account for enleanment and/or steps to change from adjustable jet carburetors to fixed jet carburetors. EPA estimates that no engine manufacturer will utilize adjustable carburetors due to the added cost of certification in the full range of all adjustable parameters. EPA also estimates that nearly 100% of the carburetors used in this class are purchased from an outside source. As a result, the variable hardware cost estimate for this change is $0.50 per engine based on carburetor manufacturer's increased costs to produce carburetors with tighter tolerances and an allocation of a portion of the tooling changes in production runs. EPA estimates the production costs to the engine manufacturer for this change to be $0.00 per engine.

EPA estimates that 100% of the 4-stroke side valve engines will utilize combustion chamber redesign for the reasons listed in Class I which include decreasing surface to volume effects and providing for more efficient combustion. Combustion chamber redesign is estimated to cost an additional $0.10 in variable hardware costs based on additional material to stiffen the cylinder. Production costs are

estimated at $0.20 per engine to account for increased maintenance and increased frequency of replacement of dies due to tighter tolerances.

EPA estimates that 25% of 4-stroke side valve, overhead valve, and other engines will require improved cooling. Improved cooling changes can consist of additional surface area, on the cylinder head and engine block, and increased fan area. EPA estimates a $0.10 increase in variable hardware cost per engine for additional material for this increased surface area. EPA estimates no increase in production costs for the same reasons as listed in Class I analyses.

EPA estimates that 1% of the 4-stroke OHV engines will utilize enleanment with minor modifications to the carburetor. This estimate is based on emission data which shows that a majority of these engines can already meet emission standards. Engines close to the 225cc cutoff may require some adjustment of the carburetor. The variable hardware cost estimate per engine is $0.50 for the same reasons cited for Class II side valve engines.

EPA estimates that all of the current 2-stroke engines in this class will be discontinued and the consumer will choose either 4-stroke side valve or overhead valve engines. There is no variable hardware cost for this change. Production costs are also nonexistent based on the estimate that 4-stroke production lines can fulfill the limited 2-stroke market in this class.

EPA estimates that for the "other" category of engines, which includes water cooled and alternative fueled engine designs, 1% will require enleanment with minor carburetor modifications. This estimation is based on the assumption that these engines are of high quality and thus will need less technology changes to meet the standards. These engines are a very small percentage of the market. They are too expensive to be considered direct substitutes, but meet high durability needs of a very small segment of the market (i.e., less

than one-tenth of 1%). The variable hardware cost estimate per engine is $0.50 based on previous statements for other engines in this Class. Previous statements also give reasons for EPA's estimate of $0.00 increase in production costs.

Each engine will require a label which indicates engine certification. The estimated hardware variable cost of the label per engine is $0.04. The production/administration cost to apply the label is estimated at $500 per engine family. This cost is included under administrative costs.

2.2.3. Handheld Equipment Engines (Classes III, IV and V)

To comply with the emission standards, manufacturers will have to enlean practically every engine. Manufacturers have said that the main constraints encountered with enleanment are engine temperature and performance loss. While specific modifications were compiled through confidential discussions with manufacturers and will be summarized below, the main areas of modification involve either strategies that offset engine temperature increases from enleanment through cooling system design, or modifications that minimize the amount of enleanment required through carburetor and combustion chamber modifications and aftertreatment options. Classes III, IV, and V are discussed separately because although these engines will utilize the same technologies, the percentage of engines that will do so will be different. This is based on estimates that engines in the higher displacement categories are less influenced by the surface to volume ratio on quenching and are of higher quality, thereby require less

improvements to meet the emission standards. The HC emission standards are proportionally decreased for each class with the CO standard for Class V being cut from 804 to 603 g/kW-hr. Technology information with respect to specific emission benefits are included in Chapter 1.

2.2.3.1. Class III--This class is for engines less than 20cc. Engines in Class III have been seen not to extend much lower 16cc and have low sales based on the limited number of models in relation to Classes IV and V. Table 2-09 summarizes the technologies EPA is estimating will be available to meet the emission standards for Class III engines. In summary, EPA estimates that increased variable hardware and production costs for Class III engines will be $1.69 and $0.40 per engine respectively. The estimates apply to the sales and annual consumption of Class III small engines in the United States. The percentages apply to the change in annual sales as a result of the first full year of regulation implementation. Cost estimates are based on confidential conversations with manufacturers of engines and engine components.

EPA estimates that 100% of Class III engines will require minor carburetor modifications consisting of a resensitizing of the carburetor adjustment and idle needles, limiter caps for adjustable carburetors and carburetor jet size changes for fixed jet carburetors. Although there are some fixed jet engines in the higher sizes, EPA estimates that these engines will remain with adjustable jets due to their sensitivity to operating conditions, including temperature, humidity, and altitude which affect the air to fuel ratio. The estimated variable hardware costs per engine is $0.50. EPA estimates that Class III engine manufacturers do not make their own carburetors and therefore will not experience any carburetor production costs.

EPA estimates that 100% of engines in this class will utilize

carburetor limiter caps. Limiter caps will be required on up to three adjustment needles (idle, low speed and high speed mixtures) on the carburetors. The use of limiter caps allows for some limited engine adjustment to maintain smooth operation when engines in actual use are exposed to temperature, humidity and altitude changes. The variable hardware cost estimate is $1.00 per engine. Production costs are estimated at $0.20 per engine based on the requirement of adding test stations and workers to test emissions throughout the limiter caps ranges as required by this regulation.

EPA estimates that 100% of Class III engines will incorporate combustion chamber, scavenging, and port timing modifications. Manufacturers will redesign the piston, combustion chamber and cylinder by tightening tolerances, increasing component stiffness to reduce distortion, optimizing port shapes and timing, and reducing dead space in the combustion chamber. Such design improvements will reduce emissions by reducing scavenging losses of raw fuel (i.e., HC emission) and ensuring more complete combustion (i.e., HC and CO emission). EPA estimates the variable hardware cost to be $0.10 per engine based on the additional material required to each engine. Production costs are estimated at $0.20 based on increased maintenance and frequency of replacement due to tighter tolerances. The number of unacceptable parts may also increase, thereby increasing the cost of production.

EPA estimates that 50% of the engines will require cooling changes. Emission data has shown that a portion of the engines already meet or are close to the emission standards while others will require extensive emission reduction. EPA assumes that engines requiring extensive emission reduction will utilize cooling changes. This is based on considerations that as engines are enleaned there is less fuel available to cool the engine and therefore additional cooling must be found in order

to assure correct engine operation. Most engines currently operate around 175 to 230°C combustion chamber temperature. One manufacturer provided data showing that engines can live at temperatures up to 290°C, at which point severe engine failure may occur. The data also indicated that the increases in combustion chamber temperature from enleaning an engine by 3% to 4%, approximately what is required to meet the emission standards, could be accommodated without causing engine damage. EPA estimates this is applicable to most engines. EPA estimates variable hardware cost to be $0.10 per engine. This is based on the estimate that cooling changes will require additional material to provide increased surface area in engine head and block and engine fan. EPA estimates there will be no production costs for this technology change.

EPA estimates that no engine will utilize catalysts. However, the option does exist and if utilized, EPA estimates that 1%of Class III engines could utilize low efficiency catalytic converters in order to account for increased variability in emission characteristics when the prototype emission reduction engine is put into production. The variable hardware cost estimate is $3.00 per catalyst or $.03 per Class III engine. The cost is based on confidential meetings with engine and catalyst manufactures. This estimated use of a low efficiency catalyst is based on the consideration that low efficiency converters (i.e., less than 30% HC conversion efficiency) would generate a small exotherm in the muffler but would not substantially increase the muffler skin temperature over that experienced by non-catalyzed systems. EPA assumes there will be no increase in production costs given EPA's understanding that catalysts will be incorporated in the engine muffler.

EPA estimates that a portion of engine models will be discontinued, however, the demand will be fulfilled by other available engine models. This is based on cost estimates that the decision by a manufacturer to

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discontinue an engine model is usually made on the basis of cost and life cycle. A mature engine that is near the end of its production cycle will not likely be modified, but will be discontinued or replaced with a newer model. Furthermore, some engine models may require such extensive modification to comply with the emission standards that it makes more sense to discontinue the model rather than modify it. In either case, manufacturers have not indicated to EPA that they intend to give up any substantial amount of market share as a result of this FRM. Manufacturers may be able to convince customers to switch over to similar engines within its product line. Therefore, EPA is assuming that the discontinued models will either be in markets for which the manufacturer has a replacement model, or in markets which the manufacturer has few sales.

Each engine will require a label which indicates engine certification. The estimated hardware varaible cost of the label per engine is $0.04. The production/administration cost to apply the label is estimated at $500 per engine family. This cost is included under administrative costs.

2.2.3.2. Class IV--Class IV engines (20cc-50cc) are similar to Class III engines (<20cc) in that they are presently all 2-stroke. As a result, many of the descriptions for the use of engine technologies discussed in the Class III section 2.2.3.1. apply to this class of engines and are referred to where appropriate. The percentages of use for each technology are different from those in Class III due to the fact that there are more commercially orientated engines of higher quality in this category. As a result, EPA estimates Class IV engines will need less changes to meet emission standards. Table 2-10 summarizes the technologies EPA is estimating will be available to meet the emission standards for Class IV engines. In summary, EPA estimates that increased variable hardware and production costs for Class IV engines

will be $1.92 and $0.25 per engine, respectively. The estimates apply to the sales and annual consumption of Class IV small engines in the United States. The percentages apply to the change in annual sales as a result of first full year of regulation implementation. All cost estimates are based on confidential conversations with manufacturers of engines and engine components.

EPA estimates that 75% of Class IV engines will require major carburetor modifications. Major carburetor modifications include an in depth redesign of the carburetor in order to deliver more precise fuel distribution to the engine as required by an enleaned engine. Major modifications consist of replacing the fuel system and carburetor with new designs. The estimated variable hardware cost per engine is $1.50 and production costs are estimated at $0.00.

EPA estimates that 25% of Class IV engines will require major carburetor modifications as described in Class III. The estimated variable hardware cost per engine is $0.50 and no production costs.

EPA estimates that 50% of Class IV engines will utilize engine limiter caps as discussed in Class III. Some Class IV engines are already using fixed jet carburetors and therefore the estimated percentage post-control use is less than that in Class III. The estimated variable hardware cost is $1.00 per engine and production cost estimate is $0.20 per engine.

EPA estimates that 75% of engines requiring major carburetor changes will also incorporate combustion chamber, scavenging, and port timing modifications for reasons specified in Chapter 1. The variable hardware cost per engine is estimated at $0.10 for additional material required for new engine designs. Production costs are estimated at $0.20 for reasons stated in Class III.

As discussed for Class III engines, EPA estimates that 50% of Class IV engines will require cooling changes. EPA estimates the variable hardware cost and production costs at $0.10 and $0.00 per engine

respectively for reasons described in Class III.

EPA estimates that 1% of the market will convert to a 4-stroke engine design. This is based on discussions with one engine manufacturer who stated that 4-stroke engines will be available in January of 1994 for use in trimmers and other medium speed handheld equipment. The cost differential between a 4-stroke engine and current 2-stroke engines, at least in the short term, will be greater than the expected cost of modifications that would be required by current 2-stroke engines to comply with the emission standards. Nevertheless, any manufacturer choosing to use 4-stroke technology for market-based reasons will have no problem complying with the standards.

As for Class III engines, EPA has determined that no catalytic converters will be utilized on Class IV engines. However, the possibility does exist that manufacturers may utilize low efficiency catalysts. If this option is chosen, EPA estimates that 1% of Class IV engines could utilize low efficiency catalytic converters in order to account for increased variability in emission characteristics when the engine is put into production. The cost estimate is $3.00 per catalyst or $0.03 per Class IV engine. EPA estimates that a small portion of Class IV engines will be discontinued and other available models will be substituted. This is based on discussions found under this topic in Class III section 2.2.3.1.

Each engine will require a label which indicates engine certification. The estimated hardware varaible cost of the label per engine is $0.04. The production/administration cost to apply the label is estimated at $500 per engine family. This cost is included under administrative costs.

2.2.3.3. Class V--This class is for handheld engines greater than 50cc. Class V engines are similar to Class III engines (<20cc) and Class IV engines (20-50cc) in that they are presently all 2-stroke. As a result,

many of the descriptions for the use of engine technologies given in Class III apply to this class of engines and are referred to where appropriate. The post control use percentages for each technology are different from those in Class III and IV due to the dominance of higher quality commercially orientated engines in this class. Table 2-11 summarizes the technologies EPA is estimating will be available to meet the emission standards for Class V engines. In summary, EPA estimates that increased variable hardware and production costs for Class V engines will be $2.37 and $0.39 per engine, respectively. The estimates apply to sales and annual consumption of Class V small engines in the United States. The percentages apply to the change in annual sales as a result of first year of regulation implementation. All cost estimates are based on confidential conversations with manufacturers of engines and engine components.

EPA estimates that 75% of Class V engines will require major carburetor modifications as described for Class IV engines. Variable hardware and production costs are estimated at $1.50 and $0.00 per engine respectively.

EPA estimates that 25% of Class V engines will require minor carburetor modifications as described for Class III engines. Variable hardware and production costs are estimated at $0.50 and $0.00 per engine respectively.

EPA estimates that 92.5% of Class V engines will utilize limiter caps. Limiter caps will be used on this class of largely fixed main jet engines in order to provide flexibility of adjustment with the enleaned engines. Limiter caps will be required for the same reasons stated for Class III engines. EPA estimates the variable hardware and production costs to be $1.00 and $0.20 per engine respectively.

EPA estimates that 100% of Class V engines will require combustion chamber redesign to reduce scavenging losses and improve combustion

efficiency. Combustion chamber redesign and related costs will consist of the same as discussed in Class III. The estimate variable hardware and production costs are at $0.10 and $0.20 per engine respectively.

EPA estimates that 50% of the Class V engines will require cooling changes for the same reasons discussed in Class III. The estimated variable hardware and production costs are at $0.10 and $0.20 per engine respectively.

EPA has determined that no catalytic converters will be utilized on Class V engines. However, the option does exist that manufacturers may utilize low efficiency catalysts. If this option is chosen, EPA estimates that 1% of the small engines could utilize low efficiency catalytic converters in order to account for increased variability in emission characteristics when the engine is put into production. The cost estimate per catalyst is $3.00 and increased variable hardware cost is $0.03 per Class V engine. This is based on reasons presented in Class III.

EPA estimates that a small portion of Class V engine models will be discontinued and substituted as discussed in the section on Class III engines.

Each engine will require a label which indicates engine certification. The estimated hardware varaible cost of the label per engine is $0.04. The production/administration cost to apply the label is estimated at $500 per engine family. This cost is included under administrative costs.

2.3 Research and Development Cost Estimates per Class

Research and development costs are considerable for small SI engines based on the fact that this is the first time engine manufacturers are being required to address the issue of HC, CO, and NO_x emission reductions for all of their engine product lines. Research and

development costs include time and resources spent to investigate emissions on current engines, investigation, design and application of engine design changes and/or emission reduction technology, and one time tooling and die design changes for the production line. Since many small engine manufacturers have begun research and development activities to address emission reductions on a portion of their production, as a result of 1991 requirements by the California Air Resources Board (CARB), only a portion of the total research and development cost is accounted for by this rulemaking. One exception is Class V engines in which all of the research and development cost estimate is applied to the federal rule, because the class contains a majority of engines utilized in farm and construction applications which are preempted from CARB rulemakings.

Information for research and development cost estimates were taken from confidential discussions with engine and component manufacturers and internal analysis. EPA has based its analysis on the assumption that research and development activities will be required on each individual engine model due to the extent of changes in engine designs. The PSR Engindata database contains information on engine manufacturers and engine models, however, PSR requested that this information remain confidential. As a result, only the number of models in each class and technology group is described in Table 2-12 and detailed worksheets in Appendix B. Confidentiality is also kept by generalizing the application of various technologies to a specified number of engine models rather than a specified number of engines. Class I engines are specifically sensitive to this due to the fact that there are only two major engine manufacturers in this class and that some engine models sell millions of engines while other engine models sell very few in comparison. As a result, research and development costs are estimated by applying the percentage of technology usage (e.g., 78%

of side valve engines are estimated to require major carburetor changes), to the number of engine models (e.g., 78% of the engine models are estimated to require major carburetor changes). No consideration was made for overlapping use of parts in several models, such as engine blocks, since this detailed information was not available. This may result in a slight overestimation of costs, however this may also account for costs not considered in this analysis.

Table 2-12 shows EPA's cost estimates for research and development activities for EPA Phase I rulemaking are $10,000,000 for Class I, $10,000,000 for Class II, $72,500 for Class III, $2,115,000 for Class IV, and $2,812,500 for Class V. Research and development costs for catalyst development were estimated separately at $100,483 for Class I, $0.00 for Class II (no catalyst use assumed), and $20,000 for each class in Class III-V. These costs are considered capital costs and therefore are amortized over time, see Chapter 3 for details.

Research and development costs appear to be the same for Classes I and II, however the numbers are the same for different reasons. Class I engine models are fairly low in number, however estimates indicate they will require a great deal of work to meet standards due to such factors as the disadvantage of high surface to volume ratios. Class II engine models are estimated to require less development for meeting emission standards, however, Class II contains a large number of engine models which must be reviewed and changed to meet emission standards. The lower research and development estimate costs for Class III-V engines indicate the less number of pieces in the current 2-stroke design in comparison to 4-stroke engine designs which are a majority in Classes I and II. Comparing estimated costs for Classes III-V show that Class III is very low. This is based on the observation that Class III has very few models in relation to the other two classes. Class IV and V have similar cost estimates even though Class V contains the entire

research and development costs, Class IV contains more engine models.

All Catalyst research and development activities are assumed to be the same for all Classes. The activities consist of the engine manufacturer working with the catalyst manufacturer to develop catalyst designs and the engine manufacturer testing the engines in the laboratory of the respective company. The only changes between each class is the percentage of models on which the catalysts may be utilized. EPA's estimated research and development costs for catalyst development are summarized in Table 2-02.

Table 2-02
Estimated Research and Development Costs for the Catalyst Option

CLASS	# OF MODELS BASED ON ENGINE SALES	ESTIMATED COST FOR R&D PER MODEL	TOTAL ESTIMATED COST PER CLASS
CLASS I (33%)	16	$20,000	$320,000
CLASS II (0%)	0		$0.0
CLASS III (1%)	1	$20,000	$20,000
CLASS IV (1%)	1	$20,000	$20,000
CLASS V (1%)	1	$20,000	$20,000

2.4. Equipment Variable Hardware and Production Cost Estimates

Small engines are utilized on a wide variety of equipment from handheld trimmers and chain saws to garden tractors and generator sets. The wide variety of equipment designs and ease of designing equipment which use small SI engines presents a challenge when estimating costs for these classes of engines. As a result, the following analysis is based on the major equipment type for each engine class. Based on PSR Engindata, the majority of Class I engines are utilized in lawnmowers, the majority of Class II engines are utilized in lawn

tractor, garden tractor engines, and generator sets, Class III engines are utilized in trimmers, Class IV engines are utilized in trimmers, blowers/vacs and chain saws, the majority of Class V engines are utilized in chain saws.

The majority of lawnmowers utilizing Class I engines consist of a revealed engine bolted to a metal or plastic deck which houses the grass cutting blade and is moved over the grass on four wheels. EPA estimates that any change in shape of the engine will not require any equipment redesign. As a result, EPA estimates that increased variable hardware and production cost changes for this equipment is $0.00. However, if the option of catalysts is utilized on these engines, then the engine and deck will require shrouding which will protect the user from the hot surfaces as well as assure that no dry grass is collected near the exhaust port which may ignite due to the hot escaping gases. EPA estimates that of the 33% of engines that may utilize catalysts, a total of 3% will require shrouding due to the hazardous exotherms developed by some catalysts. Variable hardware cost changes are estimated at $0.03 and production changes are estimated at $0.03 per Class I engine. Lastly, a label must be visible to the user as required by this regulation. It is likely that the majority of Class I engines will be uncovered, thereby it is estimated that only 10% will require labels. EPA estimates the label cost will be $1.00 per label and thereby $0.10 per engine (10% of $1.00). These estimates are based on confidential discussions with engine and equipment manufacturers.

Garden tractors general design incorporates an engine in a plastic housing either on the front or back of the rider. The engine is surrounded by a shrouding, in most cases, under which the fuel is also stored. Based on the technologies expected for this rule, EPA estimates that there will be no changes to the equipment and therefore no increased variable hardware and production costs. EPA estimates that

catalysts will not be used on any of the engines for these equipment types. Lastly, costs for an additional label will be incurred by the equipment manufacturer if the engine label is covered by the equipment housing. It is likely that the majority of Class II engines will be covered, thereby it is estimated that 100% will require labels. EPA estimates the label cost will be $1.00 per label. All cost estimates are based on confidential discussions with engine and equipment manufacturers.

Equipment impacts for the handheld engine classes include changes in shrouding designs due to the application of carburetor limiter caps. Presently, the shrouding surrounds the engine very closely and does not provide room for placement of the limiter cap on the engine. Costs include changes in plastic shrouding dies to accommodate this change. Although limiter caps were estimated to be utilized on 100% of Class III, 50% of Class IV and 50% of Class V engines, EPA estimates that changes will be required on 40% of the equipment in these categories. This is based on the assumption that not all of the equipment that will utilize engines with limiter caps will require design changes. As a result, EPA estimates that increased variable hardware and production costs will be $0.20 and $0.04 per handheld equipment.

If engine manufacturers choose the option of utilizing catalysts, then EPA estimates there will be an impact on equipment in order that it provide adequate shielding for user safety and adequate cooling such that equipment panels do not melt. An example is chain saws in which the housing is made from plastic and surrounds the equipment. Any increased temperature due to the use of a catalyst will require additional shielding or increased cooling panel designs in order to keep temperatures to a minimum and within already established surface and exhaust temperature limits. Although EPA estimated that 1% of the engines may utilize catalysts, EPA estimates that this change will affect only one half of 1% of equipment in Classes III-V. This difference is

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due to the expected range in catalyst loadings that will be utilized on these engines and the resultant variation in heat exotherms that will be generated. Variable hardware and production costs are estimated at $0.10 and $0.10 for Class III-V engines respectively.

Lastly, costs for equipment manufacturers include the addition of a label if the engine label is covered by the equipment housing. It is likely that the majority of Class III, IV, and V engines will be covered, thereby it is estimated that 100% will require labels. EPA estimates the label cost will be $1.00 per label. These estimates are based on confidential discussions with engine and equipment manufacturers.

Table 2-03
Equipment Design Changes

EQUIPMENT CATEGORY	EQUIPMENT DESIGN CHANGES	VARIABLE HARDWARE COST ESTIMATE	PRODUCTION COST ESTIMATE
Equipment with Class I Engines	10% Additional Label	$0.10	$0.00
	OPTION: 3% Alterations for Catalyst use:	$0.25	$0.25
Total Sales-Weighed Cost Estimate Per Equipment with CLASS I Engines = $ 0.10 Option: $0.10 + $0.03 VHC + $0.03 PC = $0.16			
Equipment with Class II Engines	100% Additional Label	$1.00	$0.00
Total Sales-Weighed Cost Estimate Per Equipment with CLASS II Engines = $ 1.00			
Equipment with Class III-V Engines (Handheld Equipment Engines)	100% Additional Label	$1.00	$0.00
	40% Panel Alterations for Cooling and Limiter Cap Placement:	$0.50	$0.10
	OPTION: .05% Alterations for Catalyst Use:	$0.25	$0.25
Total Sales-Weighted Cost Estimate Per Equipment with CLASS III-V Engines = $1.20 VHC +0.04 PC= $1.24 Option: $1.20 + $0.10 VHC + $0.14 PC = $1.44			

2.5 Total Costs for Implementing Emission Control Technology

Table 2-04 summarizes the estimated costs per engine per class as documented in this chapter. The retail cost of equipment in which all engines in Class I and II, ranges from $90 to $9,000. On average, the cost to install the necessary emission control technology on these engines will be approximately $2.32 per engine for Class I and $0.81 for Class II. Equipment costs to utilize post control engines is estimated at $0.10 for Class I engines and $1.00 for Class II engines. For Class I engines, this correlates to a total equipment and engine increase of $2.42 per engine/equipment. For Class II engines, this correlates to a total increase of $1.81 per engine/equipment. If the option of catalysts is utilized then the engine costs are increased by $1.32 and the equipment impact is increased by $0.06 for a total of $3.80 per Class I engine. EPA estimates that no catalysts will be used on Class II engines, therefore, there is no additional cost for this option.

The equipment in which Class III-V engines are installed range from $60 to $1,000. On average, the cost to install the necessary control technology on Class III engines will be approximately $2.09 per engine, Class IV engines will be approximately $2.17 per engine and Class V will be approximately $2.76 per engine. For Class III-V engines, equipment costs are estimated at $1.24 per engine for a total equipment and engine impact of $3.33 for Class III engines, $3.41 for Class IV engines, and $4.00 for Class V engines. If the catalyst option is chosen by an estimated 1% of the engines then the costs for all Class III-V engines are raised $0.03 and equipment $0.20 resulting in estimated increases of $3.56 for Class III engines, $3.64 for Class IV engines and $4.23 for Class V engines.

Table 2-04
Summary of Engine/Equipment Estimated Costs

CLASS	PER ENGINE COST ESTIMATE($)			WITH CATALYST OPTION ($)		
	Engine (HVC & PC)	Equipment	Total	Engine	Equipment	Total
Class I	2.32	0.10	$2.42	3.64	0.16	$3.80
Class II	0.81	1.00	$1.81	NA	NA	NA
Class III	2.09	1.24	$3.33	2.12	1.44	$3.56
Class IV	2.17	1.24	$3.41	2.20	1.44	$3.64
Class V	2.76	1.24	$4.00	2.79	1.44	$4.23

Table 2-05
Change in Technology Mix
Class I and Class II Engines

Present Engine Design	Present Market % in Class	Assumed Market %: Full Implementation	Technology
Class I Engines (<225cc)			
Side Valve, Carbureted	83	84	• 78% Enleanment with major redesigns to carburetor and fuel distribution • 21% Enleanment with minor redesigns to carburetor • 50% Changes in ignition timing • 95% Combustion chamber redesign • 80% Valve System, Improvements including Valve Timing • 1% OHV with minor mods to carburetor • 50% Improved Cooling
Overhead Valve, Carbureted	6.3	10	• 100% Enleanment with minor modifications to carburetor • 50% Improved Cooling
2-Stroke, Carbureted	10.4	5.8	in 1996 • 45% converted to 4 Stroke (50/50 sv and OHV) • 55% Enleaned with Major redesigns to carburetor and fuel distribution • 55%Carburetor Limiter Cap • 55% Combustion chamber Redesign • 55% Improved Coolng in 2003 • 100% 2 Stroke (Fuel Injection/Catalys/Other)
Other (Fuel Injected)	.06	.06	• 50% Fuel carburetion optimization • 50% Improved Cooling
Class II Engines (>225cc)			
Side Valve, Carbureted	78.1	78.4	• 100% Enleanment with minor carburetor modifications • 100% Combustion Chamber Redesign • 25% Improved Cooling • 10% Change in ignition timing
Overhead Valve, Carbureted	20.40	20.66	• 1% Enleanment with minor carburetor modifications • 25% Improved Cooling
2-Stroke, Carbureted	.50	0.0	• 100% 4 Stroke, sv
Other (Water-Cooled, Altern. Fuels)	.95	.95	• 1% Enleanment with minor carburetor modifications • 25% Improved Cooling

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Table 2-06
Change in Technology Mix
Classes III, IV, and V

Present Engine Design	Present Market % in Class	Assumed Market %: Full Implementation	Technology
Class III (<20cc)			
2-Stroke, Carbureted	100	100	• 100% Minor carburetor mods • 100% Carburetor Limiter Caps • 100% Combustion Chamber/ Scavenging/ Port Timing Modifications • 50% Cooling Improvements
Class IV (20-50cc)			
2-Stroke, Carbureted	100	99	• 75% Major carburetor redesign • 25% Minor carburetor mods • 50% Carburetor Limiter Caps • 75% Combustion Chamber/ Scavenging/ Port Timing Modifications • 50% Improved Cooling • 1% 4 Stroke Engine Design
4-Stroke, Carbureted	0	1	
Class V (>50cc)			
2-Stroke, Carbureted	100	100	• 75% Major carburetor redesign • 25% Minor carburetor mods • 92.5% Carburetor Limiter Caps • 100% Combustion Chamber/ Scavenging/Port Timing Modifications • 50% Improved Cooling

Table 2-07
CLASS I ENGINES
Change in Variable Hardware Cost and Production Cost Estimates

Present Engine Design	Present Market % in Class	Assumed % Market: Full Implementation	Technology	Variable Hardware Cost: Per Engine	Production Cost: Per Engine
Side Valve, Carbureted	83	84	◦ 78% Enleanment with major redesigns to carburetor and fuel distribution system		
			80% manufactured in-house:		
			20% outsourced:	No Cost	$.20
			◦ 21% Enleanment with minor redesigns to carburetor	$1.50	No Cost
			80% manufactured in-house:		
			20% outsourced:	No Cost	$.20
			◦ 50% Changes in ignition timing:	$0.50	No Cost
			◦ 95% Combustion Chamber redesign:	No Cost	No Cost
			◦ 80% Valve System Improvements	$0.10	$0.20
			Valve Timing:		
			◦ 1% OHV with minor mods to	$0.40	$0.20
			carburetor:	$0.50	No Cost
			◦ 50% Improved Cooling:	$0.10	No Cost
				No Cost	No Cost
				$0.10	No Cost
Overhead Valve, Carbureted	6.3	10	◦ 100% Enleanment with minor modifications to carburetor		
			80% manufactured in-house:	No Cost	$0.20
			20% outsourced:	$0.50	No Cost
			◦ 50%	$0.10	No Cost
			Improved Cooling		
2-Stroke, Carbureted	10.4	5.8	In 1997 model year		
			• 45% 4 Stroke (50% sv, 50% ohv)	No Cost	No Cost
			• 55% Enleanment with major modifications to carburetor	No Cost	$0.20
			• 55% Carburetor Limiter Caps	$1.00	$0.20
			• 55% Combustion chamber Redesign		
			• 55% Improved Coolng In 2003	$0.10	$0.20
			• 100% 2 Stroke (FI, Catalyst, Other)	$0.10	No Cost
				$20.00	$1.00
Other (Fuel Injection)	.06	.06	◦ 50% Fuel carburetion optimization:	No Cost	$0.20
			◦ 50% Improved Cooling:	$0.10	No Cost
Labels			All Engines	$0.04	
TOTAL COST ESTIMATE PER CLASS I ENGINE = $2.32				$1.82	$0.50

Table 2-08
CLASS II ENGINES
Change in Variable Hardware Cost and Production Cost Estimates

Present Engine Design	Present Market % in Class	Assumed %: Full Impleme n-tation	Technology	Variable Hardware Cost Estimate per Technology	Production Cost Estimate Per Technology
side valve, carbureted	78.1	78.4	◦ 100% Enleanment with minor carburetor modifications:	$0.50	No Cost
			◦ 50% Combustion Chamber Redesign:	$0.10	$0.20
			◦ 25% Improved Cooling:	$0.10	No Cost
			◦ 10% Changes in Ignition Timing:	No Cost	No Cost
overhead valve, carbureted	20.4	20.7	◦ 1% Enleanment with minor carburetor modifications	$0.50	No Cost
			◦ 25% Improved Cooling	$0.10	No Cost
2-stroke	.50	0.0	100% 4-Stroke, SV	No Cost	No Cost
Other (Water-Cooled and Altern. Fuel)	.95	.95	◦ 1% Enleanment with minor carburetor modifications	$0.50	No Cost
			◦ 25% Improved Cooling	$0.10	No Cost
Labels			All Engines	$0.04	
TOTAL COST ESTIMATE PER CLASS II ENGINE = $0.81				$0.65	$0.16

Table 2-09
Change in Technology Mix for Class III Engines,
Variable Hardware Cost and Production Cost Estimates

Present Engine Design	Present Market %	Assumed % Market on Date of Full Implementation	Technology	Variable Hardware Cost Estimate per Technology	Production Cost Estimate per Technology
2-stroke engine, carbureted	100%	100%	• 100% Minor carburetor mods:	$0.50	No Cost
			• 100% Carburetor Limiter Caps:	$1.00	$0.20
			• 100% Combustion Chamber/Scavenging/ Port Timing Modifications:	$0.10	$0.20
			• 50% Cooling Improvements:	$0.10	No Cost
Labels			All Engines	$0.04	$0.09
TOTAL COST ESTIMATE PER CLASS IV ENGINE = $2.09				$1.69	$0.40

Table 2-10
Change in Technology Mix for Class IV Engines,
Variable Hardware Cost and Production Cost Estimates

Present Engine Design	Present Market %	Assumed % Market on Date of Full Implementation	Technology	Cost Estimate for Each Engine Technology	Production Costs Estimate per Technology
2-stroke engine, carbureted	99%	99%	◦ 75% Major carburetor redesign: ◦ 25% Minor carburetor mods: ◦ 50% Carburetor Limiter Caps: ◦ 75% Combustion Chamber/Scavenging/ Port Timing Modifications: ◦ 50% Improved Cooling: ◦ 1% 4 Stroke Engine Design:	$1.50 $0.50 $1.00 $0.10 $0.10 No Cost	No Cost No Cost $0.20 $0.20 No Cost No Cost
4-stroke engine, carbureted	1%	1%			
Labels			All Engines	$0.04	9
TOTAL COST ESTIMATE PER CLASS IV ENGINE = $2.17				$1.92	$0.25

Table 2-11
Change in Technology Mix for Class V Engines,
Variable Hardware Cost and Production Cost Estimates

Present Engine Design	Present Market %	Assumed % Market on Date of Full Implementation	Technology	Cost Estimate for Each Engine Technology	Estimated Production Costs per Technology
2 stroke engine, carbureted, air cooled	100%	100%	◦ 75% Major carburetor redesign: ◦ 25% Minor carburetor mods: ◦ 92.5% Carburetor Limiter Caps: ◦ 100% Combustion Chamber/Scavenging/Port Timing Modifications: ◦ 50% Improved Cooling:	$1.50 $0.50 $1.00 $0.10 $0.10	No Cost No Cost $0.20 $0.20 No Cost
Labels			All Engines	$0.04	
TOTAL COST ESTIMATE PER CLASS V ENGINE = $2.76				$2.37	$0.39

Table 2-12
RESEARCH AND DEVELOPMENT COST ESTIMATES

Class & Engine Design	% Number of Models per Technology (same as estimated % engines per technology)	Number of Models	Estimated Cost per Model	Total Cost
CLASS I - 51 models				
Side Valve (36 models)	78% Major Carburetor Redesign of which: - 80% models made in-house - 20% models outsourced	 226	 $30,000 $20,000	 $673,920 $112,320
	21% Minor Carburetor Adjustments of which: - 80% models made in-house - 20% models outsourced	 6 2	 $30,000 $20,000	 $181,440 $30,240
	50% Ignition Timing	18	$40,000	$720,000
	95% Combustion Chamber Redesign	34	$325,000	$1,111,500
	80% Valve System Changes	29	$70,000	$2,016,000
	1% OHV	0	0	0
	50% Improved Cooling	18	$20,000	$360,000
Overhead Valve (10 models)	100% Minor Carburetor Improvements of which: -80% models made in-house -20% models outsourced	 8 2	 $30,000 $20,000	 $240,000 $40,000
	50% Improved Cooling	5	$30,000	$150,000
2-Strokes (4 models)	1996 55% Major Carburetor Improvements 55% Combustion Chamber Redesign 55% Improved Cooling	2.2	 $20,000 $325,000 $20,000	 $44,000 $715,000 $44,000
Other (1 model)	50% Minor Carburetor Improvements	.5	$20,000	$10,000
	50% Improved Cooling	.5	$30,000	$15,000
			CLASS I TOTALS:	$16,466,920
			FEDERAL RULEMAKING:	**$10,803,000**

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CLASS II -144 Models				
Side Valve (93 models)	100% Minor Carburetor Improvements	93	$30,000	$2,790,000
	100% Combustion Chamber Redesign	93	$325,000	$3,022,500
	25% Improved Cooling	23	$20,000	$465,000
	10% Ignition Timing	9	$40,000	$372,000
Overhead Valve (42 models)	100% Minor Carburetor Modifications	42	$30,000	$1,260,000
	50% Improved Cooling	21	$30,000	$630,000
Other (9 models)	50% Minor Carburetor Modifications	4.5	$20,000	$90,000
	50% Improved Cooing	4.5	$30,000	$135,000
			CLASS II TOTALS:	$35,967,000
			FEDERAL RULEMAKING:	**$10,000,000**
CLASS III - 1 model				
	100% Minor Carburetor Adjustments	1	$40,000	$40,000
	100% Limiter Adjustment Caps	1	$5,000	$5,000
	100% Combustion Chamber Modifications	1	$80,000	$80,000
	50% Improved Cooling	.5	$40,000	$20,000
			CLASS III TOTALS:	$145,000
			FEDERAL RULEMAKING:	**$ 72,500**
CLASS IV - 27 models				
	75% Major Carburetor Redesign	20	[illegible]000	$2,025,000
	25% Minor Carburetor Adjustments	7	[illegible],000	$270,000
	50% Limiter Adjustment Caps	14	$5,000	$67,500
	75% Combustion Chamber Modifications	20	$80,000	$1,620,000
	50% Improved Cooling	14	$40,000	$540,000
	1% 4 Stroke Design	NA	NA	NA
			CLASS IV TOTALS:	$4,522,500
			FEDERAL RULEMAKING:	**$2,115,000**

CLASS V - 15 models				
	75% Major Carburetor Redesign	11	$100,000	$1,125,000
	75% Minor Carburetor Adjustments	4	$40,000	$1,500,000
	Limiter Adjustment Caps	8	$5,000	$37,500
	Combustion Chamber Modifications	15	$80,000	$1,200,000
	Improved Cooling	8	$40,000	$300,000
			CLASS V TOTALS:	$2,812,500
			FEDERAL RULEMAKING:	**$2,812,500**

Chapter 2: References

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Chapter 3: Analysis of Aggregate Costs and Economic Impacts

This chapter discusses the structure of industries producing engines and equipment affected by this FRM, aggregates the technology related pollution control costs presented in Chapter 2, and discusses possible economic effects of the regulation.

The aggregate costs are calculated from the estimated costs per engine discussed in Chapter 2. Both the estimated per-engine costs presented in Chapter 2 and the aggregate costs presented in this chapter are derived from estimates of annual consumption of these engines in the United States.[3] Manufacturers' aggregate costs for variable hardware cost increases, production cost increases, development costs and administrative costs are capitalized where appropriate and annualized over a 30 year time horizon. Further, price increases beyond manufacturers' cost increases are estimated, as well as savings in fuel costs. Total costs to society are presented as the aggregate costs to consumers.

Possible economic effects are discussed. EPA considered how to

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[3] Consumption is defined as U.S. production - exports + imports + (previous year's year-end inventory - current year's year-end inventory). Appendix B presents EPA analysis of consumption of these engines as well as projections of future consumption of these engines. Consumption of engines is frequently referred to as sales in this chapter.

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deal with the issue of how this regulation might impact the productive use of capital in the U.S., employment, and energy. On the whole, any incremental economic effects on this sector are likely to be small compared to the economy as a whole. Economic impacts on individual manufacturers, including differential effects according to plant size (e.g., large, medium, or small sized), were not specifically addressed. An analysis of the competitive structure of the industry suggested that full cost pass through of pollution control costs could be expected. These industries are characterized by monopolistic competition with high degrees of product differentiation, strong buyer power from the equipment manufacturers and mass merchandisers, tight marginal cost structures, and (in a few sectors) good potentials for substitution from other, more "environmentally friendly" power sources.

3.1. Industry Description

The industry description 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.

...

Figure 3-01 provides a schematic of the relationships and flow of goods for engine manufacturers. To begin the process, raw materials and components are purchased from suppliers. Necessary raw materials include the steel and aluminum required to manufacture engine parts. 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. 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[4] are the primary factors in 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 these 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.

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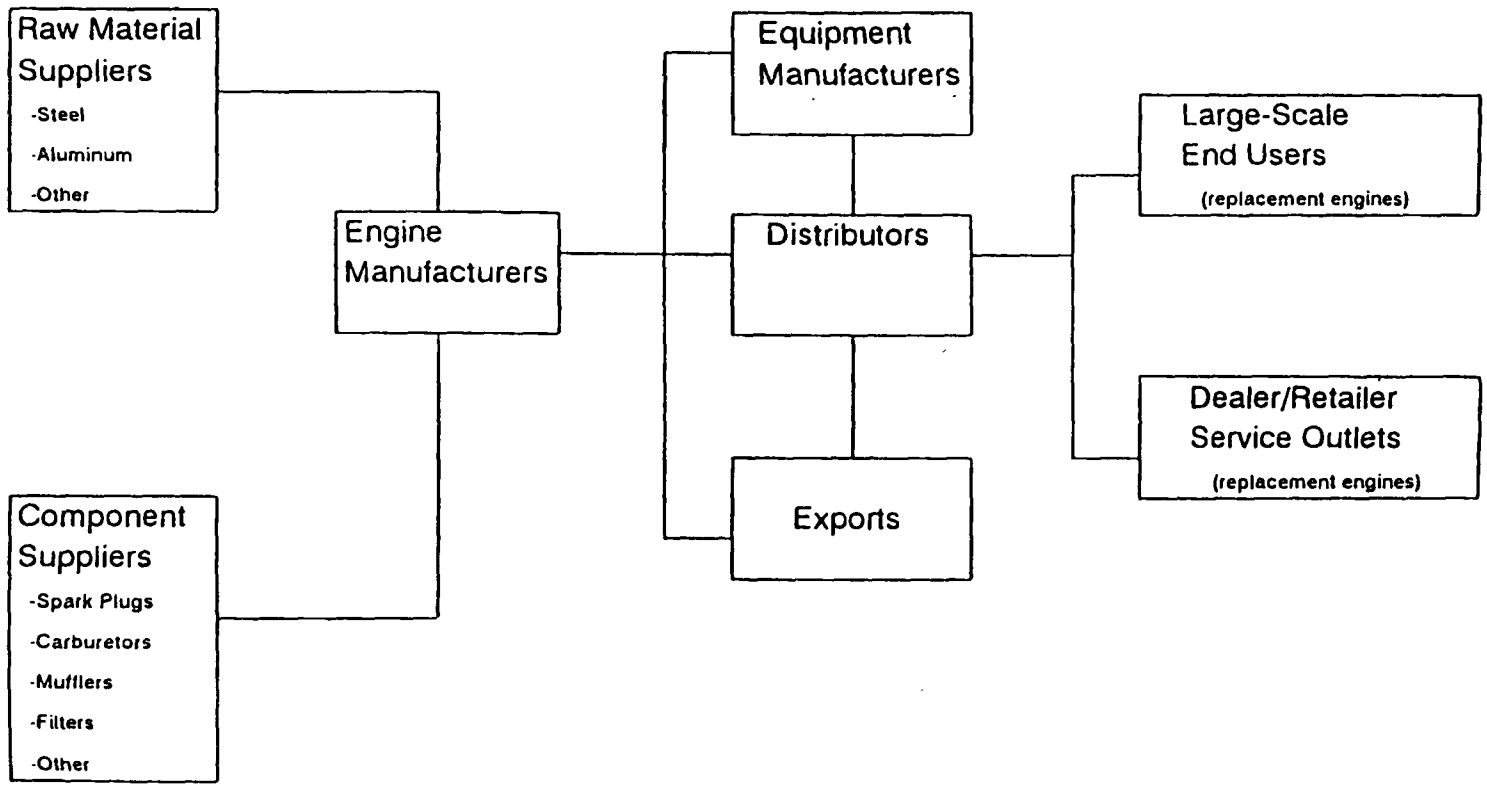
4 An economy of scale is said to exist when larger output is associated with lower average cost.

Figure 3-01: Engine Manufacturer--Product Distribution Network



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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.

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.[5] 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.

Figure 3-02 provides a schematic of the relationships and flow of goods from the viewpoint of the lawn and garden equipment manufacturers. These manufacturers design and manufacture their own parts and/or purchase components. The finished parts and components are assembled into end-user equipment. Finished goods are sent to one of three places: wholesale distributors, dealers or other retail establishments, or shipped for export.

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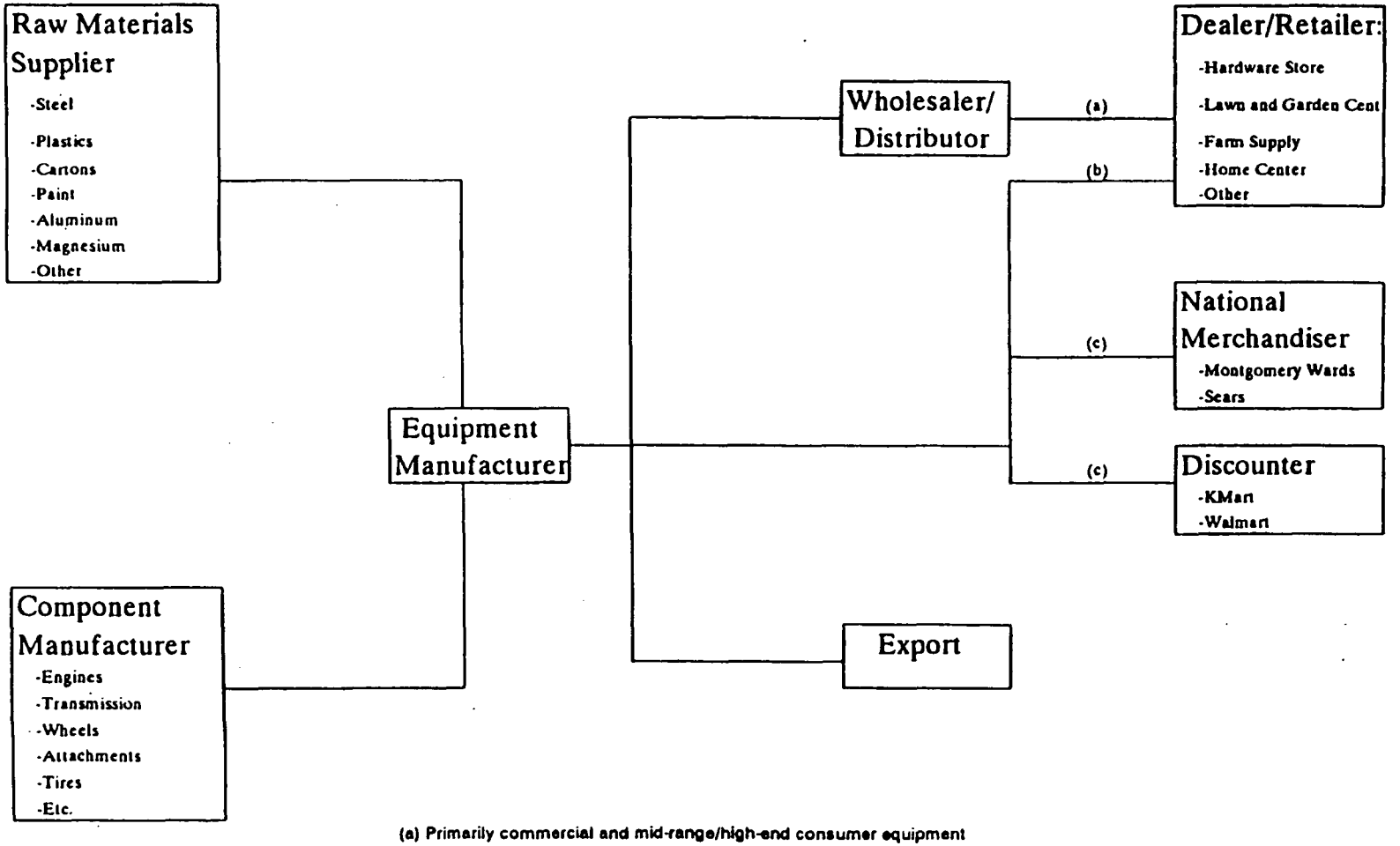
[5] For example, OPEI estimates that 90% of walk behind lawnmower sales go to the residential market.

Figure 3-02: Lawn and Garden Manufacturer--Product Distribution Network



(a) Primarily commercial and mid-range/high-end consumer equipment
(b) Primarily sales by large manufacturers to large Dealer/Retail outlets
(c) Primarily lower end consumer equipment

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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 retial 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.[6]

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."[7] 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.

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

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6 North American Equipment Dealers Association.

7 Phone conversation on June 8, 1992.

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 places 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. Honda is the most important 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 output, 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 internal combustion 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 externalitites associated with electrically powered lawn and garden equipment.(6)

3.1. Aggregate Cost Analysis

This section presents the methodology used to estimate and the numerical estimates of the aggregate costs due to this regulation. Variable hardware costs, marginal production costs, development costs, and administrative costs of compliance are presented in this section. This section also presents the costs to the consumer, including estimates of the increased profits to economic entities in the various levels of industry, including the engine manufacturer, equipment manufacturer, and mass merchandiser. Cost savings due to reduced fuel consumption are also addressed, including the valuation of the reduced fuel consumption to the consumer.

3.1.1. Profitability on Increased Costs

The aggregate cost estimates presented in this chapter take into account the potential for price increases beyond a cost increase, in other words, profit on increased costs is accounted for. As costs increase, manufacturers and retailers must pass along cost increases and markups over cost in order to maintain current percentage levels of profitability that are seen in the market. Manufacturers have indicated differing points of view on whether the total cost increases, including margins for profitability, due to pollution control regulation will be passed on to

other manufacturers, merchandisers, and consumers.

One point of view is that all costs will be successfully passed through to consumers with a margin for profitability for each type of cost. It has been argued that profitability margins are already very low implying that no further reduction in profitability margin could be tolerated without severe economic impacts. Further, manufacturers who support this view indicate that the market is so competitive that all manufacturers will seek the low cost solution to compliance, that this solution will be the same for all manufacturers of similar engines and equipment in particular market niches, and that all manufacturers will pass through cost increases that do not differ significantly among manufacturers.

EPA decided the market structure merited analyzing costs according to the following: evidence suggests that all pollution control costs can be passed through each level of the industry (e.g., engine manufacturer, equipment manufacturer, and mass merchandiser). These costs are to be imposed on consumer goods, i.e., small nonroad engines, and thus primarily displace future personal consumption expenditures. When regulatory costs displace a stream of consumption expenditures, the Kolb-Scheraga two-stage discounting procedure is appropriate to utilize to value the stream of benefits and costs to society over time. The Kolb-Scheraga two-stage discounting procedure and its appropriateness in this scenario is explained in more detail later in this chapter.

Profitability estimates are difficult to determine. Due to time constraints which limited further data collection efforts, EPA assumed that profitability estimates would be approximately equal to the return on sales for each level of the industry. Additionally, EPA had readily available annual reports for Briggs & Stratton Corporation and for Toro Company and used these to derive estimates for return on sales in the industry. For this analysis, EPA is assuming the average return on sales

for Briggs & Stratton Corporation for the years 1991, 1992, and 1993 as the average profitability of producing engines for engine manufacturers. Therefore, the profitability on engine manufacturer cost increases is assumed to be 16%. For equipment manufacturers, EPA did not have annual reports, except for Toro. Because Toro markets mainly to the mid-range to premium segments of the market, EPA didn't use Toro's gross profit percentage as Toro must recover a high percentage over cost of goods sold in order to cover high selling, general, and administrative expenses. Operating profit for Toro might be closer to the profit levels achieved by the high volume low-end equipment manufacturers because these high volume manufacturers should have low selling, general, and administrative expenses. Operating profit for Toro Company ranged from approximately 4-7% for 1989-1991. Therefore, for the majority of the market that represents the low end equipment, EPA assumed a 5% return on sales. EPA did not have income statements for mass merchandisers or dealers of equipment at the time this analysis was prepared: the dealer return on sales was assumed to be 5%. In cumulative terms, this amounts to an increase in price of approximately 26% from the engine manufacturer to the consumer. This markup is approximately equal to the markup (usually called a "retail price equivalent" (RPE) markup) EPA typically uses in regulatory analyses of on-highway emission standards. Jack Faucettt Associates has published a report(7) under contract to EPA which lists 26% as the estimated RPE for on-highway cars and light-duty trucks, 27% for on-highway heavy-duty gasoline engines, and 36% for on-highway heavy-duty diesel engines.

A second point of view is that only the variable hardware costs will be passed through to the consumer. Some manufacturers have indicated to EPA that buyer power of the mass merchandisers is so great for the majority of these engines and equipment that they will

have difficulty raising prices at all. Proponents of this point of view argue that perhaps variable hardware cost will be passed through with a profit margin, but that other costs would not be passed through. This argument does not seem very supportable because potential increases are small in absolute terms and it is in the interest of merchandisers/ dealers to ensure a continuous high degree of competition in the market, particularly at the opening price point. If all manufacturers' costs increase by approximately the same amount due to the increase in marginal cost, each manufacturer can proceed to charge a price that fully recovers costs plus markup under the (reasonable) assumption that other manufacturers are doing the same thing.[8] Therefore, EPA did not estimate costs assuming that only a portion of the costs would be passed through.

The remainder of this chapter presents costs which include the markup on manufacturers' and retailers' costs to the consumer.

3.1.2. Variable Hardware Costs

Variable hardware costs are the costs for hardware changes made to engines and equipment in order to comply with new emission standards. Hardware costs are variable because they depend on production volumes.

3.1.2.1. Per-Engine Variable Hardware Costs For Each Emission Standard Category--EPA has developed a weighted average variable hardware cost estimate for each standard category. These estimates are

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[8] The model of perfect competition shows that manufacturers in a perfectly competitive environment experience zero economic profits in the long term. Models of monopolistic competition, which is the market structure for these engines and equipment, also show that in the long term, zero economic profits exist. Therefore, attempts by manufacturers to capture market share by shaving profit margins will likely lead to negative economic profits in the long term. Negative economic profits generally are not sustainable for a company.

presented in Chapter 2 with the methodology used to derive the estimates. It should be emphasized that these estimates are representative of the relative variable hardware cost increase for the market as a whole. They do not represent the potential increase in variable hardware cost for specific engine or equipment models. Neither are they intended to imply that all engines and equipment in a particular emission standard category will increase in price by the stated amount, no less and no more. The price of specific engines and equipment is set by the market, and is reflective of the competitive structure of the market. Production volume per manufacturer, in particular, will play an essential role in what the increase in market price will be. However, production volume will have a larger cost minimization effect for marginal production costs than for variable hardware costs.

Table 3-01 presents a summary of the increased variable hardware cost estimates for both engine and equipment manufacturers.

Table 3-01
Best Estimate Technology
Per-Engine and Per-Equipment
Sales-Weighted Average Variable Hardware Cost
Per Emission Standard Category

	Emission Standard Categories				
	I	II	III	IV	V
Engine	$1.82	$0.65	$ 1.69	$ 1.92	$ 2.37
Equipment	$ 0.10	$ 1.00	$ 1.20	$ 1.20	$ 1.20
Total	$ 1.92	$ 1.65	$ 2.89	$ 3.12	$ 3.57
Customer Price	$2.40	$1.92	$3.45	$3.74	$4.31

Note: Class I has a delayed implementation for 2-strokes to meet the nhh standard. The cost from model year 1997 to 2002 is $0.73. The $1.82 per engine is the cost in 2003.

Under the catalyst option, the sales-weighted average variable hardware costs would be greater, as presented in Table 3-02

Table 3-02
Catalyst Option
Per-Engine and Per-Equipment
Sales-Weighted Average Variable Hardware Cost
Per Emission Standard Category

	Emission Standard Categories				
	I	II	III	IV	V
Engine	$ 3.14	$ 0.65	$ 1.72	$ 1.95	$ 2.40
Equipment	$ 0.13	$1.00	$ 1.30	$ 1.30	$ 1.30
Total	$ 3.27	$ 1.65	$ 3.02	$ 3.25	$ 3.70
Customer Price	$4.10	$1.92	$3.60	$3.89	$4.45

Table 3-03 presents the estimates of the non-handheld and handheld sales-weighted average variable hardware cost. These estimates are reflective of the relative variable hardware cost increase to all handheld equipment and non-handheld equipment. Therefore, the following estimates characterize the cost increases to each type of equipment in relation to the emission standard category with the highest volume sales.

Table 3-03
Sales-Weighted Average Variable Hardware Cost
for Nonhandheld and Handheld Equipment

	Nonhandheld	Handheld
Best Estimate Technology	$2.29	$ 3.75
Catalyst Option	$3.60	$ 3.90

3.1.2.2. Aggregate Annual Variable Hardware Cost--The annual variable hardware cost is calculated according to the following formula.

$$\sum_{i=I}^{V} \left(\frac{SALES_i}{TOTALSALES}\right) \cdot VHC_i$$

where

i	emission standard category, (i.e.: I, II, III, IV, or V)
$SALES_i$	annual sales in the emission standard category
TOTALSALES	total annual sales
VHC_i	variable hardware cost estimate to the consumer in the emission standard category.

In the first year of implementation of this regulation, 1996, the total variable hardware cost increase, including the manufacturers' and retailer's markup is presented in the Table 3-04. The table presents two separate results: the catalyst option estimates are not additive to the best estimate technology cost estimate.

Table 3-04
2003 Total Annual
Variable Hardware Cost Increase
to the Consumer

Emission Standard Category	$millions (1993$)	
	Best Estimate Technology	Catalyst Option
I	7.7	32.2
II	4.4	4.4
III	1.7	1.8
IV	22.5	23.8
V	1.6	1.7
TOTAL	49.6	64.0

3.1.3. Production Costs

Production costs are the costs for changes made to production line equipment in order to produce engines which comply with new emission standards. Examples of production costs are costs for changes in dies or tooling. Refer to section 2.2 for a detailed discussion of the underlying changes to production line equipment and methodology used to arrive at the following production cost estimates for the emission standard categories.

3.1.3.1. Per-Engine Production Costs For Each Emission Standard Category--EPA has developed a sales-weighted average production cost increase estimate for each emission standard category. These estimates are presented in Chapter 2 with the methodology used to derive the estimates. Production cost increase estimates are based on a set of assumptions, as outlined in Chapter 2, relating to optimum production volume output on a production line. Manufacturers who do operate their production lines at optimum output may not be able to achieve the

economies of scale that other manufacturers can achieve. These possible effects were not analyzed. Therefore, the following per-engine production cost estimates assume optimum capacity utilization in the industry.

Table 3-05 presents a summary of the increased production cost estimates for both engine and equipment manufacturers.

Table 3-05
Best Estimate Technology
Per-Engine and Per-Equipment
Sales-Weighted Average Production Cost
Per Emission Standard Category

	Emission Standard Categories				
	I	II	III	IV	V
Engine	$ 0.50	$ 0.16	$ 0.40	$ 0.25	$ 0.39
Equipment	$ 0.00	$ 0.00	$ 0.04	$ 0.04	$ 0.04
Total	$ 0.50	$ 0.16	$ 0.44	$ 0.29	$ 0.43
Customer Price	$0.63	$0.20	$0.55	$0.36	$0.54

Under the catalyst option, the sales-weighted average production cost increase would be greater, as presented in Table 3-06.

Table 3-06
Catalyst Option
Per-Engine and Per-Equipment
Sales-Weighted Average Production Cost
Per Emission Standard Category

	Emission Standard Categories				
	I	II	III	IV	V
Engine	$ 0.50	$ 0.16	$ 0.40	$ 0.25	$ 0.39
Equipment	$ 0.03	$ 0.00	$ 0.14	$ 0.14	$ 0.14
Total	$ 0.53	$ 0.16	$ 0.54	$ 0.39	$ 0.53
Customer Price	$0.66	$0.20	$0.66	$0.47	$0.65

Table 3-07 presents the estimates of the non-handheld and handheld sales-weighted average production cost increase. These estimates are reflective of the relative cost increase to all handheld equipment and non-handheld equipment. Therefore, the following estimates characterize the cost increases to each type of equipment in relation to the emission standard category with the highest volume sales.

Table 3-07
Sales-Weighted Average Production Cost
for Nonhandheld and Handheld Equipment

	Nonhandheld	Handheld
Best Estimate Technology	$ 0.53	$ 0.38
Catalyst Option	$ 0.56	$ 0.49

3.1.3.2. Aggregate Annual Production Cost Increase--The annual production cost increase is calculated according to the following formula.

$$\sum_{i=I}^{V} \left(\frac{SALES_i}{TOTALSALES}\right) \cdot PC_i$$

where

i	emission standard category, (i.e.: I, II, III, IV, or V)
$SALES_i$	annual sales in the emission standard category
TOTALSALES	total annual sales
PC_i	production cost increase estimate to the consumer in the emission standard category

In the first year of implementation of this regulation, 1996, the total production cost increase, including the manufacturers' and retailer's markup is presented in the Table 3-08. The table presents two separate results: the catalyst option estimates are not additive to the best estimate technology estimate.

Table 3-08
2003 Total Annual Production
Cost Increase to the Consumer

Emission Standard Category	$millions (1993$)	
	Best Estimate Technology	Catalyst Option
I	4.9	5.2
II	0.5	0.5
III	0.3	0.3
IV	2.2	2.9
V	0.2	0.2
TOTAL	8.1	9.2

3.1.4. Increase in Capital Costs

Potential capital cost increases include costs for development and application of engine designs with reduced emissions and costs for test facilities.

EPA has not accounted for any costs due to construction of test facilities because the California emission regulation applicable to these engines will in effect require the manufacturers to have more testing capability than will be necessary for California alone. The excess test capability will suffice for testing applicable to the Federal requirements.

EPA has included an estimate of increased costs for development and application of engine designs with reduced emissions. Chapter 2 explains the rationale behind the development cost estimate and the methodology used to estimate those costs. EPA has estimated the total development costs to be approximately $10 million for Class I, $10 million for Class II, and $5 million for Classes III, IV, and V. These costs were amortized and discounted over 5 years at a discount rate of 0.07. Then the annualized costs were discounted at a rate of 0.03 (the consumption rate of interest) to their future value in the year of recovery, 1996 through the year 2000. These discount rates were applied according to the Kolb-Scheraga two-stage discounting procedure. This procedure is further explained in the cost summary section later in this chapter.

Table 3-09 presents the estimate of the amortized and discounted capital costs for development and application of emission reduction technology in the year 1996. There are no additional development costs for the catalyst option.

Table 3-09
Amortized and Discounted Development Cost
in 1996

Emission Standard Class	$millions (1996$)
I	2.6
II	2.6
III, IV, & V	1.3
TOTAL	6.5

3.1.5. Program Administration Costs

The program administration costs presented here are the costs industry is estimated to incur due to the enforcement programs: certification, selective enforcement auditing, importation of nonconforming engines, precertification and testing exemption, engine exclusion determination, and emission defect reporting.

Appendix D contains the supporting statements for the Information Collection Requests submitted to OMB. These supporting statements contain estimates of the testing, recordkeeping, and reporting burden on industry due to the final regulations. In total, EPA estimates the regulations will cause a burden of $22 million for the initial year of regulation, with a large portion of this cost due to set up of the certification recordkeeping systems for manufacturers. EPA estimates the annual cost to be $10 million for the years following the initial year of implementation. Please refer to the supporting statements in Appendix D for additional information specific to each enforcement program.

3.1.6. Fuel Savings

As explained in Chapter 2, the technological changes necessary to bring these engines into compliance with the emission standards will

cause a decrease in fuel consumption of approximately 26% for a non-handheld engine and 13% for a handheld engine. Over the lifetime of these equipment, this amounts to a sales-weighted discounted lifetime fuel savings of $1.75 for non-handheld equipment and $0.13 for handheld equipment using a discount rate of 0.03. Table 3-10 presents the aggregate fuel consumption estimates for the 30 year time horizon of this analysis. EPA assumed that there are 42 gallons of gasoline per barrel of oil. The value of gasoline is assumed to be $ 1.25 per gallon in 1993 dollars.

Table 3-10
Aggregate Fuel Consumption Reduction Estimates

YEAR	BASELINE TONS	CONTROLLED TONS	REDUCTION TONS	REDUCTION GALLONS	REDUCTION BARRELS
1996	6805133	6534027	(271,106)	(1,725,680)	(41,088)
1997	6958270	6442717	(515,553)	(3,281,666)	(78,135)
1998	7100274	6400425	(699,849)	(4,454,771)	(106,066)
1999	7237739	6416960	(820,779)	(5,224,531)	(124,394)
2000	7374688	6475446	(899,242)	(5,723,974)	(136,285)
2001	7508215	6552609	(955,606)	(6,082,749)	(144,827)
2002	7638768	6639113	(999,655)	(6,363,136)	(151,503)
2003	7767294	6731905	(1,035,389)	(6,590,595)	(156,919)
2004	7894824	6829702	(1,065,122)	(6,779,855)	(161,425)
2005	8022001	6931590	(1,090,411)	(6,940,828)	(165,258)
2006	8147267	7035079	(1,112,188)	(7,079,446)	(168,558)
2007	8270911	7139626	(1,131,285)	(7,201,004)	(171,452)
2008	8393422	7245039	(1,148,383)	(7,309,839)	(174,044)
2009	8515276	7351304	(1,163,972)	(7,409,068)	(176,406)
2010	8636877	7458404	(1,178,473)	(7,501,372)	(178,604)
2011	8752849	7561225	(1,191,624)	(7,585,082)	(180,597)
2012	8863775	7660094	(1,203,681)	(7,661,829)	(182,425)
2013	8971064	7756119	(1,214,945)	(7,733,528)	(184,132)
2014	9076218	7850512	(1,225,706)	(7,802,025)	(185,763)
2015	9180279	7944111	(1,236,168)	(7,868,620)	(187,348)
2016	9283735	8037295	(1,246,440)	(7,934,004)	(188,905)
2017	9386836	8130265	(1,256,571)	(7,998,491)	(190,440)
2018	9489767	8223135	(1,266,632)	(8,062,533)	(191,965)
2019	9592546	8315939	(1,276,607)	(8,126,027)	(193,477)
2020	9695280	8408705	(1,286,575)	(8,189,477)	(194,988)
2021	9777433	8482989	(1,294,444)	(8,239,566)	(196,180)
2022	9840976	8540558	(1,300,418)	(8,277,592)	(197,086)
2023	9890929	8585868	(1,305,061)	(8,307,146)	(197,789)
2024	9932905	8623954	(1,308,951)	(8,331,907)	(198,379)
2025	9970735	8658197	(1,312,538)	(8,354,740)	(198,922)
2026	10006270	8690339	(1,315,931)	(8,376,338)	(199,437)

3.1.7. Consumer Cost

As explained in the beginning of this chapter, full cost pass through and profitability on increased costs are assumed. Table 3-11 summarizes the assumed profitability factors, sometimes referred to as retail price equivalent factors, which were used in this analysis to estimate the price increase to the consumer.

Table 3-11
Profitability Factors
(Retail Price Equivalent Factors)

Level	Factor
Engine Manufacturer	0.16
Equipment Manufacturer	0.05
Mass Merchandiser	0.05
Approximate Total Percent Increase	0.26

These factors were applied to the specific engine and equipment manufacturer costs identified in Chapter 2. For example, EPA has estimated some variable hardware costs and production costs specific to engines and specific to equipment. For equipment specific costs, EPA marked up the cost 10%. The cost of the engines to the equipment manufacturer was assumed to include a 16% markup on the engine manufacturer's costs. However, equipment manufacturer costs were not marked up 16% for equipment design changes which the equipment manufacturer incurs due to changes in the engine design.

Table 3-12 presents the increased per-unit costs of equipment with profitability factors applied. The estimates for variable hardware costs and production costs include costs to the engine and the equipment manufacturer. The capital cost and program administration costs are costs the engine manufacturer incurs and passes through the production chain.

Table 3-12
Specific Per-Unit Equipment Costs
With Profitability Markup

Per-Unit Cost Categories	Equipment	
	Non-Handheld	Handheld
Variable Hardware Cost	$ 2.29	$ 3.75
Production Cost	0.53	0.38
Capital Cost	0.59	0.72
Administration Cost	1.80	1.80
TOTAL	$ 5.22	$ 6.66

Fuel cost savings to the consumer over the lifetime of these equipment will substantially offset the increased price of nonhandheld equipment but will only slightly offset the price of handheld equipment. The lifetime consumer cost increase, including the discounted fuel savings, for nonhandheld equipment is $2.43 and for handheld equipment is $6.44. These fuel savings, even in the case of nonhandheld equipment, will probably not affect consumer purchase decisions because of their small magnitude. However, the small magnitude of the price increase, excluding the fuel savings, should not lead to any significant decreases in consumption (sales) of these engines in the U.S.

The above prices increases are most applicable to the lowest priced equipment, which is the high sales volume equipment. For non-handheld equipment, the percent increase would be $5.22/$100=0.05 and for handheld equipment $6.66/$69=0.10. Such small price increases should not alter consumer purchase decisions. Particularly for lawnmowers, people use the equipment until it does not start, then they simply replace it with new equipment. Few people tune up or rebuild their engines, except in the higher priced lawnmower and garden tractor equipment. For these higher priced equipment, the price increase due

to regulation will be less than that indicated here because the technological changes necessary to comply with the emission standards will only require calibration changes, which may not affect the price of such equipment. For the low priced equipment, the price increases noted here are less than the typical cost of a tune-up or a rebuild on these engines. Tune-ups cost about $20, while engine rebuilds cost about $40. These alternatives to buying a new engine are rather expensive compared to the cost of new equipment and are time consuming. As the price of new equipment, including the price increase due to regulation, is only two to three times as much as the maintenance alternatives, it is unlikely that consumers will change their buying patterns. However, if in the long run engines are more durable due to regulation and require less maintenance, there may be an effect on sales. EPA is not able to verify or refute whether engines will be more durable or require less maintenance at this time. Therefore, no decrease in sales due to regulation has been assumed.

3.1.8. Cost Summary

This section summarizes the total industry increase in cost, total retail price increase in cost, and the fuel savings accounted for over the 30 year time horizon of this analysis. EPA has analyzed the costs in the years in which they occur and the costs in the years in which they are recovered by retail price increases. Further, EPA has evaluated the stream of costs over time. Tables 3-13 through 3-17 are located at the end of this chapter.

3.1.8.1. Accounting for Costs as They are Incurred--Manufacturers incur some costs years ahead of when the costs are recovered by sales. Manufacturers must allow time to design, test, evaluate, certify, and produce the engine before sale. Typically, design work occurs in the

year before recalibration work. The following year certification is undertaken. Production begins the year after certification.

Table 3-13 shows these costs as they were accounted for in EPA's best estimate technology cost analysis and Table 3-14 presents these costs for the catalyst option.

3.1.8.2. Accounting for Costs as They are Recovered--EPA assumes that costs which occur in years preceding production are recovered over sales throughout the production cycle. For instance, EPA assumes the annualized design cost for 1993 is recovered on the 1996 sales. Similarly, annualized design costs occurring in 1994 are recovered on the 1997 sales. Therefore, the methodology attributes the first year of amortized costs to the first year of sales, the second year of amortized costs to the second year of sales, et cetera. These costs are shown in the year of recovery in future value[9].

Table 3-15 and 3-16 shows the total costs which are recovered in each sales year through 2026 for the best estimate technology analysis and the catalyst option analysis, respectively.

3.1.8.3. Evaluation of the Stream of Costs--In accounting for the "time value" of money, the stream of costs estimated to be recovered in future sales must be converted to the present value[10] of the yearly costs. The present value of the costs as recovered is stated in Table 3-17 in 1993 dollars. The methodology used to determine the present value is calculated according to recent Agency guidance (i.e., the Kolb-Scheraga

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[9] Future value means the value at a future date of money that has been paid or received in prior periods.

[10] Present value means the value of money today of a stream of amounts expected to be paid or received in future periods.

two-stage procedure).(8) Kolb-Scheraga point out that the economics literature has established the social rate of time preference as the appropriate rate for discounting the benefits and costs of public projects, once they are expressed in terms of consumption gained and foregone, and provide a procedure for doing this. According to this methodology, capital costs are amortized at a rate reflecting the marginal rate of return on private investment (7 percent). Annualized capital costs are then added to operating costs (e.g., variable hardware costs, administrative costs) to yield the stream of additional revenues that must be collected through price increases to pay for all costs imposed by a regulation. The total cost stream is then discounted to present value at 3 percent, an estimate of the consumption rate of interest (a proxy for the social rate of time preference). This methodology is appropriate in this case because capital costs imposed by this Small Gas FRM are likely to be passed directly through to consumers in the form of higher prices and thus reduce the consumption of goods and services. This methodology is more appropriate in this instance than simply discounting all costs at 7 percent because the capital stock is not permanently lowered. Thus, the two-stage procedure accounts for both displaced private investment (in the annualization process) and foregone consumption (by discounting both costs and benefits by the social rate of time preference).

Table 3-17 presents the total annualized stream of costs and the present value stream of the total annualized costs. The net present value of the stream of increased costs over the 30 year time horizon of this analysis is $1,093 million for the best estimate technology analysis and $1,445 million for the catalyst option analysis. The total national average annual cost of this rule is estimated to be $55 million. Under the catalyst option, the total national average annual cost estimate becomes $73 million.

3.2. Incremental Economic Impacts

3.2.1. Capital

Impacts on capital as a result of this rule are the result of increased investment by manufacturers in order to make their engines comply. These costs become part of the cost of manufacturing nonroad engines/ equipment and are recaptured in price increases. As a result, private capital investment is unlikely to be displaced. All expenditures related to this rule can be expected to be borne from consumer savings or consumer credit markets, not from private capital markets. EPA estimates the net present value of capital costs to be approximately $27 million over the 30 year time horizon of this analysis or approximately an average annual cost of $6.5 million for the years 1996 through 2000.

3.2.2. Employment

EPA estimates that there will be no negative impacts on employment as a result of this rule. It is possible that in time jobs will be created by the need to hire engineers, technicians, and machinists to develop and implement technological solutions for reducing emissions from these engines. The engineering staffs the manufacturers currently employ are relatively small. However, manufacturers have indicated to EPA that they do not currently plan on hiring new engineers, technicians, and machinists to fill high wage, technical jobs in order to meet production demands.

EPA examined the possibility that employment may be decreased by manufacturers' abandoning product lines for which emissions are too costly to reduce. The low absolute levels of costs added to nonroad engines/equipment due to this regulation's effect on the production line changes are too marginal to lead to the obsolescence of a product line. Furthermore, manufacturers have indicated to EPA that obsolescence of low volume engine models does not necessarily decrease employment

because low volume engine models are produced on the same production lines as other higher volume engine models. After a regulation is implemented, shifts in the market between engine models may occur, but unless total units sold decrease due to a price effect, employment should not be affected by changes in availability of engine models.

EPA explored the effect of this regulation on total industry demand and concluded that demand is unlikely to be affected. First, as already mentioned, EPA estimates that the emission standards will increase the price of the engines to the consumer by only a few dollars. Industry sales volume should be unaffected by such a small price increase. Second, even if the relative price increases between manufacturers due to this regulation are different (e.g., $1.00 versus $4.00), a manufacturer with only a slightly higher price will be unlikely to face dramatic decreases in market share because of the product differentiation characteristic of monopolistic competition. While the market is competitive at all levels and is the most competitive at the opening price point for these engines and the equipment which utilizes them, product differentiation provides a range within which prices can move without appreciably affecting demand for the product. However, for nonroad engines/equipment affected by this rule, prices for like products are expected to increase by the same amount. Thus, significant decreases in sales are not projected.

3.3 Energy

Reduced energy consumption will be the result of the FRM. Resultant increases in fuel economy of these engines mean demand for energy will decrease marginally in the U.S. EPA estimates this decrease to be approximately 0.2 million barrels of oil per year. The resultant impact on the U.S. balance of trade is approximately $9 million.

Table 3-13
Best Estimate Technology Costs as Incurred
(1993$)

Year	Variable Hardware Cost	Production Cost	Capital Cost	Program Admin. Cost	Gasoline Savings	Total
1992						0
1993			1000000			1000000
1994			6000000			6000000
1995			6000000	22000000		28000000
1996	25000000	10000000	6000000	10000000	-2000000	49000000
1997	25000000	10000000	6000000	10000000	-4000000	47000000
1998	26000000	11000000	5000000	10000000	-6000000	46000000
1999	26000000	11000000	0	10000000	-7000000	40000000
2000	26000000	11000000	0	10000000	-7000000	40000000
2001	27000000	11000000	0	10000000	-8000000	40000000
2002	27000000	11000000	0	10000000	-8000000	40000000
2003	28000000	12000000	0	10000000	-8000000	42000000
2004	28000000	12000000	0	10000000	-8000000	42000000
2005	28000000	12000000	0	10000000	-9000000	41000000
2006	29000000	12000000	0	10000000	-9000000	42000000
2007	29000000	12000000	0	10000000	-9000000	42000000
2008	30000000	12000000	0	10000000	-9000000	43000000
2009	30000000	12000000	0	10000000	-9000000	43000000
2010	30000000	13000000	0	10000000	-9000000	44000000
2011	31000000	13000000	0	10000000	-9000000	45000000
2012	31000000	13000000	0	10000000	-10000000	44000000
2013	31000000	13000000	0	10000000	-10000000	44000000
2014	32000000	13000000	0	10000000	-10000000	45000000
2015	32000000	13000000	0	10000000	-10000000	45000000
2016	32000000	13000000	0	10000000	-10000000	45000000
2017	32000000	14000000	0	10000000	-10000000	46000000
2018	33000000	14000000	0	10000000	-10000000	47000000
2019	33000000	14000000	0	10000000	-10000000	47000000
2020	33000000	14000000	0	10000000	-10000000	47000000

Table 3-13
Best Estimate Technology Costs as Incurred
(1993$)

Year	Variable Hardware Cost	Production Cost	Capital Cost	Program Admin. Cost	Gasoline Savings	Total
2021	34000000	14000000	0	10000000	-10000000	48000000
2022	34000000	14000000	0	10000000	-10000000	48000000
2023	34000000	14000000	0	10000000	-10000000	48000000
2024	34000000	14000000	0	10000000	-10000000	48000000
2025	34000000	14000000	0	10000000	-10000000	48000000
2026	34000000	14000000	0	10000000	-10000000	48000000

Table 3-14
Catalyst Option Costs as Incurred
(1993$)

Year	Variable Hardware Cost	Production Cost	Capital Cost	Program Admin. Cost	Gasoline Savings	Total
1993			1000000			1000000
1994			6000000			6000000
1995			6000000	22000000		28000000
1996	39000000	10000000	6000000	10000000	-2000000	63000000
1997	39000000	10000000	6000000	10000000	-4000000	61000000
1998	40000000	11000000	5000000	10000000	-6000000	60000000
1999	41000000	11000000	0	10000000	-7000000	55000000
2000	41000000	11000000	0	10000000	-7000000	55000000
2001	42000000	11000000	0	10000000	-8000000	55000000
2002	42000000	11000000	0	10000000	-8000000	55000000
2003	43000000	12000000	0	10000000	-8000000	57000000
2004	44000000	12000000	0	10000000	-8000000	58000000
2005	44000000	12000000	0	10000000	-9000000	57000000
2006	45000000	12000000	0	10000000	-9000000	58000000
2007	45000000	12000000	0	10000000	-9000000	58000000
2008	46000000	12000000	0	10000000	-9000000	59000000
2009	47000000	12000000	0	10000000	-9000000	60000000
2010	47000000	13000000	0	10000000	-9000000	61000000
2011	48000000	13000000	0	10000000	-9000000	62000000
2012	48000000	13000000	0	10000000	-10000000	61000000
2013	49000000	13000000	0	10000000	-10000000	62000000
2014	49000000	13000000	0	10000000	-10000000	62000000
2015	50000000	13000000	0	10000000	-10000000	63000000
2016	50000000	13000000	0	10000000	-10000000	63000000
2017	51000000	14000000	0	10000000	-10000000	65000000
2018	51000000	14000000	0	10000000	-10000000	65000000
2019	52000000	14000000	0	10000000	-10000000	66000000
2020	52000000	14000000	0	10000000	-10000000	66000000
2021	52000000	14000000	0	10000000	-10000000	66000000

Table 3-14
Catalyst Option Costs as Incurred
(1993$)

Year	Variable Hardware Cost	Production Cost	Capital Cost	Program Admin. Cost	Gasoline Savings	Total
2022	52000000	14000000	0	10000000	-10000000	66000000
2023	53000000	14000000	0	10000000	-10000000	67000000
2024	53000000	14000000	0	10000000	-10000000	67000000
2025	53000000	14000000	0	10000000	-10000000	67000000
2026	53000000	14000000	0	10000000	-10000000	67000000

Table 3-15
Best Estimate Technology Costs as Recovered
(1993$)

Year	Variable Hardware Cost	Production Cost	Capital Cost	Program Admin. Cost	Gasoline Savings	Total
1996	$25,000,000	$8,000,000	$1,000,000	$29,000,000	($2,000,000)	$63,000,000
1997	$25,000,000	$8,000,000	$8,000,000	$13,000,000	($4,000,000)	$54,000,000
1998	$26,000,000	$8,000,000	$8,000,000	$13,000,000	($6,000,000)	$55,000,000
1999	$26,000,000	$8,000,000	$8,000,000	$13,000,000	($7,000,000)	$55,000,000
2000	$26,000,000	$9,000,000	$8,000,000	$13,000,000	($7,000,000)	$56,000,000
2001	$27,000,000	$9,000,000	$7,000,000	$13,000,000	($8,000,000)	$56,000,000
2002	$27,000,000	$9,000,000	$0	$13,000,000	($8,000,000)	$49,000,000
2003	$28,000,000	$9,000,000	$0	$13,000,000	($8,000,000)	$50,000,000
2004	$28,000,000	$9,000,000	$0	$13,000,000	($8,000,000)	$50,000,000
2005	$28,000,000	$9,000,000	$0	$13,000,000	($9,000,000)	$50,000,000
2006	$29,000,000	$9,000,000	$0	$13,000,000	($9,000,000)	$51,000,000
2007	$29,000,000	$10,000,000	$0	$13,000,000	($9,000,000)	$52,000,000
2008	$30,000,000	$10,000,000	$0	$13,000,000	($9,000,000)	$53,000,000
2009	$30,000,000	$10,000,000	$0	$13,000,000	($9,000,000)	$53,000,000
2010	$30,000,000	$10,000,000	$0	$13,000,000	($9,000,000)	$53,000,000
2011	$31,000,000	$10,000,000	$0	$13,000,000	($9,000,000)	$54,000,000
2012	$31,000,000	$10,000,000	$0	$13,000,000	($10,000,000)	$54,000,000
2013	$31,000,000	$10,000,000	$0	$13,000,000	($10,000,000)	$54,000,000
2014	$32,000,000	$10,000,000	$0	$13,000,000	($10,000,000)	$55,000,000
2015	$32,000,000	$10,000,000	$0	$13,000,000	($10,000,000)	$55,000,000
2016	$32,000,000	$10,000,000	$0	$13,000,000	($10,000,000)	$55,000,000
2017	$32,000,000	$11,000,000	$0	$13,000,000	($10,000,000)	$56,000,000
2018	$33,000,000	$11,000,000	$0	$13,000,000	($10,000,000)	$57,000,000
2019	$33,000,000	$11,000,000	$0	$13,000,000	($10,000,000)	$57,000,000
2020	$33,000,000	$11,000,000	$0	$13,000,000	($10,000,000)	$57,000,000
2021	$34,000,000	$11,000,000	$0	$13,000,000	($10,000,000)	$58,000,000
2022	$34,000,000	$11,000,000	$0	$13,000,000	($10,000,000)	$58,000,000
2023	$34,000,000	$11,000,000	$0	$13,000,000	($10,000,000)	$58,000,000
2024	$34,000,000	$11,000,000	$0	$13,000,000	($10,000,000)	$58,000,000
2025	$34,000,000	$11,000,000	$0	$13,000,000	($10,000,000)	$58,000,000
2026	$34,000,000	$11,000,000	$0	$13,000,000	($10,000,000)	$58,000,000

Table 3-16
Catalyst Option Costs as Recovered
(1993$)

Year	Variable Hardware Cost	Production Cost	Capital Cost	Program Admin. Cost	Gasoline Savings	Total
1996	$39,000,000	$9,000,000	$1,000,000	$29,000,000	($2,000,000)	$78,000,000
1997	$39,000,000	$9,000,000	$8,000,000	$13,000,000	($4,000,000)	$69,000,000
1998	$40,000,000	$9,000,000	$8,000,000	$13,000,000	($6,000,000)	$70,000,000
1999	$41,000,000	$10,000,000	$8,000,000	$13,000,000	($7,000,000)	$72,000,000
2000	$41,000,000	$10,000,000	$8,000,000	$13,000,000	($7,000,000)	$72,000,000
2001	$42,000,000	$10,000,000	$7,000,000	$13,000,000	($8,000,000)	$72,000,000
2002	$42,000,000	$10,000,000	$0	$13,000,000	($8,000,000)	$65,000,000
2003	$43,000,000	$10,000,000	$0	$13,000,000	($8,000,000)	$66,000,000
2004	$44,000,000	$10,000,000	$0	$13,000,000	($8,000,000)	$67,000,000
2005	$44,000,000	$10,000,000	$0	$13,000,000	($9,000,000)	$67,000,000
2006	$45,000,000	$11,000,000	$0	$13,000,000	($9,000,000)	$69,000,000
2007	$45,000,000	$11,000,000	$0	$13,000,000	($9,000,000)	$69,000,000
2008	$46,000,000	$11,000,000	$0	$13,000,000	($9,000,000)	$70,000,000
2009	$47,000,000	$11,000,000	$0	$13,000,000	($9,000,000)	$71,000,000
2010	$47,000,000	$11,000,000	$0	$13,000,000	($9,000,000)	$71,000,000
2011	$48,000,000	$11,000,000	$0	$13,000,000	($9,000,000)	$72,000,000
2012	$48,000,000	$11,000,000	$0	$13,000,000	($10,000,000)	$72,000,000
2013	$49,000,000	$11,000,000	$0	$13,000,000	($10,000,000)	$73,000,000
2014	$49,000,000	$12,000,000	$0	$13,000,000	($10,000,000)	$74,000,000
2015	$50,000,000	$12,000,000	$0	$13,000,000	($10,000,000)	$75,000,000
2016	$50,000,000	$12,000,000	$0	$13,000,000	($10,000,000)	$75,000,000
2017	$51,000,000	$12,000,000	$0	$13,000,000	($10,000,000)	$76,000,000
2018	$51,000,000	$12,000,000	$0	$13,000,000	($10,000,000)	$76,000,000
2019	$52,000,000	$12,000,000	$0	$13,000,000	($10,000,000)	$77,000,000
2020	$52,000,000	$12,000,000	$0	$13,000,000	($10,000,000)	$77,000,000
2021	$52,000,000	$12,000,000	$0	$13,000,000	($10,000,000)	$77,000,000
2022	$52,000,000	$12,000,000	$0	$13,000,000	($10,000,000)	$77,000,000
2023	$53,000,000	$12,000,000	$0	$13,000,000	($10,000,000)	$78,000,000
2024	$53,000,000	$12,000,000	$0	$13,000,000	($10,000,000)	$78,000,000
2025	$53,000,000	$12,000,000	$0	$13,000,000	($10,000,000)	$78,000,000
2026	$53,000,000	$12,000,000	$0	$13,000,000	($10,000,000)	$78,000,000

Table 3-17
Annualized Costs and Corresponding Present Value

Year	Best Estimate Technology		Catalyst oOption	
	Annualized	Discounted	Annualized	Discounted
1996	$64,000,000	$58,000,000	$76,000,000	$69,000,000
1997	$57,000,000	$50,000,000	$70,000,000	$61,000,000
1998	$58,000,000	$49,000,000	$70,000,000	$59,000,000
1999	$58,000,000	$48,000,000	$71,000,000	$59,000,000
2000	$59,000,000	$47,000,000	$72,000,000	$58,000,000
2001	$58,000,000	$45,000,000	$71,000,000	$55,000,000
2002	$52,000,000	$39,000,000	$65,000,000	$49,000,000
2003	$52,000,000	$38,000,000	$66,000,000	$48,000,000
2004	$53,000,000	$38,000,000	$66,000,000	$47,000,000
2005	$53,000,000	$37,000,000	$67,000,000	$46,000,000
2006	$54,000,000	$36,000,000	$68,000,000	$46,000,000
2007	$54,000,000	$35,000,000	$69,000,000	$45,000,000
2008	$55,000,000	$35,000,000	$69,000,000	$44,000,000
2009	$55,000,000	$34,000,000	$70,000,000	$43,000,000
2010	$56,000,000	$33,000,000	$71,000,000	$42,000,000
2011	$56,000,000	$32,000,000	$71,000,000	$41,000,000
2012	$57,000,000	$32,000,000	$72,000,000	$40,000,000
2013	$57,000,000	$31,000,000	$72,000,000	$39,000,000
2014	$57,000,000	$30,000,000	$73,000,000	$39,000,000
2015	$58,000,000	$30,000,000	$73,000,000	$38,000,000
2016	$58,000,000	$29,000,000	$74,000,000	$37,000,000
2017	$59,000,000	$29,000,000	$75,000,000	$36,000,000
2018	$59,000,000	$28,000,000	$75,000,000	$35,000,000
2019	$59,000,000	$27,000,000	$76,000,000	$35,000,000
2020	$60,000,000	$27,000,000	$76,000,000	$34,000,000
2021	$60,000,000	$26,000,000	$77,000,000	$33,000,000
2022	$60,000,000	$25,000,000	$77,000,000	$32,000,000
2023	$60,000,000	$24,000,000	$77,000,000	$31,000,000
2024	$60,000,000	$24,000,000	$77,000,000	$30,000,000
2025	$61,000,000	$23,000,000	$77,000,000	$29,000,000
2026	$61,000,000	$23,000,000	$77,000,000	$29,000,000

Chapter 3: References

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

2. ibid, pages 68-76.

3. ibid., page 57-58.

4. ibid., p. 67.

5. Curry, B., George, K.D., *Industrial Concentration: A Survey*, The Journal of Industrial Economics, March 1983.

6. Jack Faucett Associates, *Small Nonroad Engine and Equipment Study, JACKFAU-92-413-14*, p. 123-126.

7. Jack Faucett Associates, *Update of EPA's Motor Vehicle Emission Control Equipment Retail Price Equivalent (RPE) Calculation Formula (JACKFAU-85-322-3)*, September 1985.

8. U.S. Environmental Protection Agency, Office of Policy, Planning, and Evaluation, *Guidelines for Performing Regulatory Impact Analyses, Appendix C*, EPA-230-01-84-003, March 1991, Washington, DC.

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Chapter 4: Environmental Benefit

This chapter presents the methodology used by EPA to quantify the emission reduction benefits that will be realized through the adopted HC, CO, and NO_x emission standards for small SI engines. Benefits, in terms of HC and CO emission reductions and NO_x increments , are presented in two forms: per-engine benefits and aggregate source benefits. "Per-engine" benefits are the emission reductions expected to occur during the life of an engine whose emissions are controlled in response to the adopted standard. "Aggregate source" benefits are the estimated, future nationwide emission reductions from affected engines, for a given source i.e. equipment type. Estimated "aggregate source" benefits illustrate the potential future effect of the standard on the emission inventory of the source. Air quality benefits are discussed qualitatively for all three pollutant standards.

Many of the detailed results discussed below are presented in separate tables included in Appendix F - Supplementary Tables and Appendix C (in-use emission factors).

4.1. Estimated Emissions Reductions

To estimate the average annual emissions per current nonroad small SI engine, EPA used results from the Nonroad Engine and Vehicle

Emission Study(1) (i.e., the nonroad study) to represent the baseline emissions (i.e., emissions without controls). As in the study, total emissions are calculated for each type of equipment using

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

In this equation,

$N_{i,j}$	-	nationwide population of ith 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 ith equipment type
$HOURS_i$	-	average annual hours of usage for the ith equipment type
$EF_{i,j}$	-	brake specific emission rate (kilowatts/hr) for engine type j
$MASS_{i,j}$	-	annual nationwide emissions (grams) for the ith equipment type using engine j

For the benefits analysis described here, EPA performed separate calculations for each of 12 major equipment categories (as listed in Appendix C, Table C-01), each one of which could be equipped with one or more of 14 different engine types with average power ratings displayed in Table F-01. The 'All Other Equipment Category' is a major catch-all category which includes Shredders, Pressure Washers, etc. and Loose Distributed Engines. Population and activity information used to construct the Inventories relied predominately on data available in a commercially available marketing research data base that includes most types of nonroad equipment (2).

4.1.1. Aggregate HC and CO Reductions and NO_x Increment

The calculation of aggregate HC and CO reductions and NO_x increment is described in this section. The calculation takes into account U.S consumption of these equipment types, usage , and related survival rates as described below. Together with estimates of new and in-use emissions from the engines that are used in the various equipment types, EPA has derived projected nationwide annual emissions through 2020.

4.1.1.1. Sales--To estimate future emission levels, some projection of the future population of uncontrolled and controlled engines is needed. Because engines are introduced into the field through sales, estimates are needed not only of sales prior to the standard, but also of sales after the standard goes into effect. For years between 1973 and 1992, consumption of major categories of nonroad equipment were reported by leading industry sources. The methodology used for sales projections made for years 1993 to 2026 is described in Appendix B. These sales have been adjusted to exclude those engines that are covered by California's lawn, garden, and utility engine rule.

The results of this analysis are summarized in Table F-02 in Appendix F, which presents figures reported by PSR and projected estimates by type of use i.e., Residential and Commercial. 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.

The rule allows for flexibility in the start date, with engines meeting the standards phasing in during calendar years 1996 and 1997. In

calculating total emissions, therefore, 50% of the sales in 1996 were assumed to comply with the standards. This was accounted for in 1996 sales fractions.

In addition, the rule allows 2-stroke lawnmower engines to meet handheld rather than non-handheld standards through 2002, with the restriction that the sales of 2-stroke lawnmower engines will be limited in 1998 to 75% of baseline and in 1999-2002 to 50% of baseline levels. Starting in 2003, all 2-stroke lawnmower engines will comply with non-handheld standards. The baseline levels for each manufacturer of 2-stroke lawnmower engines are the highest sales from either 1992, 1993, or 1994. In the model, this was approximated by using 1994 sales across the board.

These restrictions have been accounted for in the sales fractions of the affected years. Tables F-03 and F-04 present sales fractions used to determine sales before 1996 and after full implementation of the standards starting in 2003.

4.1.1.2. Survival Probabilities--In calculating the emission reductions that are expected to occur during the life of an equipment, the emissions of whose engine are controlled in response to the adopted standard, EPA relied on the estimates of survival rates presented by EEA to ARB (3). Table F-05 presents the parameter values *theta* and *b* of the Weibull Cumulative distribution that was determined based on data given in Table 3-3 of the Jack Faucett Report submitted to the EPA.

4.1.1.3. In-Service Population--By coupling the sales estimates and projections given in Table F-02 with the engine survival rate function described in F-05 and the pre- and post-control sales fractions in Tables F-03 and F-04, EPA calculated the estimated populations from 1973 to 2026 for all equipment types as well as engine types with which

they are equipped. In doing so, EPA distinguished between controlled and uncontrolled engines, so that the effect of the standards could be ascertained.

4.1.1.4. Aggregate Source Emissions Inventory--EPA projected future annual nationwide emissions from engines addressed in this Small Gas FRM under the baseline (no controls applied) and controlled scenarios. This was accomplished using

$$MASS_y = \sum_{j=y-25}^{y} (SALES_j \times S_{y-j} \times AU_{rel,y-j} \times MASS_{avg,j})$$

In this equation,

y	-	inventory year
j	-	year of sale
$SALES_j$	-	engine sales in year j
S_{y-j}	-	fraction of engines sold in year j that survive in year y
$AU_{rel,y-j}$	-	relative annual usage in year y of engine sold in year j, as percent of average annual usage over engine life
$MASS_{avg,j}$	-	average annual per-engine emissions of engines sold in year j

EPA calculated baseline per-equipment emissions using pre-control/baseline emission factors from the Nonroad Study. The in-use population estimates were generated by taking into account the pre-control sales mix (Table F-03) and a survival function defined by constants as displayed in Table F-06. To obtain average annual per-equipment emissions for engines controlled to the levels required to

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comply with EPA's emission standards, emissions were recalculated using post-control sales mix (Table F-04) and in-use emission factors (Refer to Appendix C).

Table F-08 presents total annual nationwide emissions from engines addressed in this Small Gas FRM under the baseline scenario, and Table F-09 presents results for the controlled scenario. These are shown graphically in Figures 4-01 to 4-03.

In Figures 4-01 to 4-03, the annual benefit of the regulation 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 period 1996 to 2020. The averaged results indicate that the adopted standard represents on average a 32%/7% reduction in annual HC/CO emissions from engines to which the standards apply.

Figure 4-01

Projected Nationwide Annual HC Emissions - 1996-2020
Nonroad SI Engines Below 19kW

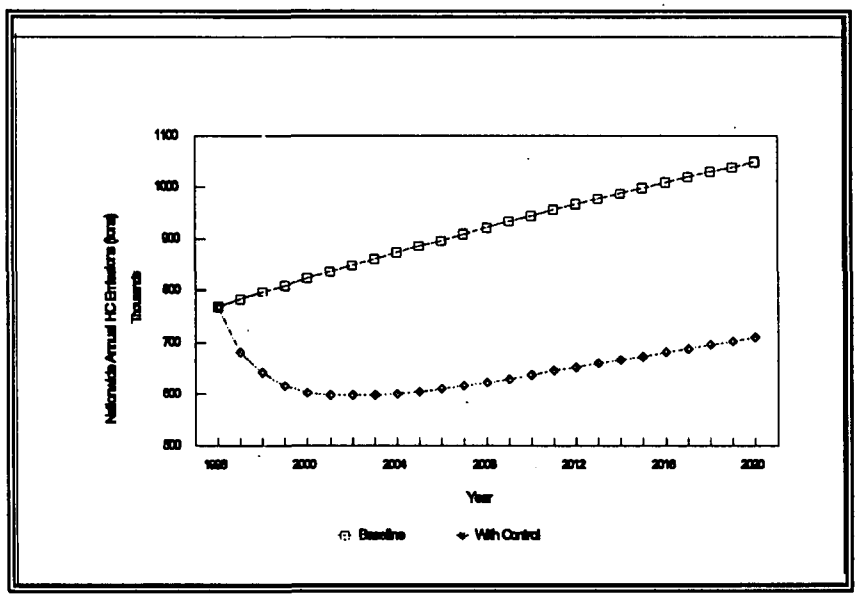


Figure 4-02
Projected Nationwide Annual CO Emissions - 1996-2020
Nonroad SI Engines Below 19kW

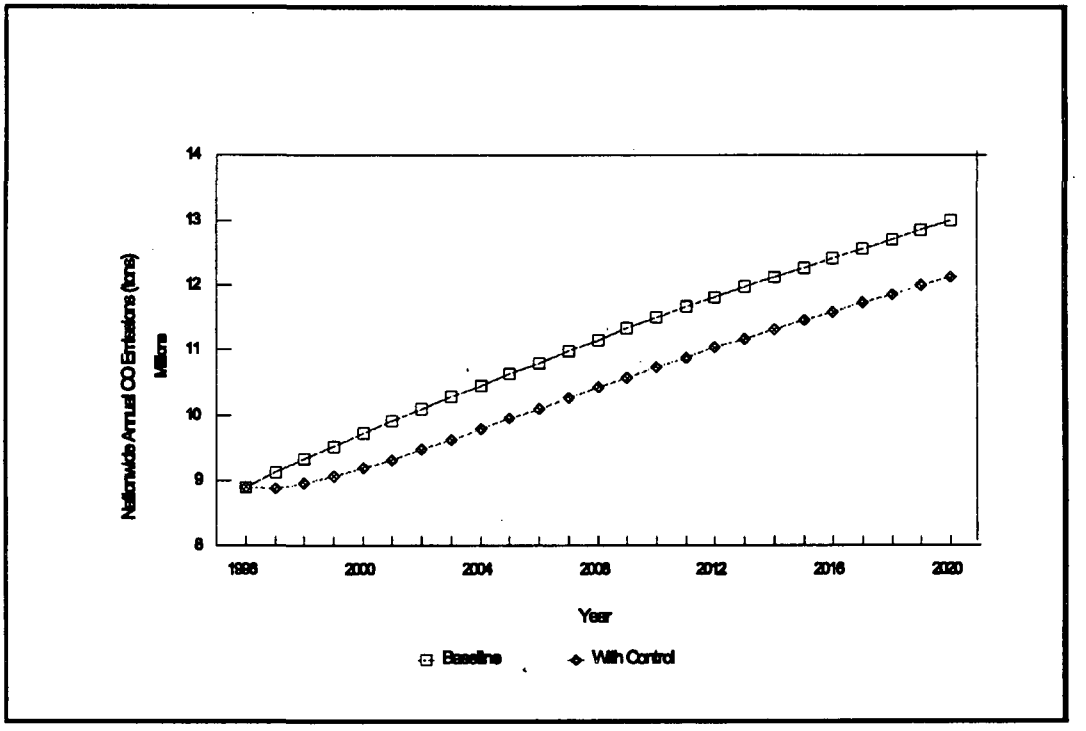
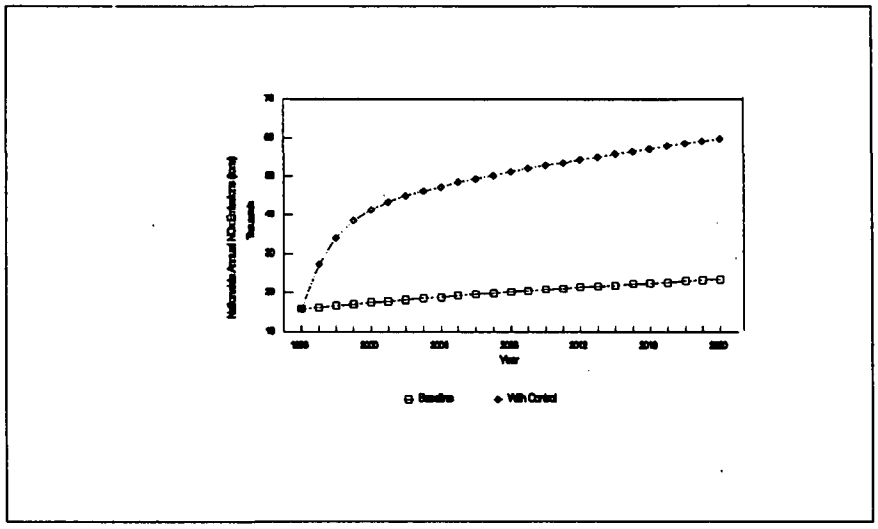


Figure 4-03
Projected Nationwide Annual NO_x Emissions - 1996-2020
Nonroad SI Engines Below 19kW



4.2 Air Quality Benefits

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

4.2.1. VOC

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

4.2.1.1. 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 criteria pollutant for which the EPA has established a NAAQS. Measures to control VOC emissions should reduce emissions of air toxics. However, the magnitude of reduction will depend on whether the control technology reduces the individual toxics in the same proportion that total VOCs are reduced. Since nonroad engines have significant VOC impacts , thay are expected to have significant toxics impacts 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.

Nonroad sources contribute substantially to summertime VOC and NO_x emissions and winter CO emissions. The median contribution of total nonroad emissions to VOC and NO_x inventories in summer, and CO inventories in winter, ranges from 7.4-12.6% VOC, 14.5-17.3% NO_x, and 5.2-9.4% winter CO, depending on the area (1). 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.

4.2.2. 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 C_6H_6. 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 evaporative emissions also depends on control technology and fuel composition and is generally about 1%.

Mobile sources account for approximately 85% of total benzene emissions, of which 30% can be attributed to nonroad mobile sources. These estimates were obtained from EPA's Nonroad Engine and Vehicle Emissions Study (NEVES EPA, 1991b). 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 2.74%.

4.2.2.1 Projected Benzene Emission Reductions--Nonroad engines account for approximately 25% of the total benzene emissions with 60% attributed to highway motor vehicles and 15% to stationary sources. Many of the stationary sources attributed with 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 emissions, once emission control technology is applied, the amount of benzene produced by new small SI engines should reduce after the rule becomes effective.

4.2.2.2 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(5) and in several journal articles.

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 <19 kW 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 microenvironments 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, 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.

4.2.2.3 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 (Infante, et al. 1977 a,b). 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 (Rinsky, et al. 1981; Ott, et al. 1978; Wong, et al. 1983) demonstrating an increased incidence of nonlymphocytic leukemia from occupational inhalation exposure. The supporting animal evidence (Goldstein, 1980; NTP, 1986; Maltoni, et al., 1983) showed an increased incidence of neoplasia in rats and mice exposed by inhalation and gavage. EPA calculated a cancer unit risk factor for benzene of $8.3x(\mu g/m)^{-1}$ 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 office of Research and Development (ORD) has recently started to review the process and update benzene risk assessment.

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 $5.2x10^{-5}$ $\mu g/m^3$.

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 $\mu g/m^3$) 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 $\mu g/m^3$) indicates adverse effects on the developing fetus, including low birth weight, delayed bone formation, and bone marrow damage.

4.2.3. 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.

1,3- Butadiene emissions appears 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. The percentage of 1,3-butadiene in unregulated small SI engines is estimated to be approximately 1.3 percent.

4.2.3.1 Projected 1,3-Butadiene Emission Reductions--Current EPA estimates indicate that mobile sources account for approximately 94% of the total 1,3-butadiene emissions, out of which 41% 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.

4.2.3.2 Health Effects of 1,3 - Butadiene Exposure--The annual average ambient level of 1,3-butadiene ranges from 0.12 to 0.56 $\mu g/m^3$. 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 .26 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 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 quick;ly dilutes the exhaust, the rate of dilution depends on the weather conditions.

4.2.3.3 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 inadequate human evidence but 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 2.8×10^{-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 has just recently started the process of updating 1,3-butadiene risk assessment.

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 (2.2×106 $\mu g/m^3$) 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.

4.2.4. 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 9ppm for a one hour average and 35 ppm for an eight hour average.

4.2.4.1. Health and Welfare Effects of CO--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-powerd 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 sytem effects, observed at peak CO Hb 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.

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.

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 above numbers provide some basis for determining the effects of exhaust CO on the operator of the engine. Laboratory animal studies reveal that CO can adversely affect the cardiovascular system, depending on the exposure conditions utilized in these studies.

4.2.4.2. 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 (Singh, 1986). The current data (Hoppenbrouwers, et al., 1981) 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 (Klees, et al, 1985; Crocker, et al, 1985) 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 (Benignus, et al, 1987, 1990) 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 such as public transportation vehicles 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 renobiotic 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 (Zebro, et al, 1983). It generally is agreed that these effects are caused by severe tissue damage occurring during acute CO poisoning.

Chapter 4: References

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4. *Jack Faucett Associates, Nonroad Mobile Source Sales and Attrition Study : Identification and Evaluation of Available Data Sources - Final Report*, Bethesda, Maryland, February 1993, p.3-11

5. National Research Council, *Rethinking the Ozone Problem in Urban and Regional Air Pollution*, National Academy Press, Washington, DC, 1991.

6. Fisher, D. and Oppenheimer, M., *Atmospheric Deposition and the Chesapeake Bay Estuary*, Journal Ambio, Volume 20, pp. 102-108 (1991).

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8. U.S. Environmental Protection Agency, *Review of the National Ambient Air Quality Standards for Ozone - Assessment of*

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9. U.S. Environmental Protection Agency, *Review of the National Ambient Air Quality Standards for Ozone - Assessment of Scientific and Technical Information: OAQPS Staff Paper*, EPA-450/2-92-001, June 1989.

10. U.S. Environmental Protection Agency, *Review of the National Ambient Air Quality Standards for Ozone - Assessment of Scientific and Technical Information: OAQPS Staff Paper*, EPA-450/2-92-001, June 1989.

11. U.S. Environmental Protection Agency, *Review of the National Ambient Air Quality Standards for Ozone - Assessment of Scientific and Technical Information: OAQPS Staff Paper*, EPA-450/2-92-001, June 1989.

12. U.S. Environmental Protection Agency, *Review of the National Ambient Air Quality Standards for Ozone - Assessment of Scientific and Technical Information: OAQPS Staff Paper*, EPA-450/2-92-001, June 1989.

Chapter 5: Cost-Effectiveness Analysis

Based upon the costs and pollutant reductions described in the preceding chapters, EPA has prepared a cost-effectiveness analysis for this Small Gas FRM. Because the benefits to society of this Small Gas FRM are not easily monetized, a cost-effectiveness analysis has been prepared.

If all program costs are allocated to hydrocarbon (HC) reductions, today's Small Gas FRM has a cost-effectiveness of $280 per ton of HC reduced. Alternatively, if all program costs are allocated to carbon monoxide (CO) reductions, the cost-effectiveness would be $113 per ton.

If the costs of the program were equally split between HC and CO, the cost-effectiveness of HC reduction would be $140 per ton and the cost-effectiveness of CO would be $57 per ton. Since the primary purpose of this rule is to control HC emissions, the most appropriate of the above ratios is the first one (i.e., $280 per ton HC abated), however, this does not include consideration of the fact that there is a value of also achieving the CO reduction.

Thus, it is important to note that the cost of technology which only acts to reduce one pollutant should only be attributable to the reduction of that pollutant. For instance, if a technology only acted to reduce CO,

the cost of that technology would not be used to calculate the cost-effectiveness of reducing HC. EPA could not identify any technologies which manufacturers would use to only reduce one pollutant.

These cost-effectiveness numbers are favorable relative to the cost-effectiveness of other control measures required under the Clean Air Act. To the extent that cost-effective nationwide controls are applied to small SI engines, the need to apply more expensive additional controls to mobile and stationary sources in the future may be reduced.

This chapter describes how the cost-effectiveness numbers presented above were calculated. Further, this chapter presents some alternative viewpoints on methodologies to calculate cost-effectiveness numbers.

5.1. Cost-Effectiveness Methodology

For both HC emissions and CO emissions, program cost-effectiveness is presented for this rule as the ratio of the net present value of the stream of costs to society divided by the net present value of the stream of emission reductions on an inventory basis. Because of the inherent pollution formation characteristics of the combustion process and the technology required by this Small Gas FRM, the associated cost of producing engines which comply with the adopted standards cannot be attributable to individual pollutants. Therefore, the per-pollutant cost-effectiveness is calculated using the same cost estimate in the numerator for each ratio, while utilizing individual pollutant impacts in the denominator. This produces the most conservative cost-effectiveness number for each pollutant. In other words, the per-pollutant cost-effectiveness number reflects the total cost incurred to achieve the needed emission reduction for that pollutant.

The per-pollutant cost-effectiveness estimates are easiest to interpret under this methodology when viewed in isolation. From this

perspective, society is concerned with the reduction of one particular pollutant. Comparing cross-pollutant cost-effectiveness estimates under this methodology can be clarified as follows. From the perspective of reducing HC emissions, the adopted FRM program would generate windfalls (i.e., unexpected gains) of CO reductions because standards are set such that the HC reducing set of technology also produces CO reductions. Two important points are 1) that the adopted level of HC reduction is not gained unless the total costs are incurred and 2) that no additional costs are incurred to achieve the CO reduction. If the rule were viewed as placing the priority on reducing CO, interpreting the cost-effectivness estimates from the perspective of reducing CO would be similar.

5.2. Annualized Costs and Annualized Pollutant Reductions

The annualized costs of the Small Gas FRM and the annualized effectiveness of the Small Gas FRM in terms of the tons of pollutants (HC, CO, and NO_x) reduced are shown in Figures 5-01 and 5-02. Figure 5-01 shows the costs annualized at 7 percent, then discounted to present value at 3 percent.

Figure 5-03
PRGRAM COSTS OVER TIME
1993 dollars

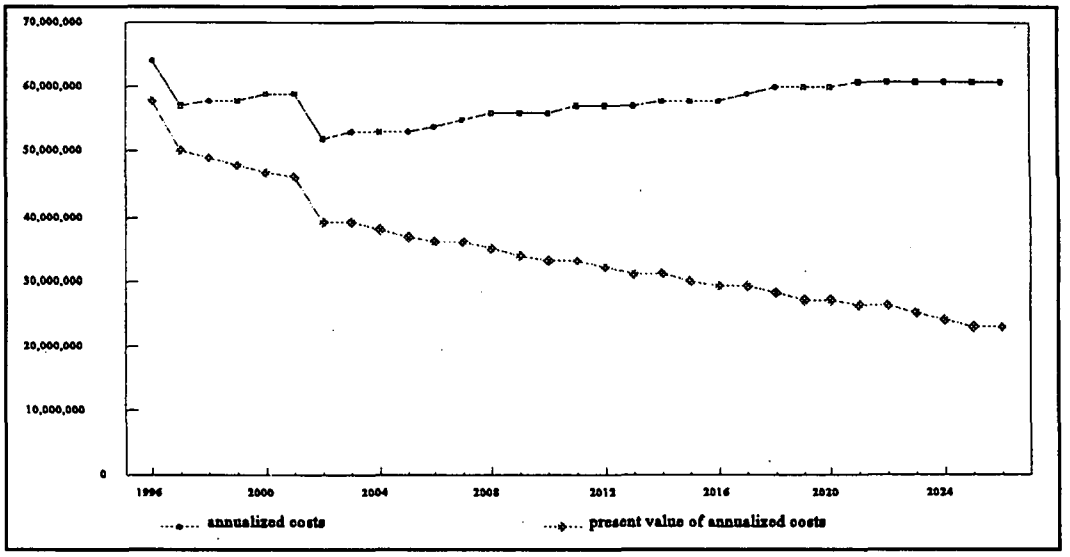
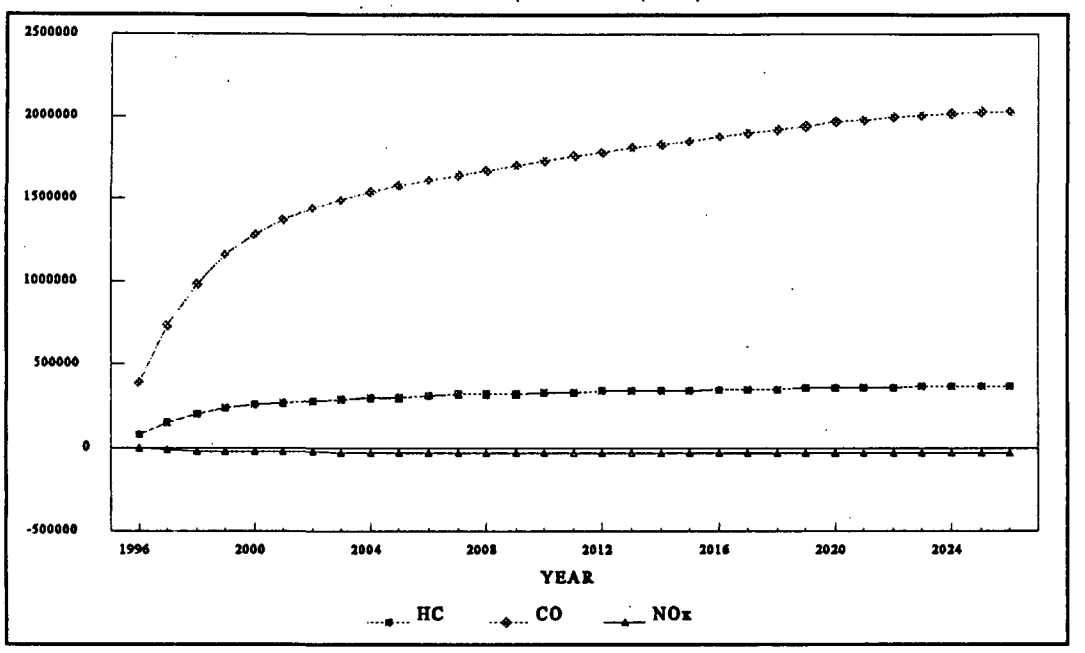


Figure 5-04
PROGRAM EFFECTIVENESS OVER TIME
reduction in pollutants (tons)



5.3. Cost-Effectiveness

This section presents the cost-effectiveness of the FRM program based on the net present value of the costs divided by the net present value of the HC and CO pollutant benefits.

5.3.1. Hydrocarbon (HC) Cost-Effectiveness

HCs are the primary target pollutant for this regulatory effort. EPA believes that the "best estimate technology" method of determining cost-effectiveness follows the Kolb-Scheraga approach.(2) After annualization at 7%, the costs (and emission reductions) are discounted at 3%. Therefore, the corresponding HC cost-effectiveness is $280 per ton applying all program costs to HC.

Table 5-01 presents the HC cost-effectiveness numbers for the Phase 1 program. These ratios take into account the total program costs

incurred in order to achieve the proposed magnitude of HC reductions. Because these ratios are based on total program costs, reductions in CO emissions are considered to be windfalls.

Table 5-01
HC Cost-Effectiveness
Using Total Program Costs

Discount Rate	Technology Assumptions	
	Best Estimate Technology	Catalyst Option
0.00	232	292
0.03	280	325
0.07	289	353

Table 5-02 presents the alternative HC cost-effectiveness numbers for the Phase 1 program. These ratios assign half the total program costs incurred to the magnitude of HC reductions.

Table 5-02
HC Cost-Effectiveness
Using Half the Total Program Costs ($/Ton)

Discount Rate	Technology Assumptions	
	Best Estimate Technology	Catalyst Option
0.00	116	146
0.03	140	163
0.07	145	177

The HC cost-effectiveness of this rule using total program costs is nearly comparable to the HC cost-effectiveness of two other CAA mandated requirements which achieve only VOC benefits. The CAA

has mandated reductions in reid vapor pressure of motor vehicle gasoline. EPA has estimated the cost-effectiveness of these HC reductions at $140 per ton. The CAA has also mandated reductions in evaporative VOC emissions from motor vehicles. The cost-effectiveness of these HC reductions have been placed at $170 per ton.

Two other CAA mandated programs which achieve only VOC benefits are considerably less cost-effective than this Phase 1 Smallgas FRM. For example, the cost-effectiveness of "Stage II" vapor recovery systems for control of vehicle refueling HC emissions at gas dispensing facilities is estimated to be $1,020 per ton. Another CAA mandate which is even less cost-effective regards reduction of VOC emissions from consumer and commercial solvents. EPA estimates the cost-effectiveness of reducing VOCs from solvents at $2,000 per ton. Also, the CAA mandate for "Tier I" on-highway motor vehicle emission standards reduced both VOCs and NO_x, with a VOC cost-effectiveness estimate of $3700 per ton. Further, the CAA mandate for on-board diagnostic equipment for on-highway motor vehicles reduces HC, CO, and NO_x, with an estimated cost-effectiveness for HC of $1974 dollars per ton.

Clearly, the HC cost-effectiveness using total program costs presented above for today's Phase 1 Small Gas FRM is very cost-effective in relative terms.

5.3.2. Carbon Monoxide (CO) Cost-Effectiveness

CO is the secondary target pollutant for this regulatory effort. The "best estimate technology" method of determining CO cost-effectiveness used the same approach as with HC. The corresponding CO cost-effectiveness is $113 per ton applying all program costs to CO.

The Phase 1 program adopted today produces the program cost-effectiveness numbers shown in Table 5-03. These ratios take into

account the total program costs incurred in order to achieve the magnitude of CO reductions. Because these ratios are based on total program costs, reductions in HC emissions are considered to be windfalls.

Table 5-03
CO Cost-Effectiveness
Using Total Program Costs

Discount Rate	Technology Assumptions	
	Best Estimate Technology	Catalyst Option
0.00	93	117
0.03	113	131
0.07	117	143

Assigning half of the total program costs to CO produces the program cost-effectiveness numbers shown in Table 5-04.

Table 5-04
CO Cost-Effectiveness
Using Half the Total Program Costs

Discount Rate	Technology Assumptions	
	Best Estimate Technology	Catalyst Option
0.00	47	59
0.03	57	66
0.07	59	72

The CO cost-effectiveness of this rule is between the cost-effectiveness estimates of three CAA mandated CO reductions for mobile sources. One mandate was to reduce the CO emissions from motor vehicles operating at cold temperatures. EPA estimated the CO

cost-effectiveness at -$84 to -$8 per ton. Another CAA mandate for on-board diagnostic equipment for on-highway motor vehicles reduces HC, CO, and NO_x, with an estimated cost-effectiveness for CO of $124 dollars per ton. A third mandate affecting CO required the use of oxygenated fuels in CO nonattainment areas during the wintertime. The CO cost-effectiveness was estimated to range from -$247 per ton to $695 per ton. Achieving CO reductions from nonroad smallgas engines by today's Small Gas FRM is not as cost-effective as the CO reductions already achieved from technological changes to mo[illegible] vehicles, but is more cost-effective than the use of oxygenated fuels in some nonattainment areas and more cost-effective than the CO reductions achievable through the use of on-board diagnostic equipment for on-highway motor vehicles.

In summary, the cost-effectiveness of the HC and CO standards included in the current Small Gas FRM is favorable relative to the cost-effectiveness of other VOC and CO control measures required under the Clean Air Act. To the extent that cost-effective nationwide controls are applied to small SI engines, the need may be reduced to apply in the future more expensive additional controls to mobile and stationary sources that also contribute to ozone nonattainment and visibility.

Chapter 5: References

1. EPA, Nonroad Engine and Vehicle Emission Study, EPA Report Number 21A-2001, Washington DC, november, 1991.

2. U.S. Environmental Protection Agency, Office of Policy, Planning, and Evaluation, *Guidelines for Performing Regulatory Impact Analyses, Appendix C*, EPA-230-01-84-003, March 1991, Washington, DC.

Appendix A: Small Engine Testing Facility, University of Michigan Walter E. Lay Automotive Laboratory

In the fall of 1992, the EPA's Certification Division entered into a Cooperative Agreement with the University of Michigan's Walter E. Lay Automotive Laboratory (the "Auto Lab"). The goals and objectives of the Agreement are outlined below.

A.1. Goals

- Provide the University of Michigan with the opportunity to develop a world-class small engine and marine outboard engine research facility.

- Provide interaction between university personnel and staff from an internationally recognized government laboratory acclaimed for its expertise and resources in the engine emission control area.

- Provide EPA access to the expertise and resources needed to investigate emissions from nonroad engine sources through cooperation with researchers and students from the College of

Engineering at the university.

A.2. Objectives

- Assemble and validate a fully operational emission test stand capable of testing small spark-ignited engine emissions.

- Measure exhaust emissions (e.g., hydrocarbons, oxides of nitrogen, and carbon monoxide) from small utility engines using SAE recommended practice J1088.

- Develop constant volume sampling (CVS) dilution exhaust measuring techniques for non-road small engines.

A.3. Description of Facility

The testing facility at the University of Michigan Walter E. Lay Automotive Laboratory is based in the following pieces of equipment.

- Beckman analyzer bench with
  - NDIR carbon monoxide and carbon dioxide measurement
  - Flame Ionization Detector for the measurement of total hydrocarbons
  - a chemiluminescent detector for the measurement of oxides of nitrogen

- Micro-Dyne 15 horsepower vertical/horizontal hydraulic motoring dynamometer

- Computer based dynamometer control system and total data

acquisition, including various voltage, temperature, and pressure measurements

- A critical flow venturi constant volume sampling system for the continuous measurement of total dilute exhaust volume flow

- A mass fuel flow measuring system using an external fuel supply tank mounted on a load cell whose voltage output was read by the control system

The Auto Lab has been utilizing the six mode non-handheld engine test cycle and the two mode handheld engine test cycle described in the February, 1993 version of the Society of Automotive Engineers (SAE) recommended test procedure J1088. The Auto Lab has reported all weighted emission results using the small engine weighting factors established by the California Air Resource Board's 1995 utility engine regulation.

The Auto Lab has been using the recommended test procedures and emission calculations established by the SAE J1088 procedure, with the exception of measuring emissions using the Constant Volume Sampling method, not the Raw Gas Method described in the J1088 procedure.

The facility has tested two correlation engines which have been run at industry emissions laboratory and has proven they are collecting valid emission data.

A-4

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. Mostly, engine manufacturers produce either 2-stroke engines or 4-stroke engines, although the major manufacturers produce some of each. Data on the manufacturers and their products is limited. EPA has purchased databases from Power Systems Research called EnginData and PartsLink which summarize data on manufacturers and their products for the engines to be regulated as well as all other types of engines consumed in North America(1). EPA used this database as a basis of information because it contains the most extensive amount of publicly available information

regarding the products of concern to this regulation. However, there are some significant problems with the information contained in the database as well as the extent of information contained in the database.

EnginData gathers information by surveying equipment manufacturers regarding purchases of engines per year, contacting private trade organizations, and contacting government agencies. As PSR itself notes, "(a)lthough Power Systems Research has gone to considerable lengths to make this information as accurate as possible, errors and omissions inveitably occur. The data is continually reviewed and updated, including both historical corrections and revised forecasting. Subscribers to the complete database receive quarterly revisions and clients requesting extracts will receive the most current data available."[11] Please refer to the EnginData Rreference Guide which is in the docket for a further discussion of the information contained in the EnginData databse.

EPA has made efforts to compare the information generated from EnginData to other sources. When the information from other sources was sufficient or better, EPA has adopted the other source information. This appendix outlines the alternative sources of information and describes the rationale for choosing data other than PSR data for purposes of analysis of technology, costs, and benefits.

B.2.1. Listing of Known Engine Manufacturers

EPA has generated a listing of engine manufacturers from the PSR EnginData database. It appears that there are approximately 28 engine manufacturers selling gasoline engines under 25 horsepower. Of these, 20 manufacturers produce 2-stroke engines and 14 manufacturers produce 4-stroke engines. There are 5 manufacturers who produce both

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[11] Power Systems Research, "EnginData North America Reference Guide, Edition 13.2," page 1.

2-stroke and 4-stroke engines. Please refer to Table B-01, which summarizes the manufacturers who produce 2- and 4-stroke engines.

B.2.2. Listing of Known Engine Models per Manufacturer

PSR's EnginData 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 the section are the number of engine models per manufacturer, the engine model codes, and the estimated number of engine models in each standard category. The estimated number of engine models in each standard category is based on an analysis of the equipment which each engine model is used in. This equipment information is contained in the PSR EnginData database, although the specific engine model and equipment type combinations are not summarized here.

B.2.2.1. Number of Engine Models--Some statistics on the 2-stroke and 4-stroke products differ substantially. There are over three times as many 4-stroke engine models as there are 2-stroke engine models. The most diverse 4-stroke manufacturer produces nearly five times as many engine models as the most diverse 2-stroke engine manufacturer. There are thirteen 2-stroke engine manufacturers who produce less than three engine models, while approximately half that number of manufacturers produce less than three 4-stroke engine models. There seems to be a much larger number of 4-stroke engine manufacturers producing diverse product lines. There are five 4-stroke engine manufacturers of moderate diversity producing between 17 and 20 engine models, or approximately 9 % of the number of 4-stroke engine models each. There are just three 2-stroke engine manufacturers in a similar situation.

Other statistics on the 2- and 4-stroke products are similar. For 2-stroke engines, the two most diverse engine manufacturers produce 40%

of the engine models, while the most diverse engine manufacturer produces 20% of the product models. For 4-stroke engines, the two largest manufacturers produce 43% of the engine models, while the most diverse engine manufacturer produces 27% of the product models.

The data these conclusions are based on are summarized in Table B-02.

B.2.2.2. Engine Model Codes--EPA identified each manufacturer's specific engine model codes as listed in the PSR EnginData database. It is unclear whether each engine model corresponds to an "engine family" as defined in the regulations.[12] In order to estimate the admininstrative costs of the proposed regulatory programs, EPA used the number of engine models as an approximation of the number of engine families.

B.2.2.3. Number of Engine Models in Each Standard Category Per Manufacturer--EPA estimated the number of each manufacturers engine models which would be likely to be in a particular standard category. This estimation was based on the definition of handheld engines. EPA considered the engine size and the specific type of equipment which the engine is used in when considering which standard category to assign a specific engine to. Some engines appeared to be used in either a handheld or nonhandheld application. For those engines, EPA assigned them to the standard category for which the engine had the highest sales volume.

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[12] See proposed regulation Subpart B.

Table B-01

Engine Manufacturers		
Manufacturer	**0-25 hp 2-Stroke**	**0-25 hp 4-Stroke**
Acme		■
Briggs & Stratton	■	■
Columbia	■	
Cushman	■	
Daihatsu Motors		■
Homelite	■	
Honda	■	
Inertia Dynamic	■	
Kawasaki		■
Kioritz	■	
Kohler	■	■
Komatsu-Zenoah	■	
Kubota		■
Lawn-boy	■	
McCulloch	■	
Mitsubishi Heavy Industries	■	■
Newton Engines		■
Onan		■
Poulan	■	
Power Bee	■	
Stihl	■	
Suzuki	■	■
Tecumseh	■	■
Teledyn-Wisconsin		■
U.S. Engines	■	
Wacker	■	
Yamaha	■	■
Yanmar		■

Table B-02

Number of Engine Models Per Manufacturer			
Manufacturer	Number of Engine Models for Each Engine Type		
	2-Stroke	4-Stroke	Total Number of Engine Models
Acme		4	4
Bombadier-Rotax	1		1
Briggs & Stratton	1	56	57
Columbia	1		1
Cushman		1	1
Daihatsu Motors		2	2
Homelite	13		13
Honda		17	17
Inertia Dynamic	2		2
Kawasaki		20	20
Kioritz	2		2
Kohler		20	20
Komatsu-Zenoah	3		3
Kubota		3	3
Lawn-boy	2		2
McCulloch	7		7
Mitsubishi Heavy Industries	1	2	3
Newton Engines		4	4
Onan		18	18
Poulan	12		12
Power Bee	3		3
Stihl	6		6
Suzuki	1	3	4
Tecumseh	5	34	39
Teledyn-Wisconsin		28	28
U.S. Engines	1.		1
Wacker	2		2
Yamaha	1	1	2
Yanmar		1	1
TOTALS	64	214	278

Table B-03

4-Stroke Engine Models				
ACME	A220	AL550W	ALN290W	ALN330W
BRIGGS & STRATTON	100700	104700	110700/111700	110900
	112200	114700	114900	121700
	122700	124700	125700	130200
	130900	131700	132200	132400
	161400	170400	170700	171400
	190400	190700	191700	192700
	193700	195400	221400	233400
	252400	252700	254400	256700
	260700	261700	281700	290400
	294400	294700	303400	303700
	326400	350400	400700	402400
	402700	422400	422700	60100
	80200	80300	82200	90700/91700
	92500	92900/94900	93900	99700
CUSHMAN	C-222			
DAIHATSU MTR	AB	EB		
HONDA	G100	G100K1	GX110	GX120
	GX140	GX240	GX270	GX340
	GX360	GX390	GXV110	GXV120
	GXV120(US)	GXV140(US)	GXV160	GXV270
	GXV340			
KAWASAKI	FA130D	FA210D	FA210V	FA76D
	FB460V(US)	FC150V(US)	FC290V	FC420V(US)
	FC540V	FD590V	FD620	FE120
	FE170D	FE250D	FE290D	FE350
	FG200D	FG300D	KF150	
KOHLER	CH18	CH20	CH22	CH5
	CV12.5	CV14	CV18	CV20
	CV22	K582	K91(MX)	L654
	M10	M12	M14	M16
	M18	M20	M8	MV-16
	MV-18			
KUBOTA	GH280	GS230	WG600-B	
MHI	G510	G910		
NEWTON ENG	400/401	404/407	410/419	418
ONAN	CCK	CCKA	CCKB	ELITE 125
	ELITE 140	ELITE 75	ELITE 95	JB
	MCCK	NHC	P216	P216V
	P218	P218V	P220	P220V
	P224	T260		
SUZUKI	S150	S80Y	V140X	

TECUMSEH	H30	H35	H50	H60
	H70	HH100	HH60	HM100
	HM70	HM80	HMSK100	HMSK80
	HMXL70	HS40	HS50	LAV50
	OH120	OH140	OH160	OH180
	OVRM40	OVRM50	OVXL120	TVM140
	TVM170	TVM195	TVM220	TVS105
	TVS120	TVS75	TVS90	TVXL105
	VH70			
TELEDYN-WISC	ACN	AENL	AGND	BKN
	EY-18-3W	EY-21W	EY-25W	EY-27W
	EY-44W	S-12D	S-14D	S-8D
	TJD	TRA-12D	W2-1230	W2-880
	WI-145	WI-145V	WI-185	WI-185V
	WI-280	WI-340	WI-390	WI-450V
	WO1-115	WO1-150	WO1-210	WO1-340
YANMAR	3TG66E			
YAMAHA	J38			

Table B-04

2-Stroke Engine Models				
BOMBRDIER-ROTAX	250			
BRIGGS&STRAN	96700			
COLUMBIA	DX			
HOMELITE	HM25	HM57	HM67	HM77
	HM31	HM39	HM47	HM26
	HM88	HM54	HM100	HM102
	HM38			
INERTIA DYNAMIC	IDC-285	IDC-310		
KIORITZ	SRM-311D	SRM-4600		
KOMATSU-ZENOAH	G2A	G4C	G4K	
LAWN-BOY	MODEL M	MODEL F		
MCCULLOCH	MC21	MC32	MC35	MC38
	MC51	MC70	MC82	
MHI	T130			
POULAN	XR20	XR50	XR80	PRO200
	1800	2300	3400	657
	2000	4900	3700	5400
POWER BEE	58021	70019	82027	
STIHL	210	262	400	700
	500	800		
SUZUKI	401			
TECUMSEH	TC200	AH520	AV520	AH600
	TVS840			
US ENGINES	354			
WACKER	WM80	WM100		
YAMAHA	S215			

Table B-05

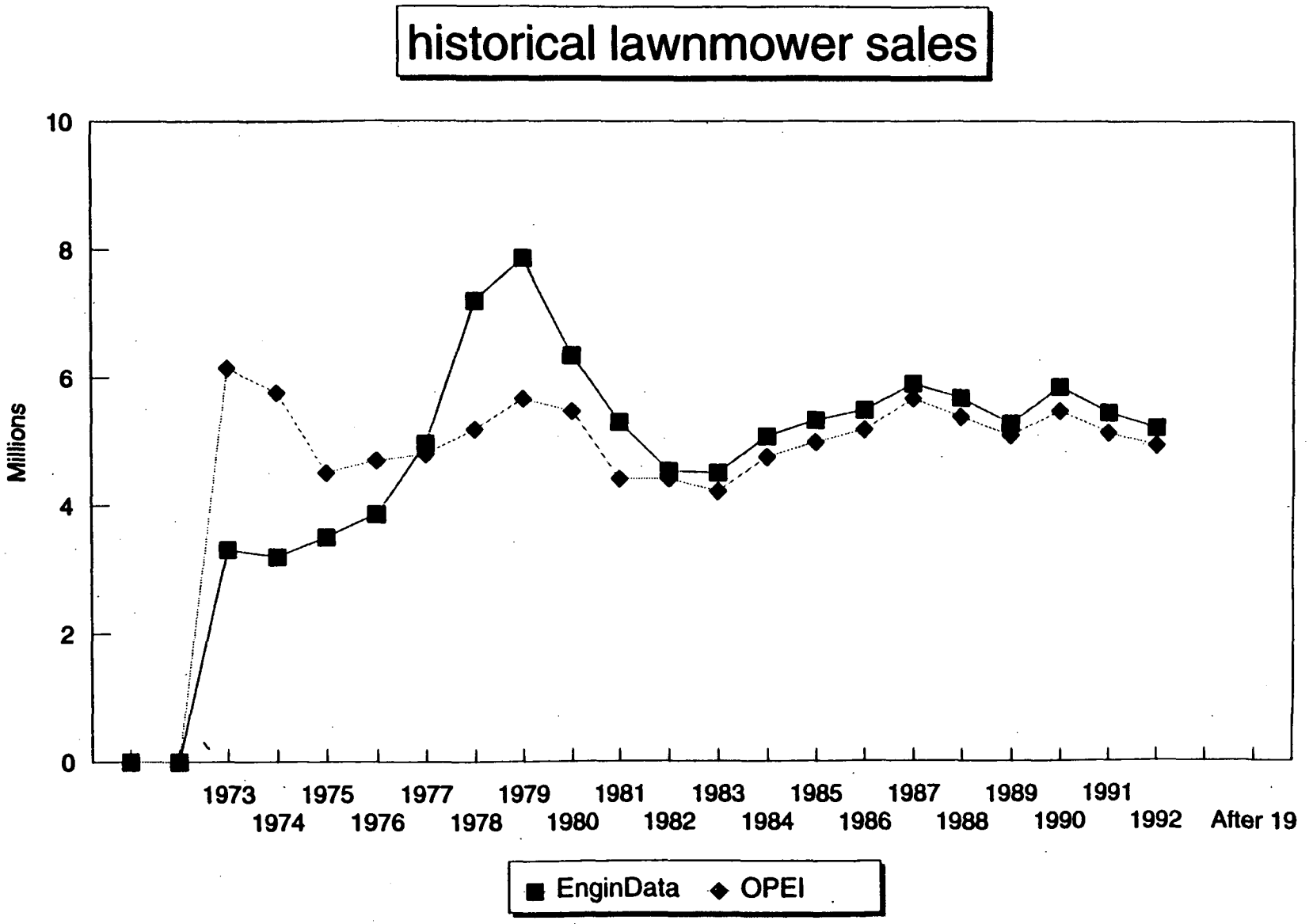
Manufacturer	Number of Engine Models for Each Standard Category				
	I	II	III	IV	V
Acme		3			
Bombadier-Rotax		1			
Briggs & Stratton	22	33			
Columbia		1			
Cushman		1			
Daihatsu Motors		2			
Homelite	5			9	6
Honda	5	7			
Inertia Dynamic				2	
Kawasaki	1	12			
Kioritz	1			2	
Kohler	1	19			
Komatsu-Zenoah				3	
Kubota		3			
Lawn-boy	2				
McCulloch	4			1	2
Mitsubishi Heavy Industries	1	1		1	
Newton Engines	3	1			
Onan		19			
Poulan	3		1	6	5
Power Bee	3				
Stihl	4			2	
Suzuki	3				
Tecumseh	12	20		1	2
Teledyn-Wisconsin	7	20			
U.S. Engines	1				
Wacker	2				
Yamaha	1	1			
Yanmar		1			
TOTALS	80	144	1	27	15

200

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

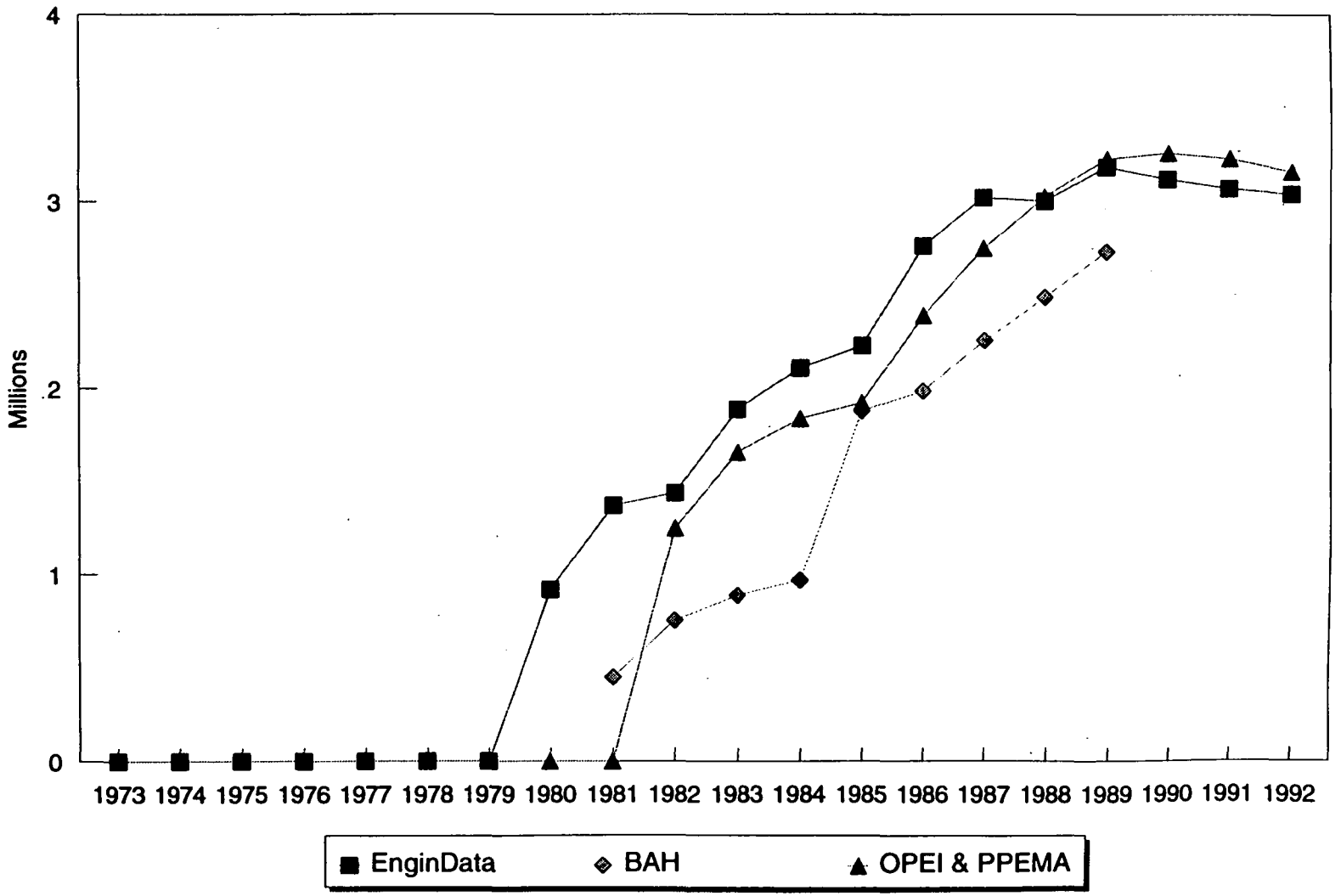
EPA analyzed the information from the PSR database as well as information from Outdoor Power Equipment Institute (OPEI), the Portable Power Equipment Manufacturers Association (PPEMA), and a study done for the California Air Resources Board by Booz, Allen, Hamiliton (BAH).

Data presented in this section shows the estimates of historical consumption from these sources. Data from two regression analyes is also presented. EPA did a regression of historical sales using ordinary least squares methodology. EPA considered using the regression equation produced from this historical sales regression to predict future sales. However, EPA decided to use the regression results from a second regression analysis in which the best estimate historical sales were regressed with estimates of historical and projected population estimates from the Bureau of Economic Analysis.(2) Some regression results predicted negative sales for a few equipment types. In those instances, EPA assumed no change in future sales levels from the last year for which historical sales were estimated. EPA's actual "best estimates" of consumption are presented in Appendix F, Table F-02.

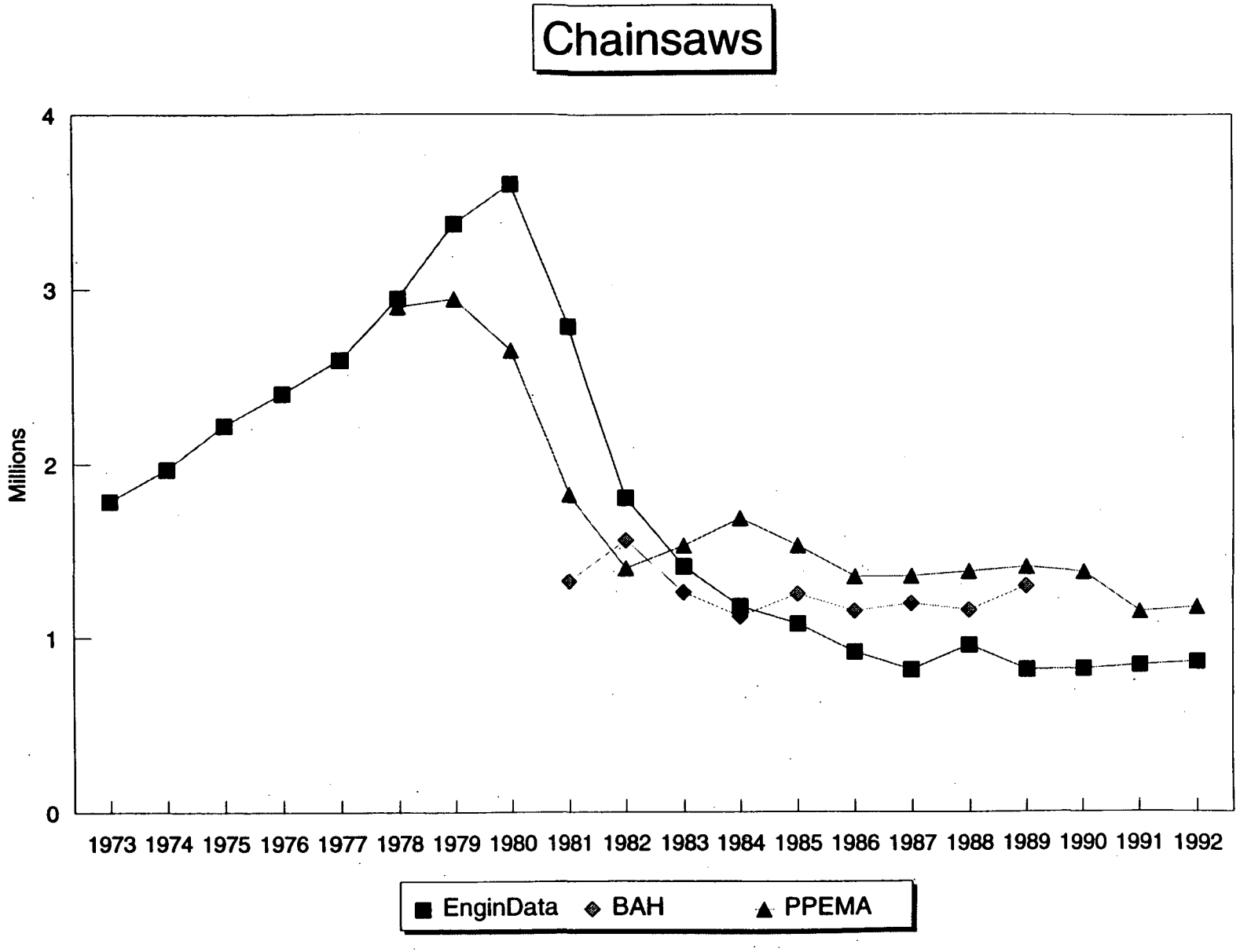

historical lawnmower sales
Millions
10
8
6
4
2
0
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
After 19
EnginData
OPEI

202

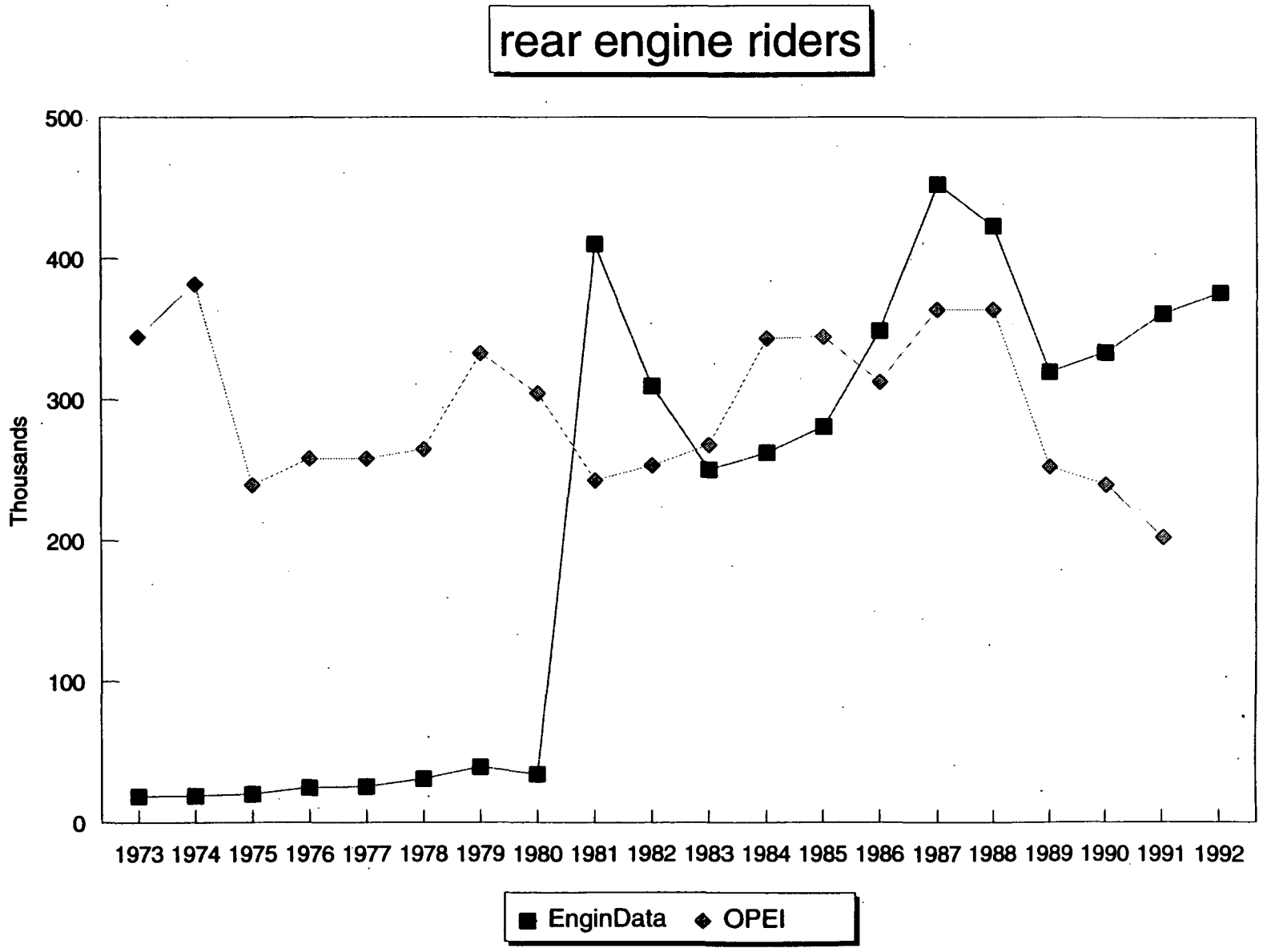
Edgers/Trimmers

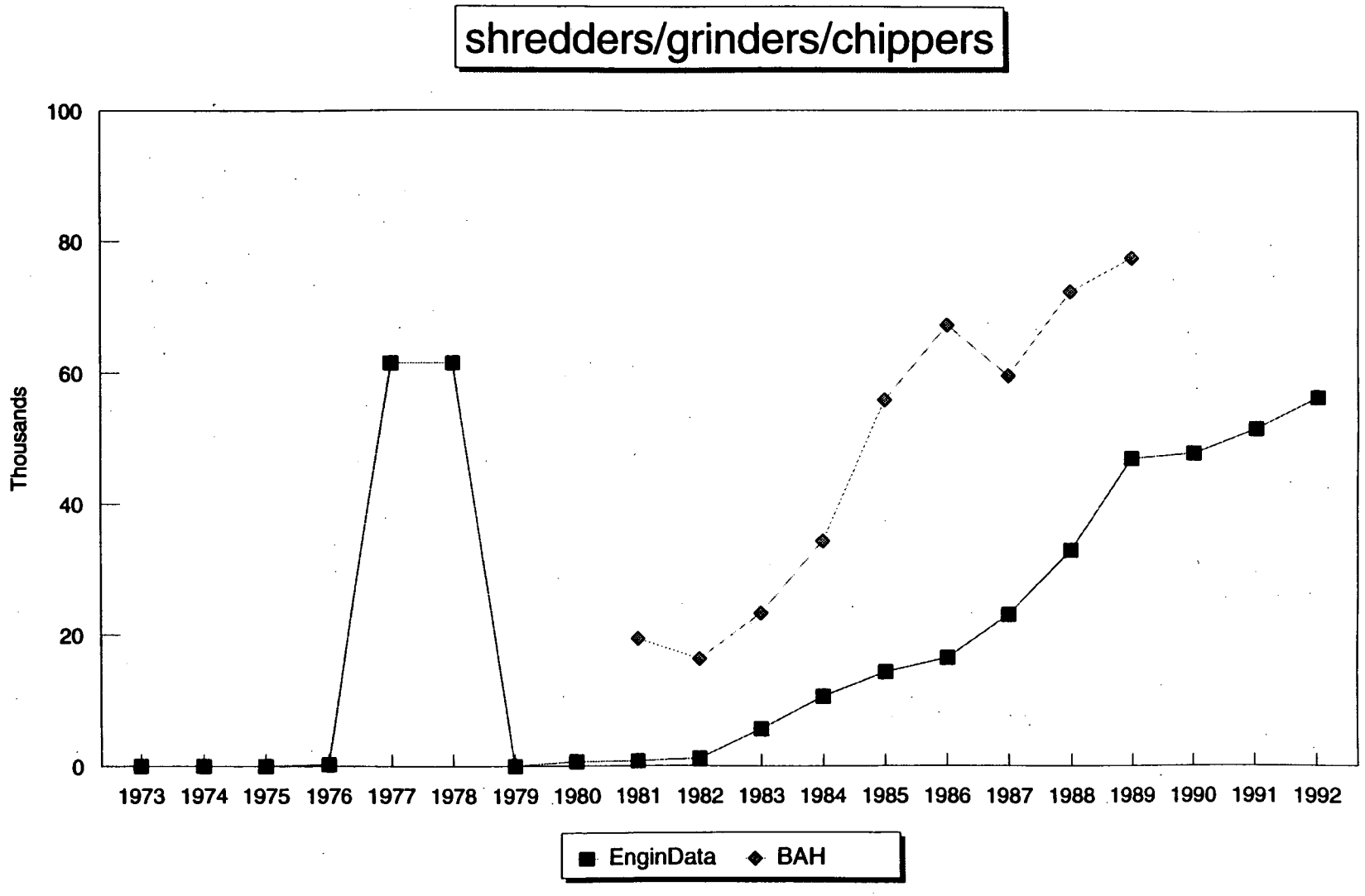


203

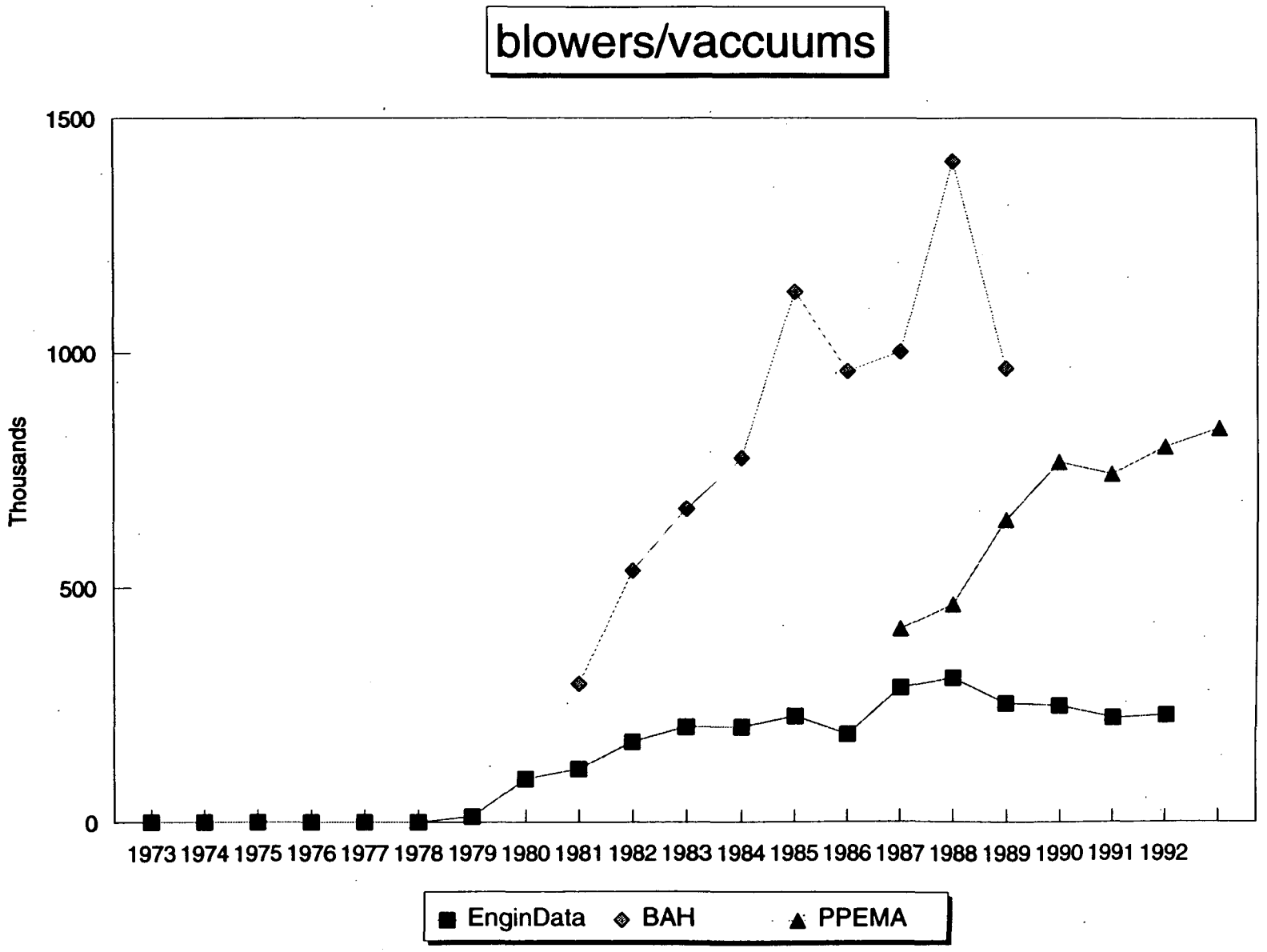

Chainsaws
Millions
4
3
2
1
0
1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992
EnginData
BAH
PPEMA

204

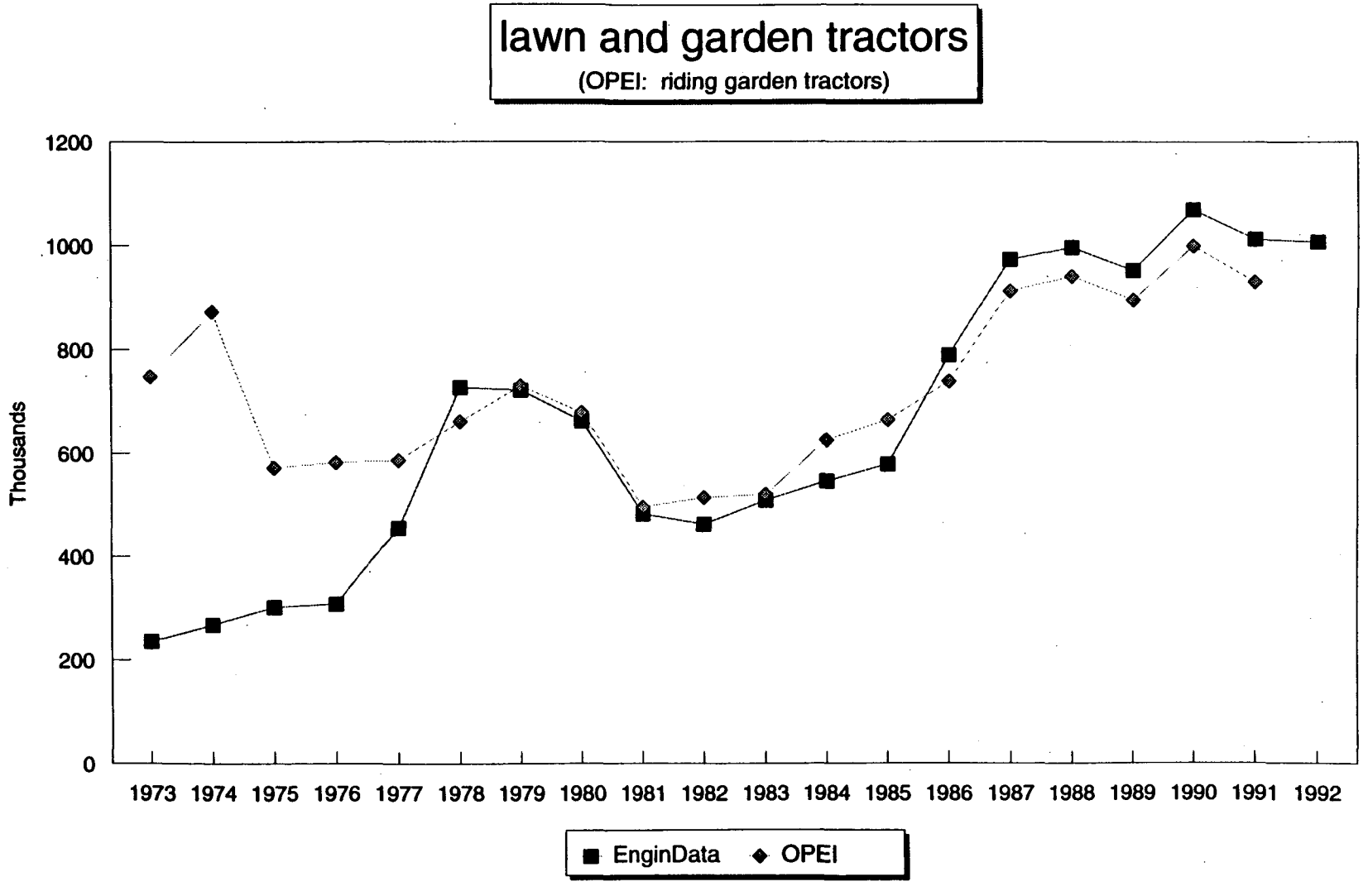

rear engine riders
500
400
300
200
100
0
Thousands
1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992
EnginData
OPEI

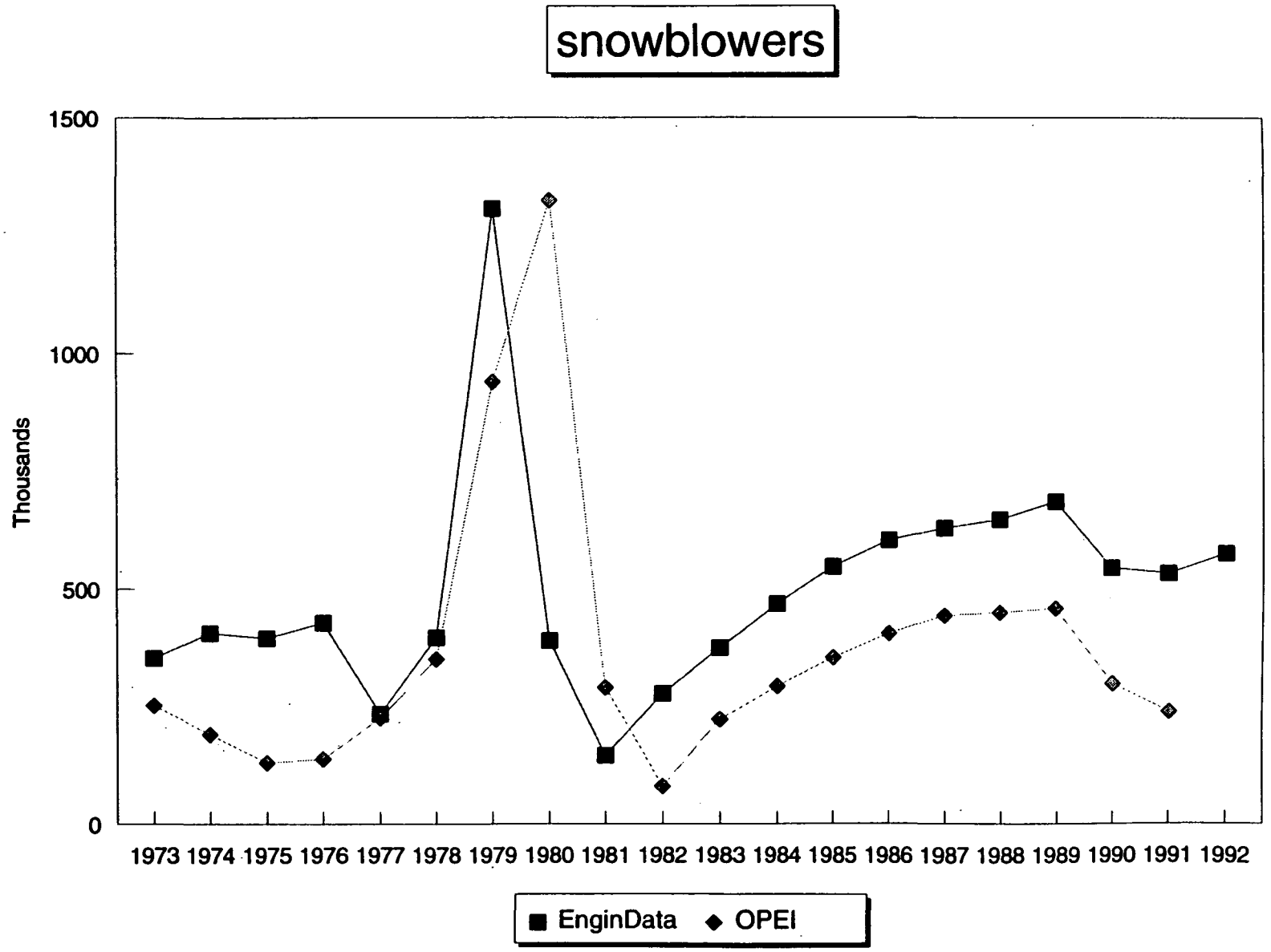

shredders/grinders/chippers
Thousands
100
80
60
40
20
0
1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992
EnginData
BAH

206

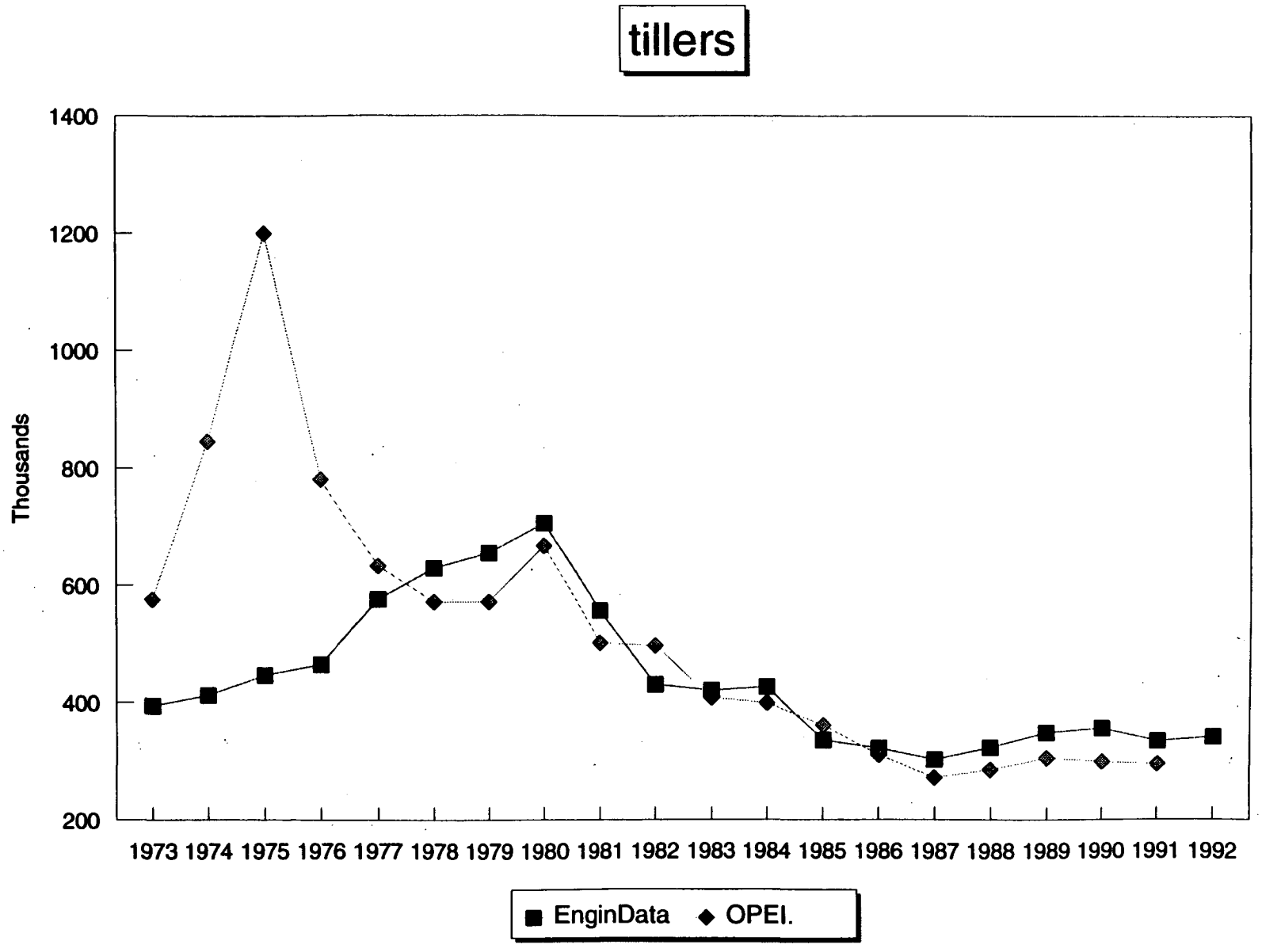

blowers/vaccuums
1500
1000
500
0
Thousands
1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992
EnginData
BAH
PPEMA

207


lawn and garden tractors
(OPEI: riding garden tractors)
Thousands
1200
1000
800
600
400
200
0
1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992
EnginData
OPEI

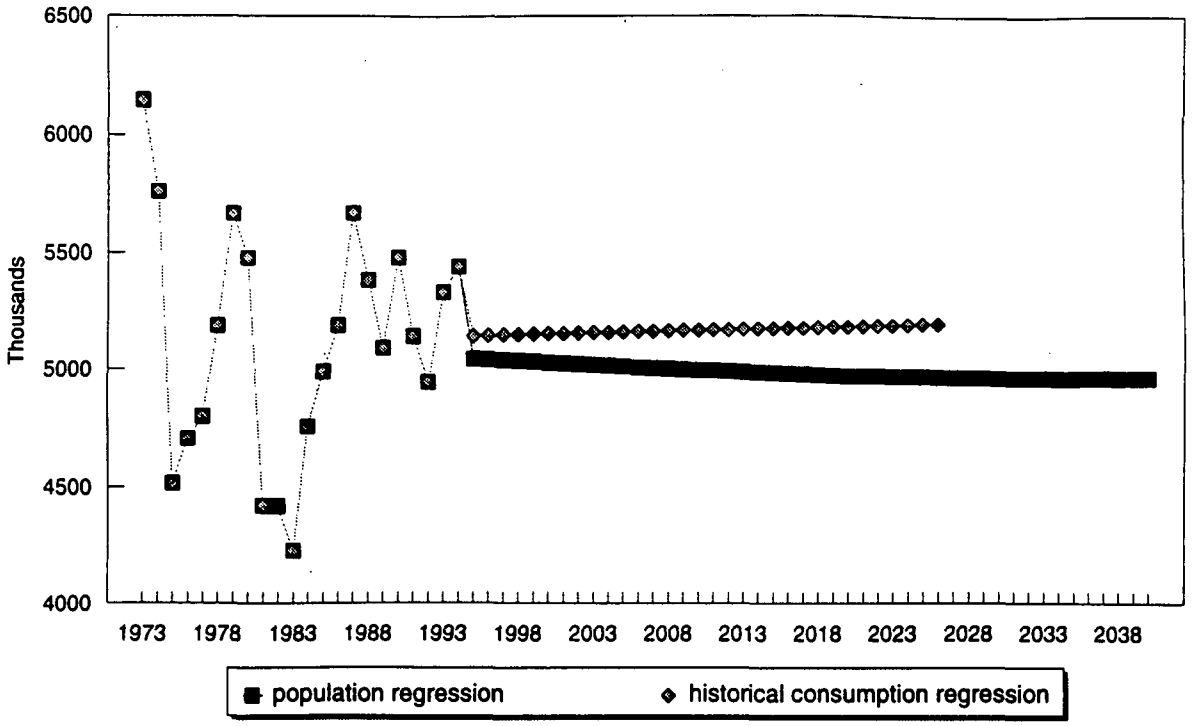

snowblowers
1500
1000
500
0
Thousands
1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992
EnginData
OPEI

209

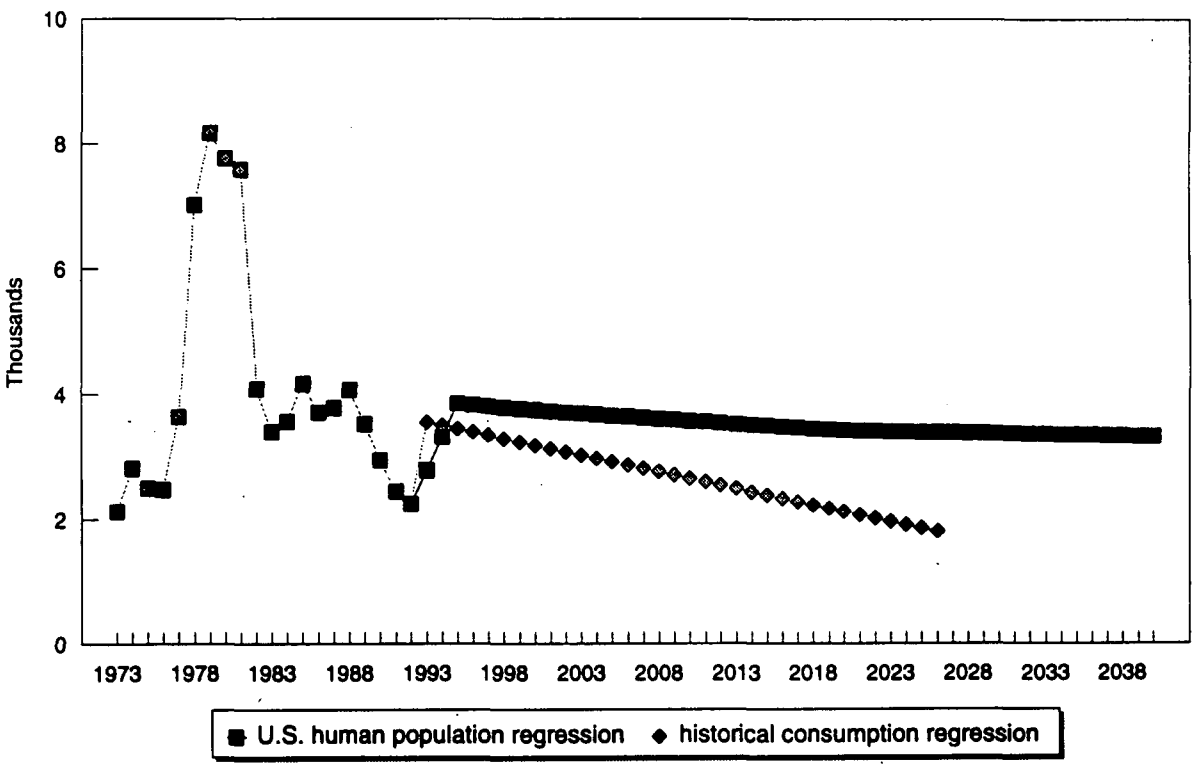

tillers
1400
1200
1000
800
600
400
200
Thousands
1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992
EnginData
OPEI.

210

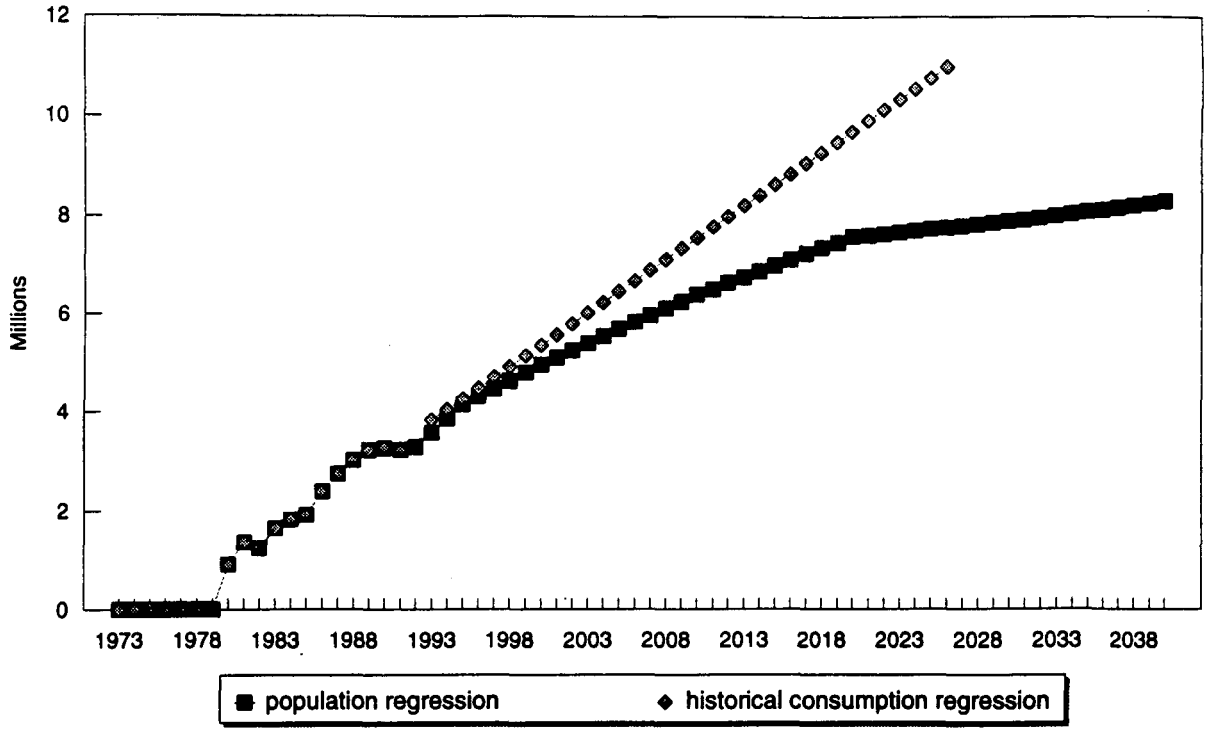
LAWNMOWER CONSUMPTION ESTIMATION



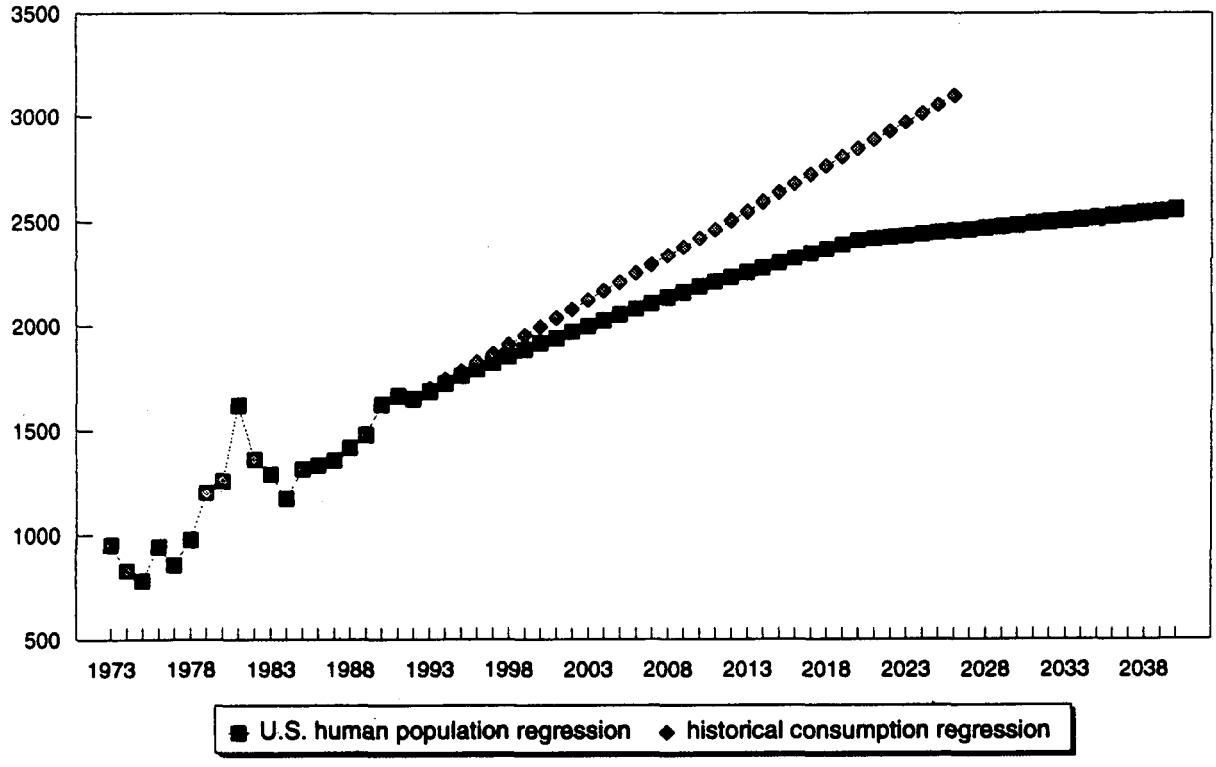
trenchers



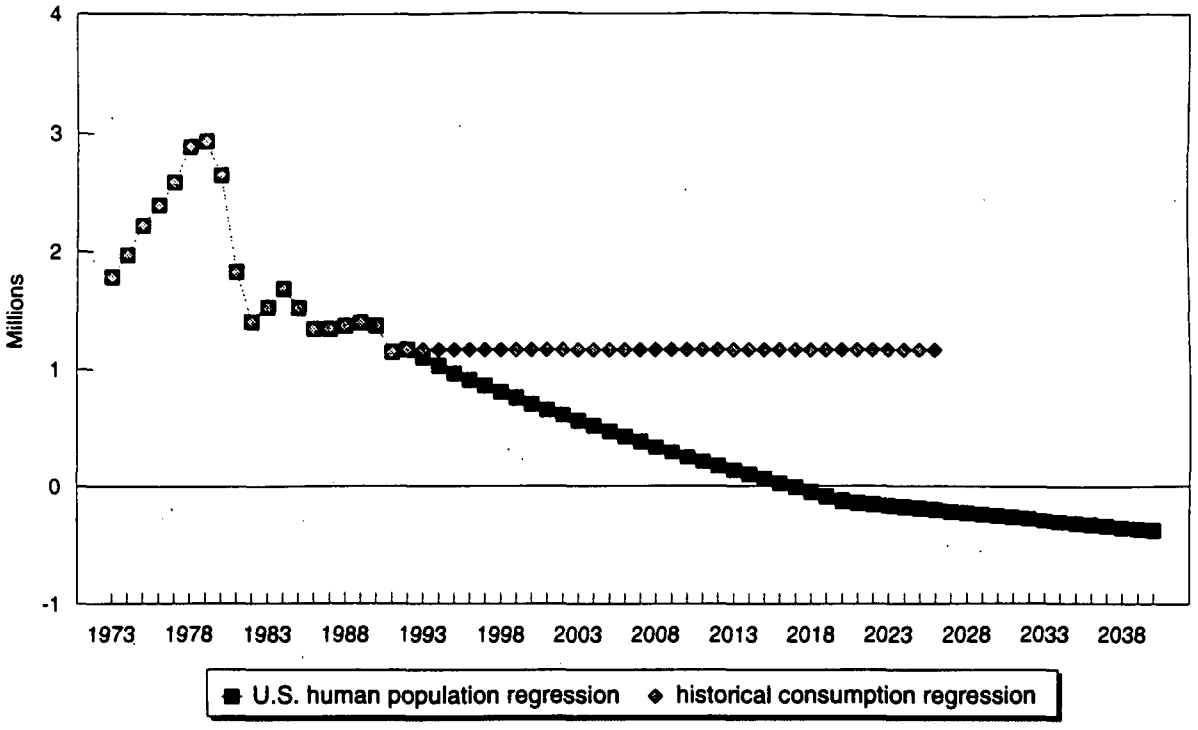
trimmers/edgers/cutters consumption estimate



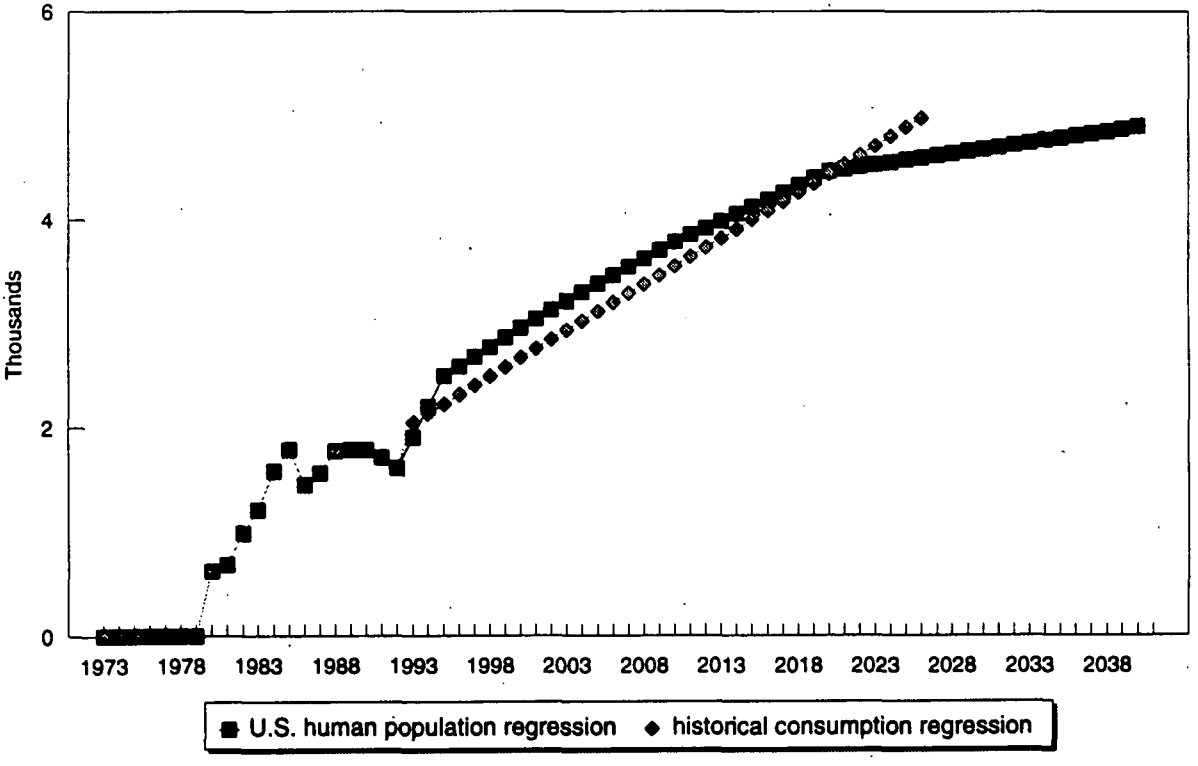
dumpers/tenders



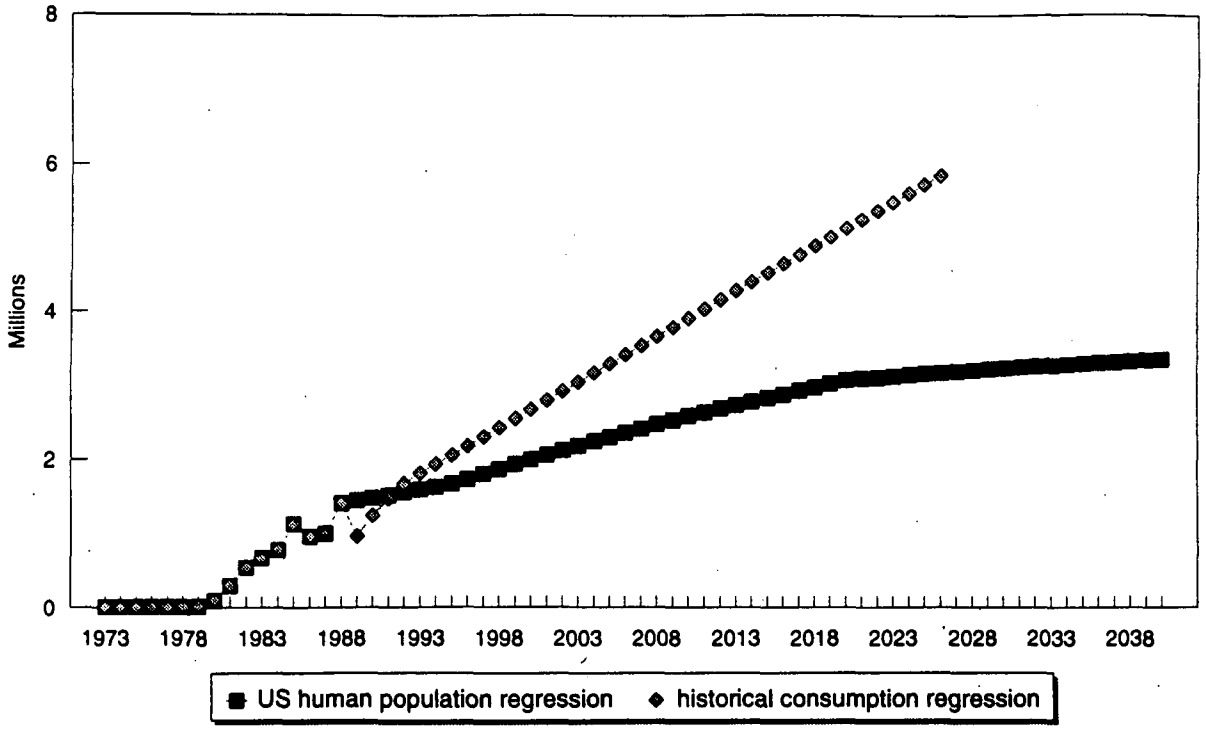
chainsaw consumption estimation



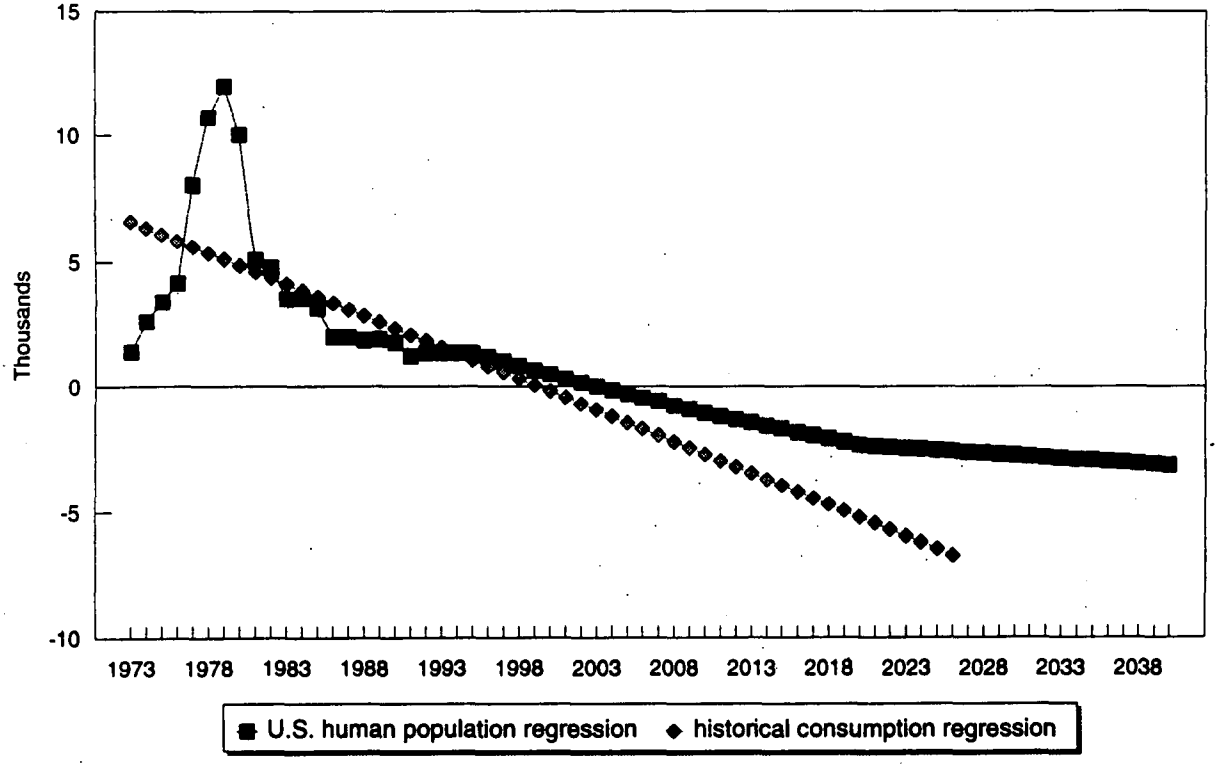
railway maintenance equipment



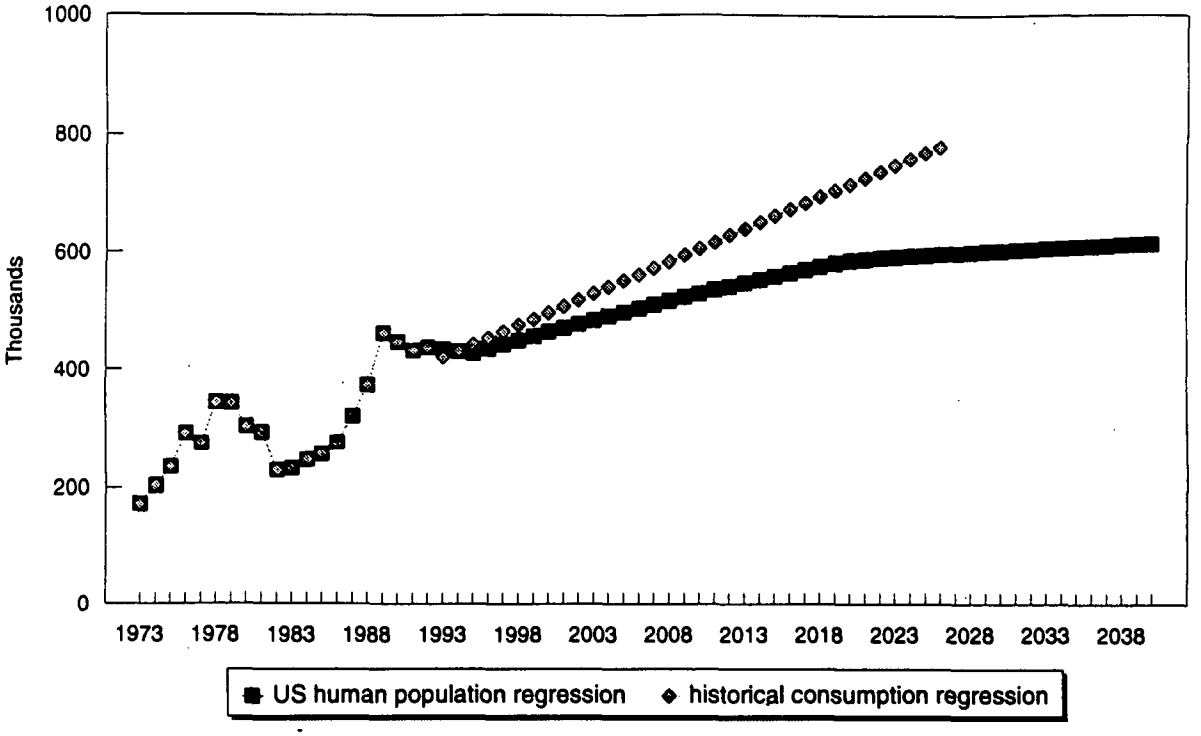
leafblower consumption estimation



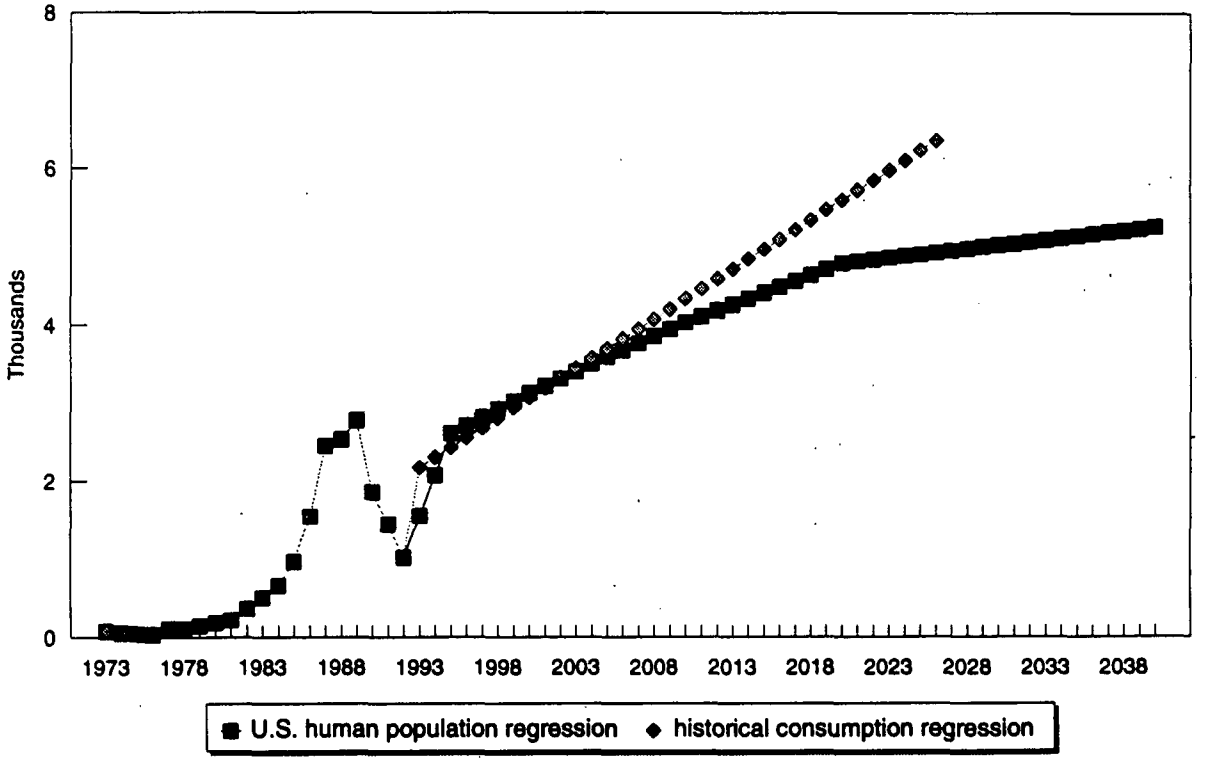
skid steer loaders

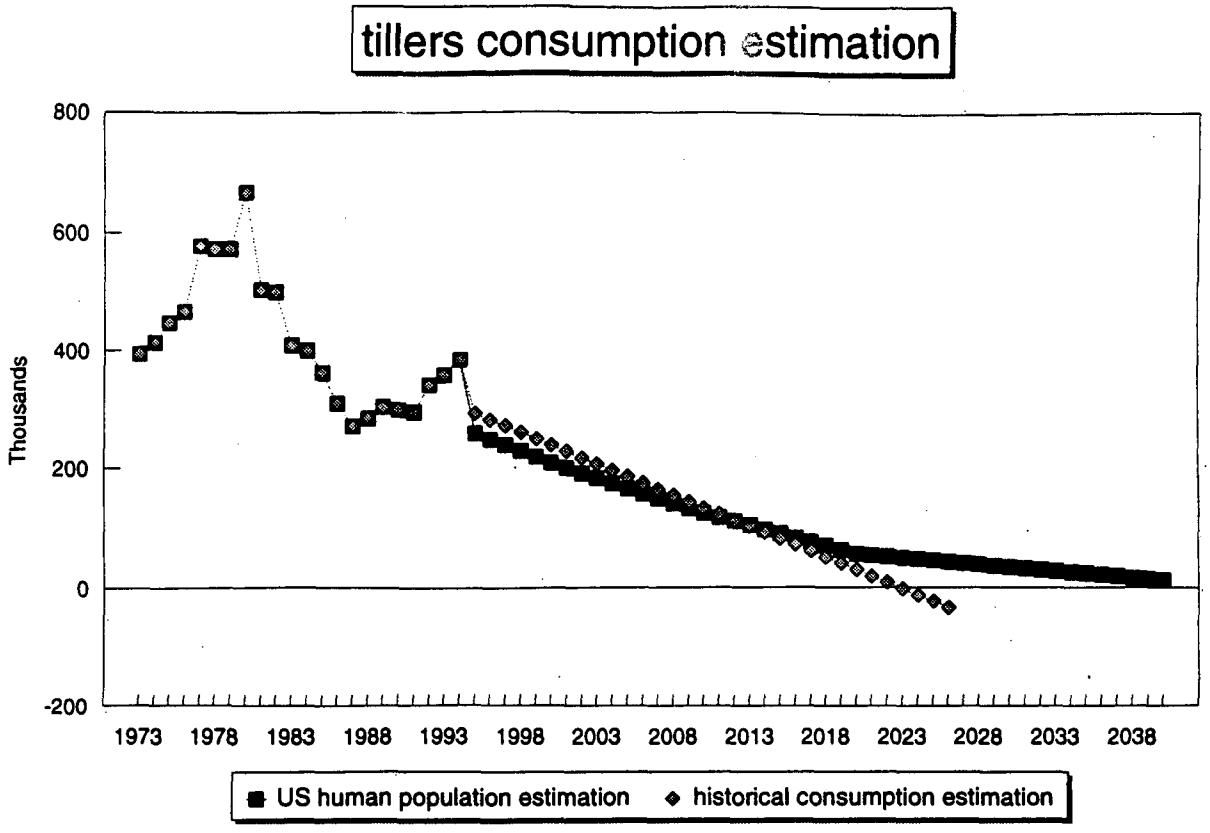


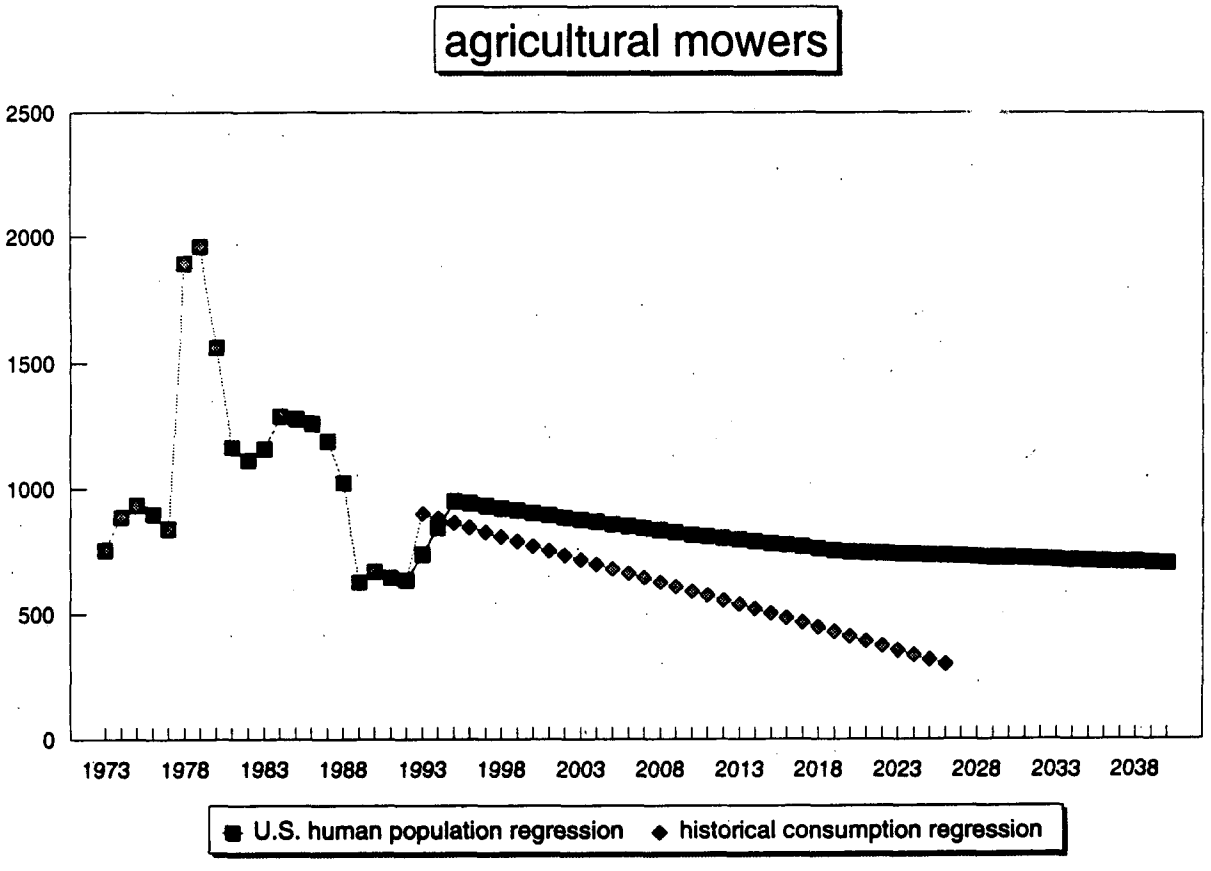
generator set consumption estimation



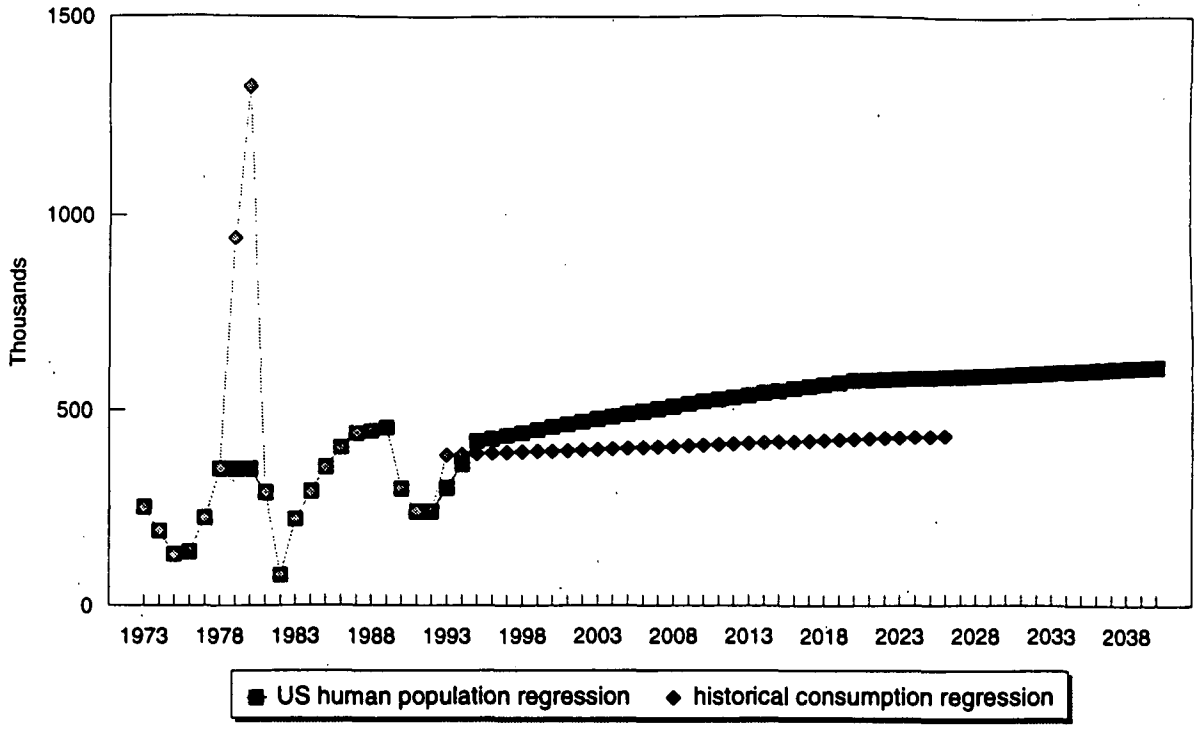
aerial lifts



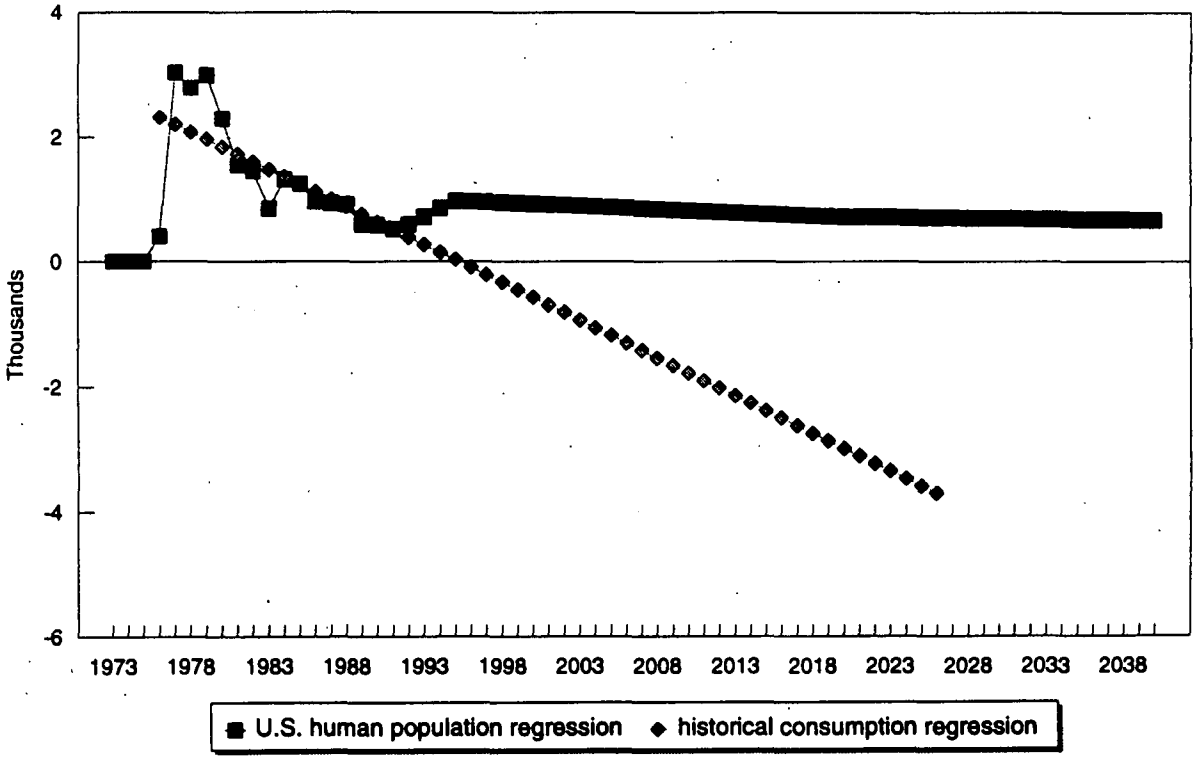

tillers consumption estimation
800
600
400
200
0
-200
Thousands
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
US human population estimation
historical consumption estimation

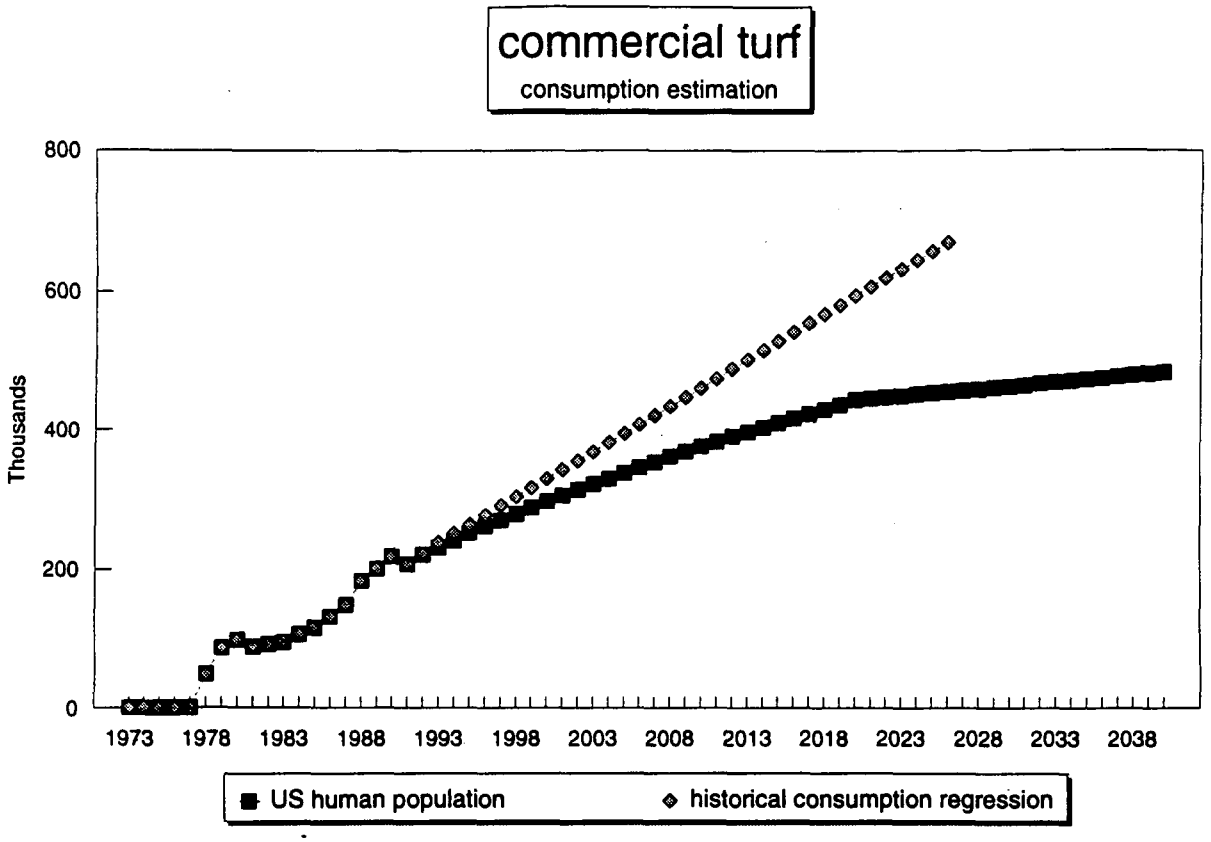

agricultural mowers
2500
2000
1500
1000
500
0
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
U.S. human population regression
historical consumption regression

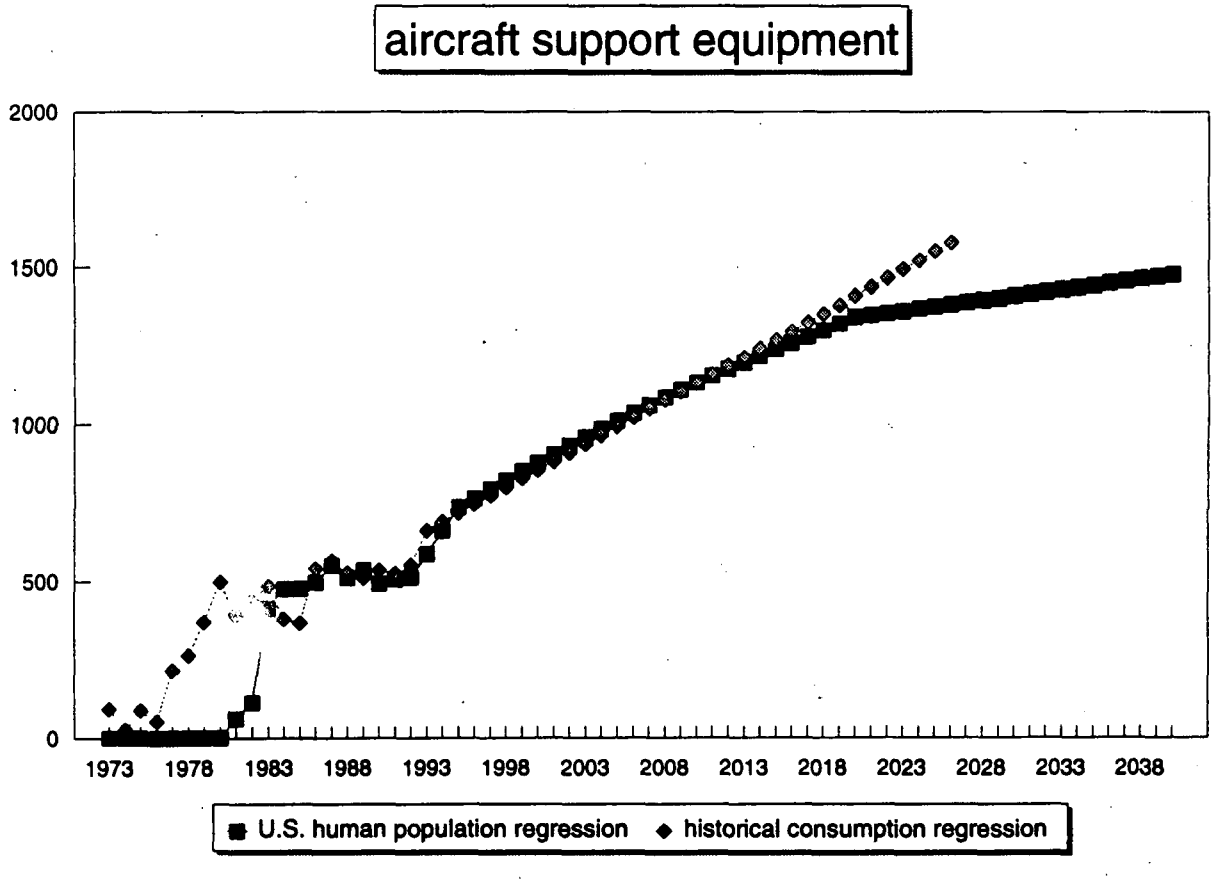
snowblower consumption estimation

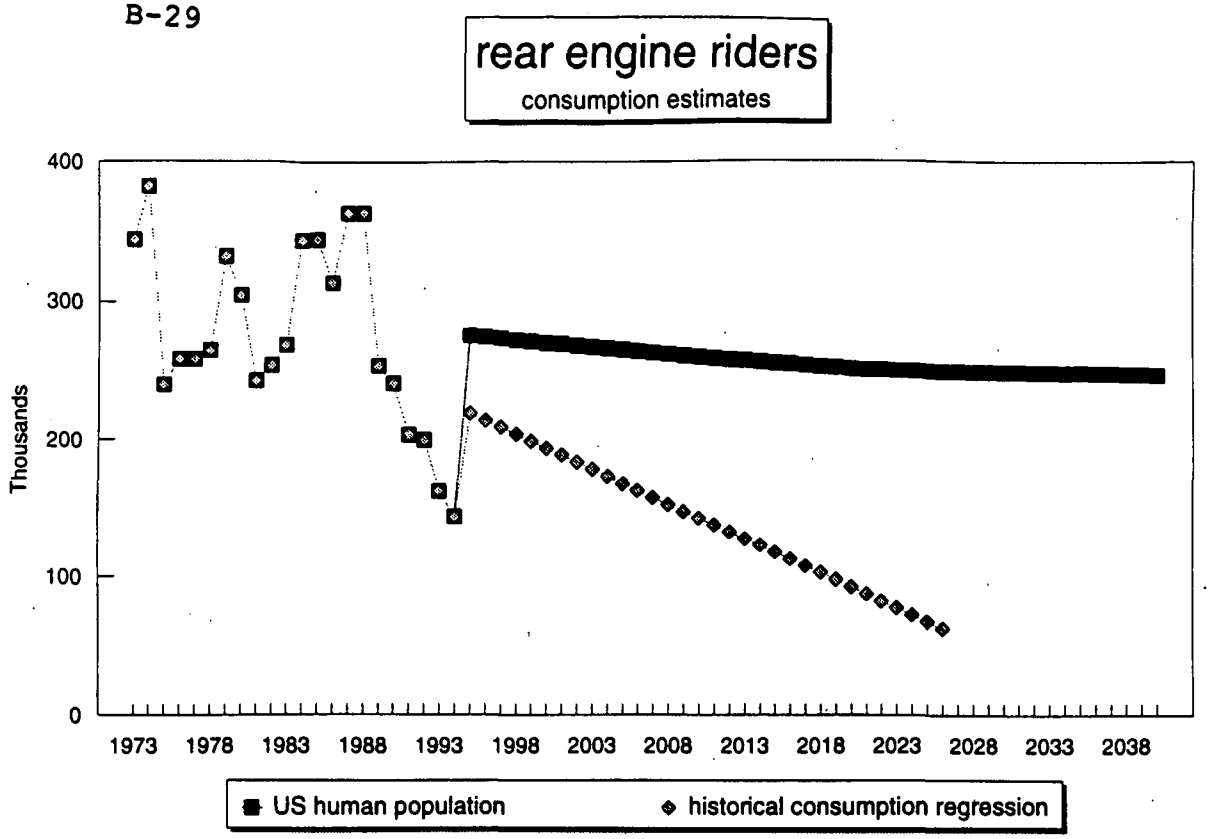


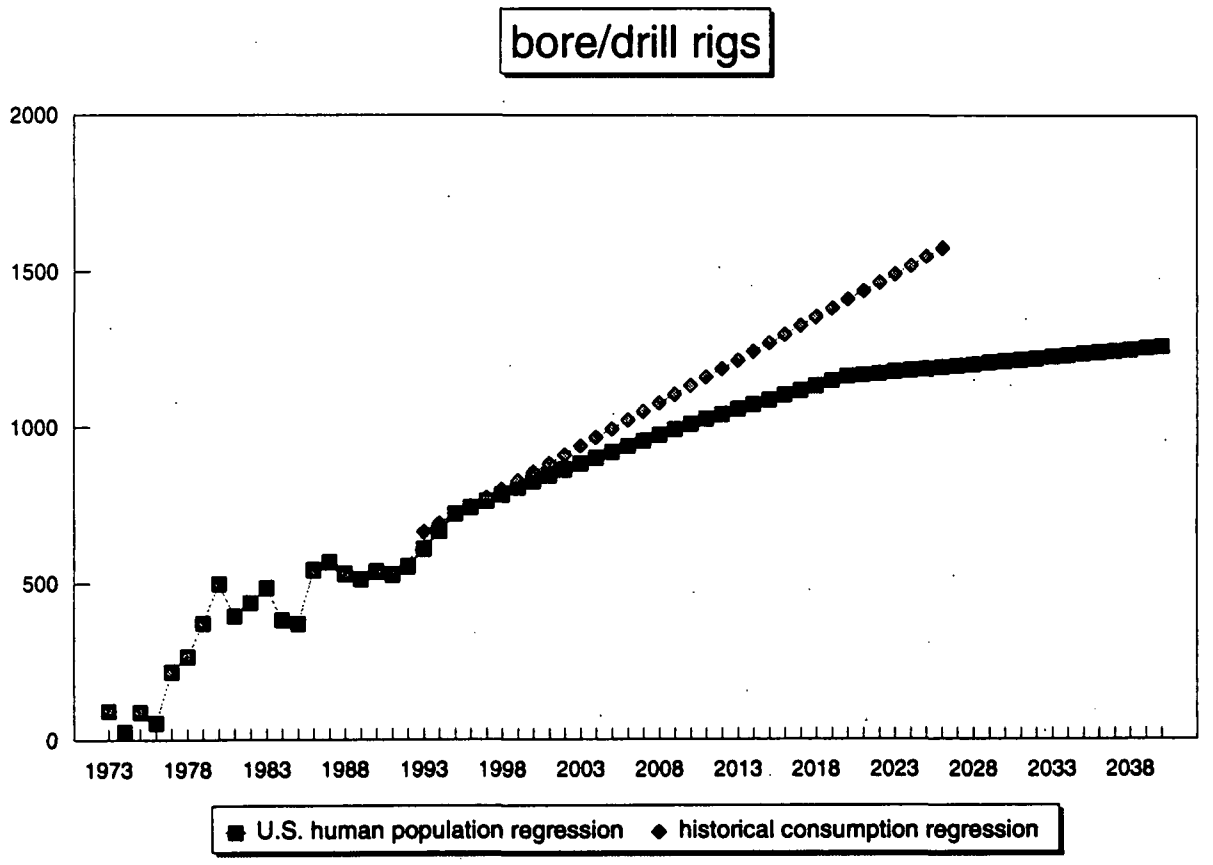
refrigeration/ac equipment

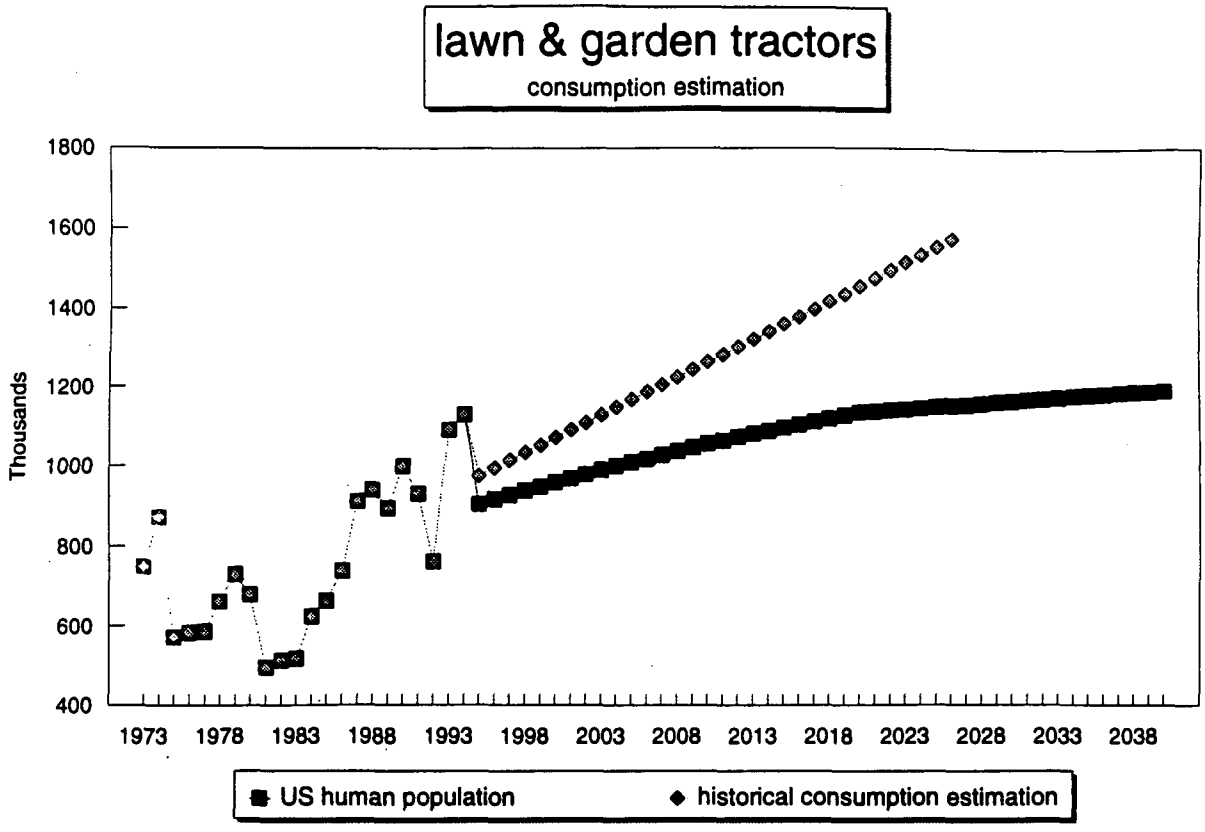


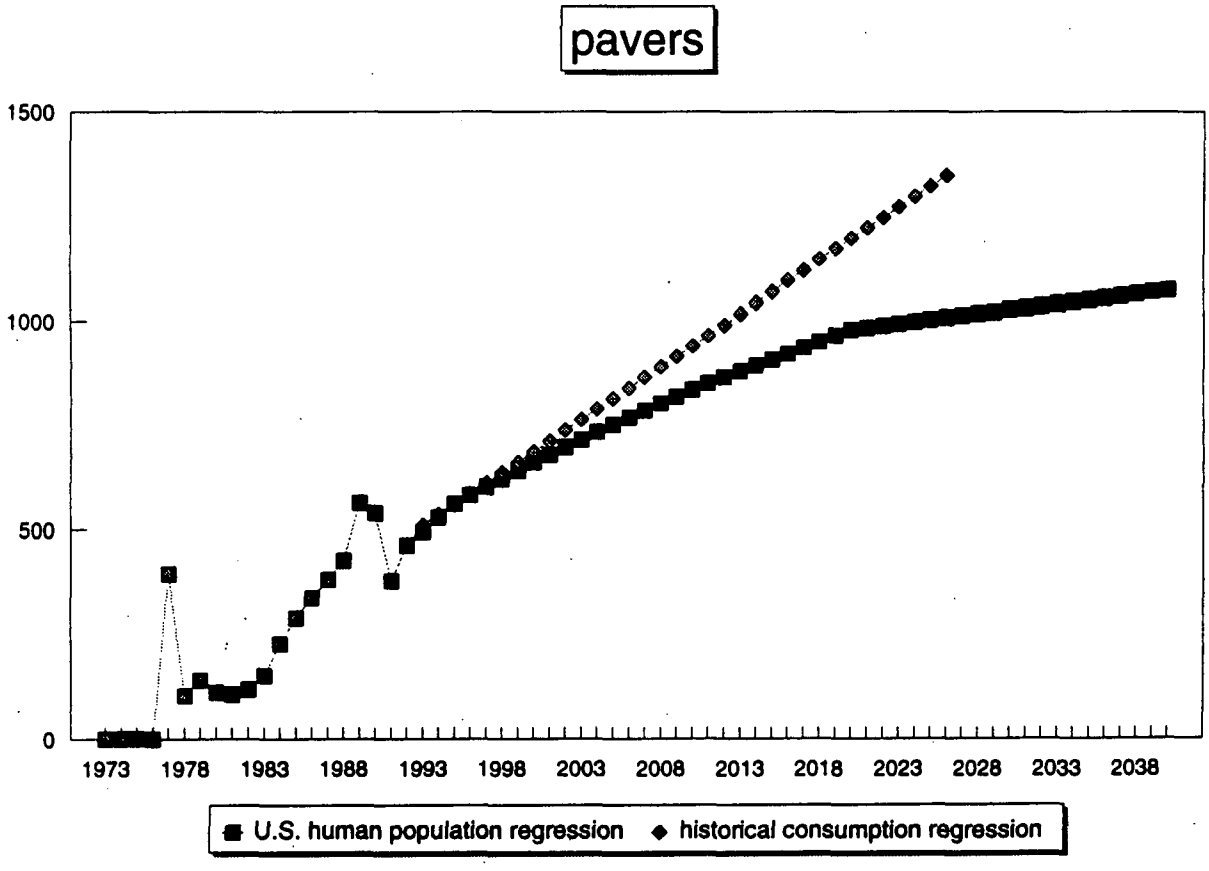

commercial turf
consumption estimation
Thousands
800
600
400
200
0
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
US human population
historical consumption regression

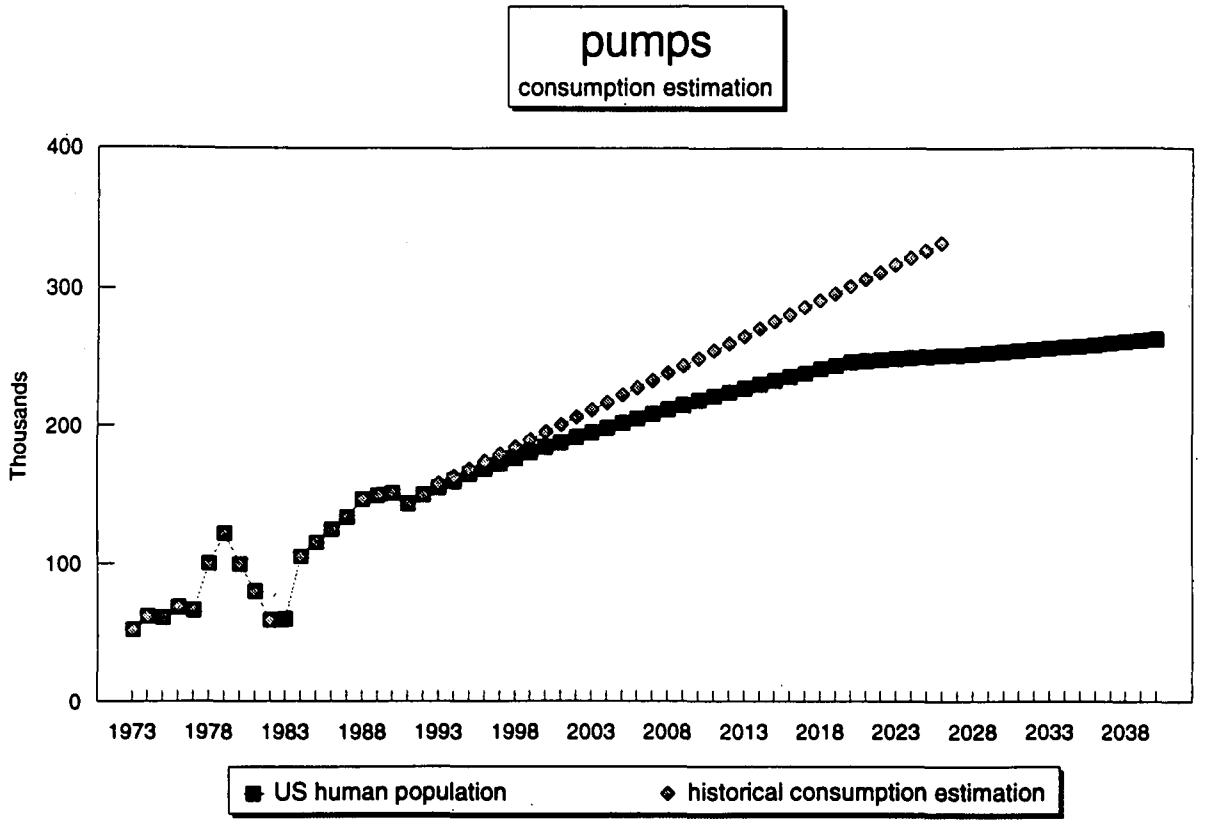

aircraft support equipment
2000
1500
1000
500
0
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
U.S. human population regression
historical consumption regression

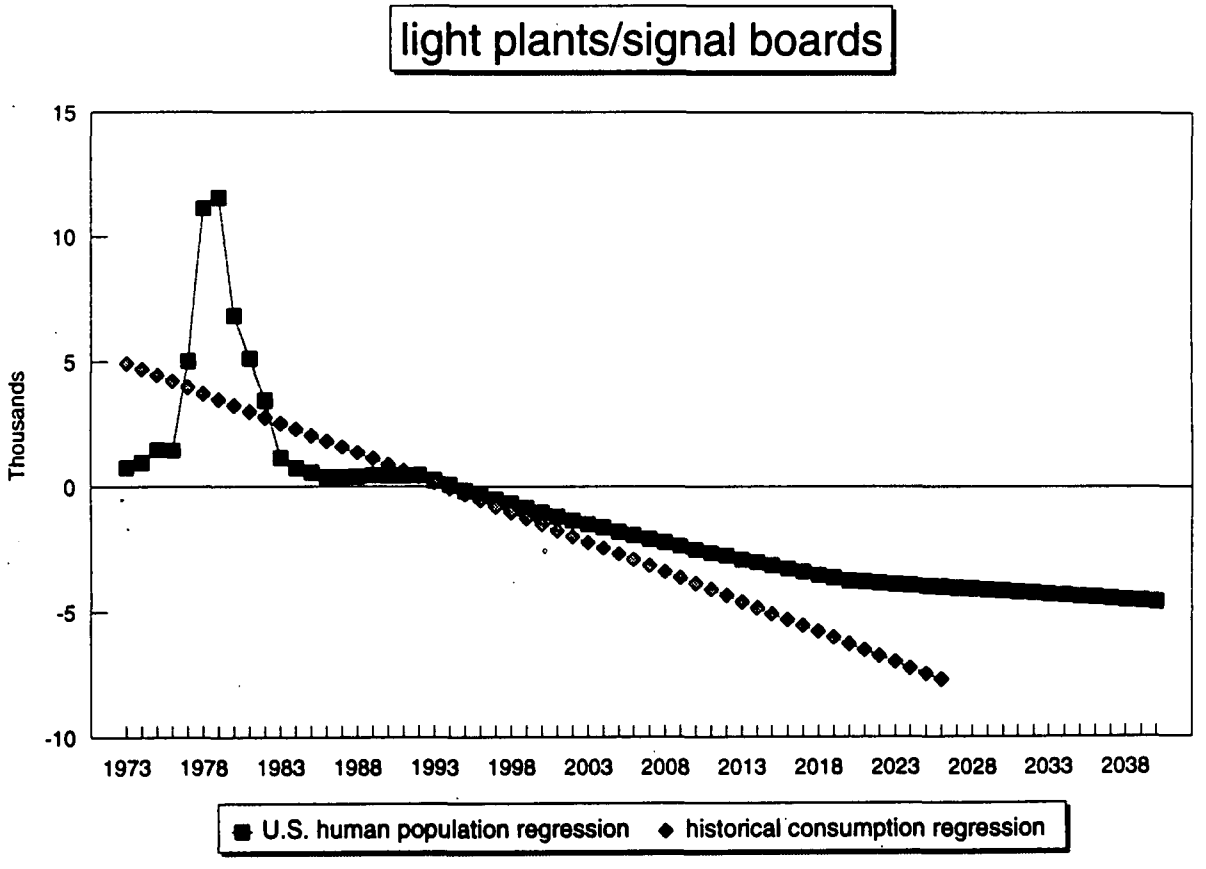

rear engine riders
consumption estimates
Thousands
400
300
200
100
0
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
US human population
historical consumption regression

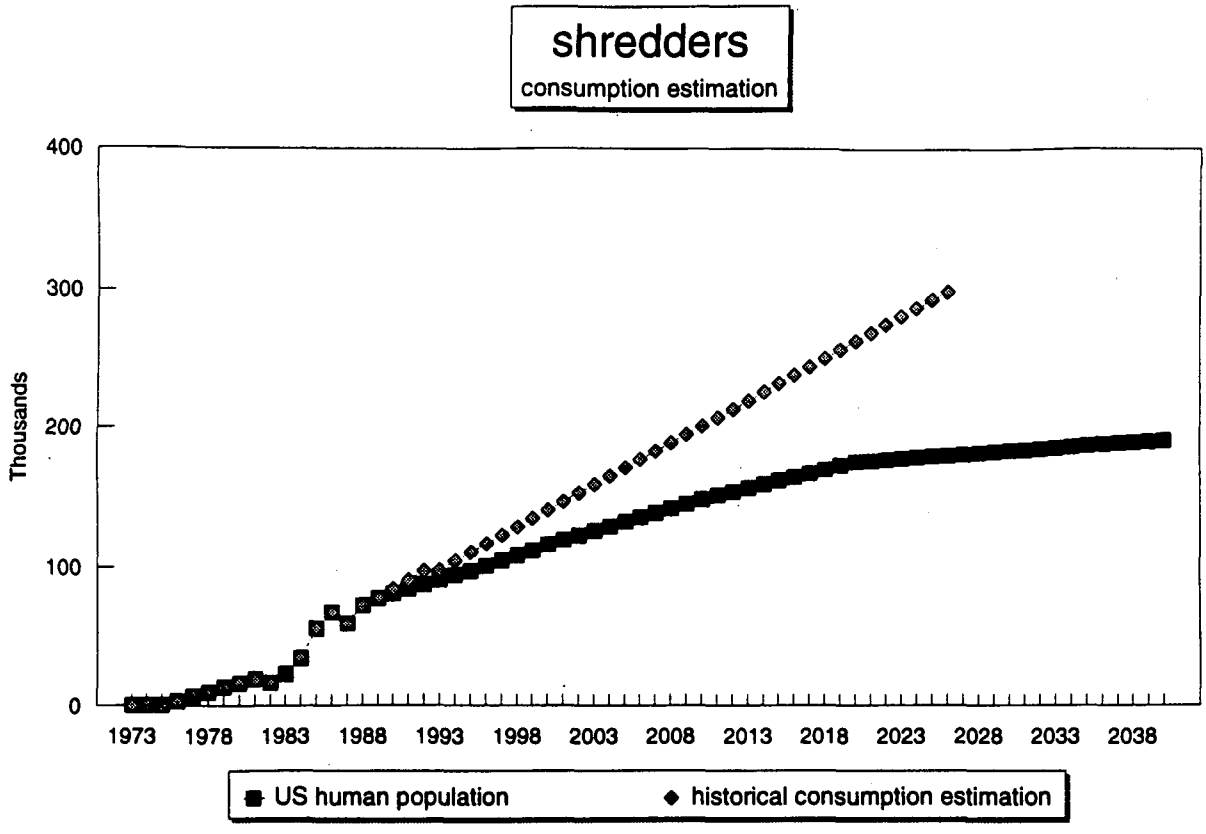

bore/drill rigs
2000
1500
1000
500
0
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
U.S. human population regression
historical consumption regression

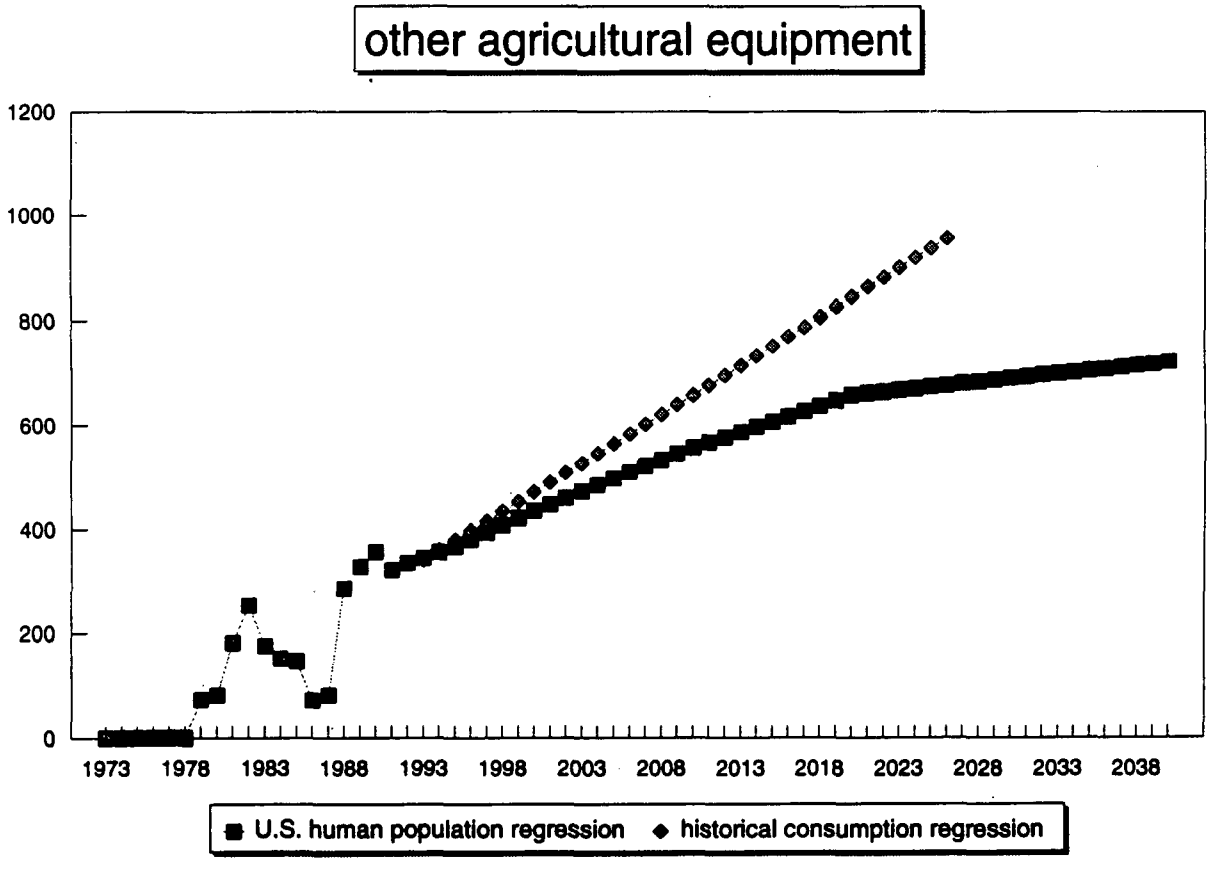

lawn & garden tractors
consumption estimation
Thousands
1800
1600
1400
1200
1000
800
600
400
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
US human population
historical consumption estimation

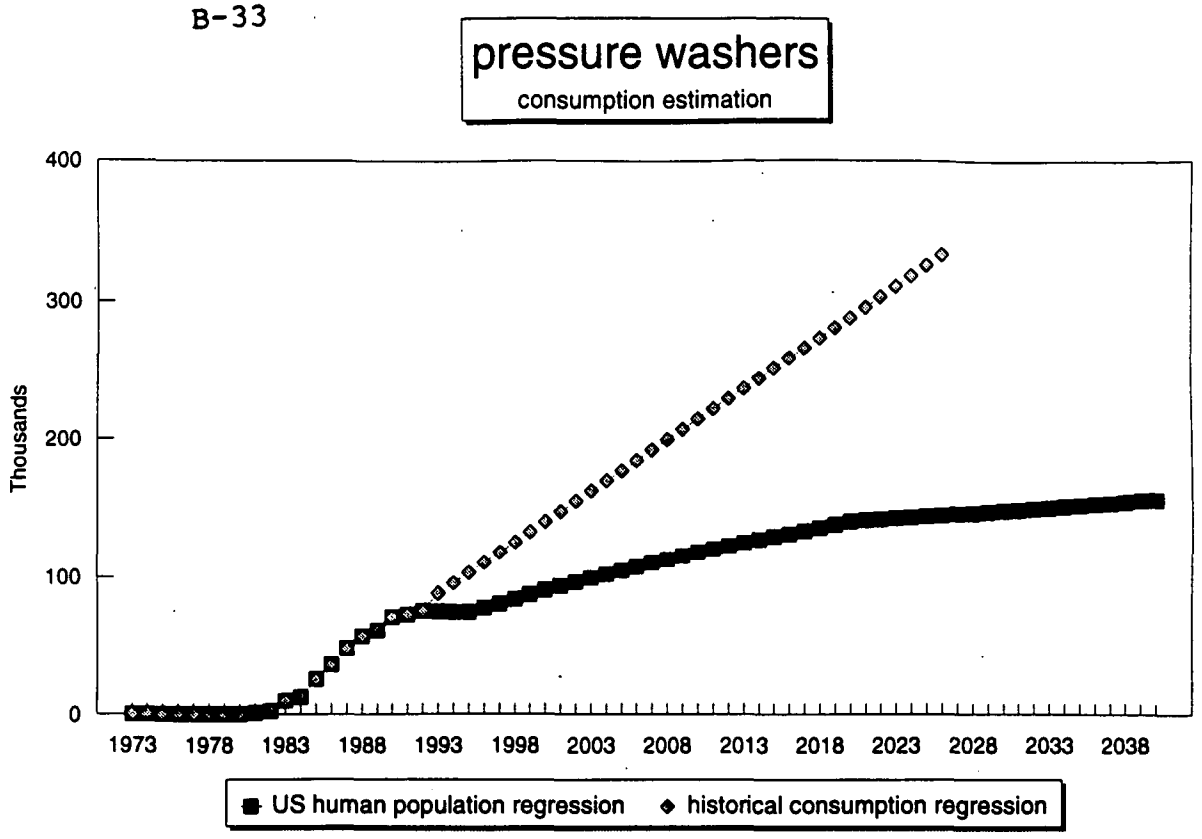

pavers
1500
1000
500
0
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
U.S. human population regression
historical consumption regression

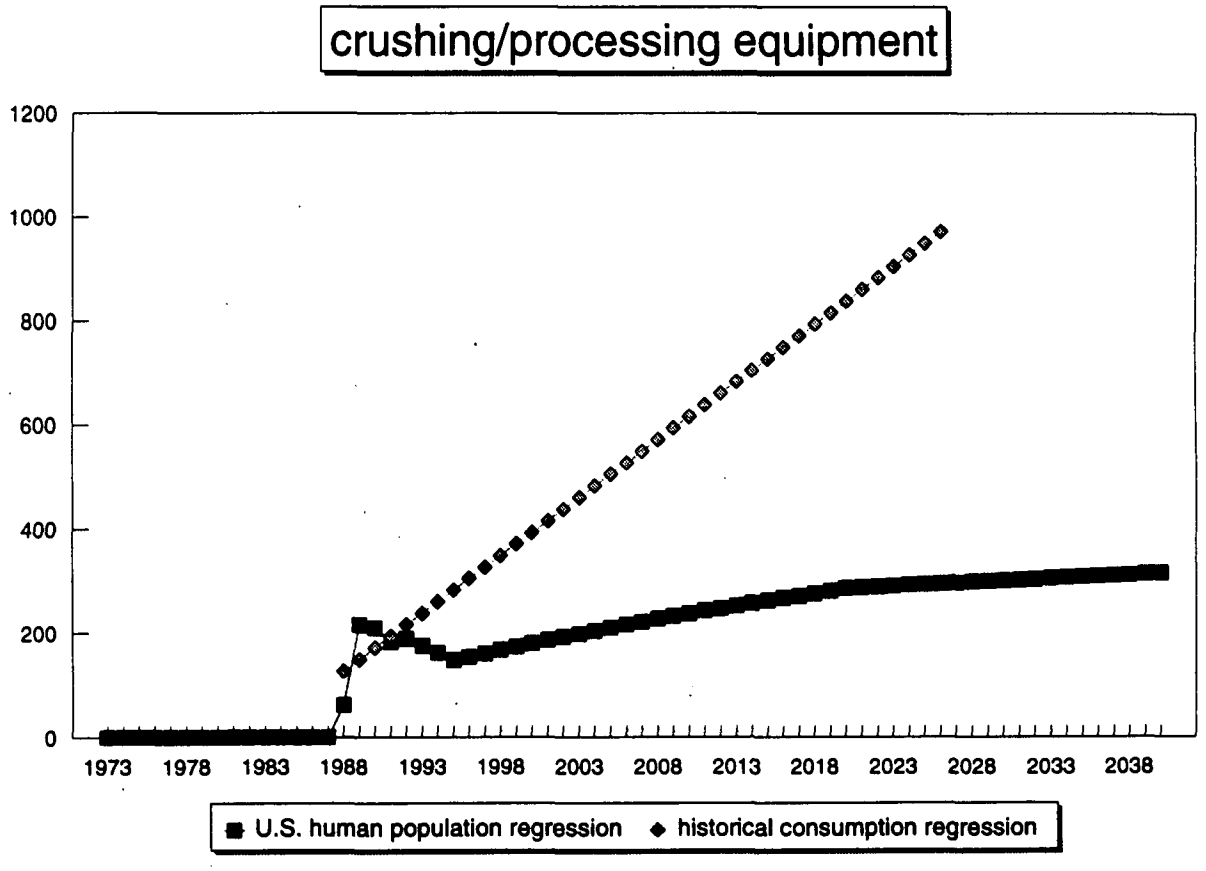

pumps
consumption estimation
400
300
200
100
0
Thousands
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
US human population
historical consumption estimation

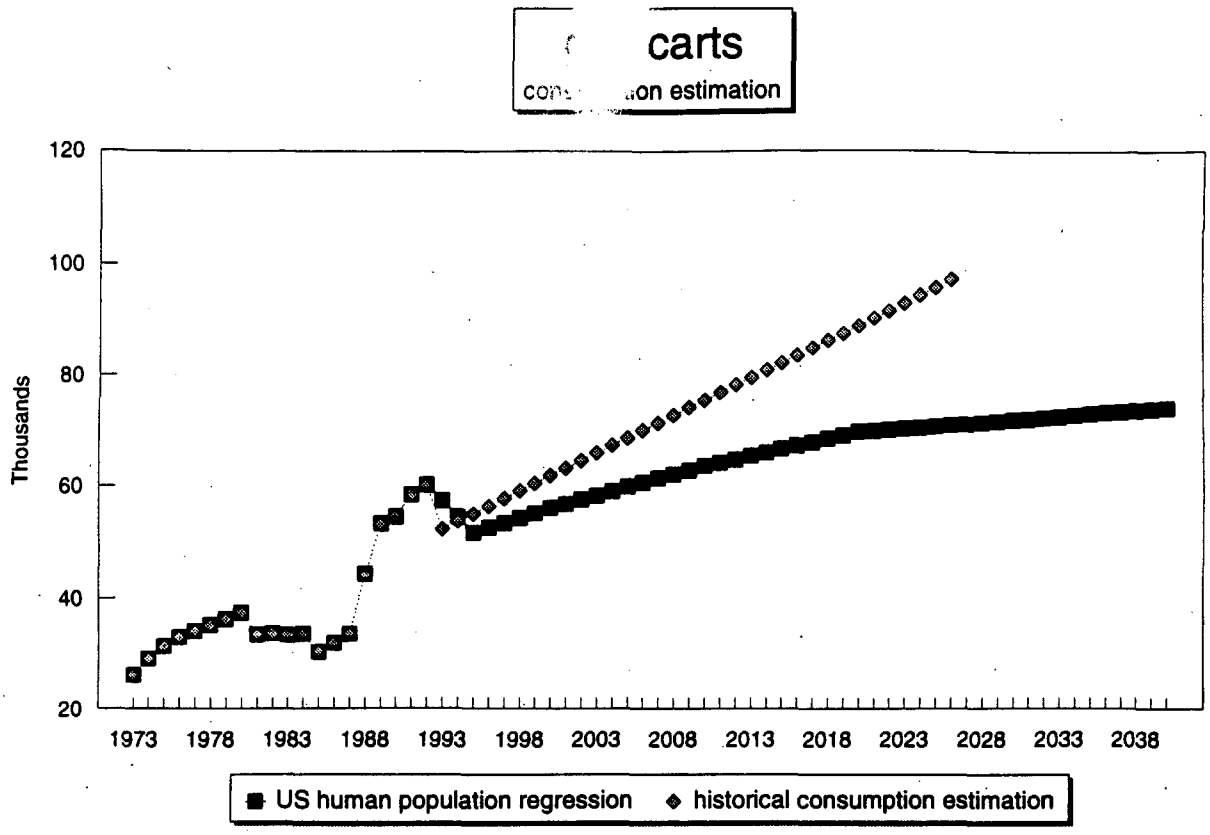

light plants/signal boards
15
10
5
0
-5
-10
Thousands
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
U.S. human population regression
historical consumption regression

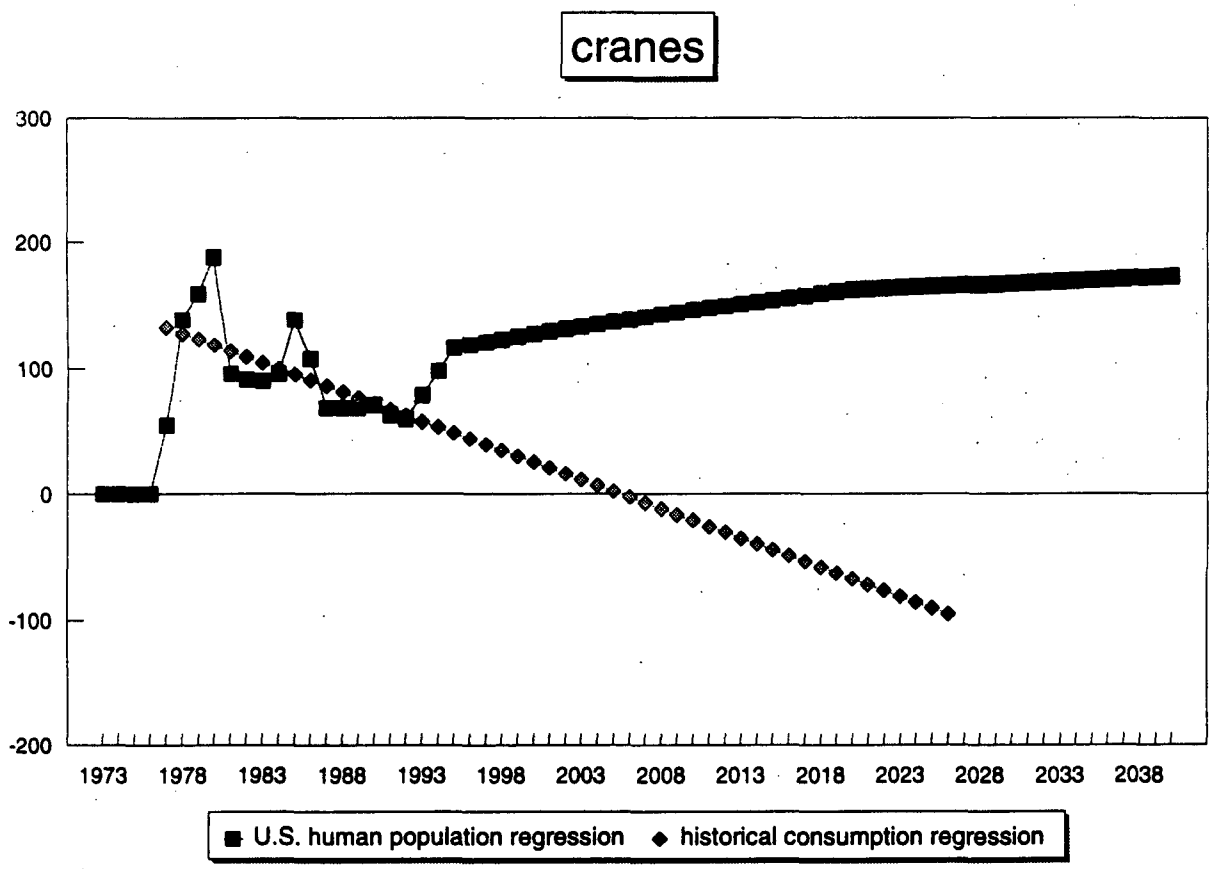

shredders
consumption estimation
Thousands
400
300
200
100
0
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
US human population
historical consumption estimation

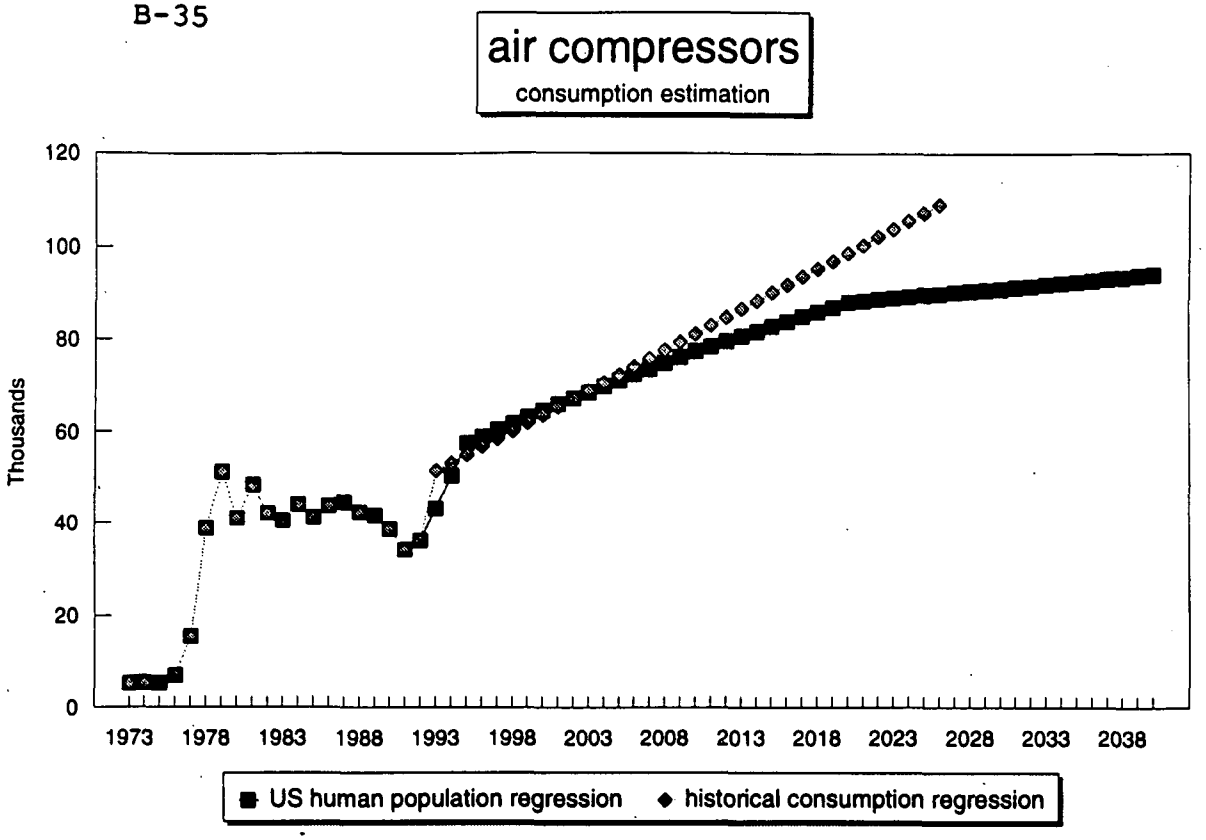

other agricultural equipment
1200
1000
800
600
400
200
0
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
U.S. human population regression
historical consumption regression

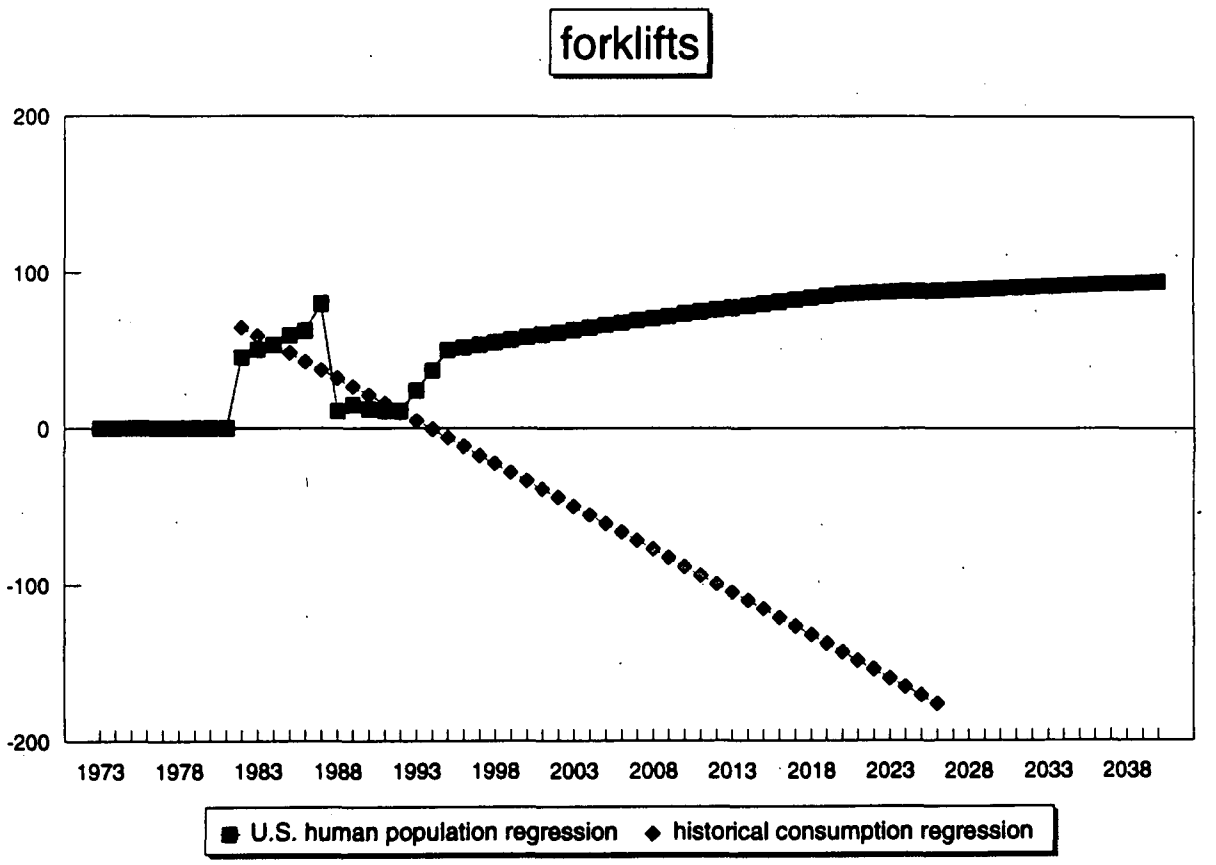

pressure washers
consumption estimation
Thousands
400
300
200
100
0
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
US human population regression
historical consumption regression


crushing/processing equipment
1200
1000
800
600
400
200
0
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
U.S. human population regression
historical consumption regression


carts
on estimation
120
100
80
60
40
20
Thousands
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
US human population regression
historical consumption estimation


cranes
300
200
100
0
-100
-200
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
U.S. human population regression
historical consumption regression


air compressors
consumption estimation
Thousands
120
100
80
60
40
20
0
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
US human population regression
historical consumption regression


forklifts
200
100
0
-100
-200
1973
1978
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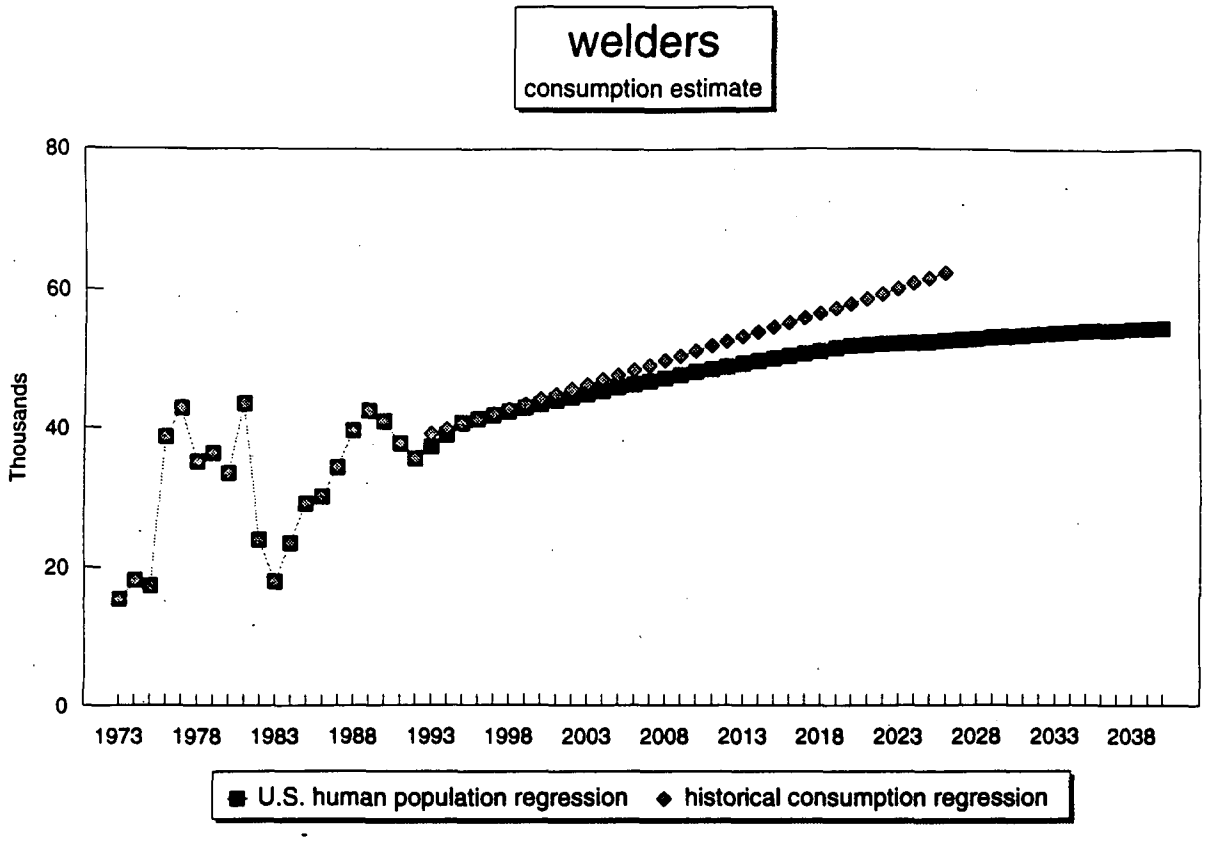
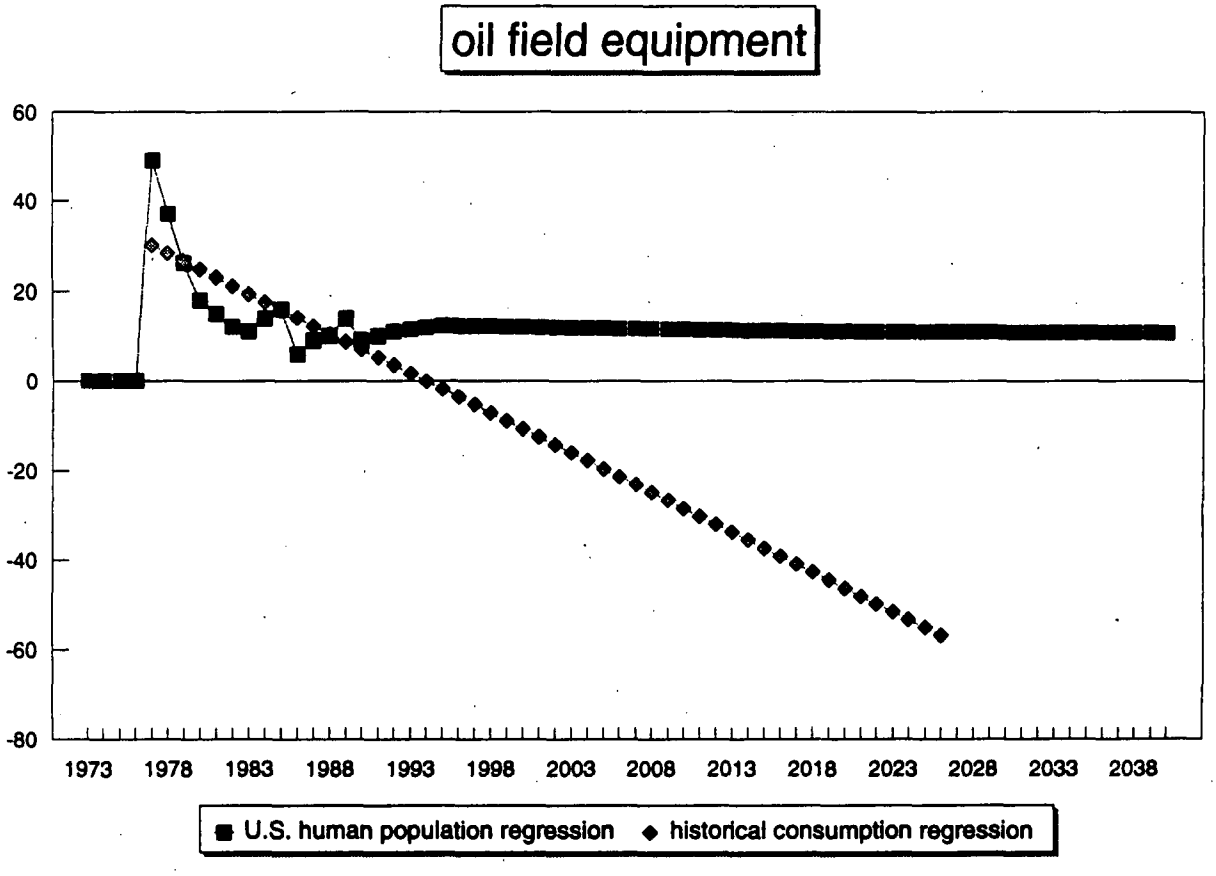
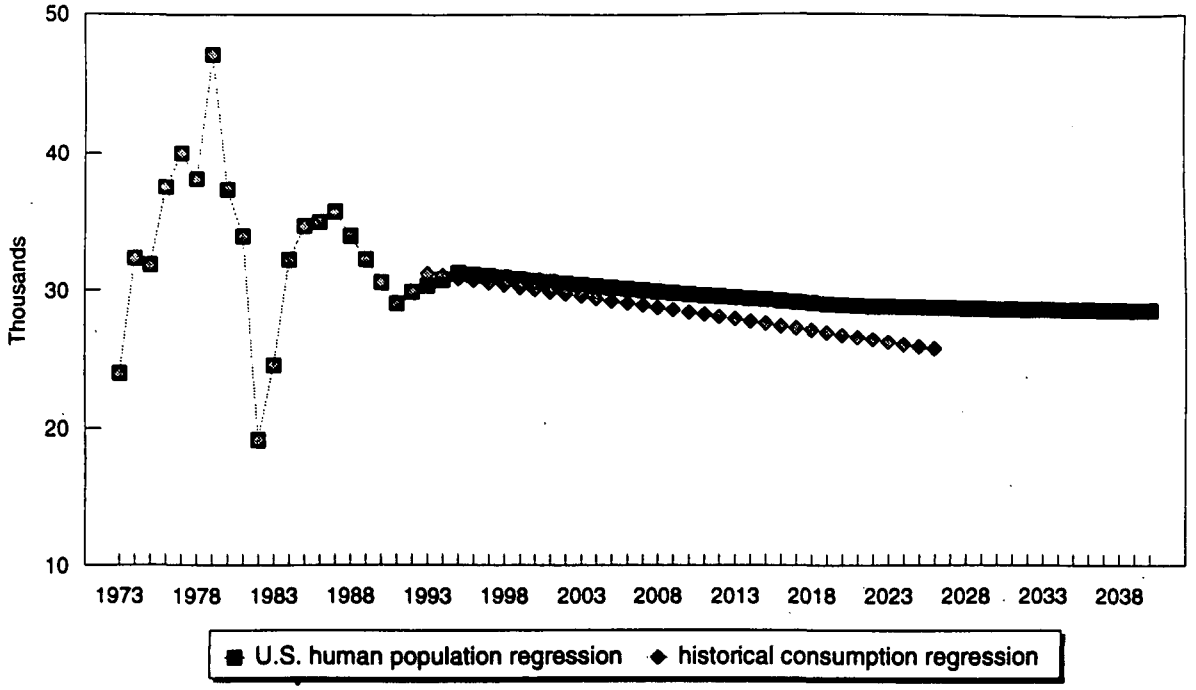
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
U.S. human population regression
historical consumption regression

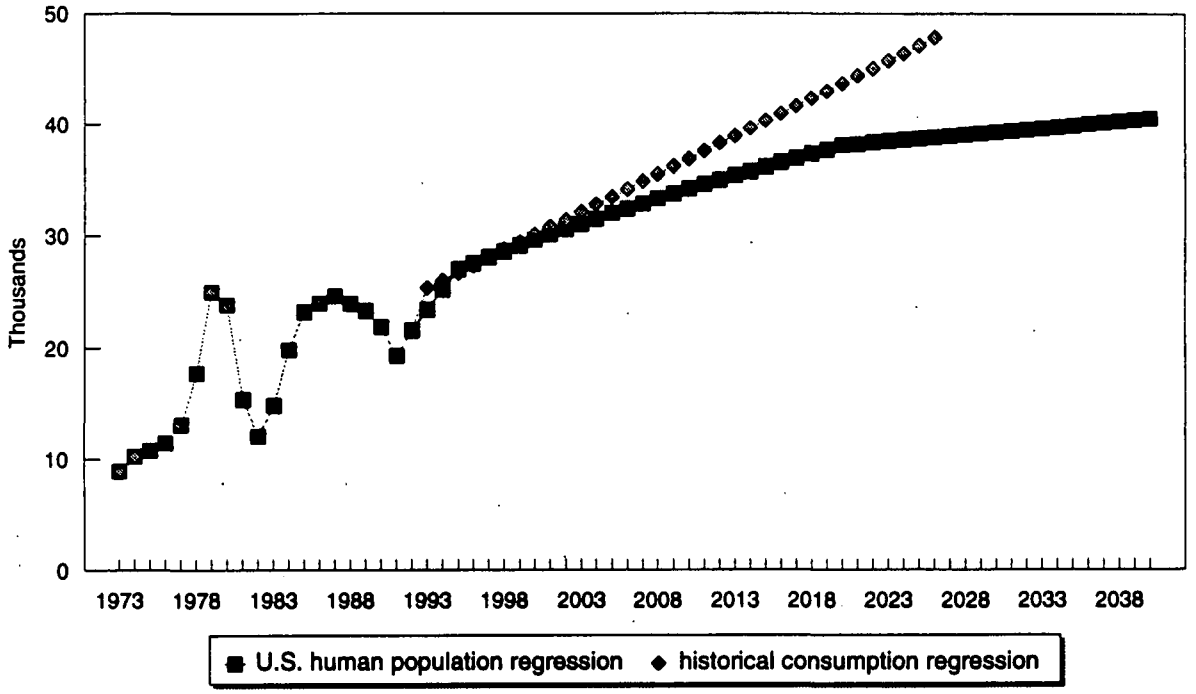

welders
consumption estimate
Thousands
80
60
40
20
0
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
U.S. human population regression
historical consumption regression


oil field equipment
60
40
20
0
-20
-40
-60
-80
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
U.S. human population regression
historical consumption regression

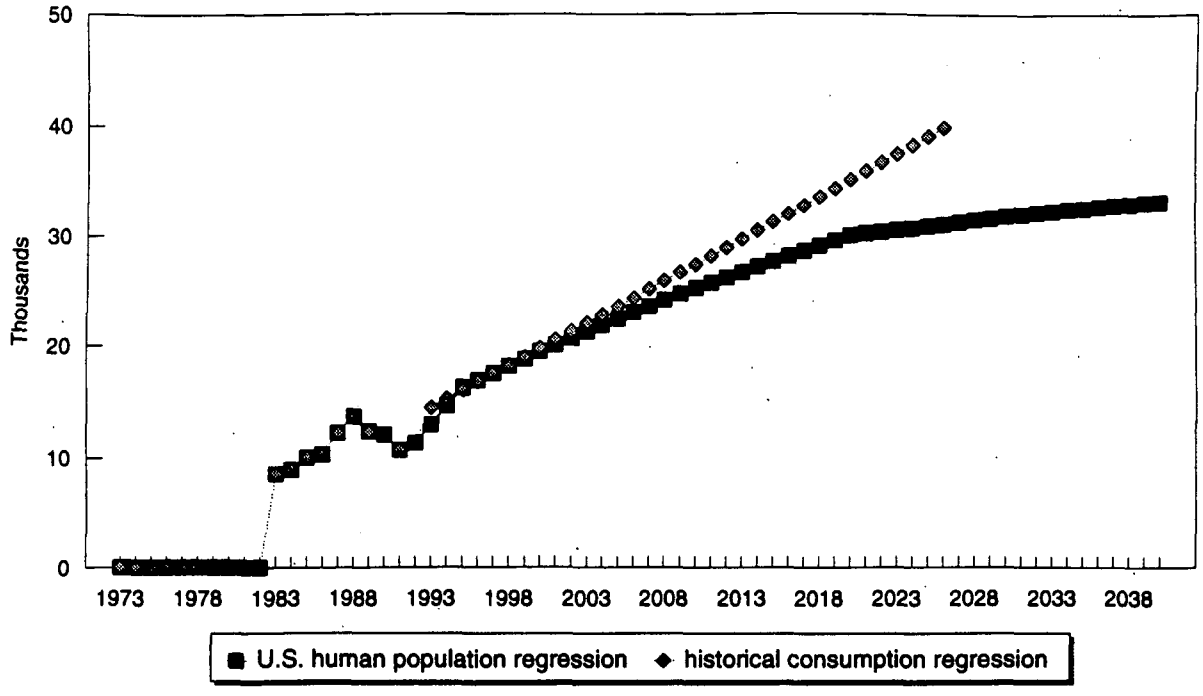
other lawn and garden equipment
consumption estimation



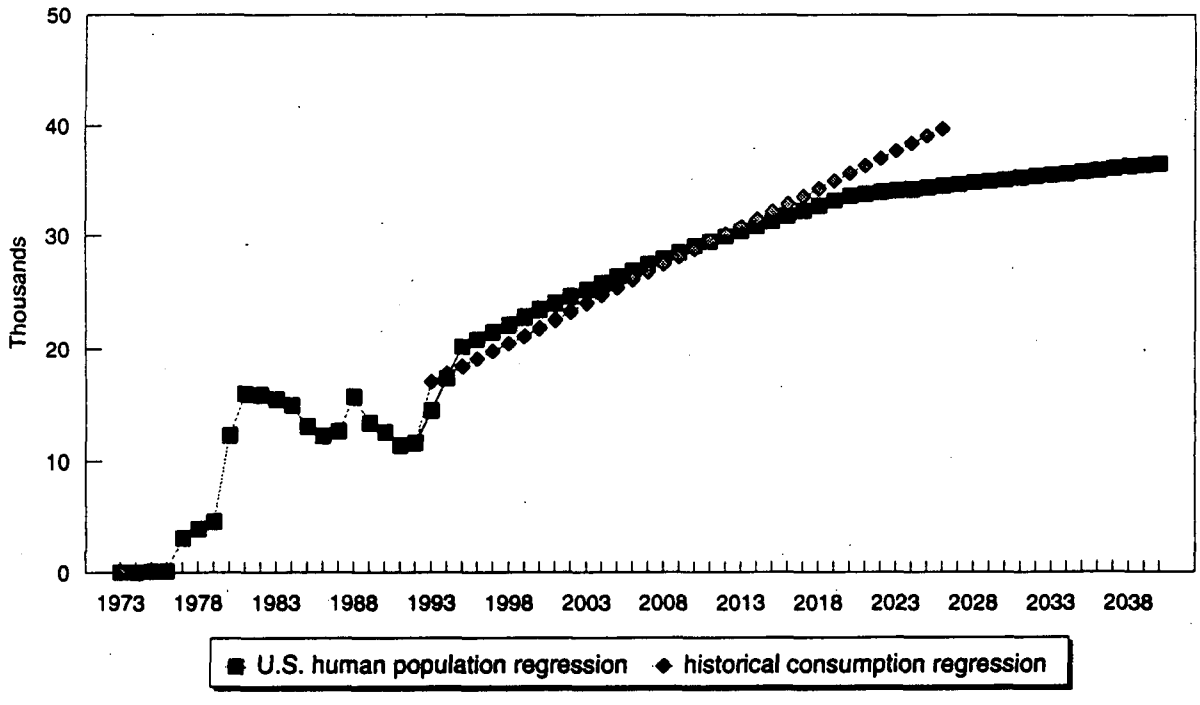
paving equipment
consumption estimation

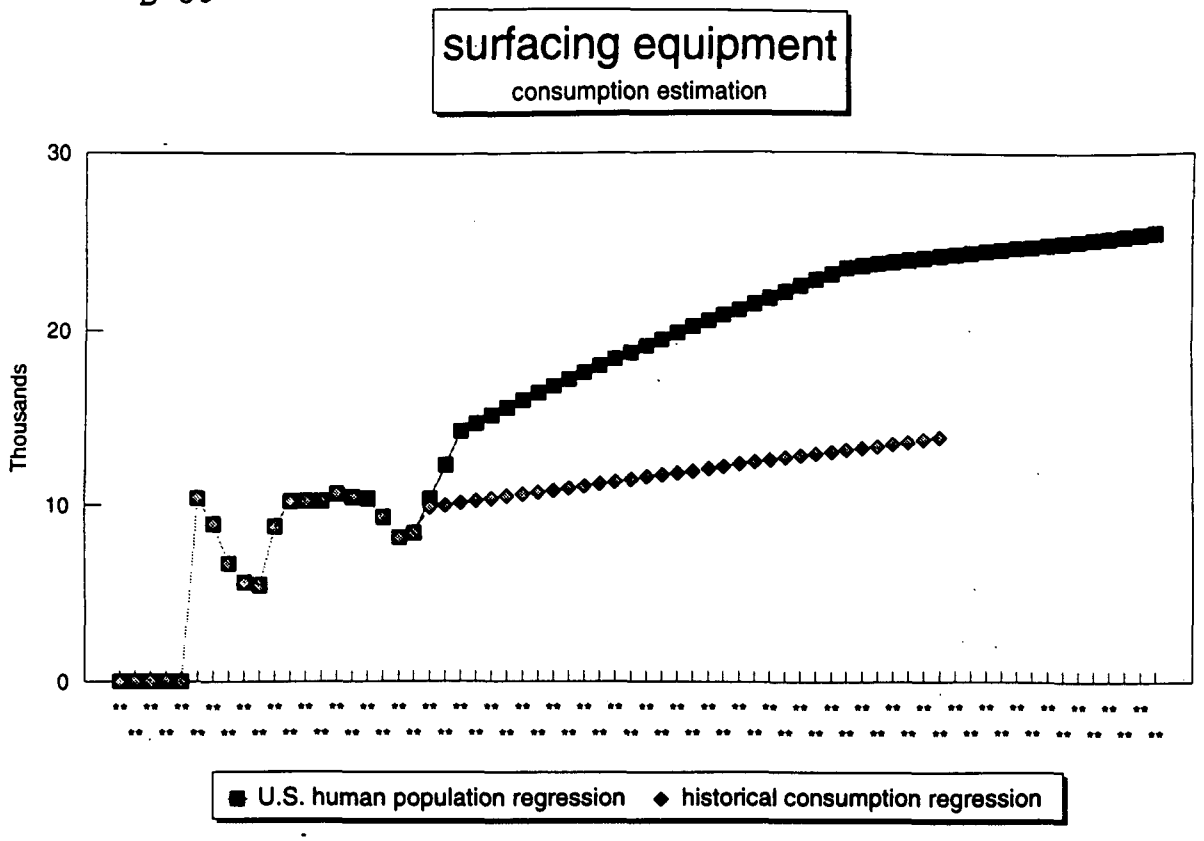


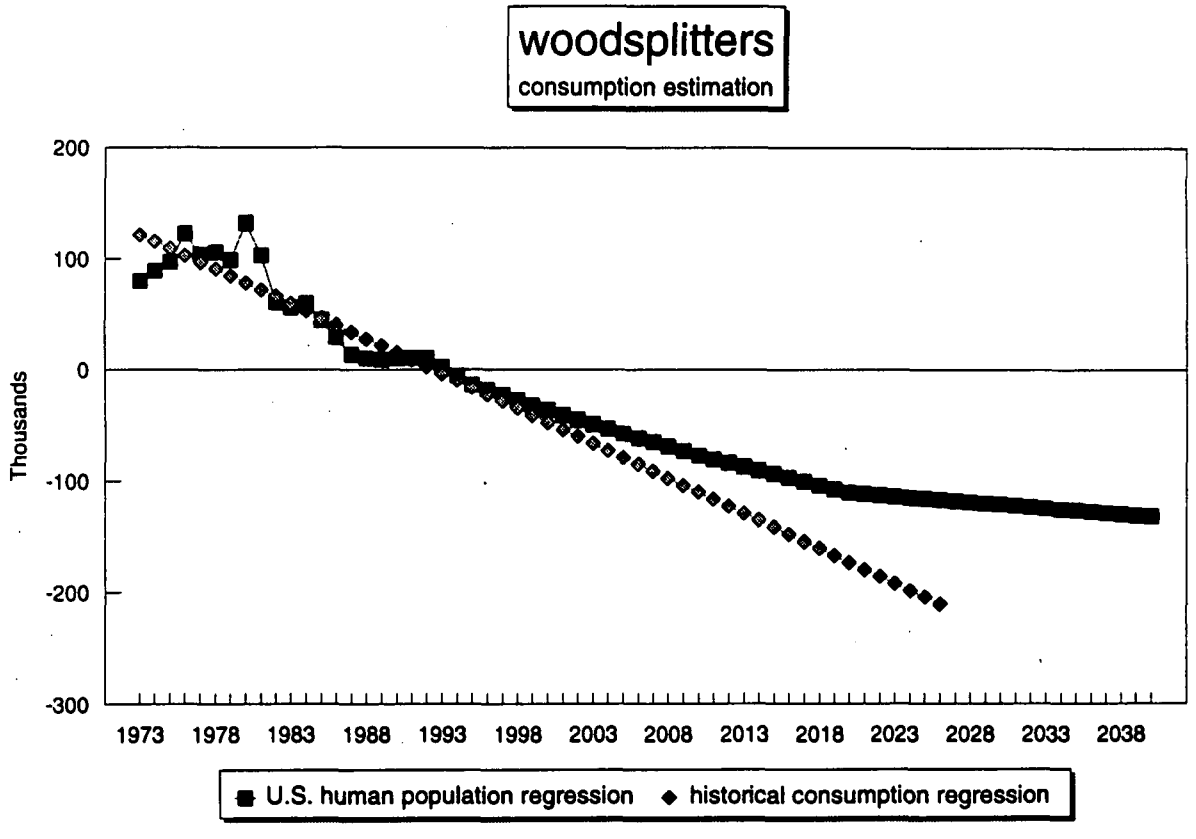
concrete/industrial saws
consumption estimation

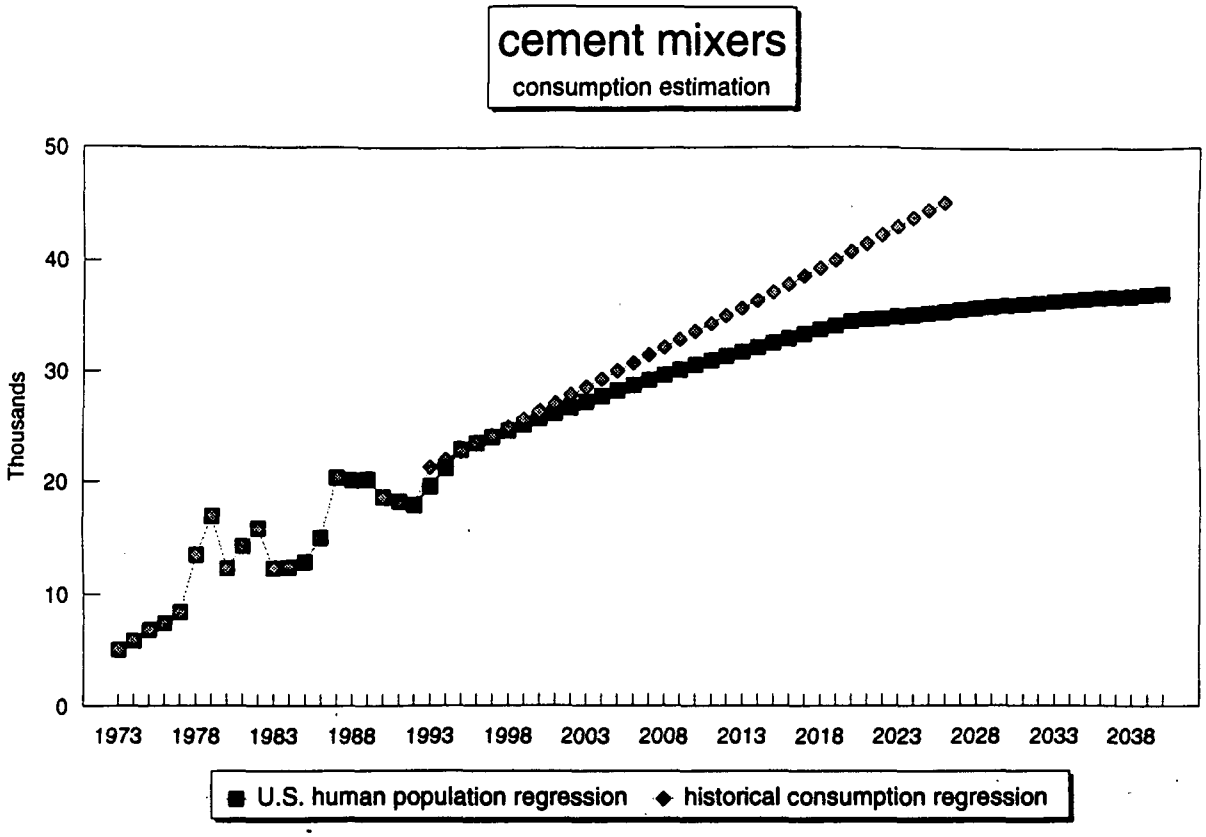


sprayers
consumption estimation




surfacing equipment
consumption estimation
30
20
10
0
Thousands
U.S. human population regression
historical consumption regression


woodsplitters
consumption estimation
200
100
0
-100
-200
-300
Thousands
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
U.S. human population regression
historical consumption regression


cement mixers
consumption estimation
Thousands
50
40
30
20
10
0
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
U.S. human population regression
historical consumption regression

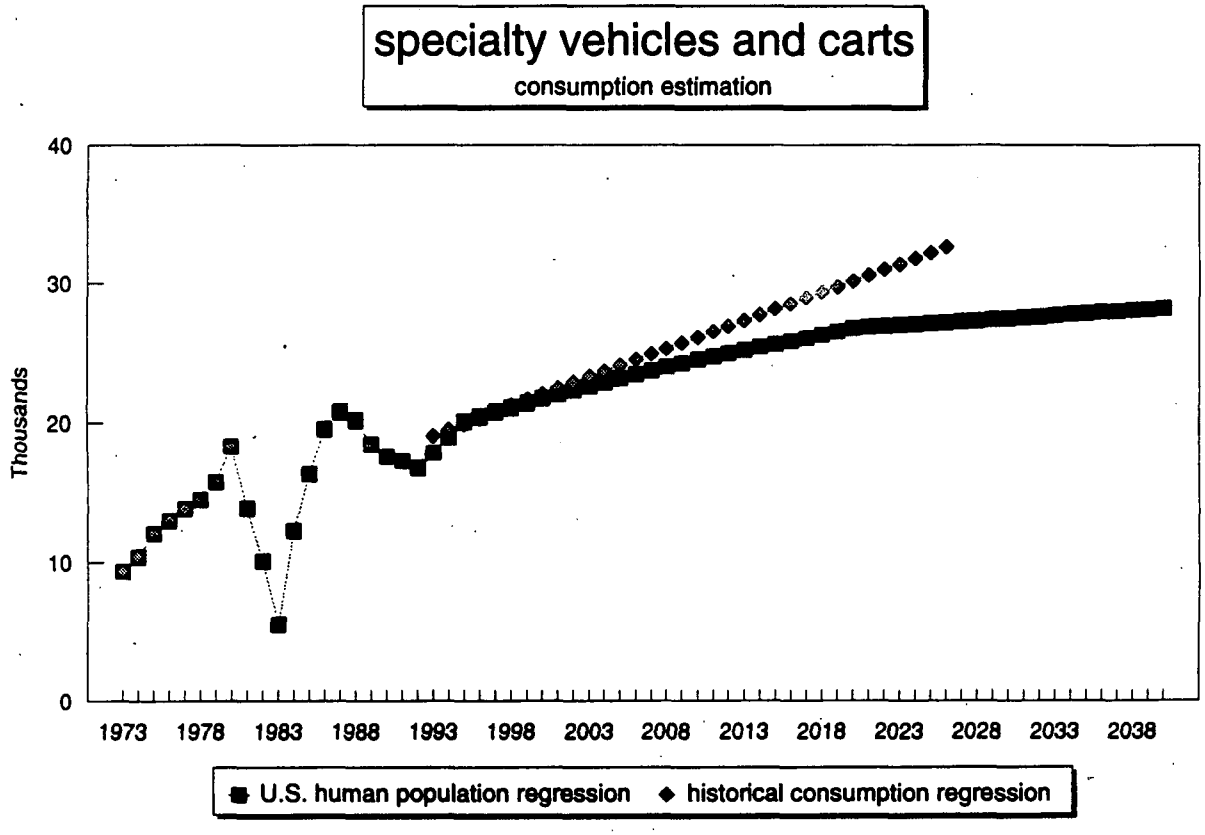
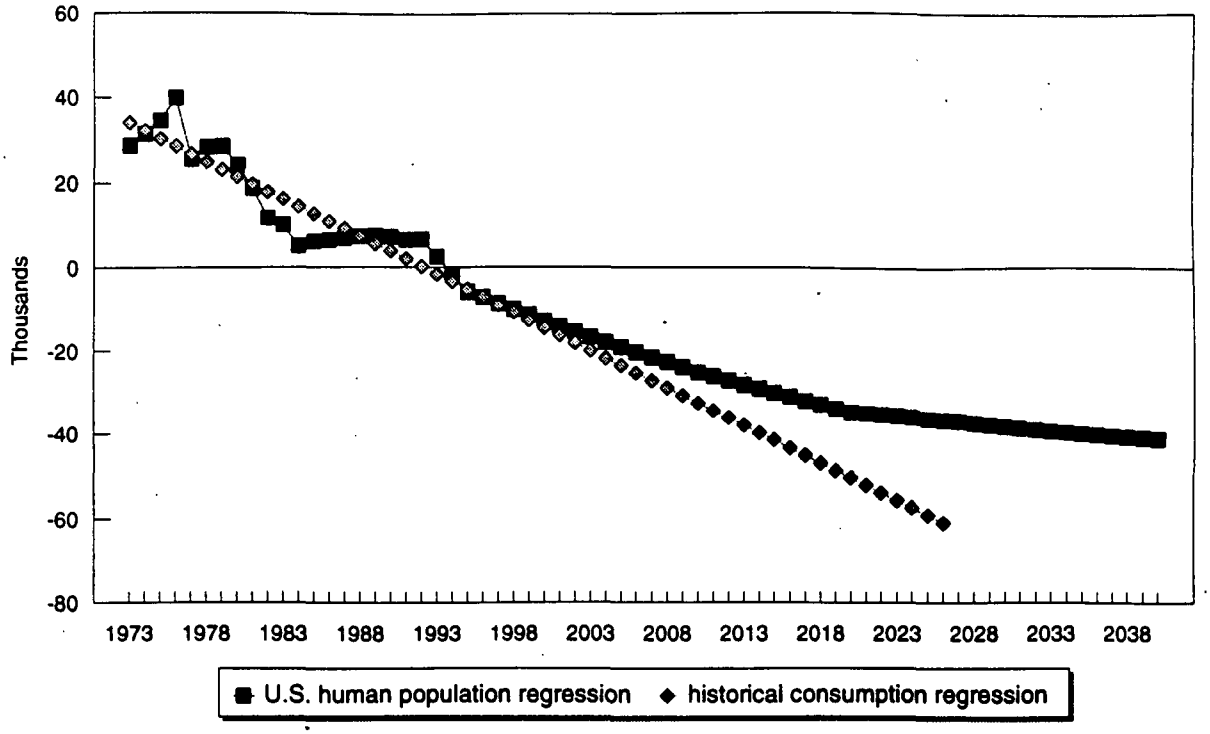
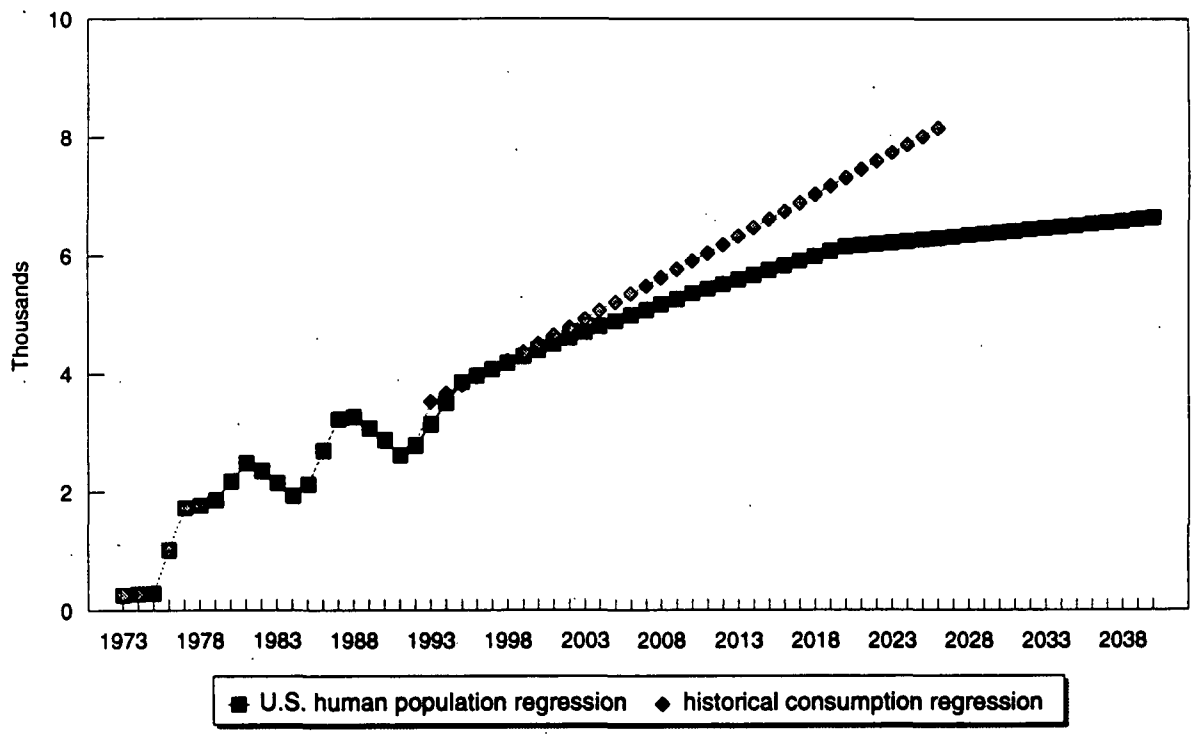

specialty vehicles and carts
consumption estimation
Thousands
40
30
20
10
0
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
U.S. human population regression
historical consumption regression

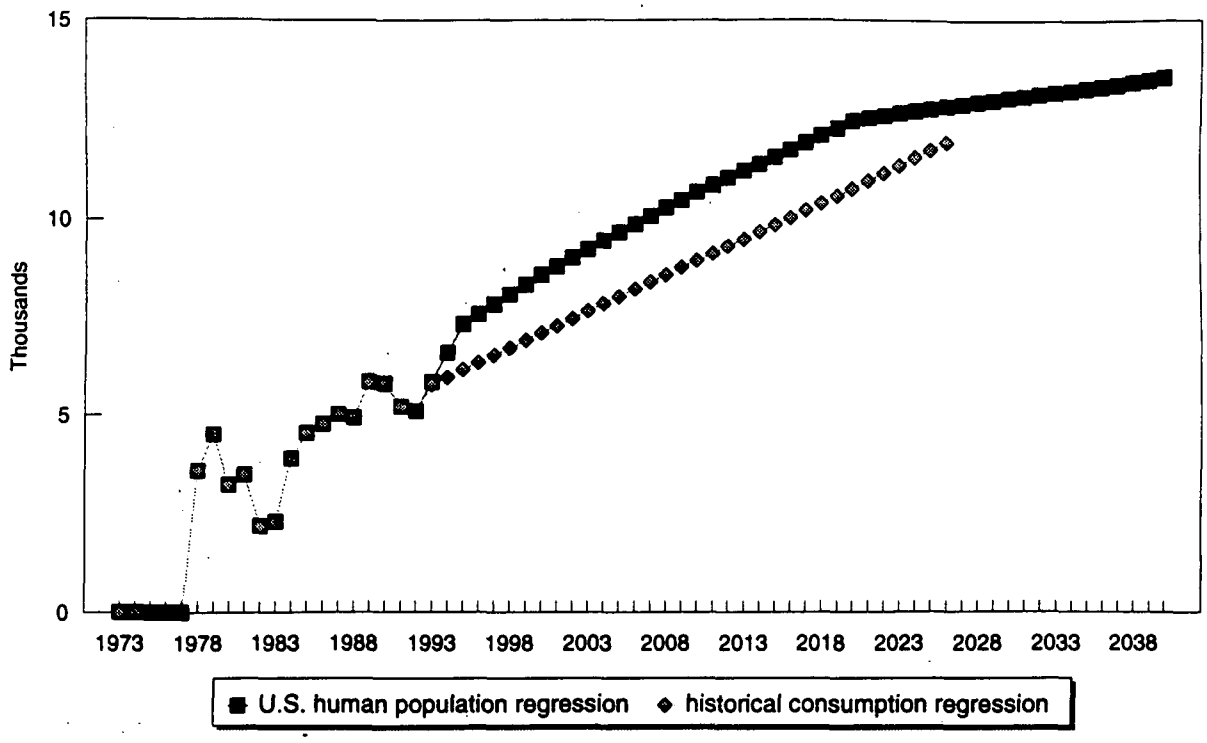
plate compactors



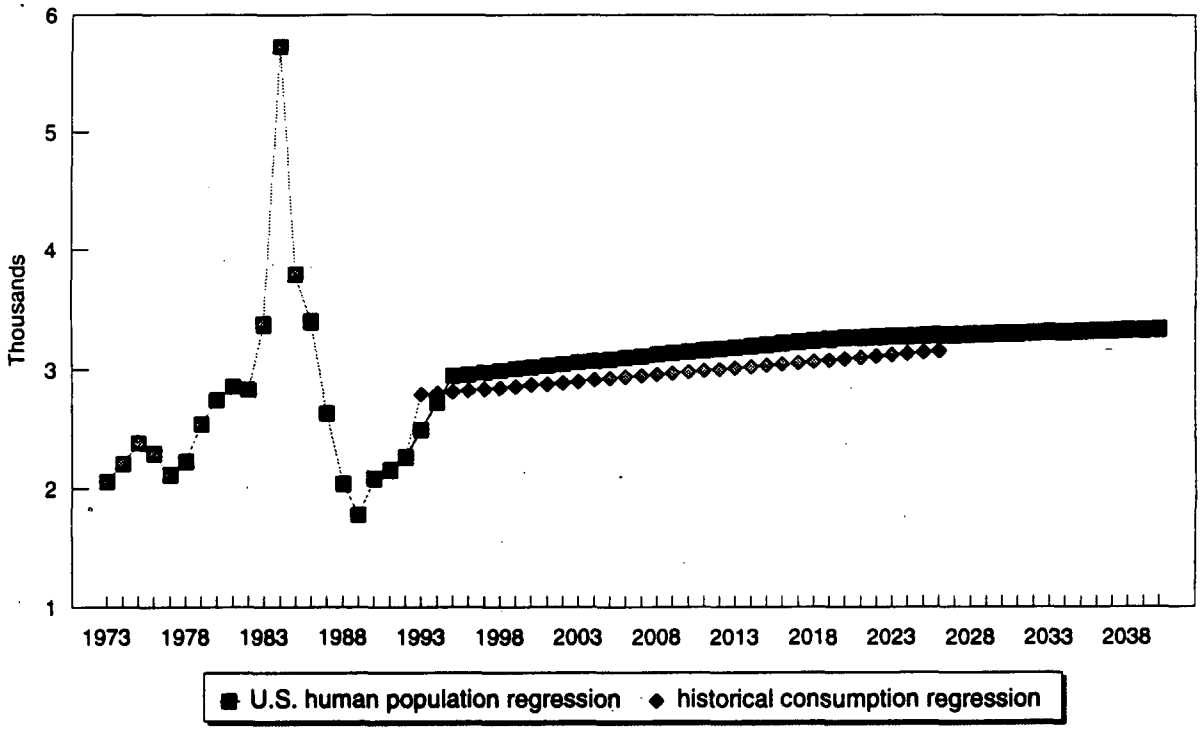
tampers/rammers



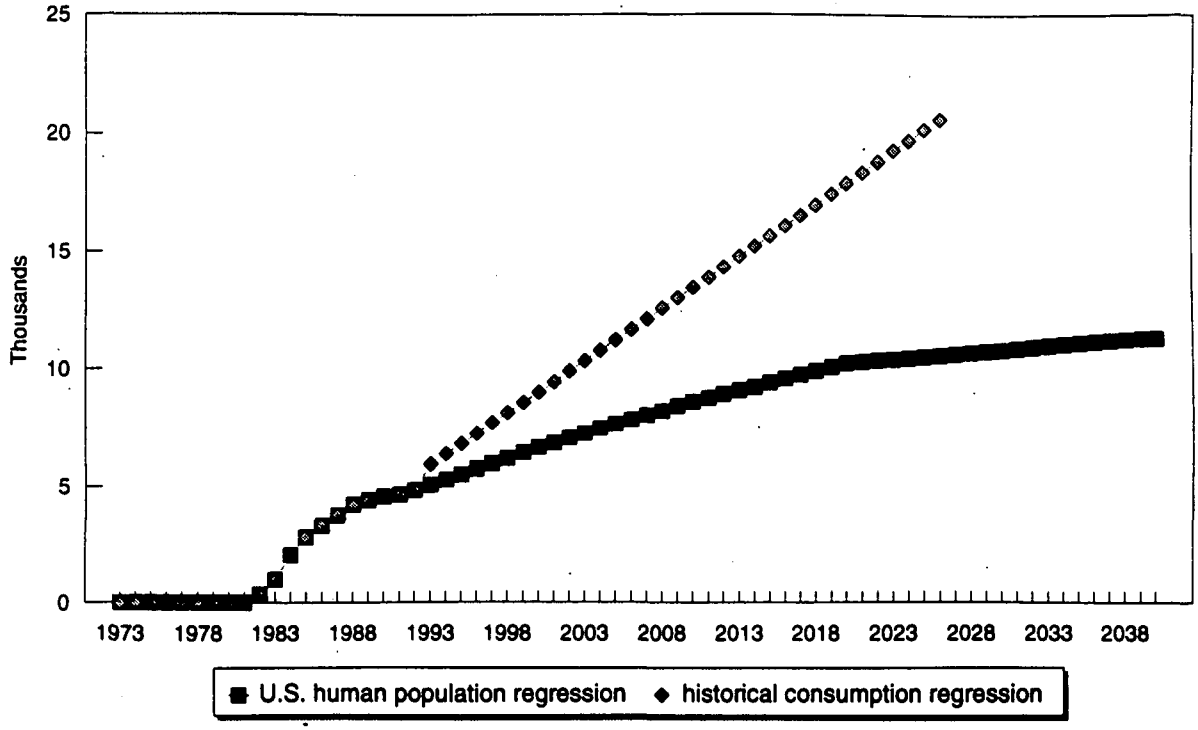
other general industrial



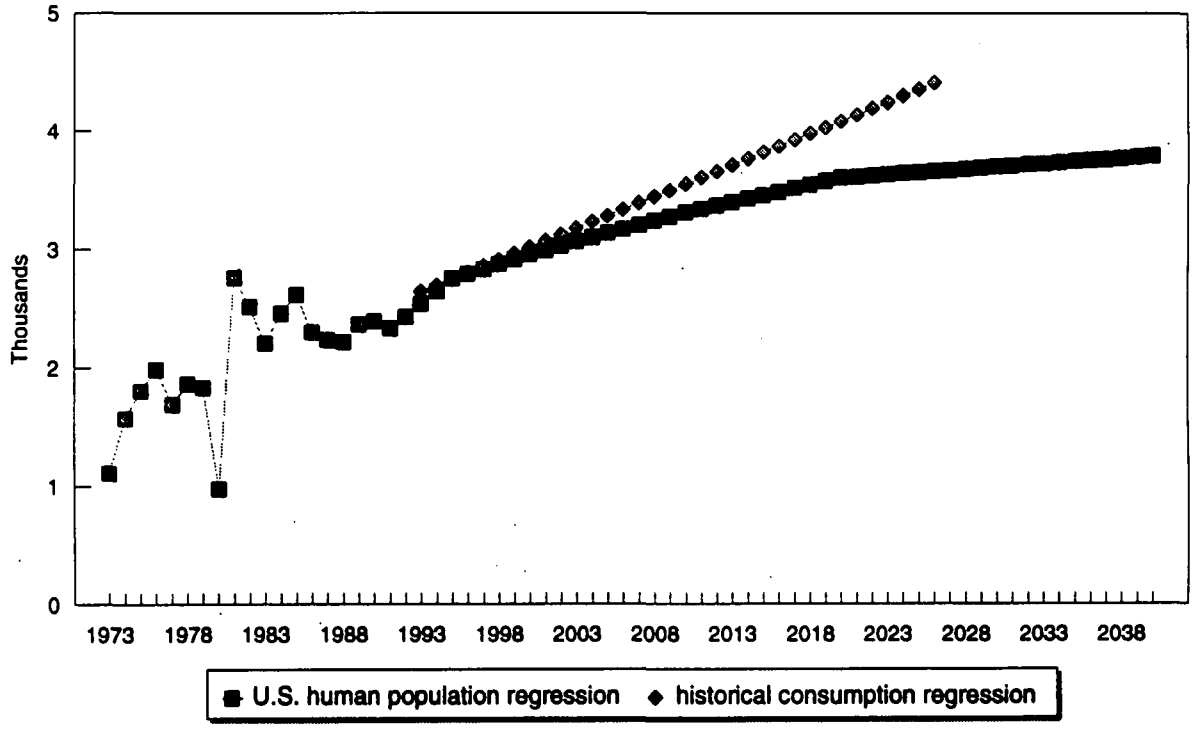
2 wheel tractors



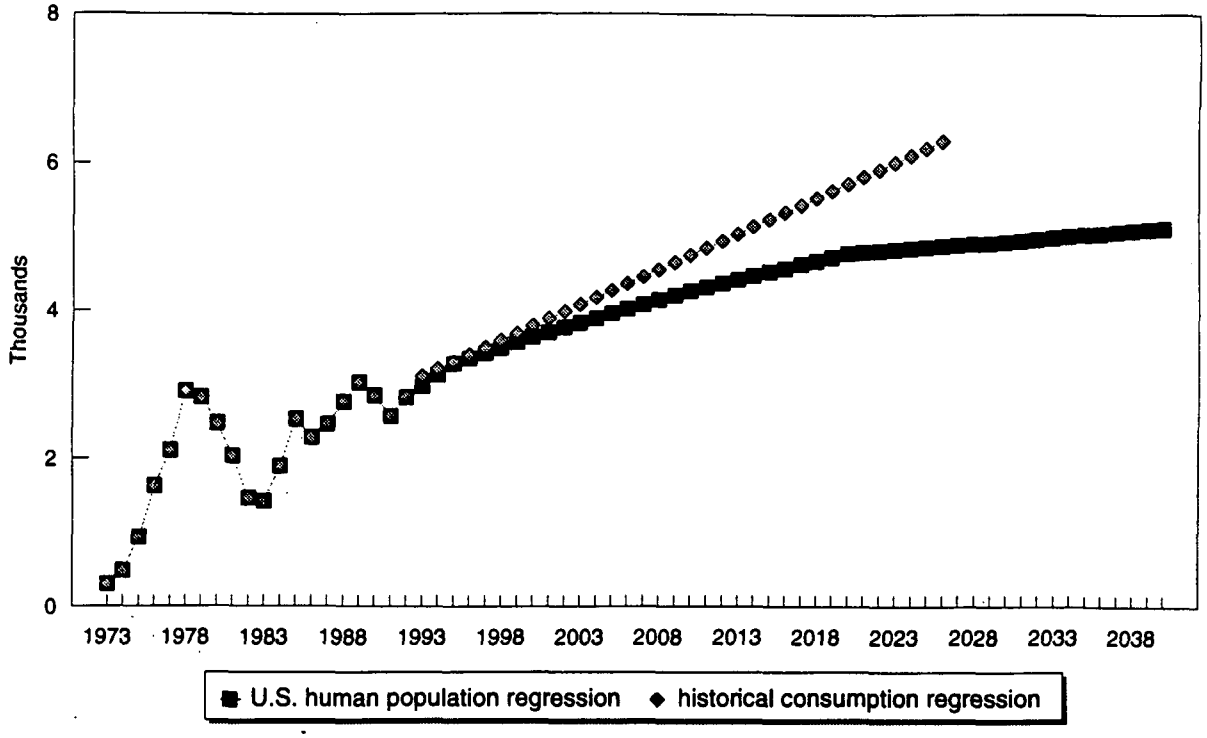
hydrolic power units



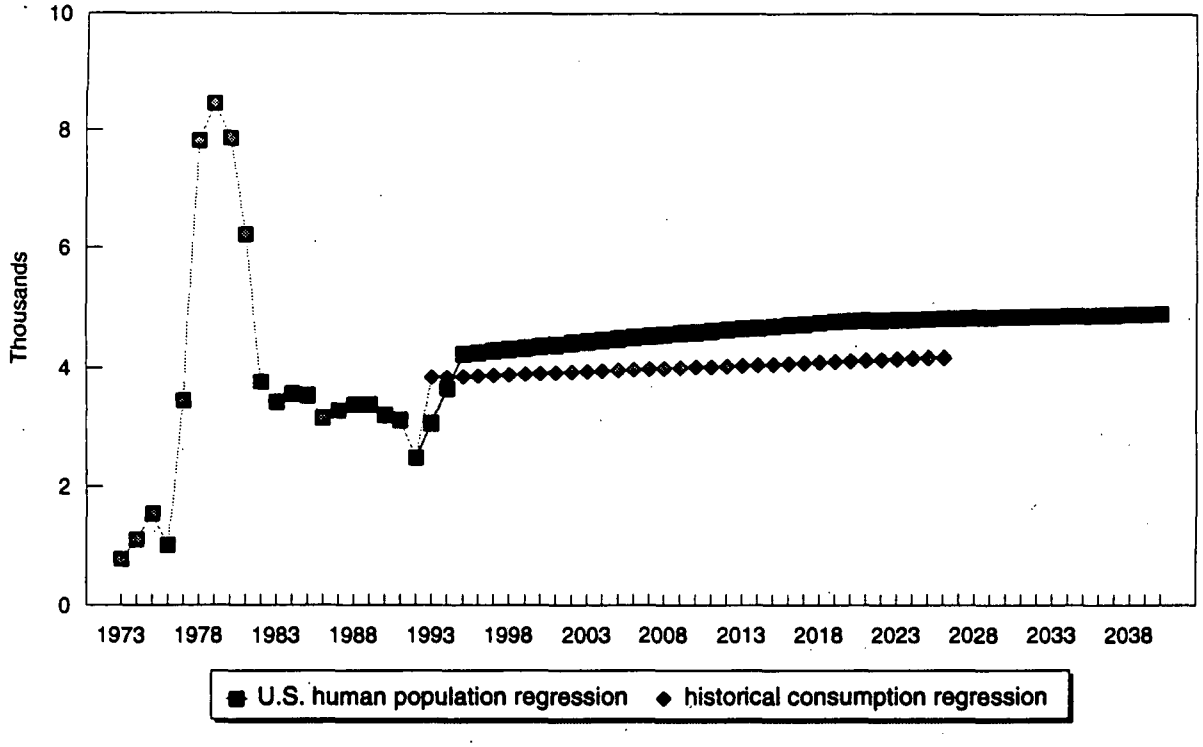
scrubbers/sweepers



rollers



irrigation sets



B.4. Analysis of Fuel Consumption and Power Changes

The following tables present the spreadsheet analysis of the estimation of changes in fuel consumption and power which may result from this regulation. The methodology used was to derive a sales-weighted estimate of any such changes.

CALCULATION OF SALES WEIGHTED FUEL CONSUMPTION CHANGE

RESULTS:

	Fuel Consumption Change
NHH	-25%
HH	-13%

PRE-CONTROL

1. CALCULATION OF % POPULATION FOR NHH & HH ENGINES
(Ref: PSR Engindata Database)

	SV	OHV	OTHER	2 STROKE	
Class 1:	6,234,570	515,849	4,745	794,029	
Class II:	1,821,659	394,804	24,025	5,347	
				NHH:	9795026
Class III:	--	--	--	484,290	
Class IV:	--	--	--	5,879,834	
Class V:	--	--	--	365,989	
				HH:	6730113

	SV	OHV	OTHER	2 STROKE
CLASS I	0.64	0.05	0.00	0.08
CLASS II	0.19	0.04	0.00	0.00
CLASS III	--	--	--	0.07
CLASS IV	--	--	--	0.87
CLASS V	--	--	--	0.05

NOTE: Class I and II percentages are calculated with total nhh population
Class III-V percentages are calculated with total hh population

POST CONTROL

1. CALCULATION OF % POPULATION FOR NHH & HH ENGINES
(Ref: EPA estimated 1996 sales)

SV	OHV	OTHER	2 STROKE	
6,569,239	975,209	4,745	--	
1,827,005	394,804	24,025	--	
			NHH:	9795026
--	--	--	484,290	
--	58,798	--	5,821,035	
--	--	--	365,989	
			HH:	6730113

SV	OHV	OTHER	2 STROKE
0.67	0.10	0.00	--
0.19	0.04	0.00	--
--	--	--	0.07
--	0.01	--	0.86
--	--	--	0.05

NOTE: Class I and II percentages are calculated with total nhh populatior
Class III-V percentages are calculated with total hh population

Assumptions to engine design changes from Pre-Control Population Numbers are:
1. Class I 2-stroke engines will not meet the NHH standard and therefore were split 50/50 between Class I SV and Class I OHV engines
2. Class II 2-stroke engines will not meet the NHH standared and are all placed in with Class II SV engines
3. 1% of SV engines in Class I are sold as OHV
4. 1% of Class IV handheld engines convert to the new 4-stroke technology

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2. FUEL CONSUMPTION (g/kW-hr)
(see references for Table 1-11 in Chapter 1)

	SV	OHV	OTHER	2 STROKE
Class 1:	830	603	603	854
Class II:	570	510	510	570
Class III:	--	--	--	830
Class IV:	--	--	--	830
Class V:	--	--	--	560

NOTES:
1. Class III fuel consumptin is copied from Class IV fuel consumption
2. "Other" fuel consumption numbers are copied from "OHV"

3. FUEL CONSUMPTION x SALES WEIGHTING

	SV	OHV	OTHER	2 STROKE	
Class I:	528.3	31.8	0.3	69.2	
Class II:	106.0	20.6	1.3	0.3	
				NHH:	757.70
Class III:	--	--	--	59.7	
Class IV:	--	--	--	725.1	
Class V:	--	--	--	30.5	
				HH:	815.32

4. % CHANGE FROM PRE-CONTROL

	SV	OHV	OTHER	2 STROKE	
Class I:	-24%	35%	-29%	-100%	
Class II:	-9%	2%	2%	-100%	
				NHH:	-25%
Class III:				-13%	
Class IV:				-14%	
Class V:				-6%	
				HH:	-13%

2. FUEL CONSUMPTION (g/kW-hr)
(see references for Table 1-11 in Chapter 1)

SV	OHV	OTHER	2 STROKE
600	430	430	0
520	520	520	0
0	0	0	720
0	253	0	720
0	0	0	529

NOTES:
1. Class III fuel consumptin is copied from Class IV fuel cons
2. "Other" fuel consumption numbers are copied from "OHV"

3. FUEL CONSUMPTION x SALES WEIGHTING

SV	OHV	OTHER	2 STROKE	
402.4	42.8	0.2	0.0	
97.0	21.0	1.3	0.0	
			NHH:	564.65
--	--	--	51.8	
--	2.2	--	622.7	
--	--	--	28.8	
			HH:	705.53

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CALCULATION OF SALES WEIGHTED FUEL CONSUMPTION CHANGE

RESULTS:

	Fuel Consumption Change
NHH	-25%
HH	-13%

PRE-CONTROL

1. CALCULATION OF % POPULATION FOR NHH & HH ENGINES
(Ref: PSR Engindata Database)

	SV	OHV	OTHER	2 STROKE	
Class 1:	6,234,570	515,849	4,745	794,029	
Class II:	1,821,659	394,804	24,025	5,347	
				NHH:	9795026
Class III:	--	--	--	484,290	
Class IV:	--	--	--	5,879,834	
Class V:	--	--	--	365,989	
				HH:	6730113

	SV	OHV	OTHER	2 STROKE
CLASS I	0.64	0.05	0.00	0.08
CLASS II	0.19	0.04	0.00	0.00
CLASS III	--	--	--	0.07
CLASS IV	--	--	--	0.87
CLASS V	--	--	--	0.05

NOTE: Class I and II percentages are calculated with total nhh population
Class III-V percentages are calculated with total hh population

POST CONTROL

1. CALCULATION OF % POPULATION FOR NHH & HH ENGINES
(Ref: EPA estimated 1996 sales)

SV	OHV	OTHER	2 STROKE	
6,569,239	975,209	4,745	--	
1,827,005	394,804	24,025	--	
			NHH:	9795026
--	--	--	484,290	
--	58,798	--	5,821,035	
--	--	--	365,989	
			HH:	6730113

SV	OHV	OTHER	2 STROKE
0.67	0.10	0.00	--
0.19	0.04	0.00	--
--	--	--	0.07
--	0.01	--	0.86
--	--	--	0.05

NOTE: Class I and II percentages are calculated with total nhh population
Class III-V percentages are calculated with total hh population

Assumptions to engine design changes from Pre-Control Population Numbers are:
1. Class I 2-stroke engines will not meet the NHH standard and therefore were split 50/50 between Class I SV and Class I OHV engines
2. Class II 2-stroke engines will not meet the NHH standared and are all placed in with Class II SV engines
3. 1% of SV engines in Class I are sold as OHV
4. 1% of Class IV handheld engines convert to the new 4-stroke technology

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CALCULATION OF SALES WEIGHTED POWER CHANGE

RESULTS

	Power Change
NHH	5%
HH	-3%

PRE-CONTROL

1. CALCULATION OF % POPULATION FOR NHH & HH ENGINES
(Ref: PSR Engindata Database)

	SV	OHV	OTHER	2 STROKE	
Class 1:	6,234,570	515,849	4,745	794,029	
Class II:	1,821,659	394,804	24,025	5,347	
				NHH:	9795026
Class III:	--	--	--	484,290	
Class IV:	--	--	--	5,879,834	
Class V:	--	--	--	365,989	
				HH:	6730113

	SV	OHV	OTHER	2 STROKE
CLASS I	0.64	0.05	0.00	0.08
CLASS II	0.19	0.04	0.00	0.00
CLASS III	--	--	--	0.07
CLASS IV	--	--	--	0.87
CLASS V	--	--	--	0.05

NOTE: Class I and II percentages are calculated with total nhh population
Class III-V percentages are calculated with total hh population

POST-CONTROL

1. CALCULATION OF % POPULATION FOR NHH & HH ENGINES
(Ref: EPA estimated 1996 sales)

SV	OHV	OTHER	2 STROKE	
6,569,239	975,209	4,745	--	
1,827,005	394,804	24,025	--	
			NHH	9795026
--	--	--	484,290	
--	58,798	--	5,821,035	
--	--	--	365,989	
			HH	6730113

SV	OHV	OTHER	2 STROKE
0.67	0.10	0.00	--
0.19	0.04	0.00	--
--	--	--	0.07
--	0.01	--	0.86
--	--	--	0.05

NOTE: Class I and II percentages are calculated with total nhh population
Class III-V percentages are calculated with total hh population

Assumptions to engine design changes from Pre-Control Population Numbers are:
1. Class I 2-stroke engines will not meet the NHH standard and therefore were split 50/50 between Class I SV and Class I OHV engines
2. Class II 2-stroke engines will not meet the NHH standared and are all placed in with Class II SV engines
3. 1% of SV engines in Class I are sold as OHV
4. 1% of Class IV handheld engines convert to the new 4-stroke technology

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2. POWER
(see references for Table 1-11in Chapter 1)

	SV	OHV	OTHER	2 STROKE
Class 1:	0.9	0.9	0.9	1
Class II:	3.25	3.06	3.06	3.25
Class III:	--	--	--	0.86
Class IV:	--	--	--	0.86
Class V:	--	--	--	2.28

NOTES:
1. Class III power is copied from Class IV power
2. "Other" power numbers are copied from "OHV"

3. POWER x SALES WEIGHTING

	SV	OHV	OTHER	2 STROKE	
Class 1:	0.57	0.05	0.00	0.08	
Class II:	0.60	0.12	0.01	0.00	
				NHH:	1.44
Class III:	--	--	--	0.06	
Class IV:	--	--	--	0.75	
Class V:	--	--	--	0.12	
				HH:	0.94

4. % CHANGE FROM PRE-CONTROL

	SV	OHV	OTHER	2 STROKE	
Class 1:	26%	83%	-3%	-100%	
Class II:	-6%	-2%	-2%	-100%	
				NHH:	5%
Class III:	--	--	--	-3%	
Class IV:	--	NA	--	-4%	
Class V:	--	--	--	-0%	
				HH:	-3%

2. POWER
(see references for Table 1-11in Chapter 1)

	SV	OHV	OTHER	2 STROKE
Class 1:	1.08	0.87	0.87	--
Class II:	3.06	3.01	3.01	--
Class III:	--	--	--	0.83
Class IV:	--	1	--	0.83
Class V:	--	--	--	2.27

NOTES:
1. Class III power is copied from Class IV power
2. "Other" power numbers are copied from "OHV"

3. POWER x SALES WEIGHTING

	SV	OHV	OTHER	2 STROKE	
Class 1:	0.72	0.09	0.00	--	
Class II:	0.57	0.12	0.01	--	
				NHH:	1.51
Class III:	--	--	--	0.06	
Class IV:	--	0.01	--	0.72	
Class V:	--	--	--	0.12	
				HH:	0.91

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B.5. Techology Cost Estimation

The following tables present the spreadsheet analysis of the estimation of technology related costs due to the final regulation. These costs include variable hardware costs, production costs and research and development costs.

The following tables present the spreadsheet analysis of the estimation of technolog related costs due to the proposed regulation. These costs include variable hardware costs, production costs and research and development costs.

I. DEVELOPMENT OF TECHNOLOGY MIX ESTIMATE TABLES

A. PRESENT MARKET % ESTIMATE FOR EACH CLASS

1. PSR "Engindata" Database, 1992 Sales

Class	Side Valve	OHV	2 Stroke	Other	TOTALS
I	8,052,156	613,380	1,039,798	12,608	9717942
II	2,183,681	570,401	13,847	26,526	2794455
III	---	---	340,596	---	340596
IV	---	---	3,598,296	---	3598296
V	---	---	337,565	11	337576

2. Calculated Percent in Each Class and Technology

Class	Side Valve	OHV	2 Stroke	Other
I	83%	6%	11%	0%
II	78%	20%	0%	1%
III	---	---	100%	---
IV	---	---	100%	---
V	---	---	100%	0.00%

Note: Contents for "Other" Category

	Fuel Inj	Water, SV	Water, OH	Alt Fuel
Class I	12,608	---	---	---
Class II	---	18,551	7,824	151
Class III	---	---	---	---
Class IV	---	---	---	---
Class V	---	---	---	11

B. ASSUMED MARKET % ON DATE OF FULL IMPLEMENTATION

1. Technology Mix Change Estimates Affecting Present Market %

Class I			
	sv	-1%	To Overhead Valve Engine Design
		0.33	From 2 Stroke Design Engines
	ohv	1%	From Side Valve
		0.67	From 2 Stroke Design Engines
	2 stroke	-x	Prior to 2003, lawnmower and snowthrower engines can meet hh stds for 1997 model year (sales are limited to 1994 sales) and the upper limit decreases 25% of 1994 sales each year and holds at 50% In 2003, all 2 strokes must meet the nhh engine std
	other	No Change	
Class II			
	sv	100%	From 2 Stroke Design Engines
	2 stroke	-100%	To SV
	other	No Change	
Class III		No Change	
Class IV		1%	To 4 Stroke OHV
Class V		No Change	

References:

1. Emission Test Data
   SAE Papers: 910560,911222,911805,911806,911807,921696
   1993 In-Use Test Program by Portable Power Equipment Manufacturer's Association
2. Confidential discussions with engine manufacturers in 1993

II. CALCULATION OF ENGINE/EQUIPMENT/TECHNOLOGY COMBINATIONS FOR IMPLEMENTATION YEAR (ASSUMED 1996)

NOTES:
1. ENGINE/EQUIPMENT/TECHNOLOGY 1992 sales combinations are available from PSR
2. Costs for ENGINE technologies apply to implementation year sales (implementation year assumed 1996)
3. EPA consumption estimates for 1996 EQUIPMENT sales were made for the implementation year in EPA's small engine nonroad model calculations

These pages present calculations to determine equipment sales percentages and corresponding engine technologies
1. Table of PSR data on equipment with corresponding 1992 sales of engines in each class and technology
2. Tabulation of percentage of engines in each class and technology
3. Application of percentages to 1996 equipment consumption estimates

A. PSR "Engindata" Database,1992 Sales

	Class I				Class II				Class III	Class IV	Class V	Total Per
	SV	OHV	2-Stroke	Other	SV	OHV	2-Stroke	Other	2-Stroke	2-Stroke	2-Stroke	Equipment
LAWNMOWERS	4274556	412392	529110	---	---	---	---	---	---	---	---	5216058
TRIM/EDGE/CUTTER	79804	332	---	---	551	---	---	---	340596	2582511	31220	3035014
LEAF BLOW/VACS	35966	4974	---	---	16899	161	---	---	---	201848	---	259848
CHAINSAW	---	---	---	---	---	---	---	---	---	813937	306345	1120282
GENTR SETS	167347	4872	---	---	226567	39304	---	2985	---	---	---	441075
TILLERS	261864	---	13383	---	66497	74	---	---	---	---	---	341818
SNOWBLOWER	255957	---	164426	---	155253	---	---	---	---	---	---	575636
COMM TURF	22826	9182	2331	---	142717	41771	---	6369	---	---	---	225196
REAR ENG RIDER	22140	---	---	---	293060	60325	---	---	---	---	---	375525
LN/GDN TRACTORS	8219	---	---	---	805991	193106	---	13247	---	---	---	1020563
PUMPS	68957	3912	32574	---	43152	1873	182	11	---	---	---	150661
ALL OTHER EQUIP	2854520	168243	297974	12608	451545	241611	13665	3763	---	---	---	4043929
TOTAL ENGINES: (per Class and Tech)	8052156	603907	1039798	12608	2202232	578225	13847	26375	340596	3598296	337565	16805605

B. Calculated %'s in Each Class and Technology (Based on A.)

	Class I				Class II				Class III	Class IV	Class V
	SV	OHV	2-Stroke	Other	SV	OHV	2-Stroke	Other	2-Stroke	2-Stroke	2-Stroke
LAWNMOWERS	81.95%	7.91%	10.14%	---	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
TRIM/EDGE/CUTTER	2.63%	0.01%	0.00%	---	0.02%	0.00%	0.00%	0.00%	11.22%	85.09%	1.03%
LEAF BLOW/VACS	13.84%	1.91%	0.00%	---	6.50%	0.06%	0.00%	0.00%	0.00%	77.68%	0.00%
CHAINSAW	0.00%	0.00%	0.00%	---	0.00%	0.00%	0.00%	0.00%	0.00%	72.65%	27.35%
GENTR SETS	37.94%	1.10%	0.00%	---	51.37%	8.91%	0.00%	0.68%	0.00%	0.00%	0.00%
TILLERS	76.61%	0.00%	3.92%	---	19.45%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%
SNOWBLOWER	44.47%	0.00%	28.56%	---	26.97%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
COMM TURF	10.14%	4.08%	1.04%	---	63.37%	18.55%	0.00%	2.83%	0.00%	0.00%	0.00%
REAR ENG RIDER	5.90%	0.00%	0.00%	---	78.04%	16.06%	0.00%	0.00%	0.00%	0.00%	0.00%
LN/GDN TRACTORS	0.81%	0.00%	0.00%	---	78.98%	18.92%	0.00%	1.30%	0.00%	0.00%	0.00%
PUMPS	45.77%	2.60%	21.62%	---	28.64%	1.24%	0.12%	0.01%	0.00%	0.00%	0.00%
ALL OTHER EQUIP	70.59%	4.16%	7.37%	0.31%	11.17%	5.97%	0.34%	0.09%	0.00%	0.00%	0.00%

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C. EPA 1996 Consumption Estimates and Resulting Classification of Engines in Classes and Technology Groups from Application of Technology Percentages Calculated in Development of Technology Mix Estimate Tables (B)

				Class I				Class II				Class III	Class IV	Class V
		1996	Total	SV	OHV	2-Stroke	Other	SV	OHV	2-Stroke	Other	2-Stroke	2-Stroke	2-Stroke
LAWNMOWERS	res	4537087	5041208	4194927	530784	315497	0	0	0	0	0	0	0	0
LAWNMOWERS	prof	504121												
TRIM/EDGE/CUTTER	res	3532130	4315455	113472	472	0	0	783	0	0	0	484290	3672046	44391
TRIM/EDGE/CUTTER	prof	783325												
LEAF BLOW/VACS	res	1513460	1742197	241140	33349	0	0	113302	1079	0	0	0	1353326	0
LEAF BLOW/VACS	prof	228737												
CHAINSAWS	res	882045	1176060	0	0	0	0	0	0	0	0	0	854462	321598
CHAINSAWS	prof	294015												
GENTR SETS	res	109026	436105	165461	4817	0	0	224014	38861	0	2951	0	0	0
GENTR SETS	prof	327079												
TILLERS	res	204133	248943	193881	6579	0	0	48429	54	0	0	0	0	0
TILLERS	prof	44810												
SNOWBLOWER	res	382556	425062	189004	0	121416	0	114642	0	0	0	0	0	0
SNOWBLOWER	prof	42506												
COMM TURF	res	0	259802	27208	12408	0	0	164648	48190	0	7348	0	0	0
COMM TURF	prof	259802												
REAR ENG RIDER	res	259707	273376	16118	0	0	0	213343	43916	0	0	0	0	0
REAR ENG RIDER	prof	13669												
LN/GDN TRACTORS	res	871431	917296	7387	0	0	0	724436	173566	0	11907	0	0	0
LN/GDN TRACTORS	prof	45865												
PUMPS	res	42307	169227	89346	29091	0	0	48470	2104	0	12	0	0	0
PUMPS	prof	126920												
ALL OTHER EQUIP	res	380102	1520408	1109778	138729	0	4740	169769	90839	0	1415	0	0	0
ALL OTHER EQUIP	prof	1140306												
		TOTAL ENGINES:		6347723	756229	436913	4740	1821837	398609	0	23633	484290	5879834	365989

III. HARDWARE VARIABLE COST ESTIMATES

Hardware Variable Costs are costs for additional parts, materials or increases in purchase prices of existing components added to engine as a result of application of a technology
Costs are based on a limited amount of confidential information.

Summary of Cost Estimates per Class per Engine		Additional Cost for the Catalyst Option	
Class I	$0.73 prior to 2003	Class I	$1.32
Class I	$1.82 after 2003	Class II	$0.00
Class II	$0.65	Class III	$0.03
Class III	$1.69	Class IV	$0.03
Class IV	$1.92	Class V	$0.03
Class V	$2.37		

A. 1996 ENGINE CONSUMPTION ESTIMATES (from II.C)

Class I				Class II				Class III	Class IV	Class V
SV	OHV	2-Stroke	Other	SV	OHV	2-Stroke	Other	2-Stroke	2-Stroke	2-Stroke
6347723	756229	436913	4740	1827179	398609	0	23633	484290	5879834	365989

B. APPLICATION OF TECHNOLOGY MIX ESTIMATES AND COST CALCULATIONS

Class I

The Phase I rulemaking states that snowblower engines may meet handheld standards.
The Phase I rulemaking states that all 2-stroke engines under a weight cap can also be considered handheld.
In 2003, 2 stroke engines must meet nonhandheld standards. All of the other 2-stroke engine applications in Classes I and II are assumed to be transferred to 4-stroke engine design. Therefore, the number of 2-stroke engines will be less than that estimated in 1996.

			Number of Engines with Technology	Estimated HVC	80%	20%	Cost for Engines with Technology
SIDE VALVE	Class I Sales (Post-Control) =	6347723					
78%	Enleanment with Major Carb Adjustments		4951224	$1.50	0	$1,485,367.18	$1,485,367.18
21%	Enleanment with Minor Carb Adjustments		1333022	$0.50	0	$133,302.18	$133,302.18
50%	Changes in Ignition Timing		3173862	No Cost			$0.00
95%	Combustion Chamber Redesign		6030337	$0.10			$603,033.69
80%	Valve System Improvements		5078178	$0.40			$2,031,271.36
1%	OHV w/ minor carb		63477.23	$0.50	0	$6,347.72	$6,347.72
50%	Improved Cooling		3173862	$0.10			$317,386.15
OHV	Class I Sales (1996) =	756229					
100%	Enleanment with Minor Carb Adj		756229	$0.50	0	$75,622.90	$75,622.90
50%	Improved Cooling		378115	$0.10			$37,811.45
OTHER	Class I Sales (1996) =	4740					
50%	Fuel Carburetion Optimization		2370	No Cost			$0.00
50%	Improved Cooling		2370	$0.10			$237.00
2-STROKES	Class I Sales (1996) =	436913					
(2-strokes consist of lawnmower engines capped sales in 1994 + snowblower sales+tillers, the rest are split in 4-strokes))							
100%	Enleanment with Major Carburetor Adjustments		436913	$0.00			$0.00
100%	Carburetor Limiter Cap		436913	$1.00			$436,913.00
100%	Combustion Chamber Redesign		436913	$0.10			$43,691.30
100%	Improved Cooling		436913	$0.10			$43,691.30
	Class I Sales (2003) =	436913					
100%	Technology to reach nhh Phase I Class I emission standards		436913	$20.00			$8,738,260.00

In 1996 and 1997, all 2 stroke lawnmowers (the amt sold in 1994) and snowblowers and other hh categorized equip are allowed to meet the hh standard (ie: 2 wheeled tillers). In 2003, 2-stroke lawnmowers must meet the nhh std. This estimate assumes the 2-strokes will have a solution costing $20.00/engine in 2003. If no solution is found by that time then it is assumed that 4-strokes will be used.

LABELS	All Engines	7545605				
	Engine Labeling		7545605	$0.04	$301,824.20	
					up to 2003	2003 and on
				TOTAL COST:	$5,516,499.43	$13,730,463.83
				TOTAL # CLASS I ENGINES:	7545605	7545605
				CLASS I COST/ENGINE:	0.73	1.82

Class II

			Number of Engines with Technology	Estimated HVC	Cost for Engine with Technolog
SIDE VALVE	Class II Sales (1996) =	1827179			
100%	Enleanment with Minor Carb Adjustments		1827179	$0.50	$913,589.50
100%	Combustion Chamber Redesign		1827179	$0.10	$182,717.90
25%	Improved Cooling		456795	$0.10	$45,679.48
10%	Changes in Ignition Timing		182717.9	No Cost	$0.00
OHV	Class II Sales (1996) =	398609			
100%	Enleanment with Minor Carb Adj		398609	$0.50	$199,304.50
50%	Improved Cooling		199305	$0.10	$19,930.45
OTHER	Class II Sales (1996) =	23633			
50%	Fuel Carburetion Optimization		11817	No Cost	$0.00
50%	Improved Cooling		11817	$0.10	$1,181.65
LABELS	All Engines	2249421			
	Engine Labeling		2249421	$0.04	$89,976.84

TOTAL COST: $1,452,380.32
TOTAL # CLASS II ENGINES: 2249421
CLASS II COST/ENGINE: **$0.65**

Class III

			Number of Engines with Technology	Estimated HVC	Cost for Engine with Technolog
2 Stroke	Class III Sales (Post-Control) =	484290			
100%	Enleanment with Minor Carb Adjustments		484290	$0.50	$242,144.96
100%	Carburetor Limiter Cap		484290	$1.00	$484,289.93
100%	Combustion Chamber Redesign		484290	$0.10	$48,428.99
50%	Improved Cooling		242145	$0.10	$24,214.50
LABELS	All Engines	484290			
	Engine Labeling		484290	$0.04	$19,371.60

TOTAL COST: $818,449.98
TOTAL # CLASS III ENGINES: 484290
CLASS III COST/ENGINE: **$1.69**

Class IV

			Number of Engines with Technology	Estimated HVC	Cost for Engine with Technolog
2 Stroke	Class IV Sales (Post-Control) =	5879834			
75%	Enleanment with Major Carb Adjustments		4409875	$1.50	$6,614,812.90
25%	Enleanment with Minor Carb Adjustments		1469958	$0.50	$734,979.21
50%	Carburetor Limiter Cap		2939917	$1.00	$2,939,916.85
75%	Combustion Chamber Redesign		4409875	$0.10	$440,987.53
50%	Improved Cooling		2939917	$0.10	$293,991.68
1%	4 Stroke Engine Design		58798		$0.00
LABELS	All Engines	5879834			
	Engine Labeling		5879834	$0.04	$235,193.35

TOTAL COST: $11,259,881.52
TOTAL # CLASS IV ENGINES: 5879834
CLASS IV COST/ENGINE: **$1.92**

Class V

			Number of Engines with Technology	Estimated HVC	Cost for Engine with Technolog
2 Stroke	Class V Sales (Post-Control) =	365989			
75%	Enleanment with Major Carb Adjustments		274492	$1.50	$411,737.72
25%	Enleanment with Minor Carb Adjustments		91497	$0.50	$45,748.64
93%	Carburetor Limiter Cap		338540	$1.00	$338,539.90
100%	Combustion Chamber Redesign		365989	$0.10	$36,598.91
50%	Improved Cooling		182995	$0.10	$18,299.45
LABELS	All Engines	365989			
	Engine Labeling		365989	$0.04	$14,639.56

TOTAL COST: $865,564.18
TOTAL # CLASS V ENGINES: 365989
CLASS V COST/ENGINE: **$2.37**

CATALYST OPTION

		# Engines	HVC	Cost	Add'l Cost per Class
Class I	33%	2490050	$4.00	$9,960,198.60	1.32
Class II	0%	0			
Class III	1%	4843	$3.00	$14,528.70	0.03
Class IV	1%	58798	$3.00	$176,395.01	0.03
Class V	1%	3660	$3.00	$10,979.67	0.03

IV. PRODUCTION COST ESTIMATES

Production Costs are any additions or charges to production lines, tooling, etc. that is more than a one time cost (ie: not a one time die change). This can include additional stations for new parts being added to an engine or increased maintenance and frequency of die replacement. Costs are based on a limited amount of confidential information.

Summary of Cost Estimates per Class per Engine			Catalyst Option	
Class I	$0.48	prior to 2003	Class I	$0.00
Class I	$0.50	after 2003	Class II	$0.00
Class II	$0.16		Class III	$0.00
Class III	$0.40		Class IV	$0.00
Class IV	$0.25		Class V	$0.00
Class V	$0.39			

A. 1996 ENGINE CONSUMPTION ESTIMATES POST CONTROL

Class I				Class II				Class III	Class IV	Class V
SV	OHV	2-Stroke	Other	SV	OHV	2-Stroke	Other	2-Stroke	2-Stroke	2-Stroke
6347723	756229	436913	4740	1827179	398609	0	23633	484290	5879834	365989

B. APPLICATION OF TECHNOLOGY MIX ESTIMATES AND COST CALCULATIONS

For engine carburetion changes: estimated 80% mfr'd in-house, 20% outsourced

Class I

			Number of Engines with Technology	Estimated PC	80%	20%	Cost for Engines with Technology
SIDE VALVE	Class I Sales (Post Control) =	6347723					
78%	Enleanment with Major Carb Adjustments		4951224	$0.20	792195.8	0	$792,195.83
21%	Enleanment with Minor Carb Adjustments		1333022	$0.20	213283.5	0	$213,283.49
50%	Changes in Ignition Timing		3173862	No Cost			$0.00
95%	Combustion Chamber Redesign		6030337	$0.20			$1,206,067.37
80%	Valve System Improvements		5078178	$0.20			$1,015,635.68
1%	OHV w/ minor carb		63477	No Cost			$0.00
50%	Improved Cooling		3173862	No Cost			$0.00
OHV	Class I Sales (Post-Control) =	756229					
100%	Enleanment with Minor Carb Adj		756229	$0.20	120996.6	0	$120,99[illegible]
50%	Improved Cooling		378115	No Cost			$0.[illegible]
2-STROKES		436913					
100%	Enleanment with Major Carburetor Adjustments		436913	$0.20	69906.08	0	$69,906.08
100%	Carburetor Limiter Cap		436913	$0.20			$87,382.60
100%	Combustion Chamber Redesign		436913	$0.20			$87,382.60
100%	Improved Cooling		436913	No Cost			$0.00
(2003) 100%	Estimated production cost with technology		436913	$1.00	436913		$436,913.00
OTHER	Class I Sales (Post-Control) =	4740					
50%	Fuel Carburetion Optimization		2370	$0.20	474		$474.00
50%	Improved Cooling		2370	No Cost			$0.00
LABELS	All Engines	7545605					
	Engine Labeling		7545605	$0.09			Inc in Admin Cos

	prior to 2003	after 2003
TOTAL COST:	$3,593,324.29	$3,785,566.01
TOTAL # CLASS I ENGINES:	7545605	7545605
TOTAL COST/CLASS I:	$0.48	$0.50

Class II			Number of Engines with Technology	Estimated PC	Cost for Engines with Technology
SIDE VALVE	Class II Sales (Post-Control) =	1827179			
100%	Enleanment with Minor Carb Adjustments		1827179	No Cost	$0.00
100%	Combustion Chamber Redesign		1827179	$0.20	$365,435.80
25%	Improved Cooling		456795	No Cost	$0.00
10%	Changes in Ignition Timing		634772	No Cost	$0.00
OHV	Class II Sales (Post-Control) =	398609			
100%	Enleanment with Minor Carb Adj		398609	No Cost	$0.00
50%	Improved Cooling		199305	No Cost	$0.00
OTHER	Class II Sales (Post-Control) =	23633			
50%	Fuel Carburetion Optimization		11817	No Cost	$0.00
50%	Improved Cooling		11817	No Cost	$0.00
LABELS	All Engines	2249421			
	Engine Labeling		2249421	$0.09	Inc in Admin Cos
				TOTAL COST:	$365,435.80
				TOTAL # CLASS II ENGINES:	2249421
				TOTAL COST/CLASS II:	$0.16

Class III			Number of Engines with Technology	Estimated PC	Cost for Engines with Technology
2-Stroke	Class III Sales (Post-Control) =	484290			
100%	Enleanment with Minor Carb Adjustments		484290	No Cost	$0.00
100%	Carburetor Limiter Cap		484290	$0.20	$96,857.99
100%	Combustion Chamber Redesign		484290	$0.20	$96,857.99
50%	Improved Cooling		242145	No Cost	$0.00
LABELS	All Engines	484289.9			
	Engine Labeling		484290	$0.09	Inc in Admin Cos
				TOTAL COST:	$193,715.97
				TOTAL # CLASS III ENGINES:	484290
				TOTAL COST/CLASS III:	$0.40

Class IV			Number of Engines with Technology	Estimated PC	Cost for Engines with Technology
2-Stroke	Class IV Sales (Post-Control) =	5879834			
75%	Enleanment with Major Carb Adjustments		4409875	No Cost	$0.00
25%	Enleanment with Minor Carb Adjustments		1469958	No Cost	$0.00
50%	Carburetor Limiter Cap		2939917	$0.20	$587,983.37
75%	Combustion Chamber Redesign		4409875	$0.20	$881,975.05
50%	Improved Cooling		2939917	No Cost	$0.00
1%	4 Stroke Engine Design		58798	No Cost	$0.00
LABELS	All Engines	5879834			
	Engine Labeling		5879834	$0.09	Inc in Admin Cos
				TOTAL COST:	$1,469,958.42
				TOTAL # CLASS III ENGINES:	5879834
				TOTAL COST/CLASS III:	$0.25

Class V			Number of Engines with Technology	Estimated PC	Cost for Engines with Technology
2-Stroke	Class V Sales (Post-Control) =	365989			
75%	Enleanment with Major Carb Adjustments		274492	No Cost	$0.00
25%	Enleanment with Minor Carb Adjustments		91497	No Cost	$0.00
93%	Carburetor Limiter Cap		338540	$0.20	$67,707.98
100%	Combustion Chamber Redesign		365989	$0.20	$73,197.82
50%	Improved Cooling		182995	No Cost	$0.00
LABELS	All Engines	365989.1			
	Engine Labeling		365989	$0.09	Inc in Admin Cos
				TOTAL COST:	$140,905.80
				TOTAL # CLASS III ENGINES:	365989
				TOTAL COST/CLASS III:	$0.39

CATALYST OPTION

		# Engines	PVC
Class I	33%	0	$0.00
Class II	0%	0	$0.00
Class III	1%	4843	$0.00
Class IV	1%	58798	$0.00
Class V	1%	3660	$0.00

Catalysts will be produced by an outside source

V. RESEARCH AND DEVELOPMENT COST ESTIMATES

Research and Development Costs are all research and development of technologies and application to engine and associated costs with application (ie: prototype, testing, etc.). One time costs associated with changes in tooling and dies is also included.
Costs are based on a limited amount of confidential information.

Summary of Cost Estimates per Engine per Technology		Catalyst Option	
Class I	$10,803,000.00	Class I	$320,000.00
Class II	$10,000,000.00	Class II	$0.00
Class III	$72,500.00	Class III	$20,000.00
Class IV	$2,115,000.00	Class IV	$20,000.00
Class V	$2,812,500.00	Class V	$20,000.00

Notes:
Analysis of costs vary depending on the number of models in each technology per class and the sales of each model.
The following analysis uses the the number of models as a basis in order to maintain manufacturer confidentiality.
The variable nature of the small engine manufacturing processes for the wide range of engines allows itself to flexibility in this analysis.
Costs associated with work for previous engine regulations, ie: CARB, are estimated and subtracted from the total estimated cost.
The estimates may be overestimates due to application of changes to more than one model.

A. NUMBER OF MODELS IN EACH CLASS (Ref: PSR "Engindata" Database)

1992 PSR Engindata Database		1996 Estimate	
CLASS I		**CLASS I**	
Side Valve	36	Side Valve	36
OHV	10	OHV	10
2-stroke	33	2-stroke	4
Other	1	Other	1
CLASS II		**CLASS II**	
Side Valve	93	Side Valve	93
OHV	42	OHV	42
2-Stroke	2	2-Stroke	
Other	9	Other	9
CLASS III		**CLASS III**	
2-Stroke	1	2-Stroke	1
CLASS IV		**CLASS IV**	
2-Stroke	27	2-Stroke	27
CLASS V		**CLASS V**	
2-Stroke	15	2-Stroke	15

Notes:
Two stroke Class I and Class II engines are dropped based on the assumption that the models will not meet the applicable standards.
No additional models in any classes are added, for it is assumed that current production will pick up the removed sales volume.
Class II Other - 3 ohv water cooled, 6 side valve water cooled

B. APPLICATION OF TECHNOLOGY MIX ESTIMATES AND COSTS CALCULATIONS

Notes:

The analysis is skewed based on several points: 1. The percentage of engine sales does not correspond directly to the number of models.
2. Some of the models also use the same components, so not all models will have to be worked on.
EPA requests actual cost data and comments on this methodology.

Class I

SIDE VALVE # OF MODELS = 36

(Note: Assumed 80% of carburetors manufactured in-house by Class I engine manufacturers)

			$/Model	# of Mod	Cost/Tech
1.	78%	Enleanment with Major Carb Adjustments		22	
		80% Manufacturer of Carburetors			
		Design carburetors	$10,000.00		$224,640.00
		make prototypes and test engines	$10,000.00		$224,640.00
		One time changes to existing tooling and dies	$10,000.00		$224,640.00
		20% Non manufacture carburetors		6	
		work with carburetor manuf	$10,000.00		$56,160.00
		One time changes to existing tooling and dies	$10,000.00		$56,160.00
2.	21%	Enleanment with Minor Carb Adjustments		6	
		80% Manufacturer of Carburetors			
		Design carburetors	$10,000.00		$60,480.00
		make prototypes and test engines	$10,000.00		$60,480.00
		One time changes to existing tooling and dies	$10,000.00		$60,480.00
		20% Non manufacture carburetors		2	
		work with carburetor manuf	$10,000.00		$15,120.00
		One time changes to existing tooling and dies	$10,000.00		$15,120.00
3.	50%	Changes in Ignition Timing		18	
		Design Ignition Timing Changes, cams, etc.	$10,000.00		$180,000.00
		Make prototypes, test engines, etc.	$10,000.00		$180,000.00
		One time changes to existing tooling and dies	$20,000.00		$360,000.00
4.	95%	Combustion Chamber Redesign		34	
		Design new engine blocks and heads, pistons, etc	$25,000.00		$855,000.00
		Make prototypes and test engines	$25,000.00		$855,000.00
		One time changes to existing tooling and dies	$275,000.00		$9,405,000.00
5.	80%	Valve System Improvements		29	
		Design new cam, research new materials	$10,000.00		$288,000.00
		Build prototypes, test engines and repeat	$10,000.00		$288,000.00
		One time changes to existing tooling and dies	$50,000.00		$1,440,000.00
6.	1%	OHV w/ minor carb		0	
		No cost - just increase in OHV production			
7.	50%	Improved Cooling		18	
		Design cooling systems	$10,000.00		$180,000.00
		Build prototypes, test engines and repeat	$10,000.00		$180,000.00
		One time changes to existing tooling and dies	Inc in Comb Cmbr		
OHV		# OF MODELS = 10			
1.	100%	Enleanment with Minor Carb Adjustments			
		80% Manufacturer of Carburetors		8	
		Design carburetors	$10,000.00		$80,000.00
		make prototypes and test engines	$10,000.00		$80,000.00
		One time changes to existing tooling and dies	$10,000.00		$80,000.00
		20% Non manufacture carburetors		2	
		Work with carburetor manufacturer	$10,000.00		$20,000.00
		One time changes to existing tooling and dies	$10,000.00		$20,000.00
2.	50%	Improved Cooling		5	
		Design cooling systems	$10,000.00		$50,000.00
		Build prototypes, test engines and repeat	$10,000.00		$50,000.00
		One time changes to existing tooling and dies	$10,000.00		$50,000.00
OTHER		# OF MODELS = 1			
1.	50%	Fuel Carburetion Optimization		0.50	
		Research and develop new program for fuel injector chip	$10,000.00		$5,000.00
		Develop prototypes and test engines, repeat	$10,000.00		$5,000.00
2.	50%	Improved Cooling		0.50	
		Design cooling systems	$10,000.00		$5,000.00
		Build prototypes, test engines and repeat	$10,000.00		$5,000.00
		One time changes to existing tooling and dies	$10,000.00		$5,000.00
					$15,663,920.00
2-STROKES		# OF MODELS = 4			
1.	55%	Major Carburetor Improvements		2.2	
		work with carburetor manuf	$10,000.00		$22,000.00
		One time changes to existing tooling and dies	$10,000.00		$22,000.00
2.	55%	Combustion Chamber Redesign		2.2	
		Design new engine blocks and heads, pistons, etc	$25,000.00		$55,000.00
		Make prototypes and test engines	$25,000.00		$55,000.00
		One time changes to existing tooling and dies	$275,000.00		$605,000.00
3.	55%	Improved Cooling		2.2	
		Design cooling systems	$10,000.00		$22,000.00
		Build prototypes, test engines and repeat	$10,000.00		$22,000.00
		One time changes to existing tooling and dies	Inc in Comb Cmbr		
					$803,000.00
			TOTAL COST:		$16,466,920.00
			CARB COST:		$5,663,920.00
			Phase I Cost:		$10,803,000.00

Class II		Note: assumed no engine manuf made carb's			
SIDE VALVE		# OF MODELS = 93			
1	100%	Enleanment with Minor Carb Adjustments		93	
		Manufacturer of Carburetors			
		Design carburetors	$10,000.00		$930,000.00
		make prototypes and test engines	$10,000.00		$930,000.00
		One time changes to existing tooling and dies	$10,000.00		$930,000.00
2.	100%	Combustion Chamber Redesign		93	
		Design new engine blocks and heads, pistons, etc	$25,000.00		$2,325,000.00
		Make prototypes and test engines	$25,000.00		$2,325,000.00
		One time changes to existing tooling and dies	$275,000.00		$25,575,000.00
3.	25%	Improved Cooling		23	
		Design cooling systems	$10,000.00		$232,500.00
		Build prototypes, test engines and repeat	$10,000.00		$232,500.00
		One time changes to existing tooling and dies (may be incorporate (COMB CHBR)			$0.00
4.	10%	Changes in Ignition Timing		9	
		Design Ignition Timing Changes, cams, etc.	$10,000.00		$93,000.00
		Make prototypes, test engines, etc.	$10,000.00		$93,000.00
		One time changes to existing tooling and dies	$20,000.00		$186,000.00
OHV		# OF MODELS = 42			
1.	100%	Enleanment with Minor Carb Adj		42	
		Manufacturer of Carburetors			
		Design carburetors	$10,000.00		$420,000.00
		make prototypes and test engines	$10,000.00		$420,000.00
		One time changes to existing tooling and dies	$10,000.00		$420,000.00
2.	50%	Improved Cooling		21	
		Design cooling systems	$10,000.00		$210,000.00
		Build prototypes, test engines and repeat	$10,000.00		$210,000.00
		One time changes to existing tooling and dies	$10,000.00		$210,000.00
OTHER		# OF MODELS = 9			
1.	50%	Fuel Carburetion Optimization		4.5	
		Research and develop new program for fuel injector chip	$10,000.00		$45,000.00
		Develop prototypes and test engines, repeat	$10,000.00		$45,000.00
2.	50%	Improved Cooling		4.5	
		Design cooling systems	$10,000.00		$45,000.00
		Build prototypes, test engines and repeat	$10,000.00		$45,000.00
		One time changes to existing tooling and dies (may be incorporate	$10,000.00		$45,000.00
			TOTAL COST:		$35,967,000.00
			CARB COST:		$25,967,000.00
			Phase I Cost:		$10,000,000.00
Class III		# OF MODELS = 1			
1.	100%	Enleanment with Minor Carb Adjustments		1	
		Conduct research with carburetor manufacturer	$30,000.00		$30,000.00
		Develop prototypes and test carburetors on bench an	$10,000.00		$10,000.00
2.	100%	Carburetor Limiter Cap		1	
		Develop finely adjustable needles (up to 3)	$5,000.00		$5,000.00
		Purchase plastic cap for adjustment (R&D COST??)	$0.00		$0.00
3.	100%	Combustion Chamber Redesign		1	
		Design new block	$30,000.00		$30,000.00
		Make prototypes, test engines and repeat	$30,000.00		$30,000.00
		One time cost of changing die design and tooling changes	$20,000.00		$20,000.00
4.	50%	Improved Cooling		0.5	
		Design cooling system (additional fins, fans, etc.)	$20,000.00		$10,000.00
		Build prototypes and test	$20,000.00		$10,000.00
			TOTAL COST:		$145,000.00
			CARB COST:		$72,500.00
			Phase I Cost:		$72,500.00
Class IV		# OF MODELS = 27			
1.	75%	Enleanment with Major Carb Adjustments		20	
		Conduct research with carburetor manufacturer	$50,000.00		$1,012,500.00
		Develop prototypes and test carburetors on bench an	$50,000.00		$1,012,500.00
2.	25%	Enleanment with Minor Carb Adjustments		7	
		Conduct research with carburetor manufacturer	$30,000.00		$202,500.00
		Develop prototypes and test carburetors on bench an	$10,000.00		$67,500.00
3.	50%	Carburetor Limiter Cap		14	
		Develop finely adjustable needles (up to 3)	$5,000.00		$67,500.00
		Purchase plastic cap for adjustment (R&D COST??)	$0.00		
4.	75%	Combustion Chamber Redesign		20	
		Design new block	$30,000.00		$607,500.00
		Make prototypes, test engines and repeat	$30,000.00		$607,500.00
		One time cost of changing die design and tooling changes	$20,000.00		$405,000.00
5.	50%	Improved Cooling		14	
		Design cooling system (additional fins, fans, etc.)	$20,000.00		$270,000.00
		Build prototypes and test	$20,000.00		$270,000.00
6.	1%	4 Stroke Engine Design			
		Research, design, develop, build prototypes, test engines			
		(not a required technology, more like a company choice)			
			TOTAL COST:		$4,522,500.00
			CARB COST:		$2,407,500.00
			Phase I Cost:		$2,115,000.00

Class V		# MODELS = 15			
1.	75%	Enleanment with Major Carb Adjustments		11.25	
		Conduct research with carburetor manufacturer	$50,000.00		$562,500.00
		Develop prototypes and test carburetors on bench and engi	$50,000.00		$562,500.00
2.	25%	Enleanment with Minor Carb Adjustments		3.75	
		Conduct research with carburetor manufacturer	$30,000.00		$112,500.00
		Develop prototypes and test carburetors on bench and engi	$10,000.00		$37,500.00
3.	93%	Carburetor Limiter Cap		13.875	
		Develop finely adjustable needles (up to 3)	$5,000.00		$69,375.00
		Purchase plastic cap for adjustment (R&D COST??)	$0.00		$0.00
4.	100%	Combustion Chamber Redesign		15	
		Design new block	$30,000.00		$450,000.00
		Make prototypes, test engines and repeat	$30,000.00		$450,000.00
		One time cost of changing die design and tooling changes	$20,000.00		$300,000.00
5.	50%	Improved Cooling		7.5	
		Design cooling system (additional fins, fans, etc.)	$20,000.00		$150,000.00
		Build prototypes and test	$20,000.00		$150,000.00
		Tooling costs incoporated in comb cmbr redesign			
			TOTAL COST:		$2,844,375.00
			CARB COST:		$0.00
			Phase I Cost:		$2,812,500.00

C. CATALYST OPTION

For all Classes, research and development will be performed in conjunction with catalyst manufacturers

	Est Use of Catalysts	# of Models Per Class	% x Total # of Models	# of Models Used for C.	Est Cost Per Model	Total Cost Per Class
Class I	33%	47	15.51	16	$20,000.00	$320,000.00
Class II	0%	144	0	0	$20,000.00	$0.00
Class III	1%	1	0.01	1	$20,000.00	$20,000.00
Class IV	1%	27	0.27	1	$20,000.00	$20,000.00
Class V	1%	15	0.15	1	$20,000.00	$20,000.00

Appendix B: References

1. Power Systems Research, Engindata and PartsLink Databases, St. Paul Minnesota, 1992

2. U.S. Department of Commerce, Bureau of Economic Analysis, *BEA Regional Projections to 2040, Volume 3: BEA Economic Areas*, Washington, DC, 1992.

Appendix C: Baseline Emissions, In-Use Deterioration, and Development of In-Use Emission Function

Information on in-use emissions from small SI engines is utilized in EPA's efforts to quantify the emission benefits that would be realized, through the adopted HC, CO, and NO_x emission standards for new small nonroad SI engines, as presented in Chapter 4 Environmental Benefits. This chapter presents supporting information to the assumptions on in-use deterioration estimates for each class and small SI engine design as well as background to the development of the in-use emission equation estimate for pre-control engines and post-control engines used to calculate engine emissions at each year along an engine's useful life.

EPA also considered setting in-use emission standards as part of this rule. While the data available are adequate to adjust the inventory for the various in-use effects, sufficient data are not available to set in-use emission standards at this time.

C.1. Baseline and In-Use Emissions Estimates for Pre- and Post Control Engines

The category of small SI engines consists of a wide variety of engines utilized in a wide range of equipment which are used by people, in both residential and professional settings, with unique usage and maintenance habits. In-use emissions deterioration of small SI engines is influenced by several variables including engine design, engine quality, the manner in which and where the equipment is used as well as how well the engine and equipment is maintained and stored. Some of the variables, such as engine design and engine quality, are directly influenced by the regulation, however factors such as user maintenance and use habits are not directly affected.

EPA estimates that the rule will result in many of the designs and features of higher cost engines being incorporated in lower cost engines in order to meet the emission standards. The features that result in reduced emissions such as more rigid cylinders and closer tolerances are the same features currently used to increase performance and durability on higher quality engines. These changes are estimated to reduce in-use emission deterioration. On the other hand, in-use emissions of a regulated engine may be a greater percentage of a new engines total lifetime emissions due to the lower new engine emissions.

Unique user habits, including the manner in which and where the equipment is used as well as how well the engine and equipment is maintained and stored, effects engine in-use emissions deterioration. For example, a user that routinely keeps the fins on the engine block free from debris will allow the engine to maximize the use of one of its cooling mechanisms, thereby allowing the heat to transfer away from the engine block and keep component tolerances in an acceptable range. This contributes to a more efficiently running engine by reducing the

change for engine damage, such as burnt piston rings. However, user habits vary widely and thus adds an unpredictable variable in the task of estimating small engine in-use emissions deterioration.

All of these factors affect the ability to predict in-use emission deterioration for the engines covered by this rule. The following discussion presents EPA's methodology to estimate baseline and in-use deterioration estimates for pre and post control engines while keeping in mind all factors just mentioned.

C.1.1. Determination of Baseline Emissions and In-Use Deterioration Estimates for Pre-Control Engines

The baseline and in-use emissions estimates for pre-control engines in this analysis were based on information presented in the EPA's 1991 Nonroad Vehicle and Emission Study Report and Appendices(1) and the California Air Resources Board Technical Support Document for their Lawn and Garden Regulation(2). Information from SAE technical papers(3), and industry submitted engine emission data(4)(5)(6)(7)(8)(9) was utilized to fill in holes and support or suggest changes to the existing information from the 1991 Nonroad Study and CARB technical support document.

The 1991 Nonroad Study presents baseline and in-use emission numbers per small SI equipment type. Table C-01 presents the baseline emissions, in-use emissions and resulting factors from the nonroad study for equipment utilizing 2- and 4-stroke engines. The choice of equipment categories represents the most popular usages of small SI engines with the category of All Other Equipment containing miscellaneous applications.

Baseline emissions for engine Classes I-V and engine design characteristics (i.e., side valve, overhead valve and 2-stroke) within those classes cannot be obtained directly from information from the 1991

Nonroad study emissions per equipment types. The equipment types contain engines with a number of different engine designs, which result in different emission characteristics, and can be spread over several engine Classes. Baseline emissions for Class I and II engines were taken from CARB's technical support document(10) which were also utilized in EPA's 1991 Nonroad Study. The CARB technical support document and its sources did not provide emissions break out for engines in Classes III-V. Classes IV and V were based on industry data utilized in the Heiden report(11). Class III engines were assumed to have similar emission characteristics to Class IV engines and therefore estimates for Class IV were utilized for Class III. Table C-02 contains the summary of baseline emissions assigned to each class and technology within each class.

In-use emissions were calculated by applying deterioration factors to baseline emissions. Deterioration factors per equipment were determined from those numbers utilized in EPA's 1991 Nonroad Study and those calculated from information collected by industry and EPA after publication of the Study. Industry information provided further validation for the choice of some of the in-use deterioration estimates utilized in the Study as well as provide a basis for changing a few of the deterioration estimates. Hydrocarbon deterioration factors for 2-stroke handheld engines, presented in Table C-01, were adjusted from 2.1 to 1.2 based on industry submitted data and EPA analysis. Industry data, presented in C.3 In-Use Pre-Control and Post-Control Engine Testing and Table C-12, indicate that 2-stroke emissions deteriorated less than 2.1 percent times that of new engine emission numbers as indicated by the study. Industry data was collected by an accelerated accumulation of in-use operation time on engines with emission taken at interval points. EPA estimated that the numbers may represent professional use of the engines and related equipment due to the fast

accumulation of operation hours. However, this simulation of in-use operation may result in low estimates for consumer usage patterns which would include effects of maintenance and time effects, such as usage of old fuel or malmaintenance. The second change made to the study numbers was the change of HC and NO_x deterioration estimates of 2-stroke engines used in pumps from 2.1 to 1.2 for HC and .4 to 1.0 for NO_x. This was done to keep consistency with other like engines.

The deterioration factors were then determined for each Class of engines broken out by OHV, SV and 2-stroke, 4-stroke. Deterioration factors presented in Table C-01 for 4-stroke and 2-stroke engine equipment were applied to the corresponding engine Classes and engine designs. For example, 4-stroke equipment deterioration factors were applied to Class I 4-stroke OHV engines and 2-stroke equipment deterioration factors were applied to Class III 2-stroke engines. The deterioration factors for each Class and engine design are shown in Table C-03. Distinction in relative in-use emissions for various engine designs, i.e., side valve, ohv, 2-stroke, is found when the deterioration estimates are multiplied by the new engine emission numbers, i.e., baseline, which are different for each engine design. The resultant pre-control engine Baseline and Minimum In-Use Exhaust Estimate utilized in EPA's analysis is summarized in Table C-04.

C.1.2. Determination of Baseline and In-Use Deterioration for Post-Control Engines

Baseline emissions and in-use deterioration factor estimates for post control engines were based on adopted emission standards and a calculation of deterioration from pre-control engines. The expected mix of emission reduction technologies are presented in technology market mix Tables 2-02 and 2-03 in Chapter 2-Technology Market Mix and Cost Estimates for Small SI Engines and Related Equipment. The following

summarizes expected changes in in-use emission deterioration for small SI engines.

The Agency assumed that all engine designs within each class would start with the same new engine emission number, i.e., the respective emission standards, in each class. Table C-05 lists baseline numbers to the corresponding engine classes and engine designs. Two- stroke engines in Classes I and II were assumed to transfer to 4-stroke side valve and overhead valve designs. The explanation for other classes and technologies are as follows.

Class 1 side valve engines are expected to utilize enleanment to reduce emissions. Emission data on Class I OHV engines show a 50/50 split in HC and NO_x (Table 2-05 in Chapter 2). EPA expects that the same result applies to enleaned side valves. As a result, the 16 g/kw-hr standard is split with 8g/kw-hr for HC and 8 g/kw-hr for NO_x. The CO standard is set as the exhaust limit for these engines based on data which shows the CO limits of pre-control engines are higher than the standard. It is expected that enleanment will cause CO to be reduced.

Class II OHV engines already meet the standards and as a result, it is expected that their emission values will not change. For side valve engines, it is expected that enleanment and other minor engine changes will occur that will result in a 70% of the standard being HC and 30% of the standard for NO_x.

Classes III-V post-control engine baseline numbers are based on the emission standards. Class IV 4-stroke handheld engine emission numbers were provided by one engine manufacturer.

The post control technologies were then analyzed to determine if in-use deterioration would increase or decrease based on EPA's knowledge of the technologies. Refer to C.3 In-Use Pre-Control and Post-Control Engine Testing for an in-depth discussion.

Expected emission reduction technologies consist of engine structure

(e.g., more rigid cylinder walls, tighter tolerances, etc.) and production changes that will tend to improve engine performance quality, and emission reduction strategies such as enleanment, valve and ignition timing and possible use of catalysts. As a result, EPA estimates that improvements in engine structure and production practices tend to increase component life and thus in-use deterioration to post control engines would be the same or less than occurs to pre-control engines. At the same time, emission control strategies such as enleanment or limited use of catalytic converters could marginally increase the rate of deterioration of post-control engines if not optimized. Based on the limited amount of available data of in-use emissions on post control engines (Tables C-11 and C-12) and EPA's technical assessment of directional change in deterioration, EPA decided it reasonable at this time to estimate the same deterioration amount as was seen in pre-control engines.

EPA assumed that the deterioration of pre-control engines is additive to post-control engines baseline emissions and the amount of deterioration will not change based on the technologies that will be utilized for meeting emission standards. Therefore, Minimum In-Use Exhaust Estimates for post-control engines are calculated by taking the difference of the in-use and new engine emission levels from pre-control and adding that number to the post control baseline numbers.

C.2. EPA Development of Emissions Deterioration Equation for Environmental Benefit Analysis

EPA's analysis for Chapter 4 on Environmental Benefit considers emissions deterioration over a period of time. As a result, a function is constructed to provide emission numbers for each year over the specified number of years for pre- and post-control engines. Information from the emission factors presented in sections C.1.1. and

C.1.2. and EPA and industry in-use emission collection test data were utilized to determine the emission equation.

EPA's 1991 Nonroad Study calculations of in-use emission deterioration utilized a straight line deterioration from new engine emission levels to end of useful life emission levels with the average deterioration representing the emission factors presented in Table C-01. For example, small 4-stroke engines, such as lawnmowers, were portrayed to emit an average of 2.1% times increase for HC, a 1.9% times increase for CO and a decrease of 60% for NO_x over its new engine emission levels for its entire useful life.

Additional in-use emission data collected by EPA and industry since the study, Tables C-8, C-9, C-11 and C-12, indicates that the in-use emissions deterioration was very random, however showed a general trend to increase more rapidly at the beginning of an engines useful life and then stabilizes to the end of its useful life (Figures C1-C4). Thereby data would correlate better to an exponential curve rather than a linear line as utilized in the 1991 Nonroad Study. As a result, an exponential function was developed to represent emission deterioration and was formulated as follows (hydrocarbons (HC) is used as an example)

$$HC=HC_{in\text{-}use}+ (HC_{in\text{-}use} - HC_{new})(1-e^{-age/(B50/3)})$$

where:

HC_{new}	-	Hydrocarbon Emission numbers for new engines (pre-Table 4, post-Table 5)
$HC_{in\text{-}use}$	-	Hydrocarbon Minimum In-use Estimates (pre-Table 4, post-Table 5)
age	-	Number of Years After New
B_{50}	-	Implied B_{50} from Attrition Constants (Weibull Function) (see Chapter 4 Environmental Benefits)

Concerns for differences in use by consumer and professional users

are considered in Chapter 4 Environmental Benefits through use of usage rates of hours/yr and estimated useful lives. The quality of the engine is distinguished in estimates for HC_{new} and $HC_{in\text{-}use}$.

C.3 In-Use Pre-Control and Post Control Engine Testing

Since 1991, EPA and industry have been involved in individual testing programs to collect emission data on in-use small SI engines. EPA conducted an in-use emissions program at Southwest Research Institute on four walk-behind mower engines and a string trimmer engine in 1991 which was utilized for EPA's 1991 Nonroad Study (Table C-08 and C-09). In 1993, two small engine test cells were established and operated to perform emission tests including testing of in-use engines. The labs were at EPA's National Vehicle Fuel Emissions Laboratory (NVFEL) and at the University of Michigan's Walter E. Lay Automotive Laboratory through a Cooperative Research Agreement with EPA (Appendix A). Emissions testing of pre and post-control in Classes I and II was performed through an industry program and shared with EPA (Table C-11). Emissions testing of pre and post-control engines in Classes III-V was performed through an industry program and shared with EPA, as stated previously in C.1.1. and presented in Table C-12. Initial analysis of the test data has shown that in-use emissions from small SI engines is variable. Many factors influence the result including the variety of engine quality currently being manufactured, varieties in engine carburetors (adjustable and fixed jet), engine quality control during manufacture, user engine maintenance and amount of equipment use.

Many holes exist for in-use data on post control engines, as a result, engineering judgment is used as a tool to estimate in-use emission deterioration changes based on technologies. Section C.3.1. presents assumptions made for estimating engine deterioration for HC, CO and

NO_x pollutants in various engine designs for Classes I and II. C.3.2. presents assumptions made for same in Classes III-V. Expected engine changes are presented in technology market mix tables in Chapter 2 Technology Market Mix and Cost Estimates for Small SI Engines and Related Equipment. Combinations of several of the technologies will most likely be used on the majority of engine models with smaller displacement engines requiring more than one emission reduction technology more often than larger displacement engines. The trade-offs in in-use emission deterioration are assumed to be of no significance. In summary, EPA estimates that the in-use deterioration for post control engines will be less variable than pre-control engines due to factors including improvements in quality control during engine and carburetor manufacture and more uniform use of combustion efficient engine designs amongst engine manufacturers.

C.3.1 Estimated Emission Deterioration per Technology for Classes I and II

Due to the limited number of available test results of in-use emissions from post-control engines, engineering judgement is used to provide a best guess on the effect of each emission reduction technology on in-use emissions deterioration. The following is a description of such for each technology.

C.3.1.1. Enleanment with Major redesigns to carburetor and fuel distribution system and Enleanment with Minor redesigns to carburetor-- Enleanment requires the addition of other emission reduction technologies in order to reduce the effects of engine wear. Addition technologies such as improved cooling and optimization of materials can be used to enhance heat transfer from the engine combustion chamber and related components. Deterioration can occur from the expansion of engine component materials beyond acceptable tolerance ranges for proper engine operation and improper valve seating due to warped engine block mating surfaces. Enleanment may result in slightly harder starting and higher temperatures, however, it is expected that the affect will be minimized due to redesign of the carburetor to inject additional fuel when required.

OHV engines are estimated to require less degree of enleanment to meet emission standards. In addition, the portion of overhead valve engines which utilize enleanment with minor modifications to carburetor are expected to experience little to no change in engine wear due to less fuel cooling available to the engine. This will not result in increased valve/seat sealing for the combustion cylinder is not directly linked to the valve seat area.

Alternative fueled engines and fuel injected engines are estimated to utilize fuel carburetion optimization. This may also result in an enleaned engine for which the manufacturer will have to make

compensation for harder starting and higher combustion temperatures. However, the changes may be so slight as to not affect the engine deteriorating negatively.

C.3.1.2. Changes in ignition timing, valve timing--Changing the ignition timing before top dead center will result in more efficient burning of the fuel. Thereby emission deterioration is expected to be no greater than current engines.

C.3.1.3. Combustion Chamber Redesign--Combustion chamber redesign is estimated to include tighter tolerances and restructuring of the engine block for stiffer cylinders and better heat transfer for less valve seat warping. Deterioration is expected to remain constant or decrease due to tighter tolerances of piston within the cylinder wall.

C.3.1.4. Valve System Improvements Including Valve Timing--Valve system improvements are estimated to include of the addition of valve guides where none exist, tighter tolerances between valve guides and valve stems, improvements in valve cam design, better quality materials for valves and optimization of valve timing. In-use emission deterioration is expected to remain unchanged from current engines.

C.3.1.5. OHV with minor mods to carburetor--This technology change is estimated to be for Class I side valve engines only. Therefore, in-use emission deterioration would be the same as this technology for overhead valve engines with minor modifications to the carburetor as presented in C.3.1.1.

C.3.1.6. Improved Cooling--This technology is estimated to be utilized on a portion of each engine Class to reduce engine deterioration

from the use of enleanment. Improved cooling is expected to include increased fin area on the engine block and redesign of air from fan for maximum cooling. Neither of these changes affect combustion processes of the engine however do influence, indirectly, the amount of temperature seen in the combustion chamber. No deterioration of these parts are expected. However, user use of the engine and equipment may result in some blocking or covering of fin surface area, thereby reducing the available space for cooling.

C.3.1.7. Conversion of 2 Stroke to 4 Stroke Engine Design--Four-stroke technologies exist for the applications in which 2-stroke engines are utilized. As a result, EPA estimates that 2-stroke engine designs will convert to 4-stroke engine designs due to the difficulty of the 2-stroke meeting Class I and Class II emission standards. EPA estimates that this will result in changes of emission deterioration from 2-stroke characteristics to 4-stroke characteristics. Two-strokes have fewer moving parts than the 4-stroke counterparts which have valve systems. Two-stroke engines are also run extremely rich and as a result may or may not result in the observation of emission deterioration except due to decreased power which may result from inefficient combustion. This results in a higher g/kw-hr number.

C.3.1.8. OPTION: Catalyst--Based on discussion with catalyst manufacturers and information provided at the SAE Fuels and Lubricants Conference in 1993, EPA expects that catalysts used on small engines will deteriorate in-use. EPA has incorporated a durability demonstration requirement in this rulemaking, see Chapter 1, for all catalysts utilized on small SI engines. EPA feels the durability demonstration requirement will ensure that catalyst deterioration is reasonable.

The catalyst may deteriorate quickly if oil is emptied into the catalyst by tilting the engine such that oil drips into the catalyst. Oil may also enter the catalyst each time the engine is used and shut off for fuel and oil do enter and exit the engine as the engine is winding down. Four-stroke engines generally use ash oils which poison the catalyst. These factors influence the emission deterioration by providing an emission reduction technology which may have a limited useful life of its own. This thereby sways the in-use estimate for side valve engines close to the present engine level for deterioration. EPA estimates that engines utilizing catalysts will also require a majority of the previous technologies applied to the engine design in order to reduce the required amount of conversion for minimum heat exotherms. As a result, the same deterioration for engines without catalyst is used for engines with catalyst.

C.3.2. Estimated Emission Deterioration per Technology for Class III-V Engines

Two-stroke handheld engines have very few moving parts, however, they have been shown to encounter exhaust port clogging due to excess fuel exiting the combustion chamber unburned. The quality of the engine has indicated how long the engine will last with power loss being one of the main contributors to increases in emissions on pre-control engine designs. Chapter 2 shows that similar technologies are utilized on all three engine classes. As a result, each technology is described with some general references to each class where appropriate.

C.3.2.1. Major and Minor Carburetor Modifications--Handheld 2-stroke engines operation can be sensitive to carburetor settings when utilized in under a wide variety of conditions such as temperature, humidity and altitude. Many engine designs will convert to fixed jet

carburetors to reduce the production costs of adding a limiter adjustment cap. In-use emission deterioration will be limited due to the shortened or nonexistent ability of the user to adjust the carburetor to leaner or richer mixtures. This is estimated to decrease emission deterioration for the user will submit the engine to increased maintenance in order to obtain acceptable operation when plugging occurs in the engine carburetor or air filter. Enleanment also reduces exhaust port plugging which results in reduced emission deterioration.

C.3.2.2. Carburetor Limiter Adjustment Caps--Adjustment limiter caps are utilized to restrict the range of carburetor adjustment that the user may access in order to keep the engine in compliance with emission regulations. This adjustment will only occur at time of maintenance. EPA estimates there will be no deterioration of the limiting cap or mechanisms that are used to perform this function.

C.3.2.3. Combustion Chamber /Scavenging/Port Timing Modifications- Better fuel transfer or the addition of third ports in the combustion cylinders are possible technologies for this heading. Chamber designs to reduce scavenging may result in smaller exhaust ports to increase backpressure in the chamber thereby forcing less raw fuel through the engine. Smaller exhaust ports may result in more frequent exhaust port plugging which will require the user to clean it out more frequently or take it in for service to be cleaned. This may well be offset by reduced port plugging due to the enleaned fuel mixture. Port timing modifications will reduce fuel/oil scavenging as the timing of the opening of inlet and exhaust ports with the position of piston during power strokes is optimized. EPA estimates that this will not contribute to increased in-use engine emissions.

C.3.2.4. Cooling Improvements--Cooling improvements are expected to consist of those mentioned for Class I and II engines which include the reduction in wear of other components. No deterioration of cooling components is expected.

C.3.2.5. 4-Stroke--This is a new engine technology expected on the market in 1994. EPA has no test data on in-use deterioration characteristics of this engine, however, it is estimated that the engines that utilize this technology will have similar emission in-use deterioration to other 4 stroke engines.

C.3.2.6. OPTION: Catalyst--Only a small portion of engines may choose to use catalyst as an option. In-use emission deterioration Engines with catalyst are expected to be similar to those for Class I and II engines. EPA has estimated that engines utilizing catalyst will have made all of the prior technology changes before utilizing catalysts and as a result, the same deterioration for engines without catalyst is used for engines with catalyst.

Based on discussion with catalyst manufacturers, EPA expects that catalysts used on small engines will deteriorate in-use. EPA has submitted a durability demonstration requirement in this rulemaking, see Chapter 1, for all catalysts utilized on small SI engines. EPA feels the durability demonstration requirement will ensure that catalyst deterioration is reasonable.

The following is a summary for each regulated pollutant:

- HC: For many engine designs, the carburetors will be fixed jet which thereby results in much less variability in emissions from use in the real world. Tolerances will be improved thereby increasing

the efficiency of burn and reducing scavenging in both 2- and 4-stroke side valve engine designs. The use of better materials and quality control is expected to yield less HC deterioration. The optional catalyst use will result in in-use emission characteristics of engines with other changes and therefore will not go to present pre-control emission levels if the catalyst should fail.

- CO Deterioration of CO is estimated to be limited due to the use of fixed carburetor jets and limiter caps on adjustable carburetors. Small engine equipment owners will increase frequency of maintenance due to the inability enrich or enlean the engine. NOx: As seen for pre-control engines, NOx is estimated to decrease as the engine ages, thereby resulting in favorable emission deterioration for NO_x.

Table C-01

Baseline and In-Use Emission Numbers from EPA's 1991 Nonroad Study(12)

EQUIPMENT CATEGORY	BASELINE (g/kW-hr)			IN-USE (g/kW-hr)			IN-USE FACTOR			ADJUSTED IN-USE FACTORS		
	HC	CO	NO_x	HC	CO	NO_x	HC	CO	NO_x	HC	CO	NO_x
4-STROKE ENGINES							2.1	1.9	0.4	2.1	1.9	0.4
Lawnmowers	50.5	576.4	2.71	106.13	1095.17	1.09						
Trimmers/Edgers/Brush Cutters	32.41	527.27	2.71	68.07	1001.81	1.09						
Chainsaws	NA	NA	NA	NA	NA	NA						
Leaf Blowers/Vacuums	26.01	509.79	2.72	54.61	968.59	1.09						
Generator Sets	12.73	473.19	2.72	26.74	899.06	1.09						
Tillers	50.54	576.41	2.71	106.13	1095.17	1.09						
Snowblowers	50.54	576.41	2.71	106.13	1095.17	1.09						
Commercial Turf	12.6	474.53	2.83	26.46	901.61	1.13						
Rear Engine Riders	12.47	473.19	2.72	26.18	899.06	1.09						
Lawn and Garden Tractors	12.6	474.53	2.83	26.46	901.61	1.13						
Pumps	12.47	473.19	2.72	26.18	899.06	1.09						
All Other Equipment												
2-STROKE ENGINES							2.1	1.9	1.0	1.2	1.9	1.0
Lawnmowers	278.82	486	.39	585.52	1237.8	.39						
Trimmers/Edgers/Brush Cutters	301.01	728.22	1.22	632.14	1854.72	1.22						
Chainsaws	399.46	699	1.29	842.9	1780.29	1.29						

EQUIPMENT CATEGORY	BASELINE (g/kW-hr)			IN-USE (g/kW-hr)			IN-USE FACTOR			ADJUSTED IN-USE FACTORS		
	HC	CO	NO_x	HC	CO	NO_x	HC	CO	NO_x	HC	CO	NO_x
Leaf Blowers/Vacuums	288.59	716.81	1.29	606.05	1825.66	129						
Generator Sets	278.82	486	.39	585.52	1237.8	.39						
Tillers	278.82	486	.39	585.52	1237.8	.39						
Snowblowers	278.82	486	.39	585.52	1237.8	.39						
Commercial Turf	278.82	486	.39	585.52	1237.8	.39						
Rear Engine Riders	NA	NA	NA	NA	NA	NA						
Lawn and Garden Tractors	NA	NA	NA	NA	NA	NA						
Pumps	5.74	113	9.44	12.05	287.8	3.78	2.1	1.9	.4	1.2	1.9	1.0
All Other Equipment												

NA = Not Applicable

Note: All Other Equipment include the following: Distributed Loose Engines, Commercial Turf Equipment, Other Lawn and Garden, Wood Splitters, Pressure Washers, Front Mowers, Welders, Specialty Vehicles and Carts, Shredders, Cement/Mtr Mixers, Golf Carts, Paving Equipment, Air Compressors, and Sprayers.

Table C-02
Pre-Control Engines
New Engine Baseline Numbers

CLASS	Engine Design	HC g/kW-hr	CO g/kW-hr	NO_x g/kW-hr	Reference
Class I	Side Valve	52.3	578	2.68	CARB
	Overhead Valve	18.0	548	2.4	CARB
	2-Stroke	279	651	.389	SAE 910560
Class II	Side Valve	12.9	463	2.75	CARB
	Overhead Valve	6.97	681	4.69	CARB
	2-Stroke	(279)	(651)	(.389)	(Class I - 2- Stroke)
Class III	2-stroke air-cooled	(350)	(964)	(1.26)	(Class IV - 2-Stroke)
Class IV	2-stroke air- cooled	350	964	1.26	Industry Data
Class V	2-stroke air-cooled	214	696	(1.26)	Industry Data (NO_x:Class IV - 2-Stroke)

Key:

(xxx) means the no data was available, therefore numbers were implied from other classes and categories

CARB = (13)

SAE = (14)

Industry = Number is an average of a number of engines from Industry Data presented in Table 17 in Chapter 1

Table C-03
Adjustment Factors As Applied to Engine Classes and Technologies

Class	Engine Design	HC	CO	NO_x
Class I	4-Stroke - OHV	2	2	0
	4-Stroke - SV	2	2	0
	2-Stroke	1	2	1
Class II	4-Stroke - OHV	2	2	0
	4-Stroke-SV	2	2	0
	2-Stroke	1	2	1
Class III	2-Stroke	1	2	1
Class IV	2-Stroke	1	2	1
Class V	2-Stroke	1	2	1

Table C-04
EPA Analysis Baseline and Minimum In-Use Estimates Pre-Control

Class	Engine Design	NEW ENGINE EXHAUST (g/kW-hr)			MINIMUM IN-USE EXHAUST ESTIMATE		
		HC	CO	NO_x	HC	CO	NO_x
Class I	4-Stroke - OHV	18	548	2.4	37.7	1042	.4
	4-Stroke - SV	52.3	578	2.7	109.8	1098	1.9
	2-Stroke	279	651	.4	334.8	835.2	1.3
Class II	4-Stroke - OHV	7	681	4.7	14.6	1294	1.9
	4-Stroke-SV	13	463	2.8	27.2	879	1.1
	2-Stroke	279	651	.4	224.8	781.2	0.4
Class III	2-Stroke	350	964	1.3	420	1156.8	1.3
Class IV	2-Stroke	350	964	1.3	420	1156.8	1.3
Class V	2-Stroke	214	696	1.3	256.8	835.2	1.3

Table C-05
Post-Control
In-Use Adjustment Factors for Small SI In-Use Deterioration

CLASS AND TECHNOLOGY	BASELINE POST CONTROL ENGINE EMISSIONS (g/kW-hr) (Class Standards)			EMISSIONS DIFFERENCE (Pre-Control Engines; In-Use - Baseline Estimate)			MINIMUM IN-USE EXHAUST ESTIMATE		
	HC	CO	NO_x	HC	CO	NO_x	HC	CO	NO_x
CLASS I									
4-Stroke - OHV	8.0	402	8.0	19.7	494	-2	27.8	895	6.6
4-Stroke - SV	8.0	402	8.0	57.5	520	-.8	65.5	922	6.4
OPTIONAL: 4-Stroke - SV w/Catalyst	8.0	402	8.0				65.5	922	6.4
2-Stroke	0.0	0.0	0.0				–	–	–
CLASS II									
4-Stroke - OHV	7.0	402	4.7	7.6	613	-2.8	14.6	1015	1.9
4-Stroke-SV	9.4	402	4.0	14.2	416	-1.7	23.6	818	2.4
2-Stroke	0.0	0.0	0.0				–	–	–
CLASS III									
2-Stroke	295	805	5.4	70	192.8	0	365	997.8	5.4
OPTIONAL: 2-Stroke w/ Catalyst	295	805	5.4				365	997.8	5.4
CLASS IV									
2-Stroke	241	805	5.4	70	192.8	0	365	997.8	5.4
4-Stroke	20	170	5.4				42	323	2.1
OPTIONAL: 2-Stroke w/Catalyst	241	805	5.4				365	997.8	5.4
CLASS V									
2-Stroke	161	402	5.4	42.8	139.2	0	203.8	541.2	5.4
OPTIONAL: 2-Stroke w/Catalyst	161	402	5.4				203.8	541.2	5.4

Table C-06
Post-Control
In-Use Adjustment Factors for Small SI In-Use Deterioration

Class	Engine Design	HC	CO	NOx
Class I	4-Stroke - OHV	3.43	2.23	0.815
	4-Stroke - SV	8.10	2.29	0.790
	4-Stroke - SV w/ Catalyst	8.10	2.29	0.790
	2-Stroke	--	--	--
Class II	4-Stroke - OHV	3.09	4.22	1.40
	4-Stroke-SV	5.06	3.19	1.16
	2-Stroke	--	--	--
Class III	2-Stroke	2.31	2.08	1.00
	2 Stroke w/ Catalyst	2.31	2.08	1.00
Class IV	2-Stroke	2.60	2.08	1.00
	4-Stroke	2.13	2.10	0.40
	2-Stroke w/Catalyst	2.60	2.08	1.00
Class V	2-Stroke	2.46	2.56	1.00
	2-Stroke w/Catalyst	2.46	2.56	1.00

Table C-07
Pre-Control In-Use Exhaust Emissions
Class I and Class II(15)(16)

Class	Engine Design	Engine Specifics	HC (g/kw-hr)	CO (g/kw-hr)	NOx (g/kw-hr)	Wtd A/F	Wtd Power (kW)	BSFC (kg/kW-h)
Class I	Side Valve	*2yr, Tecumseh (1st test)	91	871	1.26	10.4	0.67	1.33
		*2yr Tecumseh (2nd & 3rd test)	363	1795	4.76	0.67	0.39	1.95
		*4yr, Tecumseh	132	1314	0.56	10.1	0.63	1.27
		*8yr, B&S	102	1115	1.09	10.1	0.65	1.08
	Overhead Valve	NA						
	2-Stroke	*11yr, 126cc, Lawn-Boy	244	559	0.68	13.2	0.86	0.88
		7-10yr, Lawn-Boy	802	1737	1.53	--	0.41	2.38
		7-10yr, Lawn-Boy	1246	1621	0.92	--	0.53	2.54
Class II	Side Valve	NA						
	Overhead Valve	NA						
	2-Stroke	NA						

Key:
NA= not available
* = used in EPA 1991 Nonroad Study

(Note: EPA recognizes the submittal of a June 1990 report entitled "Toro Small Air-Cooled Engine Exhaust Emissions Baseline" by Toro which performed testing on a number of small SI engines. Data in this report is worthwhile to note, however cannot be compared to the data above for emissions were not collected on all modes of the test cycle used above.)

Table C-08
Pre-Control In-Use Exhaust Emissions
Classes III, IV and V(17)(18)

Class	Engine Design	Engine Condition	HC (g/kw-hr)	CO (g/kw-hr)	NOx (g/kw-hr)	Wtd A/F	Wtd Power (kW)	Wtd BSFC (kg/kW-h)
Class III	2-stroke 3yr, 17.5cc Trimmer	As-Is	435	974	0.41	--	0.38	1.34
		Lt Maint.	221	235	1.21	--	0.45	0.864
		Heavy Maint	185	255	1.07	--	0.50	0.71
Class IV	2-stroke 3 yr, 22cc Blower	As-Is	200	310	0.36	--	0.63	0.60
	2-stroke 30.5cc Trimmer Commercial Use	As-Is	143	375	1.37	--	0.82	1.52
		Lt Maint.	273	168	1.89	--	0.80	0.75
	2-stroke *4yr, 31cc Trimmer	As-Is	1725	2802	0.98	9.4	0.16	3.90
	2-stroke 6 yr, 29.5cc Chainsaw	As-Is	339	221	6.0	--	0.62	0.94
		Lt Maint.	413	435	3.6	--	0.52	1.20
		Heavy Maint	424	801	0.92	--	0.63	1.19
Class V	2-stroke 65cc Chainsaw Commer-cial Use	As-Is	199	195	3.24	--	2.72	0.89
		Lt Maint.	259	558	0.72	--	2.52	1.53

*utilized in EPA 1991 Nonroad Study

Table C-09
In-Use Deterioration Estimates:
Examples for Comparison of Pre-Control Baseline Factors and In-Use Engine Emission Results

Class I: 4-Stroke Side Valve Engines

Pollutant	New Engine (Class I Side Valve) (g/kW-hr)	Used Engine #1 (8 year -148cc) (g/kW-hr)	Factor (In-Use/New)	Used Engine #2 (4 year -164cc) (g/kW-hr)	Factor (In-Use/New)	Factors Utilized in EPA Analysis for 4-Stroke Engines
HC	52.3	102	1.95	132	2.5	2.1
CO	578	436	0.75	1276	2.2	1.9
NO_x	2.7	1.1	0.41	0.57	0.21	0.4

New Engine from Table C-02
Used Engine numbers are from Table C-07

Class I: 2-Stroke Engines

Pollutant	New Engine (Class I 2-Stroke) (g/kW-hr)	Used Engine #1 (11 yr 126cc) (g/kW-hr)	Factor (In-Use/New)	Used Engine #2 (7-10 yr) (g/kW-hr)	Factor (In-Use/New)	Factors Utilized in EPA Analysis for 2- Stroke Engines
HC	279	244	0.87	802	2.9	1.2
CO	651	559	0.86	1737	2.7	1.9
NO_x	0.4	0.68	1.71	1.53	3.8	1.0

New Engine from Table C-02
Used Engine numbers are from Table C-07

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Table C-11
Classes I and II
Industry In-Use Emission Test Program
Pre and Post Control Engines(19)

Engine Design and Specifics	Pre- or Post-Control Design	Hours	Number of Engines Reported	Before or After Maintenance	$HC+NO_x$ (% from baseline)	CO (% from baseline)
Class I (<225cc)						
Composite of Engine Designs	Pre-Control ("Best")	50	11	Before	147.2	98.3
				After	144.6	93.3
		100	11	Before	199.2	106.8
				After	181.6	101.6
		150	9	Before	203.1	103.9
				After	192.7	100.6
	Post-Control (Worst")	50	7	--	173.3	121.0
		100	7	--	197.3	107.6
		150	5	--	201.4	114.2
Class II (>225cc)						
Composite of Engine Designs			Work in progress, Information not available to date-			

- The testing was performed by small engine manufcturers during 1992 and 1993 and was limited to lawn mowing equipment, both walk behind and ride on
- "Future" technology means fuel system calibrations and other engine modifications that are implemented to bring the engines into compliance with CARB's Tier 1 rule.
- The maintenance performed on the "best" maintenance engines was that recommended by the manufacturer of the enigne. "Worst" maintenance allows only repairs - no routine maintenance was performed on worst maintenance engines.
- All of the data (above) is from 4-stroke engines
- The numbers (above) are the percentag eof the respective emissiosn relative to those measured on a new engine (new engine = 100%)

Table C-12
Classes III-V
Industry In-Use Emission Test Program
Pre and Post Control Engines (20)(21)(22)(23)(24)

ENGINE	Pre- or Post-Control Design (How Aged)	Hours	HC (g/kW-hr)	CO (g/kW-hr)	NOx (g/kW-hr)
CLASS III					
NA					
CLASS IV					
30.1cc Chain Saw	Pre (dyno)	0	177.87	347.92	0.49
		12.5	203.16	383.64	.43
		25	175.09	227.81	0.72
		37.5	216.37	276.36	0.69
		50	190.38	287.03	0.74
	Post (dyno)	0	176.14	293.87	0.57
		12.5	188.66	338.37	0.48
		25	157.31	299.37	0.56
		37.5	156.09	206.58	0.91
		50	173.82	315.95	0.81
	Post (field)	0	181.91	370.88	0.47
		12.5	161.68	124.84	1.40
		25	167.33	107.31	1.14
		37.5	159.38	119.77	2.24
		50	1.43	282.21	0.58
25cc Trimmer	Pre (dyno)	2.5	186.18	465.38	.74
		15	188.51	469.17	0.63
		25	161.55	409.02	1.07
		39	229.1	548.38	0.61
	*unclog exhaust port	39*	190.89	551.46	0.64
		50	186.65	551.46	0.68
	Post (dyno)	2.5	167.56	440.95	1.15
		3.5?	148.94	251.34	1.02
		15	212.4	613.6	0.57
		25	172.09	398.52	1.13

		37.5	200.01	585.13	0.80
		50*	189.04	223.41	1.07
		51.3	190.89	602.37	0.59
	Post (field)	2.5	167.56	352.76	0.88
		3.5?	167.56	524.46	0.75
		12.5	198.43	596.16	0.71
		25	172.09	326.06	1.13
		37.5	161.55	237.16	1.29
		50*	229.53	528.85	0.73
24cc Blower	Pre (dyno)	0.75	531.57	1280.39	0.17
		3	507.76	1356.73	0.13
		15	319.65	632.43	0.35
		30	345.17	603.22	0.34
		42.5	322.93	688.52	0.23
		55.5	273.80	604.64	0.19
	Post (dyno)	0.25	443.10	927.17	0.18
	adj for Stds	3	409.02	556.82	0.24
		15	336.61	691.09	0.23
		29.5	354.48	759.61	0.15
		42.5	345.10	630.31	0.31
		55	365.84	818.25	0.31
	Post (field)	3	345.17	331.77	0.64
		15	317.97	445.79	0.62
		30.5	408.68	971.03	0.16
		43	388.74	891.42	0.64
		54	360.44	411.08	1.56
38cc chainsaw	Pre (dyno)	Break-in	239.71	543.29	0.80
		12.5	263.10	503.33	0.95
		25	294.66	672.05	0.94
		37.5	274.26	637.17	0.99
		50	384.81	694.04	0.98
	Post (dyno)	break-in	234.95	525.88	0.66
		after mod	211.18	530.95	0.85
		12.5	217.93	467.61	0.92

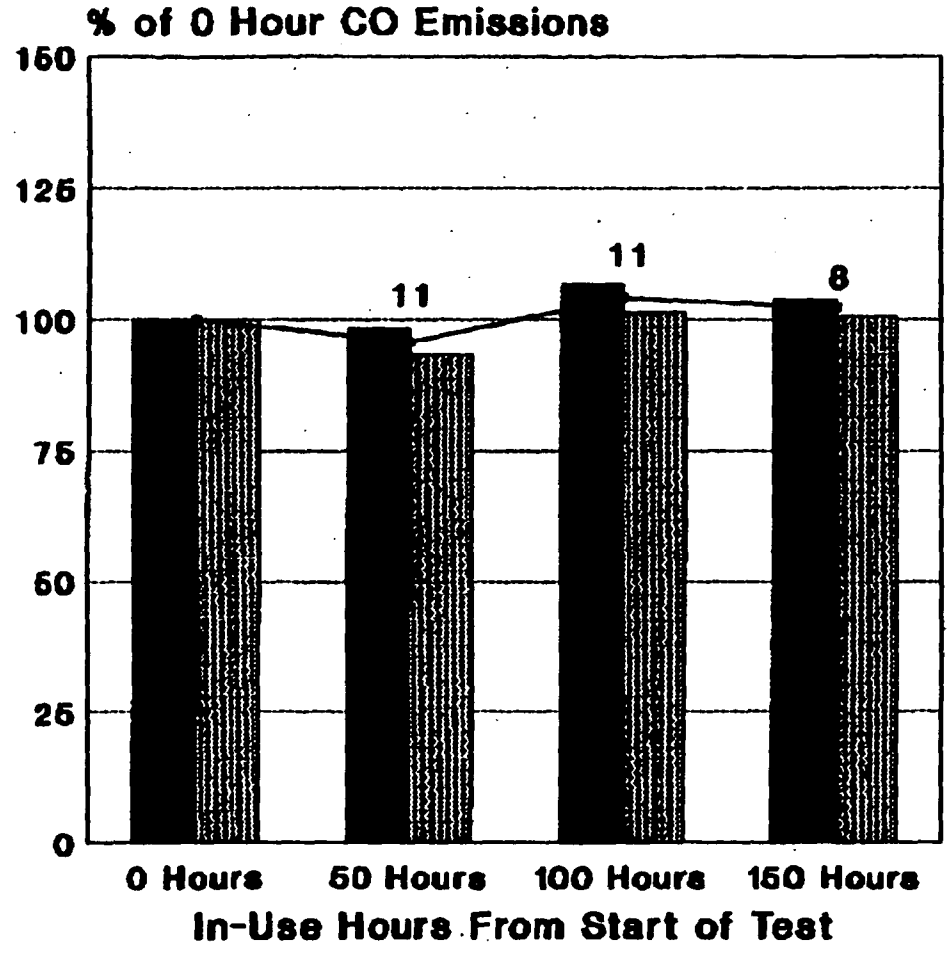
		25	214.48	533.26	0.93
		37.5	244.83	629.59	0.73
		50	255.74	649.25	0.98
	Post (field)	break-in	220.74	505.60	0.50
		after mod	213.48	466.69	0.67
		12.5	199.49	443.56	0.76
		25	199.17	401.38	0.73
		37.5	223.54	475.19	0.50
		50	247.14	565.81	0.57
21cc Trimmer	Pre (dyno)	break-in	256.93	323.95	0.78
		12.5	223.47	398.40	0.65
		25	246.65	501.24	0.56
		37.5	236.36	429.15	0.62
		50	241.48	431.27	0.64
	Post (dyno)	break-in	244.58	378.63	0.49
		after mod	205.86	299.21	0.65
		12.5	164.06	276.10	0.60
		25	168.85	317.16	0.70
		37.5	180.17	340.23	0.56
		50	164.44	265.71	0.79
	Post (field)	break-in	393.01	475.26	0.52
		after mod	201.07	327.94	0.57
		12.5	190.72	403.87	0.71
		25	184.32	305.35	0.85
		37.5 before maint	150.80	299.64	0.72
		37.5 after maint	158.80	333.06	0.70
		50	133.79	145.50	1.20
CLASS V					
53cc Chain Saw	Pre-(dyno) (Engine #1)	3	119.50	426.84	0.69
		75	119.72	462.86	0.50
		150	109.75	408.53	0.57
		225	111.80	470.99	0.49

		300	134.99	505.62	0.57
	Pre (dyno) (Engine #2)	3	114.45	378.10	0.80
		75	101.39	308.35	0.87
		150	149.37	337.78	0.78
		225	117.61	357.58	0.73
		300	127.23	431.03	0.73
	Post (dyno) (Engine #1)	3	104.69	357.05	0.73
		75	92.21	288.01	0.93
		150	93.29	305.92	0.93
		225	105.34	348.81	0.77
		300	126.23	466.66	0.57
	Post (dyno) (Engine #2)	3	115.41	355.50	0.85
		75	112.81	332.51	0.77
		150	102.04	288.33	0.86
		225	108.60	292.74	0.87
		300	105.57	309.69	0.80
	Post (field) (Engine #1)	3	113.60	358.32	0.80
		75	116.84	372.57	0.76
		150 -300	not yet finished		
	Post (field) (Engine #2)	3	113.72	363.03	0.78
		75	113.86	387.29	0.69
		150	118.83	413.39	0.74
		225	112.10	340.39	0.83
		300	not yet finished		

Note: All data is based on the WOT mode of the two mode J1088 test

IN-USE EMISSIONS DATA - CO

< 225 cc, 4 Stroke, Future Technology



NOTE: Numbers shown above bars indicate the number of engines reported.

Before Maintenance

Average Before/After

After Maintenance*

BFB/12-17-93

*Maintenance performed per manufacturers recommendations

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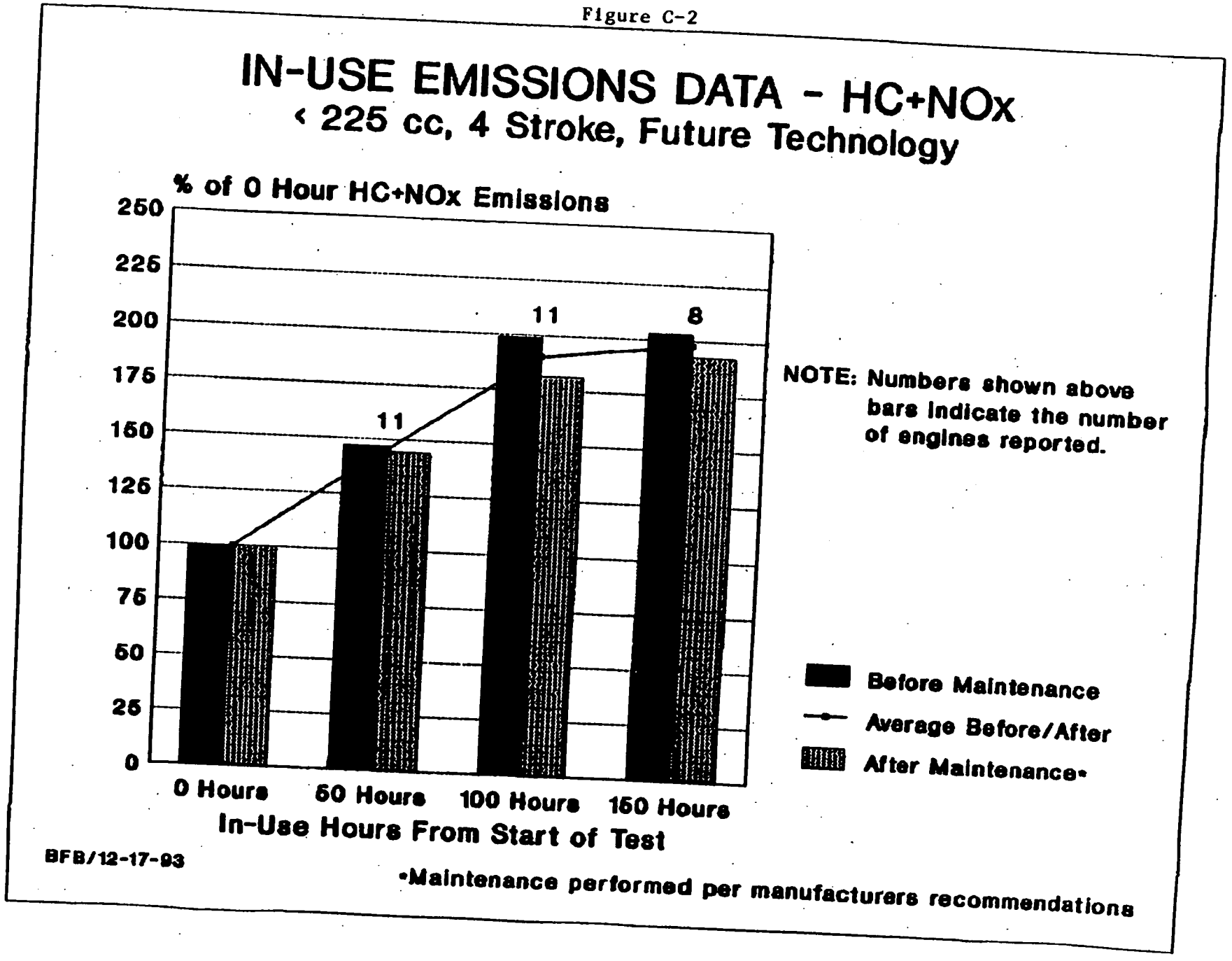
Figure C-2



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IN-USE EMISSIONS DATA - CO
< 225 cc, 4 Stroke, Future Technology

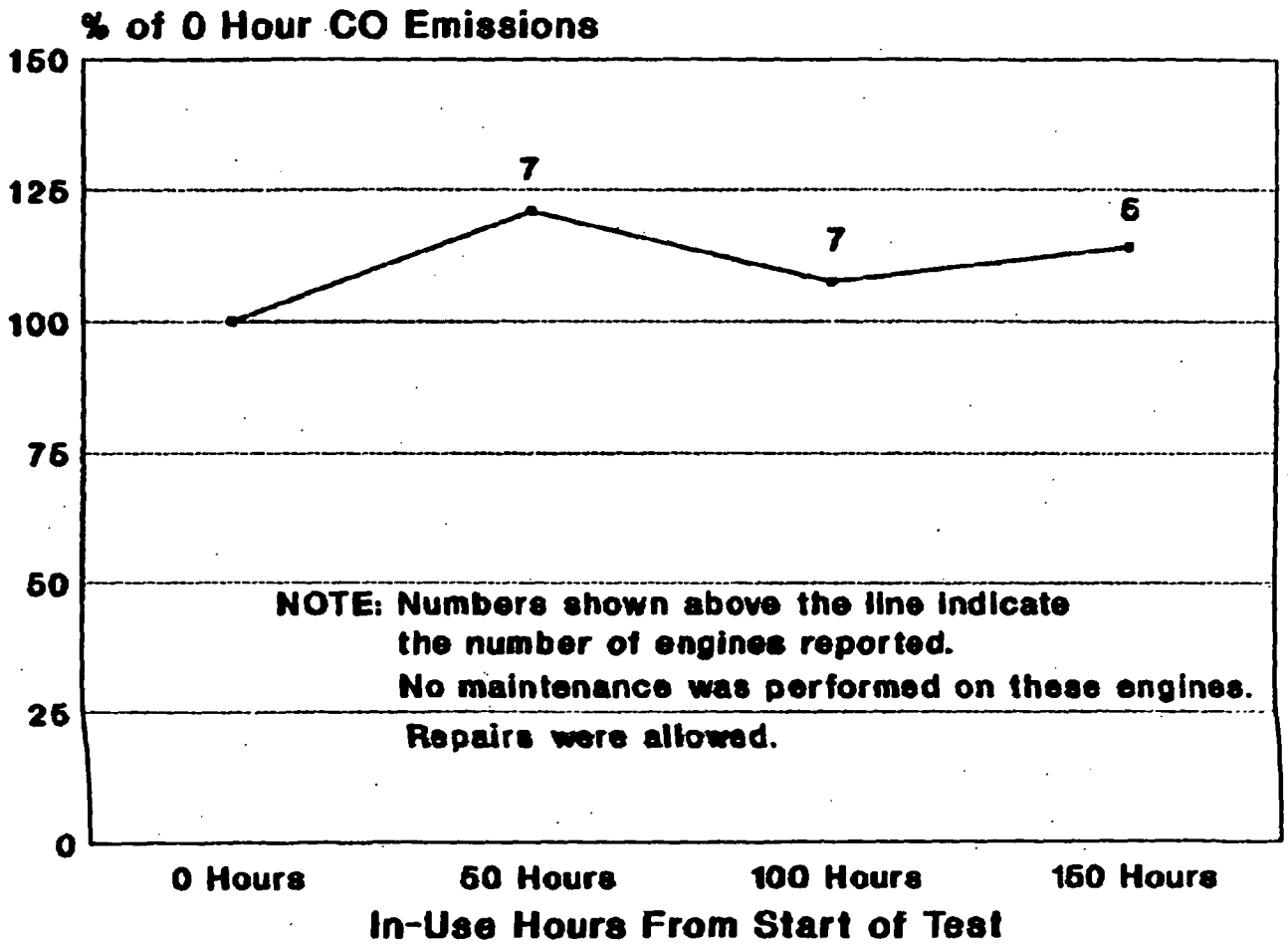

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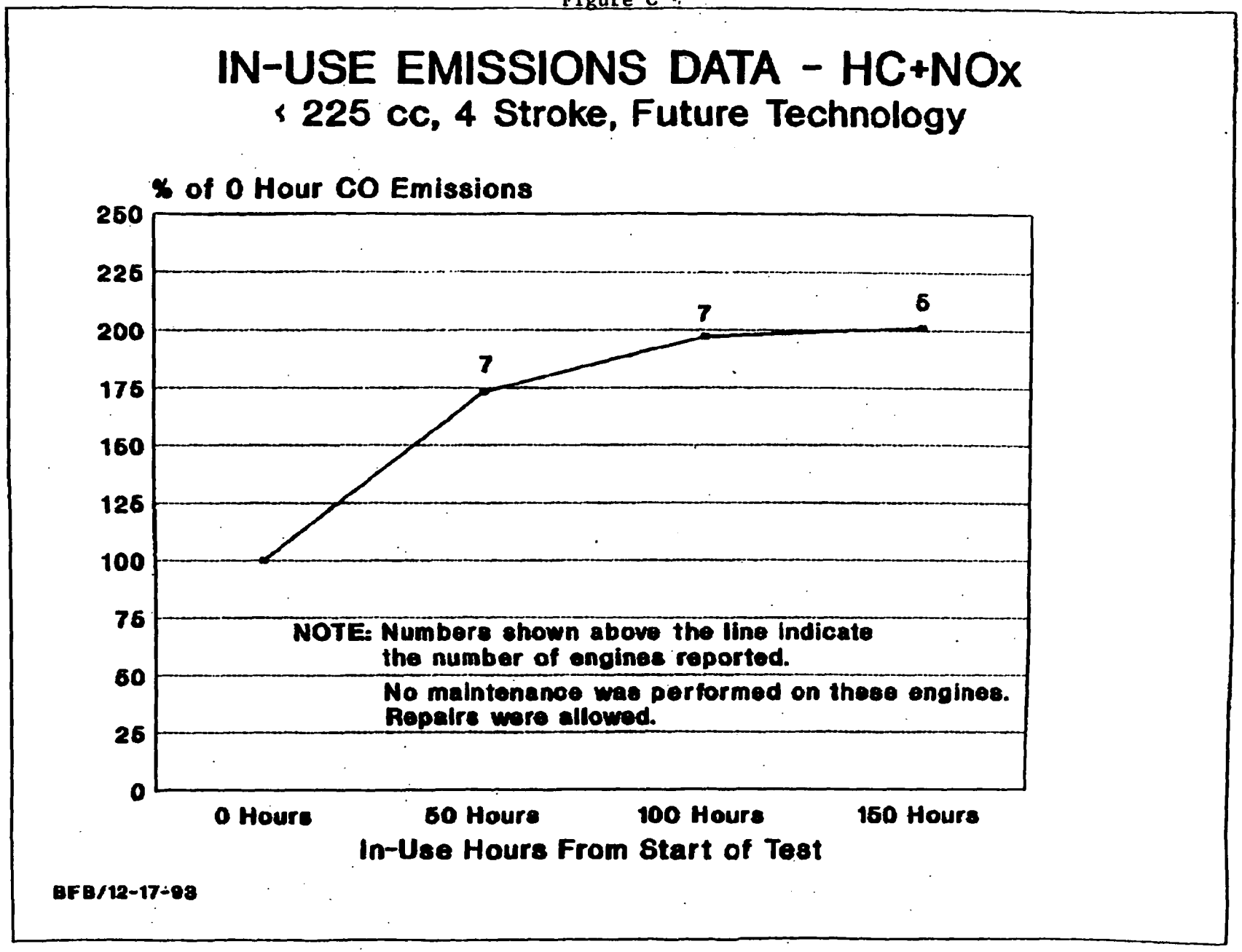
Figure C-


IN-USE EMISSIONS DATA - HC+NOx
< 225 cc, 4 Stroke, Future Technology
% of 0 Hour CO Emissions
250
225
200
175
150
125
100
75
50
25
0
7
7
5
NOTE: Numbers shown above the line indicate the number of engines reported.
No maintenance was performed on these engines. Repairs were allowed.
0 Hours
50 Hours
100 Hours
150 Hours
In-Use Hours From Start of Test
BFB/12-17-93

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APPENDIX C REFERENCES

1. United Environmental Protection Agency, National Vehicle and Fuel Emissions Laboratory, *Nonroad Engine and Vehicle Emission Study Report and Appendicies*, EPA 21A-2001, November 1991

2. State of California Air Resources Board, *Technical Support Document for California Exhaust Emission Standards and Test Procedures for 1994 and Subsequent Model Year utility and Lawn and Garden Equipment Engines*, Mail Out #92-06, January 30, 1992.

3. White, Jeff, et al, *Emission Factors for Small Utility Engines*, SAE #910560, 1991

4. OPEI In-Use Emissions Testing, facsimile to Cheryl Caffrey, EPA from Brad Bohlman, December 17, 1993

5. PPEMA/AQC, In-Use Emissions Test Report (25cc String Trimmer), February 5, 1993

6. PPEMA/AQC, *EPA/PPEMA In-Use Emissions Test Report (30.1cc Chainsaw)*, February 8, 1993

7. PPEMA/AQC, *PPEMA/AQC Test Report* (for 24cc Blower), March 15, 1993

8. PPEMA/AQC *In-Use Emission Testing 38cc Chain Saw*, March 1993

9. PPEMA/AQC *In-Use Emissions Test Report (53cc Chain Saw)*, March 12, 1993

10. State of California Air Resources Board, supra note 2, pages 28 & 30

11. Heiden Associates Report, *A 1989 California Baseline Emissions Inventory for Total Hydrocarbon and Carbon Monoxide Emissions from Portable Two-Stroke Power Equipment*, July 1990.

12. US EPA, supra note 1, pages 29,31,33,35

13. State of California Air Resources Board, supra note 2

14. White, supra note 3

15. SwRI, *Emission Tests of In-Use Small Utility Engines*, September 1991

16. University of Michigan Small Engine Test Facility, 1993 Cooperative Agreement with the U.S. Environmental Protection Agency

17. SwRI, *Emission Testing of In-Use Handheld Engines*, March 1994

18. Ibid.

19. OPEI, supra note 4

20. PPEMA/AQC, supra note 5

21. PPEMA/AQC, supra note 6

22. PPEMA/AQC, supra note 7

23. PPEMA/AQC, supra note 8

24. PPEMA/AQC, supra note 9

Appendix D: Summary of Burden Imposed by the Information Collection Requirements

The information collection requirements of the rule have been submitted for approval to the Office of Management and Budget (OMB) under the Paperwork Reduction Act, 44 U.S.C. 3501 et seq. EPA has prepared six Information Collection Request (ICR) documents for this Smallgas FRM. The supporting statements in each of the ICRs reflects the Agency's estimates, in hours and dollars, of burden imposed by specific sections of the regulations on certain nonroad engines--specifically spark-ignition engines at or below 19 kilowatts, excluding marine and nonroad recreational vehicles, such as snowmobiles, all terrain vehicles (ATVs), offroad motorcycles.

The regulation associated with these ICRs fulfills, in part, the Agency's obligations found in §213 of the Clean Air Act, as amended. EPA has regulated similar on-highway engines for many years and these nonroad regulations are patterned after that program and will impose very similar information collection and reporting requirements. A summary of the estimated total annual burden imposed by the Small

Gas FRM is presented in Table D-1[13], below. Copies of the complete ICR documents may be obtained from Sandy Farmer, U.S. EPA, Information Policy Branch, Mail Code 2136, 401 M St., S.W., Washington, DC 20460 or by calling (202) 260-2740.

[13] Table D-1 presents estimates of burden for years after the first effective year of the regulation. It is assumed for this previously unregulated industry, that the first year resource requirements will be higher than in subsequent years, because manufacturers will have to establish physical and procedural systems to comply with the information collection and reporting requirements. The estimated first year costs of compliance are broken down and presented in the ICRs.

Table D-1
Summary of Estimated Total Annual Burden Imposed by the Information Collection and Reporting Requirements

EPA ICR Number	Type of Information	OMB Control Number	Time (Hours)	Cost (Dollars)
N/A	Emission Certification	N/A	144,245	7,933,475
282	Emission Defect Information	2060-0048	262	12,838
N/A	Importation of Nonconforming Engines	N/A	7,329	354,447
N/A	Selective Enforcement Auditing	N/A	15,647	1,604,958
12	Engine Exclusion Determination	2060-0124	90	3,420
95.03	Pre-certification and Testing Exemption	2060-0007	346	13,167
N/A	In-use Testing (Proposed --Not Finalized)	N/A	0	0
		Annual Totals	167,919	9,922,305

Note: The hours spent by a given manufacturer on information collection activities in any given year is highly dependent upon manufacturer specific variables such as numbers of engine families, running changes, emission defects, etc.

Appendix E: Hourly Test Length Estimate

The test procedure for this rulemaking is based on the SAE J1088 6-mode and 2-mode procedures. The procedure has been modified by EPA in many ways. These modifications to SAE J1088 include tightening of testing and measuring equipment specifications and calibration requirements, specification of acceptable certification fuel and the acceptable option of constant volume (dilute) sampling. The modifications to SAE J1088 are intended to ensure greater uniformity in practices and results among manufacturers for gaseous emission measurement. This is an explanation of the time estimate derived for the modified test procedure.

There are two test time estimate categories. One is the "set up" time and the other is the "test" run time.

The set up time will depend on whether the test has previously been run on a particular engine block. If the test has been run on the particular engine block, then less time will be required to set up the test than if no test had been run.

If the test has been run before on the engine block in question, then the following 3 steps must be done:

1. make engine adapters for the dynamometer,
2. make flywheel adapters for the dynamometer,
3. make exhaust system hook ups to the measurement system. (This involves setting the measurement system up with the correct back pressure.)

These are time consuming tasks. This estimate represents the minimum time required. It is assumed that these three steps are performed once per engine family. However, it is likely to be several times per engine family because the boring holes for screws may be different for each flywheel. There may be other changes between models in the same engine family as well. Ignoring these differences, the "first time set up" estimate is two 8-hour days (i.e., 16 hours).

If an emission test has been run on the engine block in question, then the first time set up work is complete. The necessary equipment can be retrieved and re-assembled for another test. The set up in this case is termed the "yearly set up" because it would be the set up done to perform a certification test after the first model year in which an engine family is certified. The yearly set up includes connecting the

- throttle linkage,
- wiring,
- pressure transducers, and
- fuel line hookup;
- initial service accumulation on new engine.

EPA estimates 10 hours to do the yearly set up. In addition, a selective enforcement audit test would require this yearly set up.

Therefore, the estimated total set up time required for the first time the test is performed is 16 hours plus 10 hours (i.e., 26 hours). Each yearly test would only require 10 hours for set up.

"Running the test" and gathering emissions involves the following five steps.

1. Setting the exhaust restrictions. Minimal time is required for this.
2. Testing performed to stabilize the test conditions. Full emissions are not taken. This takes about .5 hours.
3. Testing done with full emissions measurement. For the 6-mode test, EPA estimates 2 hours, for the 2- mode test EPA estimates 1 hour. (The average of 1.5 hours is used for calculation below.)

4. Documentation of the test. This takes about 2 hours.
5. Taking the engine out of the test cell. This takes about 1 hours.

Therefore, it is estimated that approximately 5 hours are required to run the test.

The Table E-01 summarizes the hourly test estimates. EPA requests comments on all time estimates.

Table E-01
Hourly Test Estimates

Category	First Test Performed	Yearly Tests or SEA Tests
First Time Set Up	26	0
Yearly Set Up	10	10
Running the Test	5	5
TOTAL	41	15

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Appendix F: Supplementary Tables

for

Chapter 4

Table F-01-Average Power Ratings (kW)

Equipment Type	Use	G2H1	G2H1C	G2H2	G2H2C	G4H2	G2H3	G2H3C	G2N1	G2N2	G4N1O	G4N1S	G4N1SC	G4N2O	G4N2S
LN MOWERS	Res.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	3.0	2.8	2.8	0.0	6.0
LN MOWERS	Prof.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	3.0	2.8	2.8	0.0	6.0
TRIM/EDGE/CUTTER	Res.	0.7	0.7	0.9	0.9	0.9	2.3	2.3	0.0	0.0	2.6	2.0	2.0	0.0	6.0
TRIM/EDGE/CUTTER	Prof.	0.7	0.7	0.9	0.9	0.9	2.3	2.3	0.0	0.0	2.6	2.0	2.0	0.0	6.0
CHAINSAWS	Res.	0.6	0.6	1.2	1.2	1.2	2.2	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHAINSAWS	Prof.	0.6	0.6	1.2	1.2	1.2	2.2	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LEAF BLOW/VACS	Res.	0.7	0.7	1.0	1.0	1.0	2.5	2.5	0.0	0.0	3.6	3.3	3.3	6.9	6.1
LEAF BLOW/VACS	Prof.	0.7	0.7	1.0	1.0	1.0	2.5	2.5	0.0	0.0	3.6	3.3	3.3	6.9	6.1
GENTR SETS	Res.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	3.5	3.3	3.3	8.4	9.9
GENTR SETS	Prof.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	3.5	3.3	3.3	8.4	9.9
TILLERS	Res.	0.0	0.0	1.2	1.2	1.2	0.0	0.0	0.0	0.0	0.0	3.1	3.1	8.2	5.2
TILLERS	Prof.	0.0	0.0	1.2	1.2	1.2	0.0	0.0	0.0	0.0	0.0	3.1	3.1	8.2	5.2
SNOWBLOWER	Res.	0.0	0.0	0.0	0.0	0.0	2.4	2.4	0.0	0.0	0.0	3.3	3.3	0.0	6.4
SNOWBLOWER	Prof.	0.0	0.0	0.0	0.0	0.0	2.4	2.4	0.0	0.0	0.0	3.3	3.3	0.0	6.4
COMM TURF	Res.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	3.8	3.6	3.6	11.2	10.6
COMM TURF	Prof.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	3.8	3.6	3.6	11.2	10.6
REAR ENG RIDER	Res.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	3.7	7.2	7.4
REAR ENG RIDER	Prof.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	3.7	7.2	7.4
LN/GDN TRACTORS	Res.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	3.7	10.5	9.5
LN/GDN TRACTORS	Prof.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	3.7	10.5	9.5
PUMPS	Res.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	9.0	3.4	3.0	3.0	8.1	7.8
PUMPS	Prof.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	9.0	3.4	3.0	3.0	8.1	7.8
ALL OTHER EQUIP.	Res.	0.0	0.0	1.0	1.0	1.0	3.0	3.0	2.2	5.4	3.3	3.0	3.0	9.7	8.5
ALL OTHER EQUIP.	Prof.	0.0	0.0	1.0	1.0	1.0	3.0	3.0	2.2	5.4	3.3	3.0	3.0	9.7	8.5

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Table F-02
Historical and Projected Consumption

Equipment Type	Use	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
LN MOWERS	Res.	5,186,765	4,862,592	3,809,030	3,971,117	4,052,160	4,376,333	4,781,549	4,619,462	3,727,987	3,727,987
LN MOWERS	Prof.	576,307	540,288	423,226	441,235	450,240	486,259	531,283	513,274	414,221	414,221
TRIM/EDGE/CUTTER	Res.	0	0	0	0	0	0	0	678,776	1,011,050	921,817
TRIM/EDGE/CUTTER	Prof.	0	0	0	0	0	0	0	150,533	224,222	204,433
CHAINSAWS	Res.	1,258,573	1,389,490	1,565,374	1,693,455	1,829,150	2,043,852	2,074,905	1,867,767	1,284,465	988,050
CHAINSAWS	Prof.	419,524	463,163	521,791	564,485	609,717	681,284	691,635	622,589	428,155	329,350
LEAF BLOW/VACS	Res.	0	0	0	0	0	0	10,231	74,136	238,957	433,540
LEAF BLOW/VACS	Prof.	0	0	0	0	0	0	1,546	11,205	36,115	65,523
GENTR SETS	Res.	40,636	47,867	55,483	69,089	64,813	81,588	81,478	71,900	69,241	53,766
GENTR SETS	Prof.	121,909	143,602	166,448	207,266	194,438	244,764	244,435	215,700	207,724	161,297
TILLERS	Res.	306,416	321,421	347,383	362,191	449,239	444,809	445,043	519,593	390,279	387,163
TILLERS	Prof.	67,262	70,556	76,255	79,505	98,613	97,641	97,692	114,057	85,671	84,987
SNOWBLOWER	Res.	223,398	169,226	116,763	123,192	199,532	309,779	309,779	309,779	256,684	70,743
SNOWBLOWER	Prof.	24,822	18,803	12,974	13,688	22,170	34,420	34,420	34,420	28,520	7,860
COMM TURF	Res.	0	0	0	0	0	0	0	0	0	0
COMM TURF	Prof.	0	0	281	308	331	43,538	77,526	87,635	78,381	81,302
REAR ENG RIDER	Res.	323,473	358,633	225,025	242,605	242,605	248,711	312,598	286,168	227,841	237,866
REAR ENG RIDER	Prof.	17,025	18,875	11,843	12,769	12,769	13,090	16,453	15,061	11,992	12,519
LN/GDN TRACTORS	Res.	672,262	784,058	513,073	522,414	526,463	593,580	655,080	609,225	445,147	461,170
LN/GDN TRACTORS	Prof.	35,382	41,266	27,004	27,495	27,709	31,241	34,478	32,064	23,429	24,272
PUMPS	Res.	12,474	14,745	14,502	16,259	15,773	23,648	28,915	23,465	18,804	14,062
PUMPS	Prof.	37,422	44,234	43,507	48,778	47,320	70,943	86,746	70,395	56,412	42,185
ALL OTHER EQUIP.	Res.	97,637	117,595	122,897	145,662	158,254	200,759	215,996	228,774	233,515	207,720
ALL OTHER EQUIP.	Prof.	292,911	352,786	368,692	436,985	474,761	602,277	647,988	686,321	700,545	623,160

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Table F-02 (contd.)
Historical and Projected Consumption

Equipment Type	Use	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
LN MOWERS	Res.	3,565,901	4,011,638	4,208,573	4,376,333	4,781,549	4,538,419	4,295,290	4,619,462	4,335,811	4,173,725	4,494,621
LN MOWERS	Prof.	396,211	445,738	467,619	486,259	531,283	504,269	477,254	513,274	481,757	463,747	499,402
TRIM/EDGE/CUTTER	Res.	1,219,749	1,353,228	1,415,912	1,762,515	2,026,524	2,229,176	2,379,027	2,402,809	2,382,714	2,428,775	2,640,476
TRIM/EDGE/CUTTER	Prof.	270,505	300,107	314,008	390,875	449,424	494,367	527,599	532,874	528,417	538,632	585,581
CHAINSAWS	Res.	1,077,680	1,188,483	1,077,680	952,763	952,763	971,818	990,873	972,524	813,730	830,004	830,004
CHAINSAWS	Prof.	359,227	396,161	359,227	317,588	317,588	323,939	330,291	324,175	271,243	276,668	276,668
LEAF BLOW/VACS	Res.	540,271	626,891	914,166	777,307	810,497	1,138,770	1,169,779	1,200,787	1,231,795	1,262,803	1,293,811
LEAF BLOW/VACS	Prof.	81,654	94,745	138,163	117,479	122,495	172,108	176,795	181,481	186,168	190,854	195,541
GENTR SETS	Res.	54,505	58,015	60,199	64,931	75,836	88,297	109,013	105,407	102,189	103,280	102,542
GENTR SETS	Prof.	163,514	174,044	180,596	194,792	227,507	264,891	327,039	316,221	306,567	309,839	307,625
TILLERS	Res.	317,832	310,821	281,998	242,269	211,888	222,015	237,595	233,700	230,584	267,197	279,587
TILLERS	Prof.	69,768	68,229	61,902	53,181	46,512	48,735	52,155	51,300	50,616	58,653	61,373
SNOWBLOWER	Res.	196,590	259,142	313,502	358,926	391,691	396,159	404,350	264,354	212,228	212,228	264,882
SNOWBLOWER	Prof.	21,843	28,794	34,834	39,881	43,521	44,018	44,928	29,373	23,581	23,581	29,431
COMM TURF	Res.	0	0	0	0	0	0	0	0	0	0	0
COMM TURF	Prof.	84,686	94,196	102,491	116,773	131,628	163,110	178,810	194,763	184,656	196,944	206,495
REAR ENG RIDER	Res.	251,536	322,623	323,534	293,459	341,761	341,761	236,955	225,107	190,475	186,830	152,637
REAR ENG RIDER	Prof.	13,239	16,980	17,028	15,445	17,987	17,987	12,471	11,848	10,025	9,833	8,034
LN/GDN TRACTORS	Res.	466,603	561,148	597,242	664,311	819,581	846,247	804,566	898,615	836,675	685,803	980,776
LN/GDN TRACTORS	Prof.	24,558	29,534	31,434	34,964	43,136	44,539	42,346	47,296	44,036	36,095	51,620
PUMPS	Res.	14,147	24,817	27,232	29,550	31,634	34,770	35,427	35,782	33,913	35,531	36,692
PUMPS	Prof.	42,440	74,452	81,695	88,650	94,902	104,311	106,280	107,345	101,740	106,592	110,075
ALL OTHER EQUIP.	Res.	210,633	241,136	259,011	262,007	268,766	283,215	297,154	293,709	300,008	283,521	309,249
ALL OTHER EQUIP.	Prof.	631,900	723,409	777,033	786,022	806,298	849,644	891,463	881,127	900,023	850,564	927,748

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Table F-02 (contd.)

Historical and Projected Consumption

Equipment Type	Use	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
LN MOWERS	Res.	4,586,246	4,258,667	2,127,894	4,252,908	4,250,028	4,247,149	4,244,269	4,241,670	4,239,070	4,236,470	4,233,871
LN MOWERS	Prof.	509,583	473,185	236,433	472,545	472,225	471,905	471,585	471,297	471,008	470,719	470,430
TRIM/EDGE/CUTTER	Res.	2,852,176	3,063,877	1,591,225	3,301,021	3,419,594	3,538,166	3,656,738	3,763,786	3,870,834	3,977,881	4,084,929
TRIM/EDGE/CUTTER	Prof.	632,530	679,480	352,888	732,071	758,367	784,663	810,959	834,699	858,439	882,179	905,919
CHAINSAWS	Res.	830,004	830,004	415,002	830,004	830,004	830,004	830,004	830,004	830,004	830,004	830,004
CHAINSAWS	Prof.	276,668	276,668	138,334	276,668	276,668	276,668	276,668	276,668	276,668	276,668	276,668
LEAF BLOW/VACS	Res.	1,324,820	1,355,828	704,516	1,462,236	1,515,439	1,568,643	1,621,847	1,669,880	1,717,912	1,765,945	1,813,978
LEAF BLOW/VACS	Prof.	200,227	204,913	106,477	220,995	229,036	237,077	245,118	252,378	259,637	266,897	274,156
GENTR SETS	Res.	101,804	101,065	51,406	104,558	106,304	108,051	109,797	111,374	112,950	114,527	116,103
GENTR SETS	Prof.	305,411	303,196	154,218	313,674	318,913	324,152	329,391	334,121	338,850	343,580	348,310
TILLERS	Res.	299,896	201,439	96,963	186,414	178,901	171,389	163,876	157,094	150,311	143,529	136,746
TILLERS	Prof.	65,831	44,218	21,285	40,920	39,271	37,622	35,973	34,484	32,995	31,506	30,017
SNOWBLOWER	Res.	317,537	370,191	188,409	383,445	390,072	396,698	403,325	409,308	415,291	421,273	427,256
SNOWBLOWER	Prof.	35,282	41,132	20,934	42,605	43,341	44,078	44,814	45,479	46,143	46,808	47,473
COMM TURF	Res.	0	0	0	0	0	0	0	0	0	0	0
COMM TURF	Prof.	216,046	225,596	116,911	242,047	250,272	258,498	266,723	274,149	281,575	289,001	296,427
REAR ENG RIDER	Res.	135,747	257,878	128,425	255,822	254,795	253,767	252,739	251,812	250,884	249,956	249,028
REAR ENG RIDER	Prof.	7,145	13,573	6,759	13,464	13,410	13,356	13,302	13,253	13,204	13,156	13,107
LN/GDN TRACTORS	Res.	1,014,812	815,330	412,623	835,161	845,077	854,993	864,909	873,861	882,813	891,765	900,717
LN/GDN TRACTORS	Prof.	53,411	42,912	21,717	43,956	44,478	45,000	45,522	45,993	46,464	46,935	47,406
PUMPS	Res.	37,852	39,013	19,956	40,811	41,710	42,609	43,508	44,319	45,131	45,942	46,754
PUMPS	Prof.	113,557	117,040	59,868	122,433	125,130	127,826	130,523	132,958	135,392	137,827	140,261
ALL OTHER EQUIP.	Res.	334,990	360,475	184,920	379,203	388,567	397,931	407,296	415,749	424,203	432,657	441,111
ALL OTHER EQUIP.	Prof.	1,004,970	1,081,425	554,759	1,137,610	1,165,702	1,193,794	1,221,887	1,247,248	1,272,610	1,297,972	1,323,334

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Equipment Type	Use	G2H1	G2H1C	G2H2	G2H2C	G4H2	G2H3	G2H3C	G2N1	G2N2	G4N1O	G4N1S	G4N1SC	G4N2O	G4N2S
LN MOWERS	Res.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.050000	0.000000	0.070000	0.880000	0.000000	0.000000	0.000000
LN MOWERS	Prof.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.150000	0.000000	0.060000	0.790000	0.000000	0.000000	0.000000
TRIM/EDGE/CUTTER	Res.	0.050130	0.000000	0.917271	0.000000	0.000000	0.007745	0.000000	0.000000	0.000000	0.001564	0.023077	0.000000	0.000000	0.000213
TRIM/EDGE/CUTTER	Prof.	0.050130	0.000000	0.917271	0.000000	0.000000	0.007745	0.000000	0.000000	0.000000	0.001564	0.023077	0.000000	0.000000	0.000213
CHAINSAWS	Res.	0.003480	0.000000	0.642622	0.000000	0.000000	0.353898	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CHAINSAWS	Prof.	0.003480	0.000000	0.642622	0.000000	0.000000	0.353898	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
LEAF BLOW/VACS	Res.	0.052795	0.000000	0.629887	0.000000	0.000000	0.208551	0.000000	0.000000	0.000000	0.000694	0.072079	0.000000	0.000086	0.035908
LEAF BLOW/VACS	Prof.	0.052795	0.000000	0.629887	0.000000	0.000000	0.208551	0.000000	0.000000	0.000000	0.000694	0.072079	0.000000	0.000086	0.035908
GENTR SETS	Res.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001713	0.000000	0.005727	0.285285	0.000000	0.055057	0.652218
GENTR SETS	Prof.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001713	0.000000	0.005727	0.285285	0.000000	0.055057	0.652218
TILLERS	Res.	0.000000	0.000000	0.010133	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.793762	0.000000	0.000088	0.196018
TILLERS	Prof.	0.000000	0.000000	0.010133	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.793762	0.000000	0.000088	0.196018
SNOWBLOWER	Res.	0.000000	0.000000	0.000000	0.000000	0.000000	0.320526	0.000000	0.000000	0.000000	0.000000	0.373202	0.000000	0.000000	0.306272
SNOWBLOWER	Prof.	0.000000	0.000000	0.000000	0.000000	0.000000	0.320526	0.000000	0.000000	0.000000	0.000000	0.373202	0.000000	0.000000	0.306272
COMM TURF	Res.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.009866	0.000000	0.040016	0.064715	0.000000	0.365753	0.519650
COMM TURF	Prof.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.009866	0.000000	0.040016	0.064715	0.000000	0.365753	0.519650
REAR ENG RIDER	Res.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.049877	0.000000	0.156253	0.793870
REAR ENG RIDER	Prof.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.049877	0.000000	0.156253	0.793870
LN/GDN TRACTORS	Res.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.022245	0.803968	0.000000	0.001254	0.172533
LN/GDN TRACTORS	Prof.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.022245	0.803968	0.000000	0.001254	0.172533
PUMPS	Res.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.004857	0.000000	0.142077	0.853066
PUMPS	Prof.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.004857	0.000000	0.142077	0.853066
ALL OTHER EQUIP.	Res.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.097388	0.002384	0.037479	0.406449	0.000000	0.008111	0.448188
ALL OTHER EQUIP.	Prof.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.097388	0.002384	0.037479	0.406449	0.000000	0.008111	0.448188

Table F-04- Post-Control Sales Mix

Equipment Type	Use	G2H1	G2H1C	G2H2	G2H2C	G4H2	G2H3	G2H3C	G2N1	G2N2	G4N1O	G4N1S	G4N1SC	G4N2O	G4N2S
LN MOWERS	Res.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.125000	0.875000	0.000000	0.000000	0.000000
LN MOWERS	Prof.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.125000	0.875000	0.000000	0.000000	0.000000
TRIM/EDGE/CUTTER	Res.	0.048626	0.001504	0.900000	0.000000	0.018345	0.007513	0.000000	0.000000	0.000000	0.001564	0.020000	0.000000	0.000000	0.000213
TRIM/EDGE/CUTTER	Prof.	0.048626	0.001504	0.900000	0.000000	0.018345	0.007513	0.000000	0.000000	0.000000	0.001564	0.020000	0.000000	0.000000	0.000213
CHAINSAWS	Res.	0.003376	0.000104	0.640000	0.000000	0.000000	0.350000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
CHAINSAWS	Prof.	0.003376	0.000104	0.640000	0.000000	0.000000	0.350000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
LEAF BLOW/VACS	Res.	0.051211	0.001584	0.630000	0.000000	0.000000	0.210000	0.000000	0.000000	0.000000	0.000694	0.070000	0.000000	0.000086	0.035908
LEAF BLOW/VACS	Prof.	0.051211	0.001584	0.630000	0.000000	0.000000	0.210000	0.000000	0.000000	0.000000	0.000694	0.070000	0.000000	0.000086	0.035908
GENTR SETS	Res.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.005761	0.290000	0.000000	0.055057	0.652218
GENTR SETS	Prof.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.005761	0.290000	0.000000	0.055057	0.652218
TILLERS	Res.	0.000000	0.000000	0.009829	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.800000	0.000000	0.000088	0.196018
TILLERS	Prof.	0.000000	0.000000	0.009829	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.800000	0.000000	0.000088	0.196018
SNOWBLOWER	Res.	0.000000	0.000000	0.000000	0.000000	0.000000	0.320000	0.000000	0.000000	0.000000	0.000000	0.370000	0.000000	0.000000	0.306272
SNOWBLOWER	Prof.	0.000000	0.000000	0.000000	0.000000	0.000000	0.320000	0.000000	0.000000	0.000000	0.000000	0.370000	0.000000	0.000000	0.306272
COMM TURF	Res.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.045000	0.065000	0.000000	0.365753	0.519650
COMM TURF	Prof.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.045000	0.065000	0.000000	0.365753	0.519650
REAR ENG RIDER	Res.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.050000	0.000000	0.156253	0.793870
REAR ENG RIDER	Prof.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.050000	0.000000	0.156253	0.793870
LN/GDN TRACTORS	Res.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.022245	0.800000	0.000000	0.001254	0.172533
LN/GDN TRACTORS	Prof.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.022245	0.800000	0.000000	0.001254	0.172533
PUMPS	Res.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000971	0.000000	0.142077	0.853066
PUMPS	Prof.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000971	0.000000	0.142077	0.853066
ALL OTHER EQUIP.	Res.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.090000	0.460000	0.000000	0.008154	0.450530
ALL OTHER EQUIP.	Prof.	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.090000	0.460000	0.000000	0.008154	0.450530

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Table F-05
Weibull Constants

Equipment Type	Use	Theta	b	Implied B50
LN MOWERS	Res	7.3	1.6	5.8
LN MOWERS	Prof	2.5	1.6	2.0
TRIM/EDGE/CUTTER	Res	5.1	2.1	4.3
TRIM/EDGE/CUTTER	Prof	2.7	2.5	2.3
CHAINSAWS	Res	5.1	2.1	4.3
CHAINSAWS	Prof	1.0	3.0	0.9
LEAF BLOW/VACS	Res	5.1	2.1	4.3
LEAF BLOW/VACS	Prof	2.7	2.5	2.3
GENTR SETS	Res	7.3	1.6	5.8
GENTR SETS	Prof	2.7	2.5	2.3
TILLERS	Res	7.3	1.6	5.8
TILLERS	Prof	5.4	1.7	4.4
SNOWBLOWER	Res	5.4	1.7	4.4
SNOWBLOWER	Prof	5.4	1.7	4.4
COMM TURF	Res			
COMM TURF	Prof	3.7	1.6	2.9
REAR ENG RIDER	Res	7.3	1.6	5.8
REAR ENG RIDER	Prof	3.7	1.6	2.9
LN/GDN TRACTORS	Res	7.3	1.6	5.8
LN/GDN TRACTORS	Prof	3.7	1.6	2.9
PUMPS	Res	7.3	1.6	5.8
PUMPS	Prof	2.7	2.5	2.3
ALL OTHER EQUIP.	Res	7.3	1.6	5.8
ALL OTHER EQUIP.	Prof	2.7	2.5	2.3

Table F-07
Average Annual Use, Load Factor

Equipment Type	Use	Hr/Yr	Avg. Load Factor (%)	Hrs/Yr Load Factor
LN MOWERS	Res.	25	33	8
LN MOWERS	Prof.	406	33	134
TRIM/EDGE/CUTTER	Res.	9	50	5
TRIM/EDGE/CUTTER	Prof.	137	50	69
CHAINSAWS	Res.	13	50	6
CHAINSAWS	Prof.	303	50	151
LEAF BLOW/VACS	Res.	10	50	5
LEAF BLOW/VACS	Prof.	282	50	141
GENTR SETS	Res.	9	68	6
GENTR SETS	Prof.	143	68	97
TILLERS	Res.	17	40	7
TILLERS	Prof.	472	40	189
SNOWBLOWER	Res.	8	35	3
SNOWBLOWER	Prof.	136	35	47
COMM TURF	Res.		50	0
COMM TURF	Prof.	682	50	341
REAR ENG RIDER	Res.	36	38	14
REAR ENG RIDER	Prof.	569	38	216
LN/GDN TRACTORS	Res.	45	44	20
LN/GDN TRACTORS	Prof.	721	44	317
PUMPS	Res.	14	69	9
PUMPS	Prof.	217	69	149
ALL OTHER EQUIP.	Res.	15	50	7
ALL OTHER EQUIP.	Prof.	234	50	117

Table F-08
Projected Annual Nationwide Nonroad SI Engine Emissions in Tons/Year
1996-2020, Baseline Scenario

Year	Baseline HC	Baseline CO (exhaust)	Baseline No_x (exhaust)
1996	767,794.09	8,892,921.81	15,877.35
1997	782,746.42	9,115,293.81	16,274.24
1998	796,289.25	9,320,055.38	16,654.29
1999	809,319.86	9,516,966.64	17,023.24
2000	822,374.09	9,712,174.88	17,399.83
2001	835,156.41	9,902,869.27	17,749.50
2002	847,690.91	10,088,881.21	18,097.07
2003	860,070.75	10,271,413.42	18,443.42
2004	872,352.57	10,452,066.32	18,772.76
2005	884,673.93	10,631,865.23	19,144.85
2006	896,699.69	10,806,945.20	19,461.75
2007	908,725.46	10,982,025.17	19,778.65
2008	920,751.22	11,157,105.14	20,095.55
2009	932,605.62	11,328,766.23	20,418.07
2010	944,460.03	11,500,427.32	20,740.59
2011	955,564.80	11,661,582.98	21,032.57
2012	966,669.58	11,822,738.63	21,324.55
2013	976,953.04	11,971,891.37	21,600.51
2014	987,236.50	12,121,044.11	21,876.46
2015	997,519.96	12,270,196.85	22,152.42
2016	1,007,603.00	12,415,530.81	22,426.47
2017	1,017,686.05	12,560,864.78	22,700.52
2018	1,027,769.09	12,706,198.74	22,974.57
2019	1,037,810.61	12,850,875.77	23,239.63
2020	1,047,852.13	12,995,552.79	23,504.69

Table F-09
Projected Annual Nationwide Nonroad SI Engine Emissions in Tons/Year
1996-2020, Controlled Scenario

Year	HC	CO (exhaust)	NO_x (exhaust)
1996	767,809.20	8,892,925.08	15,876.15
1997	679,966.77	8,870,690.48	27,259.79
1998	640,627.27	8,945,831.89	33,786.07
1999	615,552.65	9,046,691.48	38,344.24
2000	600,789.08	9,173,426.42	41,344.41
2001	597,108.96	9,314,827.02	43,388.18
2002	597,628.98	9,463,911.39	44,971.64
2003	597,358.68	9,620,007.27	46,232.00
2004	599,198.51	9,777,341.34	47,406.34
2005	603,491.02	9,945,515.28	48,506.23
2006	609,696.89	10,103,826.70	49,403.81
2007	615,902.77	10,262,138.11	50,301.39
2008	622,108.64	10,420,449.53	51,198.97
2009	629,541.67	10,579,342.37	52,037.23
2010	636,974.70	10,738,235.21	52,875.50
2011	644,388.77	10,887,941.98	53,629.73
2012	651,802.84	11,037,648.74	54,383.96
2013	658,926.56	11,176,492.58	55,073.03
2014	666,050.28	11,315,336.42	55,762.10
2015	673,173.99	11,454,180.26	56,451.17
2016	680,304.00	11,589,647.32	57,122.42
2017	687,434.01	11,725,114.38	57,793.67
2018	694,564.03	11,860,581.44	58,464.92
2019	701,717.06	11,995,479.16	59,130.36
2020	708,870.10	12,130,376.89	59,795.79