California Environmental Protection Agency

Air Resources Board

STAFF REPORT
INITIAL STATEMENT OF REASONS FOR PROPOSED RULEMAKING
PUBLIC HEARING TO CONSIDER AMENDMENTS TO THE CURRENT REGULATIONS FOR LARGE SPARK-IGNITION ENGINES WITH AN ENGINE DISPLACEMENT LESS THAN OR EQUAL TO ONE LITER

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EXECUTIVE SUMMARY

To address California's acute air quality problems, the federal Clean Air Act granted California the unique authority to adopt and enforce rules to control mobile source emissions within California. The California Clean Air Act requires the Air Resources Board (ARB or Board) to achieve the maximum degree of emission reductions possible from vehicular and other mobile sources in order to attain the State ambient air quality standards by the earliest practicable date.

The large spark-ignition (LSI) engine category is defined as off-road spark-ignition engines greater than 19 kilowatts. New LSI engines with an engine displacement less than or equal to one liter (≤ 1.0 L) are typically used in such applications as portable generators, large turf care equipment, and industrial equipment. The Board initially adopted exhaust emission standards for these engines in 1998. The existing regulations for LSI engines ≤ 1.0 L include exhaust emission standards, emissions test procedures, and provisions for warranty and production compliance programs (California Code of Regulations, Title 13, Chapter 9, Sections 2430 through 2439). The regulations were first implemented in 2002.

In May of 2006, the Board approved more stringent regulations for LSI engines with an engine displacement greater than one liter. LSI engines ≤ 1.0 L were not addressed in that regulation. In recent years, the population of LSI engines ≤ 1.0 L, the number of engine families, and the maximum power ratings of these engines have grown significantly, making emissions from these engines a greater concern. To address this concern, staff's proposal would amend the existing California exhaust emission regulations for new LSI engines ≤ 1.0 L to include more stringent exhaust emission standards and, for the first time, evaporative emissions requirements. The proposed exhaust emissions standards are presented in the following table.

Current and Proposed Exhaust Emissions Standards for LSI Engines ≤ 1.0 L

Model Year	Engine Displacement	$HC+NO_x$ (g/kW-hr)	CO (g/kW-hr)
Current 2002 - 2010	≤ 1.0 L	12.0	549
2011 and subsequent	≤ 825 cc*	8.0	549
2011 - 2014	> 825 cc* - ≤ 1.0 L	6.5	375
2015 and subsequent	> 825 cc* - ≤ 1.0 L	0.8	20.6

* cc: cubic centimeters

The major proposed amendments include the following:

- More stringent exhaust emission standards,
- Evaporative emission standards and requirements,
- Off-highway recreational vehicles (OHRV) test procedures for LSI engines used in OHRV-like applications.

Staff's proposal would reduce hydrocarbons plus oxides of nitrogen ($HC+NO_x$) by 4.5 tons per day in 2020, at an estimated cost of \$0.01 - \$7.16 per pound.

Staff held two public workshops to allow for continuing public involvement and input throughout the development of the proposed regulations. In addition, staff considered alternatives to the proposal, including taking no action, setting more stringent standards, adopting the United States Environmental Protection Agency emission standards, and adopting an Engine Manufacturers Association proposal. Staff has determined that adopting its current proposal is both technologically feasible and cost-effective.

PUBLIC HEARING TO CONSIDER AMENDMENTS TO THE CURRENT REGULATIONS FOR LARGE SPARK-IGNITION ENGINES WITH AN ENGINE DISPLACEMENT LESS THAN OR EQUAL TO ONE LITER

1. INTRODUCTION

Off-road large spark-ignition (LSI) engines run on gasoline or an alternative fuel such as liquefied petroleum gas (LPG) or compressed natural gas (CNG), and are rated above 19 kilowatts (kW). Typical applications for off-road LSI engines include forklifts, portable generators, large turf care equipment, irrigation pumps, welders, air compressors, scrubber/sweepers, airport ground support equipment, and a wide array of other agricultural, construction, and general industrial equipment. Exhaust and evaporative emissions from LSI engines and equipment are a significant source of hydrocarbon (HC) and oxides of nitrogen (NO_x) emissions in California.

This report presents staff's proposal for amending the current LSI engine regulations to include more stringent exhaust and evaporative emission requirements for LSI engines less than or equal to one liter (≤ 1.0 L) in displacement. Compliance with the proposed emission standards will substantially reduce HC and NO_x emissions from new 2011 and later engines.

This report addresses the need for the proposed regulatory changes, provides a summary of the proposed changes, presents the environmental and economic impacts of the proposal, and discusses alternatives to staff's proposal. Appendix A contains the proposed amendments to the current regulation, and Appendix B contains the proposed amendments to the test procedures.

2. BACKGROUND

2.1 Legal Authority

In 1988, the Legislature enacted the California Clean Air Act, which declared that attainment of state ambient air quality standards is necessary to promote and protect public health, particularly the health of children, older people, and those with respiratory diseases. The Legislature also directed that these standards be attained by the earliest practicable date.

Health and Safety Code sections 43013 and 43018 direct ARB to achieve the maximum feasible and cost-effective emission reductions from all off-road mobile source categories.

2.2 Regulatory History

The Board first approved regulations for LSI engines and equipment in 1998. The regulations include exhaust emission standards and test procedures, labeling requirements, warranty, in-use compliance testing, production line testing, and fleet requirements (California Code of Regulations (CCR), Title 13, Chapter 9, Sections 2430 through 2439).

The LSI engine category is divided based on engine displacement. For LSI engines larger than one liter (> 1.0 L) in displacement, emission control requirements were implemented beginning with the 2001 model year (MY). This engine size category is almost exclusively made up of automotive-derived engines which are readily adapted to use existing automotive emission controls. The smaller displacement engines, LSI engines ≤ 1.0 L, are typically used in such applications as portable generators (approximately 40 percent), large turf care equipment (approximately 30 percent), and industrial equipment (approximately 30 percent). At the time of the initial rulemaking for LSI engines in 1998, industry argued that the LSI engines ≤ 1.0 L were more similar to small off-road engines (SORE) than to the LSI engines > 1.0 L and therefore it would be more appropriate that they be required to meet the SORE emission standards. The Board agreed and approved emission standards equivalent to those for SORE engines greater than or equal to 225 cubic centimeters (SORE ≥ 225 cc). Thus, beginning with the 2002 MY (see Table 2.1, below), LSI engines ≤ 1.0 L were subject to a 12.0 grams per kilowatt-hour (g/kW-hr) $HC+NO_x$ standard and a 549 g/kW-hr carbon monoxide (CO) standard. In 2003, the Board approved an 8.0 g/kW-hr $HC+NO_x$ standard for SORE ≥ 225 cc for 2008 MY and later. Staff did not propose to tighter the smaller LSI engine exhaust emission standards at that time.

Table 2.1
Exhaust Emission Standards
For SORE ≥ 225 cc and LSI Engines ≤ 1.0L

Model Year	Engine Category	$HC+NO_x$ (g/kW-hr)	CO (g/kW-hr)
2002	SORE ≥ 225 cc	12.0	549
	LSI ≤ 1.0 L	12.0	549
2008	SORE ≥ 225 cc	8.0	549
	LSI ≤ 1.0 L	12.0	549

In May 2006, the Board approved new regulations for LSI engines > 1.0 L. As shown in Table 2.2, for the 2007 through 2009 MY, these engines are required to meet emission standards of 2.7 g/kW-hr $HC+NO_x$ and 4.4 g/kW-hr CO. For 2010 and subsequent MY, the $HC+NO_x$ emission standard drops to 0.8 g/kW-hr. Note that the CO emission standard was relaxed to allow for the "trade-off" of significantly more $HC+NO_x$ benefits. Like the 2003 rulemaking, this rulemaking did not include revisions to the emission standards for LSI engines ≤ 1.0 L.

Table 2.2
Exhaust Emissions Standards for LSI Engines > 1.0 L

Model Year	$HC+NO_x$ (g/kW-hr)	CO (g/kW-hr)
2007 - 2009	2.7	4.4
2010 and subsequent	0.8	20.6

2.3 Emissions Inventory

Figures 2.1 and 2.2 illustrate the total statewide population and HC+NOx emissions inventory, respectively, for LSI engines ≤ 1.0 L in 2000, 2010, and 2020. Since the implementation of exhaust emission standards for these engines, their engine-out emission levels have decreased substantially. However, as a result of population growth between 2010 and 2020, the emissions contribution from these engines is expected to rise.

Figure 2.1
LSI Engines ≤ 1.0 L
Statewide Population Estimates

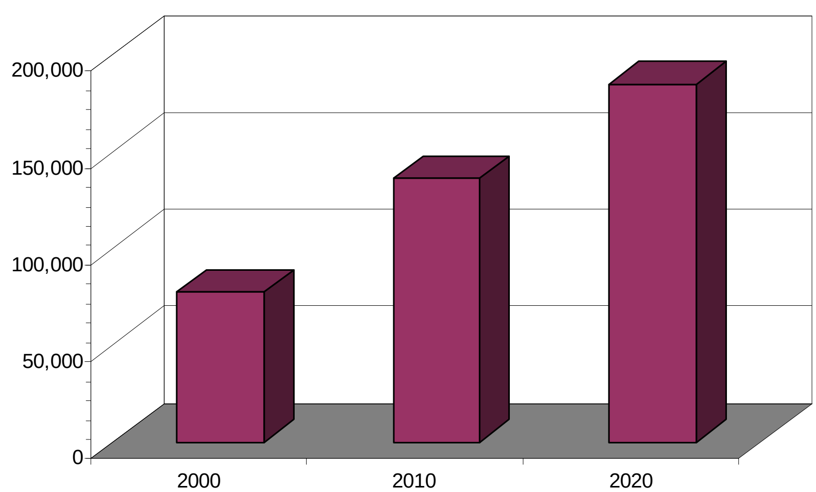
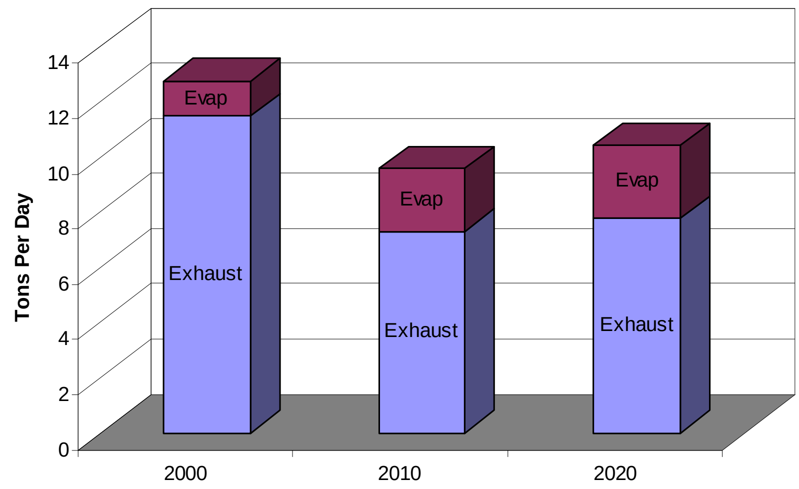


Figure 2.2
LSI Engines ≤ 1.0 L
Statewide $HC+NO_x$ Emissions



2.4 Related Federal Regulations

Large spark-ignition engines are regulated federally under Title 40 of the Code of Federal Regulations (CFR), part 1048, which generally harmonizes with the California emission standards until 2010, when more stringent California standards go into effect for LSI engines > 1.0 L. The federal LSI engine regulations allow manufacturers to certify LSI engines ≤ 1.0 L that are between 19 kW and 30 kW to the nonroad spark-ignition engines (i.e., SORE) requirements of 40 CFR Part 90 or 1054.

On September 4, 2008, the United States Environmental Protection Agency (U.S. EPA) finalized its phase 3 $HC+NO_x$ emission standard of 8.0 g/kW-hr for the SORE ≥ 225 cc and LSI engines ≤ 1.0 L starting in the 2011 MY, as shown in Table 2.3 (U.S. EPA 2008). Both the phase 2 and phase 3 U.S. EPA standards are less stringent than staff's proposed exhaust emissions standards for LSI engines ≤ 1.0 L.

Table 2.3
U.S. EPA Exhaust Emissions Standards for LSI Engines ≤ 1.0 L
(also apply to SORE ≥ 225 cc)

Model Year	$HC+NO_x$ (g/kW-hr)	CO (g/kW-hr)
Phase 2 2005 - 2010	12.1	610
Phase 3 2011 and subsequent	8.0	610

2.5 Public Process

Staff met with interested stakeholders and solicited input numerous times during the development of this proposal. Staff conducted public workshops on November 14, 2007 and April 21, 2008 to aid in developing the proposed regulations. Workshop notices were sent out via email on the msprog listserve list and orspark listserve list to all stakeholders, including environmental organizations, engine manufacturers, equipment manufacturers, and trade associations, as well as other interested parties. At the workshops and subsequently, staff shared draft proposed regulatory language. Public information concerning the development of this proposal was also made available on ARB's website at www.arb.ca.gov/msprog/offroad/orspark/orspark.htm.

Staff met with many of the engine and equipment manufacturers to discuss individual concerns. Staff also sent an extensive survey to LSI engine and equipment manufacturers to help evaluate the level of technology currently utilized by industry as well as examine specific issues including equipment cost, engine durability, and market trends. Staff received replies from 14 manufacturers (including some who have indicated they do not intend to participate in the LSI engine ≤ 1.0 L market), representing approximately 70 percent of the market. A listing of stakeholder meetings, along with meeting dates, is shown below in Table 2.4.

Table 2.4
Stakeholder Meetings and Survey Responses

Stakeholder	Date(s)
Briggs & Stratton Corp.	2/8/08, 4/3/08, 8/12/08, 8/14/08
China Motor Company	3/14/08*
Daihatsu Motor Company, LTD	3/14/08*
Engine Manufacturers Association	2/8/08, 4/24/08, 6/24/08, 8/12/08
Generac Power Systems, Inc.	3/14/08*
John Deere	8/12/08
Kawasaki Heavy Industries, LTD	2/8/08, 8/12/08
Kohler Company	2/7/08, 2/8/08, 4/21/08, 4/24/08, 8/12/08
Kubota Corp.	3/16/08*
MECA	11/29/07, 5/16/08
Nissan Motor Co., Ltd.	2/27/08*
Outdoor Power Equipment Institute	2/8/08, 4/24/08, 5/6/08, 8/12/08
Polaris Industries Inc.	2/19/08, 4/8/08, 7/8/08
The Toro Company	2/8/08, 4/24/08, 8/12/08
Toyota Industrial Equipment Mfg. Inc.	2/27/08*
Vantage Power Vehicle, Inc.	3/5/08, 3/20/08
Wisconsin Motors	2/25/08*
Zenith Power Products, LLC	3/5/08*

* Survey only

As a result of the oral and written comments received, staff made significant changes to the proposed regulations and test procedures, which are reflected in the staff's proposal.

3. DISCUSSION

3.1 Exhaust Emission Standards

As shown in Figure 3.1, the current standards for LSI engines ≤ 1.0 L (2nd bar) are significantly less stringent than those for LSI engines > 1.0 L, and in fact are even less stringent than ARB's recently implemented tier 3 emission standards for SORE ≥ 225 cc. In addition, the growing population and power ratings within this category also concern staff. As shown previously in Figure 2.1, and shown below in Figure 3.2, the population and number of engine families of the LSI engines ≤ 1.0 L have grown significantly since 2002, when emission standards first went into effect.

Figure 3.1
Adopted HC+NO_x Emission Standards
for SORE ≥ 225 cc and LSI Engines

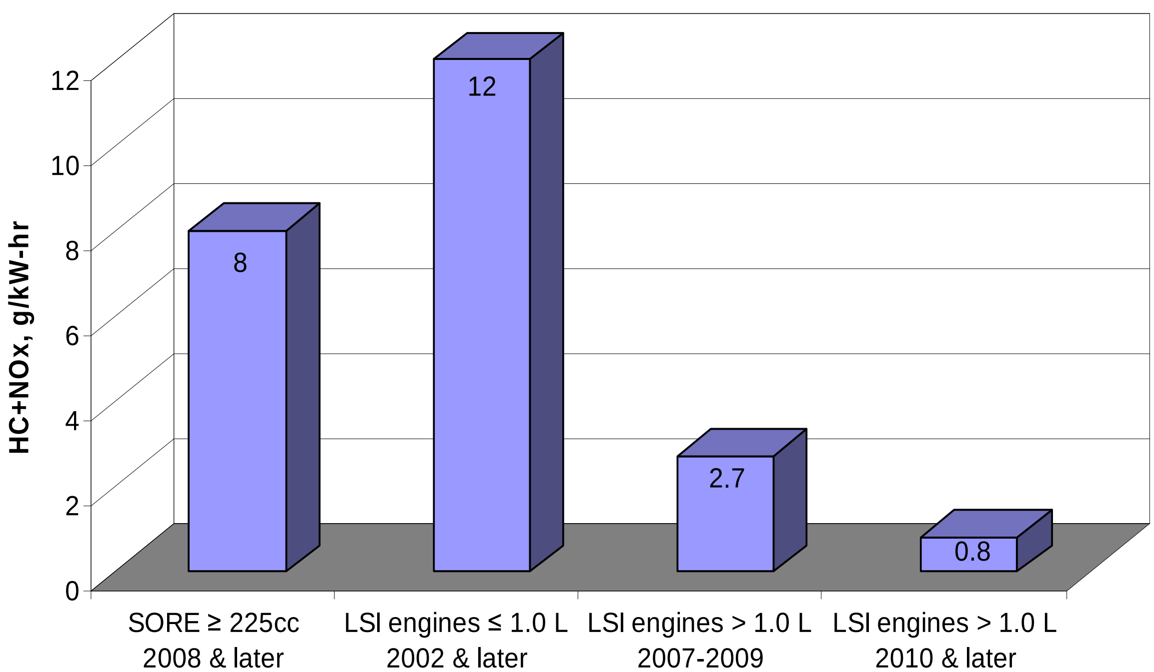
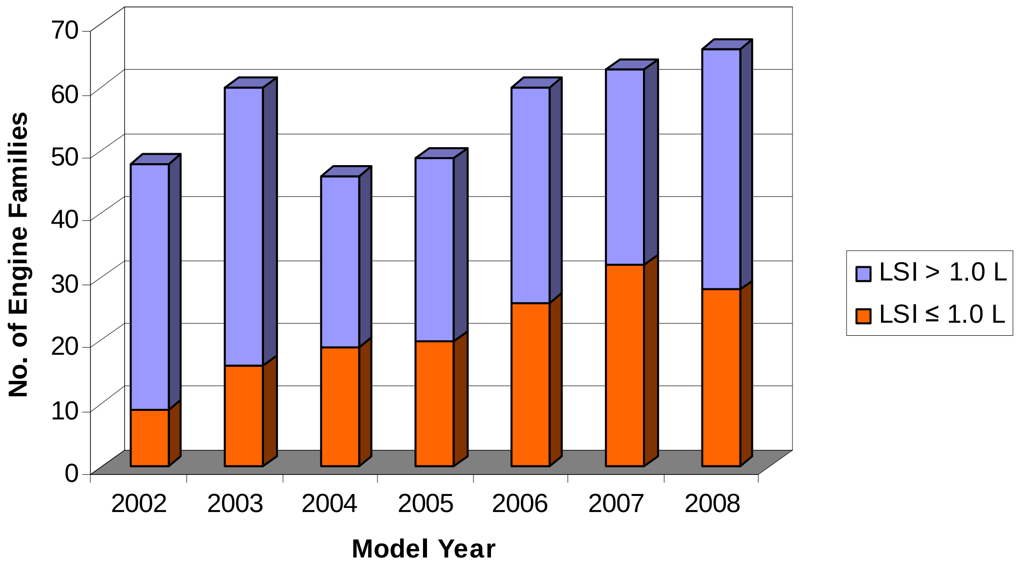


Figure 3.2
Number of Certified LSI Engine Families



3.1.1 Overview

To evaluate the industry's ability to meet more stringent standards, staff examined data from a variety of sources[1], including the most recent certification emission data submitted by manufacturers. As shown below in Table 3.1, the $HC+NO_x$ emission levels for gasoline powered LSI engines ≤ 1.0 L without catalysts are in the range of 5.1 to 11.2 g/kW-hr (standard is 12.0 g/kW-hr). However, catalyst-equipped engines within the category display emission levels as low as 0.5 g/kW-hr $HC+NO_x$. This demonstrates the technical feasibility of achieving significantly lower $HC+NO_x$ emissions utilizing currently available emission control technologies.

Table 3.1
$HC+NO_x$ Emissions Levels of 2008 MY Certified LSI Engines ≤ 1.0 L (g/kW-hr)

2008 MY Certification Data		Gasoline Fueled LSI Engines ≤ 1.0 L without Catalyst	All LSI Engines ≤ 1.0 L
$HC+NO_x$	Max	11.2	11.2
	Avg	7.9	6.6
	Min	5.1	0.5

(1) Southwest Research Institute (1999), Southwest Research Institute (2004), U.S. EPA (2007), and MECA (2008).

Based on a review of the available data and an assessment of available technology, staff proposes the emissions standards summarized in Table 3.2 below. In addition to the more stringent emission standards, staff is proposing a new engine displacement cutpoint at 825 cc, as explained in further detail below.

Table 3.2
Current and Proposed Emission Standards for LSI Engines ≤ 1.0 L

	Model Year	Engine Displacement	$HC+NO_x$ (g/kW-hr)	CO (g/kW-hr)
Current	**2002 and subsequent**	≤ 1.0 L	12.0	549
Proposed	**2011 and subsequent**	≤ 825 cc	8.0	549
	2011 - 2014	> 825 cc - ≤ 1.0 L	6.5	375
	2015 and subsequent	> 825 cc - ≤ 1.0 L	0.8	20.6

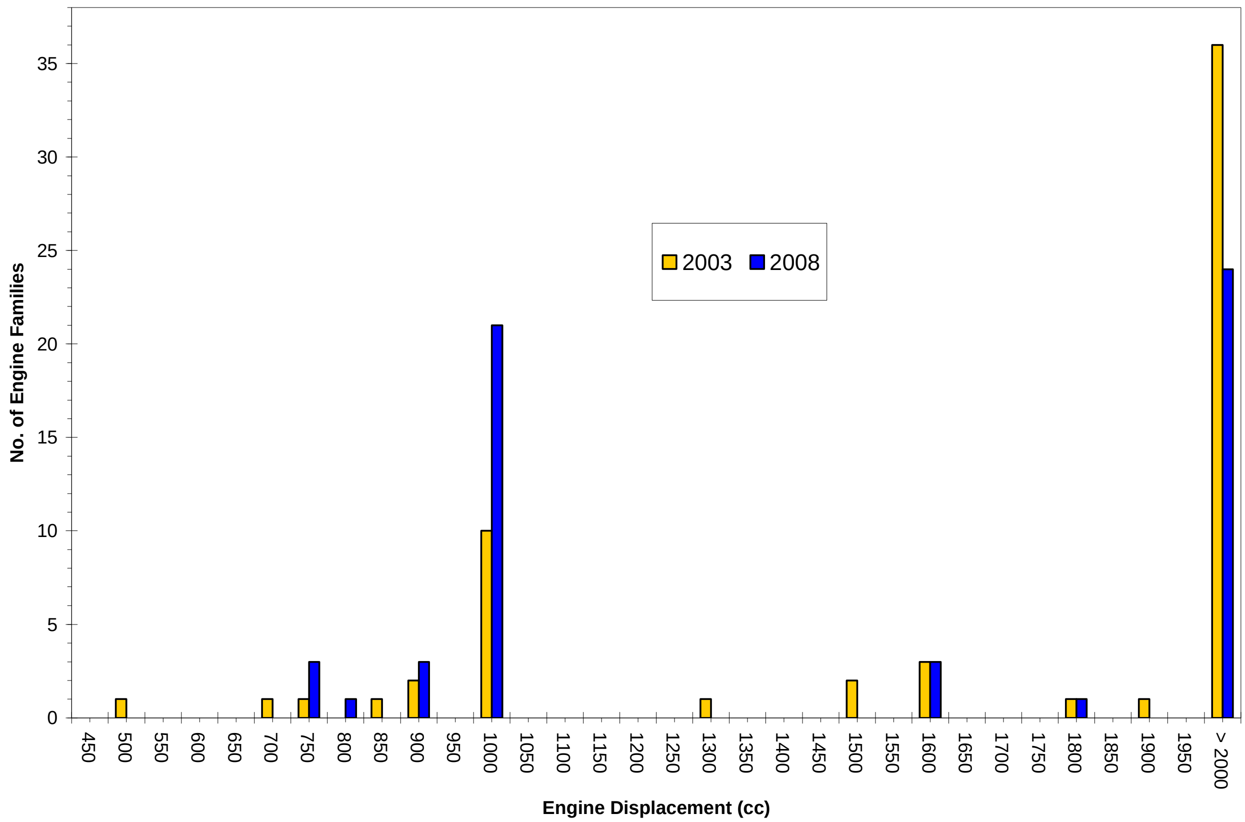
3.1.2 Engines ≤ 825 cc

There are currently no engine families certified with displacements between 775 cc and 850 cc. During development of staff's proposal, EMA suggested that engines below 825 cc should be treated separately from those between 825 cc and 1.0 L. Although the engines below 825 cc do not currently differ in technology from engines between 825 cc and 1.0 L, they do tend to be used in much less expensive equipment, which would be less able to absorb increased costs of more advanced technologies like an electronic fuel injection system. Thus, staff proposes that these engines meet emission standards equivalent to the tier 3 emission standards for SORE ≥ 225 cc. Most of these smaller LSI engines are designed for turf care equipment, and their performance and operation characteristics are comparable to those of SORE ≥ 225 cc. Currently, three out of four certified 2008 MY LSI engine families in this range can meet the proposed emission standards, demonstrating both the technical and the economic feasibility of the proposal.

3.1.3 Engines > 825 cc - ≤ 1.0 L

Engines greater than 825 cc are a larger concern. Currently, 86 percent of the certified 2008 MY LSI engine families ≤ 1.0 L have engine displacements greater than 825 cc. As shown in Figure 3.3, this is an increase of 11 engine families compared to the 2003 MY.

Figure 3.3
Comparison of the Number of Certified LSI Engine Families in 2003 MY and 2008 MY



The projected sales of LSI engines ≤ 1.0 L are approaching 50 percent of the total LSI engines sales, up from the 15 percent estimated in 2002. Simultaneously, the number of engine families offered with displacements between 1.0 L and 1.6 L has declined to zero. This suggests that there is a migration from the more stringently regulated LSI engines > 1.0 L category to the significantly more lenient LSI engines ≤ 1.0 L category. Staff's proposal would result in the same emission standard for LSI engines > 825 cc, in a two-step process.

3.1.3.1 Near-Term (2011) Emission Standards

As shown previously in Table 3.2, staff proposes a 6.5 g/kW-hr $HC+NO_x$ emission standard to be implemented in 2011. During development of the 1998 LSI engine rulemaking, staff had originally considered a 6.5 g/kW-hr $HC+NO_x$ emission standard, based on testing performed by the Southwest Research Institute (SwRI, 1999). But, as mentioned previously, industry argued that the engines had more similarities to SORE than to the larger LSI engines and therefore it would be more appropriate that they meet the less-stringent SORE standard. Currently, however, with the increase in engine size and power ratings, staff believes 6.5 g/kW-hr $HC+NO_x$ and 375 g/kW-hr CO are appropriate near-term emission standards. These proposed emission standards are already being met, as shown below in Table 3.3. Thirty-seven percent of the 2008 MY LSI engine families ≤ 1.0 L were certified with emissions of 6.5 g/kW-hr HC+NO_x or less, representing 48 percent of the projected California sales.

Table 3.3
Engine Families Certified in 2008 Model Year
Meeting the Proposed Near-Term HC+NO_x Emission Standard

Scenario	**HC+NO_x** **(**g/kW-hr)	**Engine Families**	**No. of Manufacturers**	**Projected Sales**
Proposed > 825 cc - ≤ 1.0 L 2011 – 2014 standard	6.5	37% (9 out of 24)	8	48% (4,000)

3.1.3.2 Long-Term (2015) Emission Standards

For the longer term, beginning with the 2015 MY, staff proposes to harmonize the emission standards for LSI engines between 825 cc and 1.0 L with the existing emission standards for LSI engines > 1.0 L (0.8 g/kW-hr HC+NO_x, 20.6 g/kW-hr CO). As shown in Table 3.4, three engine families are already certified at the proposed long-term HC+NO_x emission standard.

Table 3.4
Engine Families Certified in 2008 Model Year
Meeting Proposed Long-Term HC+NO_x Emission Standard

Scenario	**HC+NO_x** **(**g/kW-hr)	**Engine Families**	**No. of Manufacturers**	**Projected Sales**
Proposed > 825 cc - ≤ 1.0 L 2015 and later standard	0.8	12% (3 out of 24)	3	6% (500)

Some manufacturers have expressed concerns primarily over the economic impact of staff's proposal, citing that these three engine families represent only a small segment of the market, and that the engines are primarily used in vehicular applications, such as utility vehicles. Manufacturers have also indicated that the proposed emission standards would require liquid-cooling, closed-loop electronic fuel injection systems, and three-way catalysts.

Staff agrees with industry with regard to the technology most likely needed to comply with the proposed emission standards. However, although many engines in the category are air-cooled currently, almost every manufacturer has experience with liquid cooling[2]. The 2008 MY certification applications show that 15 of the 24 engine families above 825 cc are liquid-cooled. Although some manufacturers have expressed concern that liquid-cooled engines might not be accepted in the market, liquid-cooled engines offer several advantages, primarily because they are capable of running cooler than air-cooled engines. With adequate cooling, a manufacturer can usually increase the horsepower of a given engine without increasing its size[3]. This trend of achieving more horsepower without increasing engine size is a common marketing tool and design goal of manufacturers. In addition, liquid-cooled engines run more fuel efficiently reducing production of carbon dioxide, a greenhouse gas.

Closed-loop electronic fuel injection and catalysts, although not as common in this category, are also well understood technologies commonly used on LSI engines > 1.0 L. Of the 24 engine families between 825 cc and 1.0 L that are certified for the 2008 MY, four of them have a three-way catalyst and closed-loop electronic fuel injection system.

While staff acknowledges industry's concerns, the feasibility of the proposed standards is technically sound. With regard to the potential economic impact, the proposed emission standards are also cost-effective, as discussed in greater detail later in this report. Furthermore, the proposed 2015 implementation would allow seven years of lead time for manufacturers who do not yet meet the proposed standards to develop the requisite technology to be compatible with their engine designs and products.

3.2 Evaporative Emission Requirements

As shown previously in Figure 2.2, equipment with LSI engines ≤ 1.0 L contribute 1.3 tons per day of evaporative HC emissions statewide in 2000. If left uncontrolled, the emissions will increase to 2.6 tons per day in 2020, due to population growth.

To control the evaporative emissions, staff proposes that 2011 and later MY equipment with LSI engines ≤ 1.0 L meet the same evaporative emission requirements as SORE ≥ 225 cc equipment, as shown below in Table 3.5. However, while the evaporative requirements for SORE equipment allow for a small volume exemption for fuel tanks produced in less than 400 units, staff's proposal for the LSI engines ≤ 1.0 L does not allow for this exemption. This is because there are several cost-effective solutions available that enable manufacturers to produce low-cost compliant fuel tanks[4].

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(2) Only one manufacturer of currently-certified LSI engines does not offer at least one liquid-cooled engine family in the SORE or LSI engine categories.
(3) For a given displacement engine, increasing horsepower is usually accomplished by modifying a variety of engine parameters (e.g., increased compression ratio, higher engine speeds). Because these modifications cause the engine to "work harder", more heat is generated.
(4) The cost of complying fuel tanks are also more easily absorbed for LSI engines and equipment than for SORE because of the higher base prices of LSI engines and equipment.

Table 3.5
Proposed Evaporative Emissions
Performance and Design Standards

Requirements		2011	2012	2013+
Performance Requirements	Diurnal Standard *g HC/day*	1.20 + 0.056 × tank vol.(L)		
Design Requirements	Fuel Hose Permeation *g ROG*/m²/day*	15		
	Fuel Tank Permeation *g ROG/m²/day*	2.5		1.5
	Carbon Canister or Equivalent Butane Working Capacity, *g* HC	1.4 g/L (tanks ≥ 3.78 L) or 1.0 g/L (tanks < 3.78 L)		

*ROG: Reactive Organic Gases[5]

3.3 Off-Highway Recreational Vehicles

Some LSI engines ≤ 1.0 L are used in vehicles that meet all the requirements of the "Off-Road Sport Vehicle," or "Off-Road Utility Vehicle" definitions in CCR, Title 13, Section 2411(a) (13),(17), or (18), with the exception of payload capacity. The current definitions of off-road sport vehicles and off-road utility vehicles include a maximum limit on rear payload capacity. This limit was established to ensure that the vehicles were truly designed and used for recreational purposes, rather than for industrial or commercial purposes. Staff now believes that this limit is inappropriate given that the current trend for recreational vehicles is to significantly increase payload, beyond the limits of the existing regulations.

Staff proposes that most LSI engines used in vehicles similar to off-highway recreational vehicles be subject to the proposed near-term 2011 emission standards, but be allowed to use the off-highway recreational vehicle test procedures and certification procedures. This would simplify the certification process and provide flexible testing options as the chassis-based testing becomes a federal requirement for off-highway recreational vehicles in 2014. These engines form a subset of LSI engines ≤ 1.0 L that would most appropriately be regulated in the off-highway recreational vehicle category. Therefore, this proposal would exclude these engines from the proposed 2015 standards; staff's long-term goal is to amend the current off-highway recreational vehicle regulations to incorporate this type of engine.

(5) Reactive organic gases (ROG) are a subset of hydrocarbons (HC) that excludes methane and other photochemically non-reactive hydrocarbons that do not contribute to the formation of ozone. The exhaust emission standards are usually established for HC, but the permeation standards and emission modeling for ozone impact use ROG.

4. ENVIRONMENTAL AND ECONOMIC IMPACTS

4.1 Environmental Impact

4.1.1 Emission Reductions

Table 4.1 shows the statewide emissions benefit of the staff's proposal in 2014 and 2020. In 2014, the statewide ROG+NO_x emissions would be reduced by 1.9 tons per day. In 2020, the proposal would reduce approximately 4.5 tons per day of ROG+NO_x.

Table 4.1
Estimated Benefit of the Proposal, Statewide Annual Average

Staff Proposal Element	ROG+NO_x Emission Reductions (tons per day)	
	2014 MY	2020 MY
Exhaust emission standards	1.7	4.1
Evaporative emission requirements	0.2	0.4
Total	1.9*	4.5*

* Benefits have been rounded to the nearest tenth.

4.1.2 Environmental Justice

State law defines environmental justice as the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies (Senate Bill 115, Solis; Stats 1999, Ch. 690; Government Code § 65040.12(c)). The Board has established a framework for incorporating environmental justice into the ARB's programs consistent with the directives of State law. The policies developed apply to all communities in California, but recognize that environmental justice issues have been raised more in the context of low income and minority communities, which sometimes experience higher exposures to some pollutants as a result of the cumulative impacts of air pollution from multiple mobile, commercial, industrial, area wide, and other sources. Over the past twenty-five years, the ARB, local air districts, and federal air pollution control programs have made substantial progress towards improving the air quality in California. However, some communities continue to experience higher exposures than others as a result of the cumulative impacts of air pollution from multiple mobile and stationary sources and thus may suffer a disproportionate level of adverse health effects. Since the same ambient air quality standards apply to all regions of the State, all communities, including environmental justice communities, will benefit from the air quality benefits associated with the proposal. Alternatives to the proposed recommendations, such as recommending no change to the current program could adversely affect all communities. As additional relevant scientific evidence becomes available, the LSI engine emission standards will be reviewed again to make certain that the health of the public is protected with an adequate margin of safety.

To ensure that everyone has an opportunity to stay informed and participate fully in the development of the proposal, staff has held workshops in El Monte and has distributed information through the internet, as described in section 2.5.

4.2 Cost and Cost-Effectiveness

To determine the economic impact of the proposed regulations, staff evaluated cost information supplied by engine and equipment manufacturers, the Outdoor Power Equipment Institute, Inc., Engine Manufacturers Association, Manufacturers of Emission Controls Association, and U.S. EPA.

4.2.1 Near-Term (2011) Emission Standards

4.2.1.1 Engine Development Costs

Based on responses to a survey sent to manufacturers, the proposed exhaust and evaporative emission standards would require minimal lead time and would impose relatively minor engine and equipment development costs, as shown in Table 4.2. The wide range of development costs reflect the situation where in some cases, there would be no need for additional engine development since the engine family already meets the proposed emission standards. In fact, 48 percent of the 2008 MY engine families already meet the proposed standards, as noted in Section 3.1.3.1.

Table 4.2
Estimated Engine and Equipment Development Costs
to Meet the 2011 Emission Standards

Item	Cost
Research, engine development, tooling, and equipment redesign cost per engine family	$0 - 100,000
Weighted average cost per engine*	$8.14

Source: LSI engine and equipment manufacturers survey results, April 2008.
* Weighted average cost per engine assumes 4 years of production meet the standards.

4.2.1.2 Emission Controls Costs

The 2011 exhaust emission standards should not require any additional emission control components. Engine modifications and air/fuel ratio calibration changes should be sufficient to bring the engines that do not meet the standards into compliance.

However, meeting the evaporative standards could require modifications to fuel tanks, fuel hoses, and fuel caps, as well as the addition of a carbon canister. Since the evaporative standards and procedures are equivalent to those for SORE ≥ 225 cc, staff has assumed costs identical to those noted in the 2003 SORE staff report. As shown in Table 4.3, the estimated emission controls cost for manufacturers of LSI engines ≤ 1.0 L would be in the range of $16.21 - $70.21 per unit.

Table 4.3
Estimated Emission Controls Cost
to Meet the 2011 Emission Standards

Item	Cost Range ($/engine)
Tank Permeation	$1.00-$27.00
Fuel Cap	$1.00
Fuel hose Permeation	$1.00 - $2.00
Venting Control (Carbon Canister)	$10.00 - $37.00
Testing	$3.21
Total	$16.21 - $70.21

Source: SORE 2003 evaporative control cost estimates.

Staff did not calculate a weighted average for the emission controls cost, since specific information is not available on whether a given currently certified engine family already is equipped with the necessary emissions controls (e.g., fuel tank permeation)[6]. Thus, it is unknown at this time whether all engines would require the addition of all the identified controls. However, to ensure that costs were not underestimated the worst case emission controls cost ($70.21) was used in all cost and cost-effectiveness calculations. Thus, the combined total engine costs would be approximately $78 per unit.

4.2.1.3 Equipment Redesign Costs

Industry did not provide specific cost-estimates for possible equipment redesign to accommodate the cleaner engines. However, the changes envisioned for the 2011 standards should not require any major equipment redesign, as engine changes would

(6) In general, information on a manufacturer's intent to use specific emission controls is provided in the manufacturer's application for certification. The emission controls discussed here are not required at this point. Thus, the information is not (yet) available because a manufacturer will not be required to note such information in its certification application until the proposed regulations are implemented.

be internal (e.g., calibration changes) and fuel system changes are primarily a matter of using improved components and the addition of a relatively small carbon canister.

4.2.1.4 Comparison of Cost Increase to Equipment Cost

The cost range for an LSI engine ≤ 1.0 L is $500 to $8,000, and equipment or vehicle costs range from $2,700 to $50,000 (covering both consumer products and professional products). A comparison of the estimated worst-case cost increase ($78) to the base price of equipment indicates that for extremely low-cost equipment, emission controls could approach three percent of the base cost. It should be recognized that many of these engines (both the smaller as well as the larger engines > 825 cc) meet the proposed exhaust standards already.

4.2.1.5 Cost-Effectiveness

To determine the cost-effectiveness of the near-term emission standards, staff divided the total cost by the ROG+NO_x emission reductions expected over the average lifetime of the equipment. Separate values were calculated for the major categories of equipment that use LSI engines ≤ 1.0 L. As shown in Table 4.4, the resulting cost-effectiveness ranges from $0.01 to $0.15 per pound of ROG+$NO_x$ reduced. The 2011 emission standards are very cost-effective when compared with recently adopted control measures.

Table 4.4
Lifetime Emission Reductions per Unit and Cost-Effectiveness
For the 2011 Emission Standards

Equipment Type	ROG, Exh (lb)	ROG, Evap (lb)	NO_x (lb)	ROG+NO_x (lb)	Cost-Effectiveness (Cost per pound ROG+NO_x reduced)
Generator Sets	2,966	746	496	4,208	$0.02
Lawn and Garden Tractors	277	338	63	678	$0.12
Commercial Turf Equipment	184	317	45	546	$0.14
Other Lawn and Garden Equipment	1,757	385	294	2,436	$0.03
Sweepers/Scrubbers	4,813	148	746	5,707	$0.01
Other General Industrial Equipment	285	173	63	521	$0.15

4.2.2 Long-Term (2015) Emission Standards

4.2.2.1 Engine Development Costs

Based on the responses to the survey sent to manufacturers, the proposed exhaust emission standards would require one to four years of lead time and would impose additional development costs, as shown in Table 4.5. The actual price increases for research and engine development are expected to be much lower than those estimated by the manufacturers, because the likely technologies to be used are the same as that used in the automotive industry for many years. Nevertheless, to be conservative, staff used the $840 figure shown in the table.

Table 4.5
Estimated Incremental Engine and Equipment Development Costs to Meet the 2015 Emission Standards

Item	Cost
Research, engine development, and tooling cost per engine family	$0 - $15,000,000
Weighted average cost per engine*	$840

Source: LSI engine and equipment manufacturers survey results, April 2008.
*Weighted average cost per engine assumes 4 years of production meet the standards.

4.2.2.2 Emission Controls Costs

Each engine manufacturer has its own strategy to meet the proposed emission standards. Some of them would convert air-cooled engines to liquid-cooled engines equipped with a three-way catalyst and closed-loop electronic fuel injection system, while some already use these technologies and can meet the proposed $HC+NO_x$ standards without the need for additional emission controls. Unlike the 2011 emission standard analysis, staff was able to calculate a weighted average for the emission control costs. As shown in Table 4.6, the weighted average emission controls cost for manufacturers of LSI engines ≤ 1.0 L would be $400 per unit. The combined weighted average engine costs would thus be approximately $1,240 per unit.

Table 4.6
Estimated Incremental Emission Controls Cost to Meet the 2015 Emission Standards

Item	Cost Range ($/engine)
Air-cooled to liquid-cooled (radiators, etc.)	$0 - $200
Closed-loop Electronic Fuel Injection	$0 - $600
Catalyst	$0 - $150
Secondary air injection	$0 - $15
Exhaust gas recirculation	$0 - $40
Total	$0 - $1005
Weighted average cost per engine	$400

Source: LSI engine and equipment manufacturers' survey results, April 2008

4.2.2.3 Equipment Redesign Costs

Industry did not provide specific cost-estimates for possible equipment redesign to accommodate the cleaner engines and exhaust aftertreatment systems. However, some products such as zero turn radius mowers are currently offered in both air-cooled and liquid-cooled configurations, at a dealer reported cost differential of approximately $700. Staff considers this to be a reasonable estimate for the cost of equipment redesign. The resulting weighted average cost increase to comply with the regulations would thus be $1,940 per unit.

4.2.2.4 Comparison of Cost Increase to Equipment Cost

A comparison of the weighted average cost increase ($1,940) to the base price of equipment ($2,700 to $50,000) indicates that for the least expensive equipment, emission controls could be more than seventy percent of the base cost. However, it should be recognized that the long lead-time allows a longer period for amortization of research and development costs, although only four years was used in staff's calculations. Additionally, manufacturers would have the option to downsize the engines to displacements below 825 cc, which would subject them to more lenient and less costly emissions standards. Although some manufacturers have expressed the opinion that all engines in the category might be downsized to avoid the more stringent standards, staff believes that customer demand for greater power and the advantages offered by liquid-cooled and electronic controlled engines would prevent this from becoming an overall trend, particularly on equipment with a higher initial base cost.

4.2.2.5 Cost-Effectiveness

To determine the cost-effectiveness of the 2015 emission standards, staff divided the weighted average cost increase by the *incremental* ROG+NO_x lifetime emission reductions (i.e., above and beyond the near-term emission standard reductions). Again, separate values were calculated for the major categories of equipment that use LSI engines ≤ 1.0 L. As shown in Table 4.7, the resulting cost-effectiveness ranges from $0.52 to $7.16 per pound of ROG+$NO_x$ reduced. The 2015 emission standards are cost-effective when compared with recently adopted control measures.

Table 4.7
Lifetime Emission Reductions per Unit and Incremental Cost-Effectiveness For the 2015 Emission Standards

Equipment Type	ROG, Exh (lb)	NO_x (lb)	ROG+NO_x (lb)	Cost-Effectiveness (Cost per pound ROG+NO_x reduced)
Generator Sets	1,636	968	2,604	$0.75
Lawn and Garden Tractors	264	110	374	$5.19
Commercial Turf Equipment	195	76	271	$7.16
Other Lawn and Garden Equipment	967	573	1,540	$1.26
Sweepers/Scrubbers	2,255	1,500	3,755	$0.52
Other General Industrial Equipment	260	111	371	$5.23

4.3 Economic Impact on the Economy of the State

The proposed regulations are not expected to impose a significant cost burden to engine or equipment manufacturers. Staff anticipates manufacturers will pass on any added costs to consumers.

Although a price increase for equipment with LSI engines ≤ 1.0 L may persuade a consumer to delay the purchase in the short-term, it is not expected to significantly impact the long-term demand because equipment eventually wears out and is replaced. Based on the above assumptions, staff expects the proposed regulations to impose no adverse impact on California competitiveness and employment. The following sections are intended to fulfill ARB's legal requirements related to economic analysis and economic impact for stakeholders affected by these proposed regulations.

4.3.1 Legal Requirement

Section 11346.3 of the Government Code requires State agencies to assess the potential for adverse economic impacts on California business enterprises and individuals when proposing to adopt or amend any administrative regulations. The assessment must include a consideration of the impact of the proposed regulations on California jobs, business expansion, elimination or creation, and the ability of California business to compete.

Also, section 11346.5 of the Government Code requires State agencies to estimate the cost or savings to any state, local agency and school district in accordance with instructions adopted by the Department of Finance. The estimate must include any non-discretionary cost or savings to local agencies and the cost or savings in federal funding to the state.

4.3.2 Businesses Affected

Any business involved in the manufacturing of LSI engines ≤ 1.0 L and equipment will potentially be affected by the proposed regulations. Also potentially affected are businesses that supply engines and parts to these manufacturers, and those businesses that buy and sell equipment in California. The focus of the discussion below, however, will be on the engine and equipment manufacturers because these businesses would be directly affected by the proposed regulations.

4.3.2.1 Engine Manufacturers

There are currently 13 manufacturers of LSI engines ≤ 1.0 L that market certified engines in California, as shown in Table 4.8. Some of these manufacturers produce engines for off-road utility vehicle or off-road sport vehicle applications, which have been certified under the off-highway recreational vehicles regulations starting with the 2008 MY. None of the manufacturers is located in California although some have small repair and distribution operations in California.

Table 4.8
Manufacturers with LSI Engines ≤ 1.0 L Certified in California

BRIGGS & STRATTON CORPORATION	POLARIS INDUSTRIES, INC.
DAIHATSU MOTOR CO., LTD.	TIGER TRUCK, LLC.
GENERAC POWER SYSTEMS, INC.	VANTAGE POWER VEHICLE, INC.
KAWASAKI HEAVY INDUSTRIES, LTD.	YAMAHA MOTOR CO., LTD.
KOHLER COMPANY	YANMAR DIESEL ENGINE CO., LTD.
KUBOTA CORPORATION	ZENITH POWER PRODUCTS, LLC
MAG INTERNATIONAL	

4.3.2.2 Equipment Manufacturers

There are over 1,000 manufacturers of equipment with LSI engines ≤ 1.0 L nationwide. Many are “small” manufacturers that do not, however, meet the definition of a “Small Business” as defined in Government Code Section 11342.610. The majority of equipment is manufactured outside California. These manufacturers produce a wide variety of products. The affected equipment manufacturers fall into different industry classifications. A list of the industries that staff has been able to identify is provided in Table 4.9.

Table 4.9
Industries with Potentially Affected Manufacturers

Standard Industrial Classification Code	Industry
3621	Motors and Generators
3523	Farm Machinery and Equipment
3524	Lawn and Garden Tractors/Equipment
3531	Construction Machinery
3561	Pumps and Pumping Equipment

4.3.3 Impact on Small Businesses

The proposed LSI engine regulations will have some impact, although not significant, on small businesses that buy and sell portable generators, large turf care equipment, and industrial equipment. For small retailers, during the initial years of implementation, the increased cost of equipment may lead to a slight drop in demand that could result in lower profits. The retailer would carry over unsold stock to the next year, possibly incurring less profit on the sale of these units.

4.3.4 Potential Impact on Distributors and Dealers

Most engine and equipment manufacturers sell their products through distributors and dealers, some of which are owned by manufacturers and some are independent. Most independently owned dealers are small businesses. Some low-volume manufacturers also deal directly with their customers. The distributors and dealers sell about 9,000 pieces of equipment with LSI engines ≤ 1.0 L per year in California. This number is expected to grow substantially by 2020, as evidenced by the expected overall population growth (Figure 2.1). Although distributors and dealers are not directly affected by the proposed amendments, the amendments may affect them indirectly. If an increase in the price of engines and equipment reduces sales volume, dealers’ revenue would be affected adversely.

4.3.5 Potential Impact on Business Competitiveness

The proposed amendments would have no significant impact on the ability of California engine and equipment manufacturers to compete with manufacturers of similar products in other states. This is because all manufacturers that produce these engines and equipment for sale in California are subject to the proposed amendments regardless of their location. Furthermore, all of the engine manufacturers, and most of the equipment manufacturers, are located outside of California.

4.3.6 Potential Impact on Employment

The proposed regulations are not expected to cause a noticeable reduction in California employment because California accounts for only a small share of manufacturing employment in off-road engine, equipment, and component production. However, some small businesses operating outside of California may leave the California market due to cost increases, which may result in a few jobs being eliminated.

5. ALTERNATIVES CONSIDERED

Staff evaluated four additional alternatives to the currently proposed regulations. These included:

- Take no action
- Adopt More Stringent LSI Engine Emission Standards
- Adopt the U.S. EPA's Emission Standards for LSI Engines ≤ 1.0 L
- Adopt EMA's proposal

These alternatives are discussed in detail below.

5.1 Take No Action

The first alternative evaluated was to take no action. Under this alternative, it is likely that few, if any, engine and equipment manufacturers would voluntarily incorporate additional emission control technology into their designs. The few manufacturers that did would be at a competitive disadvantage compared to manufacturers electing not to incorporate the emission control technology. Clearly, most of the exhaust and evaporative emission control technologies used in cars have not been adapted for use in LSI engines ≤ 1.0 L and equipment because manufacturers perceive the costs outweigh performance and fuel usage benefits. As the emission standards for LSI engines > 1.0 L, SORE, and off-road compression-ignition engines become more stringent, manufacturers would have greater incentive to market products that would fall into the LSI engines ≤ 1.0 L category.

Therefore, this alternative would result in no emission reductions and would not contribute to the State Implementation Plan's (SIP) control strategy to attain Federal and State ambient air quality standards for ozone. The cost to the state is the potential loss of Federal highway funding, should an adequate SIP not be implemented.

5.2 Adopt More Stringent LSI Engine Emission Standards

Another alternative considered was to propose emission standards for LSI engines ≤ 1.0 L to be set at 0.8 g/kW-hr earlier than the 2015 date being proposed. As noted in section 3.1, there are three engine families that meet that level today establishing both technical feasibility and some ability for the market to support the costs of cleaner engines. The emission benefits for this alternative would exceed those from staff's proposal. However, the earlier implementation would likely cause more disruption in the market, as manufacturers that do not currently offer liquid-cooled catalyst equipped engines would have less time to develop controls. Thus, this alternative was rejected in favor of a proposal which allows more time for development and cost recovery.

5.3 Adopt the U.S. EPA's Emission Standards for LSI Engines ≤ 1.0 L

A third alternative would be to adopt the U.S. EPA's emission standards for LSI engines ≤ 1.0 L. U.S. EPA's phase 3 $HC+NO_x$ emission standard, starting in 2011 MY, is at the same level of stringency as the current SORE emission standard of 8.0 g/kW-hr. The LSI engine industry supported this alternative. Although the U.S. EPA's emission standards were based on nationwide economic and environmental impacts as a whole, they do not adequately address the unique and compelling circumstances faced in California. The federal emissions standards ignore the technical capability of cleaner engines that are already available. There would be minimal emission benefit from this alternative and it would not contribute sufficiently to the SIP's control strategy to attain the Federal and State ambient air quality standards for ozone. The cost to the state is the potential loss of Federal highway funding, should an adequate SIP not be implemented.

5.4 Adopt EMA's Proposal

In the development of this control measure, ARB staff has met with industry on numerous occasions to discuss emission standards and test procedures that would ensure emission reductions while addressing concerns raised by industry. Throughout this process, industry has raised several points, many of which have been integrated into staff's proposal. In the June 24, 2008 meeting with EMA and manufacturer representatives, a proposal was brought forth to add two new classes of engines under the SORE category. A new class of SORE with an engine displacement between 225 cc and 825 cc would have an $HC+NO_x$ exhaust emission standard of 8.0 g/kW-hr, which is same as the current SORE ≥ 225 cc emission standard, beginning in 2011. For the larger engines with an engine displacement > 825 cc and ≤ 1.0 L, EMA proposed an $HC+NO_x$ exhaust emission standard of 6.5 g/kW-hr, beginning in 2011, to be reduced to 5.0 g/kW-hr in 2014. CO standard levels for both engine classes would remain equal to the CO standard for SORE ≥ 225 cc.

Staff did incorporate the majority of the proposal for LSI engines ≤ 825 cc. However, for the LSI engines > 825 cc and ≤ 1.0 L, the EMA proposal would provide less emission reductions (only 3.8 tons per day $HC+NO_x$ in 2020) and would not approach the emission levels being reached by some engines today. Similar to the alternative to adopt the U.S. EPA's emission standards, the cost to the state is the potential loss of Federal highway funding, should an adequate SIP not be implemented.

5.5 Summary of Alternatives Evaluated

Each of the alternatives to the proposal falls short of staff's proposal. The alternatives are either unnecessarily relaxed achieving little or no emission s benefit compared to staff's proposal or are overly aggressive and likely to cause major market disruption.

6. CONCLUSIONS AND RECOMMENDATIONS

In developing the proposed regulations for LSI engines ≤ 1.0 L, staff's goal was to achieve the greatest possible emission reductions in a technologically feasible and cost-effective manner. Meeting the requirements of staff's proposal is achievable using existing technologies and manufacturing processes, and the available lead time. The emission reductions are cost-effective when compared to recent control measures adopted by the Board. The proposed regulations are necessary to meet emissions reduction goals and to achieve health based ambient air quality standards.

No alternatives considered by the Board would be more effective in achieving the purpose for which the regulations are proposed or would be as effective as or less burdensome to affected private persons than the proposed regulations.

The staff recommends that the Board approve its proposal.

7. REFERENCES

Air Resources Board, “Staff Report: Public Hearing to Consider Adoption of Emission Standards and Test Procedures for New 2001 and Later Off-Road Large Spark-Ignition Engines,” September 4, 1998.

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APPENDIX A: Proposed Amendments to the Large Spark-Ignition Engines Exhaust Emission Regulation

APPENDIX B: Proposed Amendments to the California Exhaust and Evaporative Emission Standards and Test Procedures for New 2010 and Later Off-Road Large Spark-Ignition Engines