Draft Proposal to Reduce Emissions from Off-Road Large Spark-Ignition Equipment Greater Than 25 Horsepower

1 INTRODUCTION AND OVERVIEW

The California Air Resources Board (ARB or "Board") is proposing to reduce air pollution from off-road equipment with large spark ignition (LSI) engines of more than 25 horsepower. These reductions will be accomplished through a combination of more stringent new engine emission standards, fleet-average emission requirements for equipment users and the development of optional low emission certification guidelines for new engines. The proposal will also include retrofit verification protocols for in-use engines that will allow engine and control device manufacturers to provide warranted low-emission equipment.

ARB staff developed this proposal in consultation with technical working groups comprised of engine, equipment, and exhaust system retrofit kit manufacturers, propane fuel suppliers, end users, and associations representing all three groups. Staff is now making the proposal available for public comment in advance of it being considered by the Board for adoption at their June 2005 hearing.

1.1 Background

1.1.1 LSI Equipment and Emissions

The off-road LSI category consists of off-road spark-ignition engines greater than 25 horsepower and typically fueled by gasoline or liquefied petroleum gas (LPG). A small number of engines are fueled by compressed natural gas (CNG), and some have dual fuel capability. Emissions from these sources include combustion emissions, such as hydrocarbons (HC), oxides of nitrogen (NOx), and carbon monoxide (CO), as well as evaporative HC emissions. Emissions of HC and NOx combine to form ozone, or smog.

LSI engines are most commonly found in forklifts, scrubber/sweepers, specialty vehicles, portable generators, large turf care equipment, irrigation pumps, welders, air compressors, airport ground support equipment, and a wide array of other agricultural, construction and general industrial equipment. This category excludes marine propulsion engines, engines used in equipment that operate on rails, recreational vehicles, snowmobiles, and gas turbines. In addition, the United States Environmental Protection Agency (U.S. EPA) has the sole authority to control new farm and construction equipment engines less than175 horsepower.

The ARB estimates that there are approximately 65,500 non-preempt LSI engines and 22,200 federally preempted LSI engines in the 2004 statewide inventory. Statewide HC and NOx emissions from the combined LSI inventory are approximately 15 and 54 tons per day, respectively. Forklifts represent more than 62 percent of the non-preempt LSI

engine population and more than 85 percent of the HC+NOx emissions. Nearly 90 percent of the forklifts in our inventory are seven years old or newer.

Based on a 1995 report prepared for the Gas Research Institute (*Industrial Truck Market Analysis, October 1995*), 66 percent of national fleets have 1 to 4 LSI forklifts, 31 percent of fleets have 5 to 25 units and the remaining 3 percent of fleets have 26 or more forklifts. They operate an average of 1,900 hours per year and are more likely to be owned than leased or rented.

1.1.2 Existing Emission Standards

The first regulations requiring reductions in the smog-forming emissions of new LSI engines were adopted by the ARB in 1998. This first emission standard of 3.0 grams per brake horsepower-hour (g/bhp-hr) HC+NOx was phased in between 2001 and 2004. The U.S. EPA later adopted a federal LSI regulation incorporating test information obtained from the development of the 1998 ARB LSI regulation. The U.S. EPA regulation required all new LSI engines nationwide to meet the same 3.0 g/bhp-hr standard beginning in 2004 and a 2.0 g/bhp-hr standard in 2007. The 2007 requirement also specifies a more rigorous testing protocol and in-use requirement.

1.1.3 2003 State Implementation Plan for Ozone

The ARB is responsible for protecting public health and the environment in California from the harmful effects of air pollution. The ARB works in cooperation with 35 local air pollution districts and the U.S. EPA on strategies to attain State and federal health-based ambient air quality standards. These strategies are then incorporated into State Implementation Plans or SIPs that detail formal control measures. The SIPs serve as roadmaps that demonstrate to the U.S. EPA how California plans to attain those ambient air quality standards.

As a result of State and federal regulations, new LSI engines are now 75 percent cleaner than previously uncontrolled LSI engines, and will become even cleaner beginning in 2007. This is only one of many efforts that have allowed California's air quality program to achieve impressive clean air progress over the past decades. From 1980 to 2000, peak ozone concentrations in the Los Angeles area declined over fifty percent and the number of unhealthy days declined by almost half.

However, California still has a long way to go to achieve its clean air goals – over 90 percent of Californians still breathe unhealthful air at times. As a result, the ARB cannot overlook the significant opportunities that exist to further reduce emissions from LSI equipment.

LSI equipment accounted for almost nine percent of off-road emissions in 2000 and this percentage is increasing. Also, there are large numbers of older, high-emitting uncontrolled LSI engines still in use. An uncontrolled engine can emit 12 or more grams per brake horsepower-hour of HC+NOx, contributing significantly to the smog problems

in California. To put this in perspective, a piece of LSI equipment with an uncontrolled engine, a forklift for example, can emit as much in three shifts as a new car certified to California's lowest emission level would emit over its entire life. In addition, LSI engines are generally based upon automotive engine technology, and engine and emission control device manufacturers can adapt advanced automotive-inspired emission control technologies into new and in-use LSI equipment that dramatically reduce engine emissions while still meeting the operational needs of industries. Finally, advanced battery-powered zero-emission forklifts are available to provide even greater emission benefits.

In recognition of these emission reduction opportunities, the 2003 ozone SIP included two measures for LSI engines. The first measure, LSI-1, proposed that California harmonize with the 2007 U.S. EPA 2.0 g/bhp-hr emission standard. The second measure, LSI-2, proposed the use of retrofit control technologies for in-use engines and the establishment of stringent LSI requirements that reflected the availability of zero and near-zero emission equipment.

1.2. Applicability

Typical applications for off-road LSI engines include forklifts, scrubber/sweepers, specialty vehicles, portable generators, large turf care equipment, irrigation pumps, welders, air compressors, airport service vehicles, and a wide array of other agricultural, construction and general industrial equipment. The engines used in this equipment often are derived from automobile engines, though they currently use less sophisticated fuel and emission control systems. Most commonly, gasoline or LPG fuels engines in this category. The engines are generally liquid-cooled, though some air-cooled engines remain in use. Similarly, most engines, particularly those derived from automobile engines, tend to use overhead-valve designs, although some use the mechanically simpler side-valve design.

The proposal addresses new and non-new off-road LSI equipment greater than 25 horsepower and a displacement of one liter or more for which California retains regulatory authority. Off-road LSI equipment with engines greater than 25 horsepower, but a displacement of less than one liter, are currently subject to ARB's small off-road equipment requirements and are thus not included as part of this proposal.

This proposal does not address new equipment under 175 horsepower (hp) used primarily in farm equipment or vehicles and in construction equipment or vehicles as the U.S. EPA has sole authority to control emissions from this equipment. U.S. EPA's authority is based on Clean Air Act section 209(e)(1)(A) which preempts states from adopting or enforcing any standard or other requirement relating to the control of emissions of new engines in these categories.

To define the scope of the preemption U.S. EPA adopted regulations at title 40 Code of Federal Regulations section 85.1601, et seq. The federal regulations provide that a given type of equipment is treated as farm equipment if the equipment is "primarily used

in the commercial production and/or commercial harvesting of food, fiber, wood, or commercial organic products or for the processing of such products for further use on the farm." A similar determination of primary use is applied for construction equipment, defined as equipment used in construction and located on commercial construction sites.

To further identify preempted equipment, ARB provided a list of the types of equipment that did or did not constitute construction or farm equipment based on U.S. EPA regulations and discussions with various trade organizations.[1] For equipment over 25 hp, all equipment was considered to be construction or farm equipment except for 11 listed categories. In ARB's initial 1998/1999 rulemaking to establish standards for large spark-ignition engines, the non-preempted types were refined and specified as:

- Airport Ground Power
- Baggage Handling
- Forklifts that are neither rough terrain nor powered by diesel engines
- Generator Sets
- Mining Equipment not otherwise primarily used in the construction industry
- Off-highway Recreational Vehicles
- Other Industrial Equipment
- Refrigeration Units less than 50 hp
- Scrubbers/Sweepers
- Tow/Push Equipment
- Turf Care Equipment

For this reason, airport ground support equipment (GSE) would be subject to the requirements of the proposal. Examples of GSE include forklifts, tugs, belt loaders, bobtails, cargo loaders, lifts, air conditioner, service trucks, de-icers, fuel delivery trucks, and ground power units. However, GSE in the South Coast Air Basin would be exempt from the in-use requirements of this proposal through 2010. Their emissions are already addressed in a 2002 Memorandum of Understanding (MOU) between the ARB and the basin's airlines. Staff is proposing that GSE in the South Coast be phased in following the expiration of the MOU.

Diesel equipment, including diesel forklifts, would not be subject to the requirements of this proposal because the ARB typically regulates diesel or compression ignition engines separately from LSI engines. This is in part due to the different pollutants and measuring techniques. However, the particulate emissions from diesel-fueled engines have been identified as a toxic air contaminant (TAC). TACs are those air pollutants that may cause or contribute to an increase in death or serious illness or may pose a present or future hazard to human health. Consequently, the ARB is separately controlling emissions from diesel-fueled applications in an expedited timeframe, typically by establishing state-of-the-art technology requirements (e.g., a requirement to retrofit with diesel particulate filters). Requirements to control emissions from in-use diesel forklifts will be proposed in late 2005.

1.3 Original Compliance Concepts

Staff has been working with an LSI technical working group and a retrofit working group since January 2004 to identify tools for reducing emissions from LSI engines and equipment. Staff evaluated many tools and analyzed numerous regulatory options. The most promising options initially analyzed were manufacturer lower emissions standards, fleet average requirements and the required use of zero-emission equipment. Staff conducted workshops in May and August 2004 on these three options and has developed a combined proposal that includes elements of the first two.

2 DRAFT REGULATORY PROPOSAL

ARB staff is proposing a near- to mid-term fleet average requirement that addresses emissions from uncontrolled equipment and encourages fleets to procure low emission or electric equipment. The requirement would be coupled with a manufacturer lower emission standard that ensures that cleaner LSI equipment would be available in the longer term. To assist fleet users, staff would also establish optional tiered low emission standards for new engines and verification levels for retrofits.

The following sections describe the fleet average concept and compliance strategies, an alternative compliance option for agricultural fleets, the mandatory and optional tiered manufacturer lower emission standards, and the retrofit verification protocol and verification levels.

2.1 User Fleet Average Emission Levels

Staff is proposing fleet average emission requirements for large and mid-size fleets. Large LSI fleets are defined as those with more than 25 pieces of equipment. The most common example of a large fleet is a distribution facility/warehouse or a large manufacturer. Other companies that have multiple facilities statewide will likely fall into the large fleet category as well (for example, a home improvement warehouse may only have three or four forklifts per site, but could have dozens of sites statewide). Mid-size fleets have 4 to 25 pieces of equipment. A mid-size manufacturer or an agricultural packing warehouse is an example of a mid-size fleet.

Large fleets would have to meet more stringent fleet average emission levels than mid-size fleets because they have greater flexibility when incorporating combinations of emission-reduction strategies to achieve a prescribed level. The strategies include zero-emission technologies (such as electric forklifts), lower emission standards (such as new equipment certified to optional lower emission standards), and in-use reductions (such as retrofit systems).

The fleet average emission level would be more stringent for the forklift portion of the fleet than for the non-forklift LSI portion of the fleet. This reflects two observations. First, electric-powered forklifts are readily available for use in many applications and already comprise a major market share. The use of electric equipment is not as

prevalent in other applications where LSI engines are used. Second, because forklifts are the most prevalent application in the LSI category, it is more likely that there will be retrofit kits and new equipment certified to optional lower emission standards available for fleets to incorporate into their fleet average. Non-forklift equipment covered under the fleet average includes sweepers and scrubbers, industrial tugs, and GSE. Under the staff proposal, other LSI equipment would not be included in the fleet average.

The fleet average would be determined for all LSI equipment, both forklift and non-forklift using the certification levels of 2001 and newer LSI engines and the retrofit verification levels of engines with retrofit kits. Low usage equipment (fewer than 250 hours per year) must be included in the large and mid-size fleets for the purposes of the fleet average calculation. However, this equipment need not be retrofitted or replaced as long as the fleet can still achieve the prescribed fleet average emission level requirements. To make the proposal less complex and less intrusive for the fleet user while maintaining cost effective emission benefits, fleet average calculations will not incorporate load factor, horsepower, or hours of use.

Small fleets are defined as those fleets with one to three pieces of equipment. A small independent lumberyard is a good example of such a fleet. Small fleets would be exempt from the fleet average requirement, but would be required to have no uncontrolled equipment by January 1, 2011. Staff is also considering allowing small fleet users until 2013 to comply with the retrofit requirements if their equipment is used infrequently (in the range of 250 hours per year or less) and has been retrofitted to a lesser level.

Table 1 below lists the proposed HC+NOx fleet average emission levels for Forklift and Non-Forklift LSI fleets.

Table 1: Fleet Average Emission Level Requirements[1]
(g/bhp-hr)

LSI Fleet Type	Number of units	By 1/1/2009	By 1/1/2011	By 1/1/2013
Large fleet – forklift component	26 +	2.4	1.7	1.1
Mid-size fleet – forklift component	4-25	2.6	2.0	1.4
Mid-size or Large Non-forklift fleet[2]	N/A	3.0	2.3	1.7
Small fleet	1-3	No uncontrolled[3] equipment by 1/1/2011		

1. Emissions in grams per brake-horsepower-hour.
2. Sweepers, scrubbers, industrial tugs, and GSE.
3. Certified to a 3.0 grams per brake-horsepower-hour level or better.

2.1.1 Fleet Average Technology Options

Equipment users can employ a variety of techniques to achieve prescribed fleet average emission levels. New procurement can be zero- or low-emission LSI equipment. Existing or in-use equipment can be retrofitted with one or more of the same control technologies that have been incorporated into new low emission LSI equipment. Fleet owners may also repower older equipment with certified engines or purchase certified used equipment. Details of each of these options follow.

Zero-Emission Equipment

The simplest and most effective way to reduce a fleet's average emission level is through procurement of zero-emission equipment, especially forklifts. Electric forklifts are most typically used in indoor materials handling applications that do not require large lift capacities (i.e., warehouse/retail operations). There are some applications where electric forklifts are used extensively, primarily for worker safety. These applications include confined spaces, cold storage, and food retail (primarily grocery stores).

Although electric forklifts are primarily designed for indoor operations, a number of manufacturers are also including equipment features that enable electric models to be used in a wider variety of environments. These features include pneumatic tires (air filled) that allow the forklift to be used on unimproved surfaces, water proofing trucks or sealing the electronic compartment to make them more water resistant for outdoor conditions, and alternating current (A.C.) motors that provide greater lift and travel speeds. Electric forklifts compete directly with LSI forklifts for many of the same work applications.

Electric forklifts have no exhaust emissions and extremely low upstream (power plant) emissions. Thus, electric forklifts can provide significant air quality benefits. The Electric Power Research Institute (EPRI) has prepared several reports on electric forklifts that identify other benefits in addition to improved air quality. Electric forklifts can have lower life-cycle costs when compared with LSI models. This is due to lower maintenance costs, lower fueling costs, and longer useful life. Although the initial capital cost of an electric forklift is higher than that of a comparable LSI forklift, the incremental cost can be recovered during the useful life. Because of the financial benefits to the end user, electric forklifts are already prevalent in some markets.

Electric forklifts include electric motor trucks with cushion or pneumatic tires (referred to as Class 1 forklifts); electric motor narrow aisle trucks (Class 2); and electric hand trucks or hand/rider trucks (Class 3). Class 1 electric forklifts are available in a wide variety of lift capacities from 3,000 pounds to 20,000 or more pounds. According to market data evaluated by the ARB, most Class 1 forklifts sold today in the U.S. are in the 3,000-6,000 pound lift capacity range. Class 1 forklifts typically perform duties similar to LPG-powered Class 4 and 5 forklifts. The use of Class 2 forklifts has the added benefit of allowing warehouses to more easily convert to cost-saving narrow aisle

operation. For the purposes of calculating the fleet average, fleet owners would be able to assign an emission level of zero (0.0) to Class 1 and Class 2 forklifts. Fleet owners would not be allowed to count Class 3 trucks toward their fleet average, because Class 3 forklifts do not traditionally supplant Class 4 or 5 forklifts.

In general, an electric forklift can operate from one to two shifts before needing to be recharged. Some multi-shift operations employ battery swapping or fast charging to support the use of a 100 percent electric fleet. However, staff recognizes that facility or duty cycle constraints may preclude some users from moving toward a 100 percent battery electric fleet. These fleets may want to consider another zero-emission power option – fuel cell forklifts. Numerous fuel cell, battery and traditional industrial truck manufacturers are partnering to develop programs that demonstrate how hydrogen fuel cells can be successfully integrated into industrial truck operations. Several of these partnerships are expecting to commercialize their technology in the next two to three years. Depending on lift truck power requirements and applications, a proton exchange membrane (PEM) fuel cell stack is matched with an appropriate battery pack resulting in a clean, quiet and reliable operation. Benefits of fuel cell charging include time - savings from the elimination of battery changes, no loss in lift capacity or drop in power as the shift progresses, and longer battery life. Also, with fuel cell forklifts, dedicated battery-charging rooms can be eliminated, freeing up valuable floor space. Refueling a hydrogen fuel cell forklift can take as little as one minute.

New Equipment Certified to Optional Lower Emission Standards

If neither of the zero-emission options discussed above meet the needs of a particular user, they may want to consider reducing their fleet average and resulting emissions through procurement of new low-emission equipment that is cleaner than both the current 3.0 g/bhp-hr HC+NOx standard and the 2007 2.0 g/bhp-hr standard. Based on current certification data as well as discussions with manufacturers, ARB staff believes that LSI manufacturers will be able to offer forklifts at emission levels significantly below these current standards. A detailed discussion of the technologies expected to achieve even lower levels is contained in section 2.2.1. Technology Evaluation.

Under the proposal, model year 2007 and subsequent engines could be certified to optional tiered new engine standards of 0.1, 0.2, 0.4, 0.6, 1.0, and 1.5 g/bhp-hr. A January 20, 2005 Manufacturers Advisory Correspondence already provides that manufacturers can voluntarily certify their 2005 and 2006 model year engines to these interim low emission standards and one major manufacturer has already submitted two engine applications to the ARB for early certification to the 2.0 g/bhp-hr level. These engines will provide equipment users with greater flexibility in meeting the proposed fleet average emission levels in Table 1.

In-Use Controls

One of the most expedient ways to reduce LSI fleet emissions is to retrofit in-use engines. This entails modifying or upgrading components on the engine and/or fuel

system with ARB verified retrofit emission control systems. An example of a retrofit emission control system is a closed-loop fuel control system coupled with a three-way catalytic converter, which could be added at the time of scheduled engine maintenance. Such systems have demonstrated an ability to reduce emissions by 75 percent (12 g/bhp-hr to 3.0 g/bhp-hr) or more.

ARB staff is proposing a protocol for the optional verification of retrofit systems for in-use LSI engines. The proposed LSI retrofit verification protocol will ensure that the systems sold for use on existing engines and equipment are functional, durable and meet claimed emissions reductions. The proposed protocol establishes the procedures that manufacturers must follow to demonstrate that their system provides real and durable HC+NOx reductions while at the same time, limiting CO emissions to existing acceptable levels. While developing the protocol, staff addressed important issues with industry groups, including verification of reduction claims, durability, warranty, and in-use emissions. The proposed protocols are consistent with existing diesel verification protocols but adapted to consider the unique issues related to LSI engines.

High-efficiency retrofit systems may not work for all engines or equipment as anticipated in the 2002 SIP commitment. In recognition of this, and in order to facilitate the implementation of current emission control strategies, ARB staff is proposing multiple verification levels. These tiered levels provide a hierarchy for emission reduction technologies. The proposed levels should broaden both the spectrum of control technologies available and the number of applications that can be controlled.

Staff will provide manufacturers with an interim verification procedure in the spring of 2005 that they may use to verify systems introduced prior to Board approval of the final verification protocol. This will help to expedite early introduction and support of retrofit programs in California. The final approved verification protocol will have a framework consistent with the interim procedure, but would contain any revisions and additional requirements that may be determined at the time this proposal is taken to the Board.

As an alternative to retrofits, LSI equipment users may repower or replace existing engines or equipment with new engines or used equipment that are certified to lower emission standards. By using this strategy the users would have the option to either replace their in-use uncontrolled engine with an engine that is certified to a 3.0 g/bhp-hr HC+NOx or lower emissions standard, or purchase a used piece of certified equipment. Both of these are cost-effective strategies for lowering emissions from in-use equipment. Repowers can be especially cost-effective if done at the time of a normal engine rebuild.

2.1.2 Fleet Average Compliance Scenarios

One of the main advantages of the proposed fleet average requirement is that it allows individual fleet users the flexibility to tailor their compliance strategy to the specific needs of their fleet. Some fleets may decide to purchase additional electric forklifts, others may prefer to modernize their fleet, and still others may pursue low-emission

equipment. Some fleets, primarily those with a substantial percentage of electric equipment, may not need to take any additional steps. This flexibility makes it impossible to precisely determine how fleets will comply. However, the staff has developed a few scenarios for illustrative purposes.

One factor that will significantly impact a fleet average value is the number of uncontrolled LSI equipment. Uncontrolled forklifts have emissions of approximately 12 g/bhp-hr HC+NOx, while current LSI equipment meet a level of 3.0 g/bhp-hr (uncontrolled equipment was available through 2003, although it started being phased out in 2001). The scenarios discussed below assume that by 2009, fleets have no uncontrolled equipment, i.e., all uncontrolled equipment has been retrofitted, repowered or retired. The scenarios also assume an average fleet turnover of seven years. According to ARB's inventory, over 88% of the forklifts within California are seven years old or newer. Fleets with a shorter fleet turnover rate (more modern fleet) would make it easier to comply with the requirements, while a longer turnover rate (older fleet) would require the fleet to take additional measures to comply.

By January 1, 2009, a fleet with a uniform seven year turnover rate that has converted its uncontrolled equipment and has no electric equipment would have a fleet average of 2.7 g/bhp-hr HC+NOx. As proposed in Table 1, a large fleet would be required to meet a standard of 2.4 g/bhp-hr and a mid-sized fleet would be required to meet a standard of 2.6 g/bhp-hr.

Large Fleets

Under the staff proposal, large fleets would need to meet a fleet-average emission requirement of 2.4 g/bhp-hr prior to 2009. The simplest and most effective way to meet the requirement would be to establish a modest electric equipment component. A fleet could achieve the 2.4 g/bhp-hr requirement by ensuring that approximately 11 percent of its equipment is electric.

Fleets would not have to rely on electric equipment to meet the fleet average requirement – they can also comply by procuring low emission equipment. Newer fleets (those that more regularly replace older equipment) would have the easiest time complying with the requirements. Older fleets with longer turnover rates would have to be more aggressive in their procurement of low emission equipment to comply with the requirements. A fleet with a seven-year procurement cycle (and no electric equipment) could meet the proposed fleet average standard by procuring 2.0 g/bhp-hr equipment one year early in 2006 in conjunction with cleaner 1.0 g/bhp-hr equipment in 2008.

To meet the proposed 2011 fleet average requirement of 1.7 g/bhp-hr, a fleet would have to reduce their fleet average by 23 percent over the 2011 baseline. Again, the easiest way for a fleet to achieve the requirement is to incorporate electric equipment. A fleet with uniform turnover and a 23 percent electric component would meet the requirement. A fleet choosing not to incorporate any electric equipment would need to be more aggressive in their purchasing of low-emission equipment. In addition to what

they had done to meet the 2009 fleet average requirement, a fleet with a typical seven-year turnover rate would have to procure 1.0 g/bhp-hr equipment in 2009.

Finally, to meet the proposed 2013 fleet average requirement of 1.1 g/bhp-hr, a fleet would have to reduce their fleet average emission level by 27 percent over the 2013 baseline. As such, a fleet that incorporated a 27 percent electric component into their normal procurement cycle could meet the requirement. A fleet choosing not to incorporate any electric equipment would need to continue being more aggressive in their procurement of low-emission equipment. In addition to what they had done to meet the 2009 and 2011 fleet average requirements, the fleet with a seven-year procurement cycle would have to additionally procure 0.4 g/bhp-hr equipment in 2012.

Mid-size Fleets

Under the proposal, mid-size fleets would need to meet a fleet average emission level requirement of 2.6 g/bhp-hr. As with large fleets, mid-size fleets may meet the requirement through procurement of electric or low-emission equipment. Since mid-size fleets may have less flexibility than large fleets have, their requirements are less stringent. Thus, they can comply with a smaller electric component or longer procurement cycle.

A typical mid-size fleet may achieve the 2.6 g/bhp-hr requirement with a uniform seven-year turnover rate and only a 4 percent electric equipment component. The same fleet may also meet the standard without incorporating any electric equipment as long as they are on a typical seven-year procurement cycle and procure 2.0 g/bhp-hr equipment in 2006 (one year early). A fleet choosing to be on a longer eight-year procurement cycle would have to be more aggressive, procuring 2.0 g/bhp-hr equipment in 2006 and 1.5 g/bhp-hr equipment in 2008.

To meet the proposed 2011 fleet average requirement of 2.0 g/bhp-hr, a fleet would have to reduce their fleet average by 9 percent over the 2011 baseline. A fleet with uniform turnover and a 9 percent electric component would meet the requirement. A fleet choosing not to incorporate any electric equipment might need to be more aggressive in their purchasing of low-emission equipment. In addition to what they had done to meet the 2009 fleet average requirement, the fleet with a seven-year turnover rate would need to continue to procure complying equipment. The fleet with an eight-year turnover rate would have to procure 1.0 g/bhp-hr equipment in 2009 (in addition to what they had done to meet the 2009 fleet average requirement).

Finally, to meet the proposed 2013 fleet average requirement of 1.4 g/bhp-hr, a fleet would have to reduce their fleet average emission level by 7 percent over the 2013 baseline. As such, a fleet that incorporated a 7 percent electric component into their normal procurement cycle could meet the requirement. A fleet on a six-, seven-, or eight-year procurement cycle could still comply with the requirement without incorporating any electric equipment and without procuring low-emission equipment

after 2009 as long as they had procured appropriate low-emission equipment to meet the 2009 and 2011 requirements.

Non-forklift fleets or fleet component

The fleet standards for non-forklifts are set to be conservative. This allows compliance with the fleet average through a steady turnover of the fleet with an eight-year life. It also allows for some non-availability of retrofit systems in the early years. Any availability of equipment meeting optional low-emission standards in this category will make compliance with the proposed standards easier.

2.1.3 Diesel Equipment

As mentioned in the applicability discussion (section 1.2), the ARB typically regulates diesel or compression ignition engines separately from LSI engines. The ARB is beginning a regulatory effort, separate from this proposal, to address emissions from off-road in-use diesel equipment. That effort will focus on reducing toxic particulate matter emissions from diesel equipment, including forklifts, through required retrofits in an expedited time frame.

2.1.4 Fleet User Record-keeping Requirements

For enforcement purposes, the fleet average emission level proposal would require fleet users to maintain the following fleet average information on an annual basis: equipment type, make, model, serial number, and emission certification level or retrofit verification level at their facility. Users would be required to maintain the information on file for the duration of the fleet-average requirement, from 2009 to 2013. The ARB will provide a simple electronic form for fleets to record their information. For the purposes of this proposal, rental companies would be considered fleet users for any equipment rented for periods of 30 days or less.

2.1.5 Alternative Compliance Option for LSI Equipment in Agricultural Activities

The proposed fleet average emission levels discussed above are predicated upon a seven-year fleet turnover. That turnover rate reflects the fact that 88 percent of the LSI equipment inventory is seven-years old or newer. However, the average age of the forklifts owned by agricultural operations in California is 19 years. Engine, equipment, and retrofit manufacturers have indicated that retrofit kits should be readily available for LSI equipment that is currently seven years old and newer – especially forklifts. But as the equipment gets older, several factors conspire to decrease the feasibility of retrofit. Those include general state of the equipment, availability of retrofit kits (kit manufacturers need economy of scale to offer reasonably priced kits), and value of the equipment relative to the cost of performing a retrofit. As such, it is highly unlikely that a significant portion of the uncontrolled agricultural fleet will lend itself to retrofit. Consequently, agricultural operations that own the equipment will not have a lower-cost retrofit option and would have to either repower or replace their equipment.

To address this issue, staff is proposing that agricultural operations (packinghouses, cotton gins, nut hullers and processors, dehydrators, feed and grain mills, etc.) be allowed to concentrate their efforts on removing uncontrolled equipment from their baseline 2006 fleet over a longer term. Diesel forklifts and “in-field” forklifts are not affected by this proposal.

Under this proposal, fleets comprised of owned equipment would have until 2016 to completely address their uncontrolled equipment through retrofit where feasible, repower or retirement. Fleets are required to make incremental progress on this goal; each year, 10 percent of a fleet owner’s baseline fleet of uncontrolled forklifts must be controlled to a 3.0 g/bhp-hr or lower HC+NOx level. A fleet may choose to retain uncontrolled lifts in exceedance of their incremental progress provided that they are in compliance with an overall 3.0 g/bhp-hr fleet average through procurement of electric or low emission forklifts.

Lifts that are used less than 250 hours per year are not included in the incremental progress determinations provided that: (1) they have an hour-of-use meter, (2) their hours of use are logged and remain below 250 hours per year, and (3) the lift is either controlled to a 3.0 g/bhp-hr HC+NOx level or retired by the final compliance date.

Staff is working with the agricultural industry to identify the methods to be used for establishing the baseline inventory and compliance with the incremental progress requirements.

2.2 Manufacturer Lower Emission Standard

The proposed manufacturer lower emission standard has three components. The first component harmonizes with more stringent U.S. EPA Tier 2 emission standards and test procedures that become effective in 2007. Under Tier 2, manufacturers of 2007 and later model year engines must meet a nominal 2.0 g/bhp-hr HC+NOx emission standard and a 3.3 g/bhp-hr carbon monoxide (CO) emission standard. Although these standards are nominally referred to as the 2007 “2.0 g/bhp-hr standard,” the requirement actually allows manufacturers the flexibility to certify at any HC+NOx level between 2.0 and 0.6 g/bhp-hr. To do so, manufacturers may certify according to the following formula:

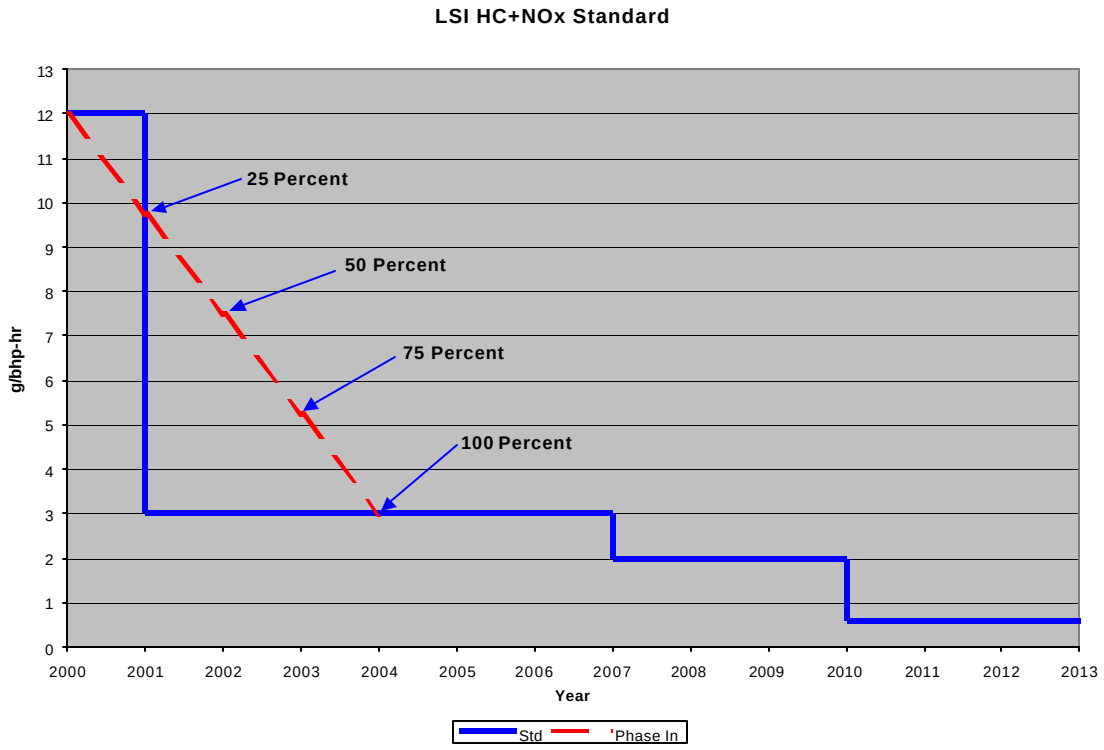
$$(HC+NOx) \times (CO)^{0.784} = 8.57$$

Thus, the certification standard provides manufacturers with the flexibility to increase CO emissions as they achieve lower HC+NOx levels. The ARB will incorporate these provisions into the first component of our manufacturer lower emission standards. In general, U.S. EPA’s analysis shows that any point along this curve is equally stringent (i.e, a high HC+NOx level with a low CO standard is equivalent to a low HC+NOx standard with a higher CO level). Manufacturers can move along this curve with

calibration changes, or they have the ability to lower all three pollutants with technology improvements, as discussed in 2.2.1. Technology Evaluation.

ARB and U.S. EPA regulatory and certification staff are working together to ensure consistency between our two regulations to the extent possible, and to identify where the two regulations diverge. In general, the ARB's certification and testing requirements will not change, with the exception that manufacturers will have to certify 2007 and subsequent model year engines using the transient test cycle. Manufacturers have requested that the ARB allow the deterioration factors (DFs) to be determined using the previous steady-state test cycle. Staff is exploring this option for model year 2007-2009 engines.

The second component of the manufacturer requirement lowers the ARB emission standard for 2010 and subsequent model year engines to 0.6 g/bhp-hr HC+NOx with a corresponding CO emission standard of 15.4 g/bhp-hr, consistent with the EPA formula. This NOx standard corresponds to the minimum HC+NOx level on the HC+NOx vs. CO emission trade off curve established by the U.S. EPA optional certification formula. As such, the proposed 2010 standard is essentially equivalent to the 2007 U.S. EPA requirement, but without the flexibility to increase HC+NOx emissions. In California, reducing ozone is a high priority, therefore the ARB proposal is able to ensure the maximum emission benefits by choosing the lowest HC+NOx point on the U.S. EPA curve. Based on an analysis by the U.S. EPA, staff believes that by staying along the curve, manufacturers will be able to meet the proposed 2010 emission standards for most engines with calibration changes. This allows California to achieve reductions of smog-forming emissions in the quickest, most-cost-effective way. The following chart graphically illustrates the current and proposed HC+NOx standards.



Staff is considering extending the 0.6 g/bhp-hr emission standard compliance deadline for small volume manufacturers to 2013. By ARB definition, small volume manufacturers produce a total of less than 2000 large spark-ignition engines annually for sale in the United States.

The third component of the manufacturer requirement establishes optional low emission standards and was discussed as a strategy for complying with the fleet average emission level requirements in section 2.1.1. Under this component, model year 2007 and subsequent engines could be certified to optional tiered new engine standards of 0.1, 0.2, 0.4, 0.6, 1.0, and 1.5 g/bhp-hr HC+NOx. The January 20, 2005 Manufacturers Advisory Correspondence already provides that manufacturers may voluntarily certify their 2005 and 2006 model year engines to these standards plus 2.0 g/bhp-hr HC+NOx, and one of the major manufacturers has already submitted two engine applications to the ARB for 2.0 g/bhp-hr certification. These low emission standards provide fleet users additional flexibility in meeting the proposed fleet average emission level requirements discussed previously. These standards also provide those manufacturers that make their equipment less polluting an opportunity to certify at the lower standard, thus providing additional value to the fleet owner.

As outlined in earlier sections, staff is pursuing a user fleet average approach as the most cost-effective and flexible method of achieving reductions in the near and mid-term. However, as staff was developing the overall proposal, it became clear that relying entirely on the fleet average in the long-term would not be appropriate. As the emission levels become lower, they become closer together and the fleet average provides less of its original flexibility. In addition, the fleet average approach is more resource intensive on the fleets, in terms of record keeping, and on the regulatory agencies, in terms of outreach and enforcement.

By focusing on the fleet average approach in the early years, the ARB is providing LSI engine and equipment manufacturers significant flexibility to establish their long-term planning. Several manufacturers have commented that their current focus is on complying with the upcoming 2007 emission standards of 2.0 g/bhp-hr, and the associated changes in test procedures. This proposal allows them to continue that focus and gives them sufficient time following the 2007 standard to design to the next level – the proposed 0.6 g/bhp-hr standard. However, other manufacturers have commented that they do not want to be continually redesigning their systems every three or four years and would like to design once for the long-term. This proposal allows them to design toward that emission level and to benefit by bringing that product to market under the optional low-emission standards.

As discussed above, for many manufacturers, the proposed changes may be accomplished with calibration changes alone. However, for those manufacturers that need further reductions, the technology to reach these levels is clearly available from the automotive sector and is cost-effective. The proposed effective date of 2010 was

established to provide manufacturers sufficient time, even if it is necessary to design and adapt this technology into the LSI applications.

When the U.S. EPA promulgated their LSI standards they stated that they believed the three-year period between the 2004 Tier 1 and 2007 Tier 2 emission standards (3.0 and 2.0 g/bhp-hr, respectively) allowed manufacturers sufficient lead time to meet the more stringent standard. They went on to state that they expected the emission control technologies for the 2004 emission standard to be able to meet the 2007 standard with additional optimization and testing. Analogously, ARB staff expects that three years will be sufficient time for manufacturers to further optimize the emission control technologies projected to meet the 2007 U.S. EPA 2.0 g/bhp-hr requirement so that it will also be able to meet the 2010 ARB 0.6 g/bhp-hr requirement.

2.2.1 Technology Evaluation

Off-road LSI engines are similar to automotive engines, but have traditionally lacked some of the automotive-style emission controls that have been in use for more than 25 years. While off-road LSI engines are exposed to duty cycles that can be more strenuous than those of their automotive cousins, they are suitable candidates for control, and manufacturers are beginning to apply automotive-style emission reduction technologies to the off-road LSI engine sector to reduce exhaust emissions. Typically these technologies include closed loop fuel controls, fuel injection, and three-way catalytic converters.

Since 1980 automotive emission control systems have used a closed-loop fuel control system to help reduce emissions. These systems use sensors to monitor exhaust gas concentrations, and feed this information back to an electronic control module which in turn keeps the air fuel mixture at an optimum level. To help ensure more precise metering of fuel and optimum combustion, carburetors have been replaced by sequential fuel injection. Today's advanced systems maintain an extremely tight stoichmetric air/fuel balance during nearly all engine operations. This is important because wide fluctuations from the stoichiometric position will result in reduced efficiency in controlling HC, NOx and CO as well as reduced durability of the control system.

Automotive emission control systems also use a proven method of controlling exhaust emissions – the three-way catalytic converter. Automotive manufacturers have installed tens of millions of them each year for more than 25 years. They are an integral component of automotive emission control systems that have allowed the automotive fleet to meet progressively lower emission standards – effectively reducing concentrations of hydrocarbons, oxides of nitrogen and carbon monoxide by more than 90 percent. Emission control catalysts make use of precious metals – platinum, palladium and rhodium.

The advanced three-way catalysts are components of new LSI retrofit kits and new engines and have been demonstrated to be robust. Staff expects that LSI

manufacturers will use a closed-loop fuel control system in conjunction with a three-way catalytic converter to achieve the 2007 standard of 2.0 g/bhp-hr. But there is still plenty of room for further reductions. After all, an engine certified to the 2.0 g/bhp-hr standard will still emit ten or more times the emissions of a new 2005 light duty vehicle. This reflects the slow adoption of newer emission control technologies into LSI equipment.

Current light-duty vehicles have emissions that are less than one-tenth of forklift emissions while in use for several reasons. Today's light-duty vehicles have larger catalytic converters, with more precious metal loading, higher cell densities and more effective washcoats than LSI engines. These differences can lead to greater efficiency of the catalytic converter as well as improved durability.

Light-duty vehicles use catalysts that are larger, as a percent of engine displacement, typically 70 to 80 percent. In contrast, LSI catalyst volumes are much lower, between 40 to 60 percent of engine displacement. Precious metal loading of the catalytic converter in a current LSI application is typically half of that in automotive applications. Finally, LSI catalysts typically have an "older automotive grade" single layer washcoat using less sophisticated materials in contrast to today's multi-layered washcoats that increase precious metals performance.

Adaptation of the improved automotive technologies noted above to LSI application can provide significant emission reductions. Already, even with less sophisticated emission control systems, more than fifty percent of the LSI engines certified by the ARB for the 2004 model year had test emission levels of less than 1.0 g/bhp-hr (less than one-third of the current standard), some less than 0.5 g/bhp-hr, with the lowest coming in at 0.1 g/bhp-hr due to the use of improved systems.

Some manufacturers have expressed concerns about the impact of the 2007 transient test cycle on these numbers. To date, information provided by the Southwest Research Institute indicates that, under the transient test cycle, hydrocarbon emissions from an LPG engine increased by about 30 percent, but NOx emissions remained relatively constant. In our 2004 certification test data (47 engine families), NOx constituted approximately 50 percent of the HC+NOx emissions compared to the 80 percent number cited in the September 1998 staff report for the LSI regulation. At 50 percent HC, the new test cycle could lead to a potential emissions increase of 15 percent over those under the steady state test cycle. To date, transient cycle test data has been limited and staff has not seen any test data that would lead us to believe that manufacturers will have difficulty achieving the proposed standards under transient testing. We welcome any additional data that manufacturers may have garnered using the transient test cycle. Meanwhile, test results from emission control device manufacturers using new catalysts and other emission control technologies, while not performed under the transient test cycle, show that emissions can be reduced by more than 90 percent when compared to the pending 2007 standard.

2.2.2 Fuel Quality

Liquefied petroleum gas (LPG) is a mixture of various hydrocarbons produced from crude oil refining or the processing of natural gas. Propane is the predominant component of LPG. LPG used for motor vehicles must meet a quality specification to ensure proper operation of motor vehicles and to achieve and maintain exhaust emission standards. LPG fuel that does not meet these motor vehicle specifications can harm engine fueling systems and components and can prevent an engine from complying with existing and future emissions standards.

In 1992, the ARB established motor vehicle fuel specifications for LPG limiting the propene content to 10% by volume. Other Heavier hydrocarbons are also limited. Not all LPG produced meets the LPG motor vehicle specifications. LPG not meeting the motor vehicle specification is considered commercial grade propane and is used mostly for space heating and recreational purposes.

There are two separate concerns about the LPG motor vehicle fuel quality; fuel contamination and high olefin content. Contaminated fuel can have an immediate and sometimes catastrophic impact on the fuel delivery system and the emissions control system. Contamination typically occurs downstream of production during storage and distribution. One example of contamination can occur from fuel hose degradation.

LPG containing high olefins, such as propene, can accumulate on fueling components and can adversely affect the fuel delivery and emission control systems. This accumulation is often the result of using commercial grade fuel in motor vehicles. Commercial grade fuel is intended primarily for heating, and has a higher olefin content than motor vehicle grade LPG. Olefins react to create a plastic-like coating in the vaporizers, carburetors, and injectors. This coating gums up these engine components, reducing the effectiveness of heat transfer and ultimately causing poor delivery of the fuel and inaccurate fuel to air ratios.

The ARB is committed to working with industry to determine if the existing specifications are adequate to support more stringent emission standards. The ARB will take the necessary steps to ensure that quality fuel is available to support existing and future LPG-fueled vehicles including developing appropriate specifications, if necessary.

The ARB is also following activities by the control device manufacturers, refiners and LPG distributors to make low olefin LPG fuel, advanced fuel filters, and fuel additives available to fleets, leading to reduced emissions and vehicle maintenance and improved fuel efficiency.

2.3. Optional Retrofit Verification Protocol

The third major component of the regulation is the Retrofit Verification Protocol. LSI equipment owners may retrofit in-use engines by making modifications or upgrading components on the engine and/or fuel system with ARB verified control system. An

example of a retrofit system is a closed-loop fuel control system coupled with a three-way catalytic converter that could be installed at the time of scheduled engine maintenance.

Because the proposed new rules would be impacting the equipment users directly, ARB has a greater responsibility to ensure those emission control systems sold for use on existing engines and equipment are functional and durable as well as a verifying claimed emissions reductions. A detailed discussion of the protocol is expected in late March. As soon as it is available, it will be placed on the following LSI web page: http://www.arb.ca.gov/msprog/offroad/orspark/documents.htm

3 AIR QUALITY AND ECONOMIC IMPACTS

3.1 Air Quality Impacts

Table 2 lists the 2010 and 2020 estimated emission benefits of the proposed regulation based on an analysis of available information, including industry market data, industry's input, and emission inventory outputs from the ARB's OFFROAD model.

Table 2: 2010 & 2020 Estimated Statewide Emission Benefits

Staff Proposal Element	HC+NOx Emission Reductions (tons per day)	
	Year 2010	Year 2020
Fleet Average Emission Requirements [1]	8.95	6.0
Retrofit Requirements [2]	1.11	0.0
0.6 g/bhp-hr Engine Emission Requirement	1.51	1.6
Total	11.57	7.6

1. These requirements apply to fleets with 4 or more pieces of off-road LSI equipment.
2. These requirements apply to fleets with fewer than 4 pieces of off-road LSI equipment.

Table 3 shows the estimated emission benefit in 2010 of the staff's proposal for the South Coast Air Basin, relative to the SIP emission reduction commitment for that region.

Table 3: Emission Benefits from Staff Proposal Compared to The 2003 SIP Target for the South Coast Air Basin in 2010

Measure	HC+NOx Emission Reductions (tons per day)
2003 SIP OFF-RD LSI-2 Consolidated	6.0
Staff's Proposal	5.3[1]

1. Assumes South Coast Air Basin LSI equipment population is 46 percent of the statewide LSI equipment population.

3.2 Economic Impacts – Cost and Cost-Effectiveness

Since the staff proposal contains different requirements applicable to fleets of different sizes, staff evaluated the cost-effectiveness of each compliance element.

Under the staff proposal, fleets of 26 or more off-road LSI engines have to achieve a fleet average emission level of 2.4 g/bhp-hr HC+NOx by 2009 for all the forklifts in the fleet. Fleets of 4 to 25 pieces of LSI equipment have to achieve a fleet average emission level of 2.6 g/bhp-hr HC+NOx by 2009 for all the forklifts in their fleet. In addition, large and mid-size fleets also have to comply with a fleet average emission level of 3.0 g/bhp-hr HC+NOx for all other non-forklift LSI equipment in their fleets. These fleets would have the flexibility to decide the mix of options to achieve the required fleet average emission levels. The fleet average approach will allow LSI fleet users to choose the lowest cost option for their particular application. Among the possible options are retrofit equipment, early purchase of certified cleaner equipment or purchase of zero emission electric equipment.

Retrofit systems provide emission reductions from older uncontrolled forklifts (12 g/bhp-hr HC+NOx equipment) to a level of 3.0 g/bhp-hr HC+NOx or lower. The cost of a retrofit system is approximately $3,000 installed. Staff expects that the cost may drop due to increased sales volume from this program. However using $3,000 as a conservative value, these systems provide a typical benefit of approximately 700 pounds of HC+NOx reductions per lift per year. Assuming a five-year life results in a cost effectiveness of less than one dollar per pound of NOx. It should also be noted that many of the 2001 through 2003 engines that were certified as uncontrolled during the phase in of the 3.0 g/bhp-hr standard already have some of the emission control components. Relatively low cost retrofit systems could be available for these engines.

Low emission equipment designed to meet the 0.6 g/bhp-hr provides an emission reduction benefit of 1.4 g/bhp-hr HC+NOx when compared with a 2 g/bhp-hr standard. Assuming a 1.4 g/bhp-hr, 60 horsepower engine operating 1,900 hours per year at a 30% load factor yields a reduction of 106 pounds per lift per year. As discussed earlier, the 0.6 g/bhp-hr HC+NOx standard (with an allowance for higher CO emissions) may be achievable with calibration changes. For those engines, the costs would be minimal - limited to engineering and laboratory time. For those systems that need additional

reductions, staff estimates that the use of improved closed loop components and a more robust catalytic converter would, at the most, increase the cost of a piece of equipment by fewer than several hundred dollars. Over a 7-year life, this would still yield a cost-effectiveness of less than one dollar per pound.

Electric forklifts are zero emission vehicles and provide emission reductions of 2 g/bhp-hr or 3 g/bhp-hr depending on what level of equipment they replace. Assuming the same LSI horsepower, hours of use, and load factor yields an emissions reduction of 220 pounds per year. Battery forklifts have a significantly greater estimated useful life than that of the typical internal combustion engine forklift. Electric forklifts have an incremental capital cost of approximately $5,000. However, due to reduced fuel and maintenance costs, and their longer life, electric forklifts can actually be less expensive on a life cycle basis, especially for those fleets that do not need to utilize the forklift for multiple shifts in a single day. For the purposes of providing preliminary information at this time, staff will simply present the cost-effectiveness of electric forklifts as a range between zero (no incremental life cycle cost) and less than $3 per pound (full incremental cost).

Table 4: Cost-Effectiveness

Compliance Option	Cost-Effectiveness (dollars per pound)
Retrofit	< 1
Low-Emission	<< 1
Zero-Emission	0 to < 3

Thus, as illustrated in Table 4 above, fleet users will have several options to comply with the fleet standards that are all cost-effective.

The emission benefits and cost-effectiveness calculations are preliminary estimates at this time. Staff will refine our estimates and complete our analysis as we continue to refine our proposal.