STAFF REPORT
Report to the Board on the Potential Electrification Programs for Small Off-Road Engines

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EXECUTIVE SUMMARY

The Air Resources Board's (ARB or Board) major goal is to provide clean, healthful air to all citizens of California. 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 ARB to achieve the maximum degree of emission reductions possible from vehicular and other mobile sources in order to attain the ambient air quality standards by the earliest practicable date. The 2003 State and Federal Strategy for the California State Implementation Plan contains specific control measures aimed at reducing emissions from off-road equipment. In September 2003, the Board adopted more stringent exhaust emission standards and new evaporative emission standards for small off-road spark-ignition engines (SORE) and equipment less than or equal to 19 kilowatts (kW). This category includes handheld and nonhandheld lawn and garden and industrial equipment such as string trimmers, leaf blowers, lawn mowers, generators, and lawn tractors. At the September 2003 hearing, the Board also directed staff to provide a report on the potential for increasing electric equipment in the small off-road category. This report satisfies that directive.

Many types of equipment have electric-powered counterparts, which have no direct fuel and no exhaust emissions. Most of the electric units currently available are designed for the residential market. These include string trimmers, hedge trimmers, blowers (non-backpack), chain saws, and lawn mowers.

Strategies will be presented in this report that have been suggested by air pollution control agencies, environmental groups, and industry. Staff has ranked and discussed them according to their cost, benefit, ease of implementation, and enforcement. We are confident that the penetration of electric equipment into the small off-road category will naturally continue to increase as zero emission technologies improve. In addition, electric equipment will remain a viable option for consumers as the price for gasoline-powered equipment increases to meet increasingly stringent emission standards. Note, however, that electric equipment has fundamental constraints with respect to power for corded units and run-time versus weight for battery-powered units.

Staff has concluded that there are strategies that may be feasible to help increase the electrification of the small off-road category. For example, additional education regarding the benefits of electric equipment may provide the best approach to increase the electric penetration in the market. Although the residential market already has a sizeable portion of electric equipment, the residential lawn mower market may be the category where more information about the benefits and the usefulness of electric lawn mowers would provide the best approach at increasing the electric penetration.

Consumer awareness programs could be expanded to not only encourage consumers to avoid using gasoline-powered equipment on “Spare the Air” days, but to also encourage them to consider purchasing electric equipment instead of gasoline-powered equipment. The Bay Area Air Quality Management District’s (BAAQMD) “Spare the Air” Program cost approximately one million dollars for the year 2000. At this funding level, BAAQMD purchased airtime for radio and television advertising to improve program recognition. Eight percent of residents chose not to use their gasoline-powered equipment on peak ozone days. This program could be expanded statewide, provided sufficient funding is available. Public awareness programs could also encourage residents to drive less on peak ozone days, lower use of consumer products, and reduce other emission-generating activities. While the staff believes that educational programs are feasible, the benefits are relatively small and expensive.

Staff also evaluated the feasibility of new regulatory programs requiring the sale of zero emission lawn mowers. Given that electric lawn mowers have limitations (e.g., cords, lower power, higher cost), they cannot meet the needs of all residential users. Thus, a zero emission mandate would be limited to a fraction of new sales. The emission benefits would be small because residential units are not operated very often or very long. The cost-effectiveness of a residential electric lawn mower mandate would be high.

We hope that the information provided in this report will help the Board make an informed decision regarding the amount of activity the staff should devote to electrifying lawn and garden equipment.

1. INTRODUCTION

As a result of federal and state regulations as well as other market forces, the state of emission control technology for off-road engines has progressed significantly in the last decade. Most recently, in 2003, the Air Resources Board (ARB or Board) adopted amendments to its regulations to include more stringent emission standards and new evaporative emission control requirements for small off-road equipment and engines less than or equal to 19 kilowatts (kW). The new regulations will provide statewide emissions reductions of 21.7 tons per day of hydrocarbons plus oxides of nitrogen (HC+NOx) by 2010.

At the 2003 Board hearing, ARB staff was directed to report back to the Board on the potential of increasing electric equipment sales in the small off-road engine category. There are many advantages to using electric-powered equipment over internal combustion engine equipment. Electric equipment does not require petroleum-based fuel and has no exhaust or evaporative emissions. In addition, engine tune-ups and oil changes are not required, thus maintenance costs are lower. The elimination of the pull-cord start also makes "starting" the equipment unnecessary.

To assess the potential of increasing electric small off-road equipment sales, staff reviewed available inventory and survey data on lawn and garden equipment, and met with a variety of interested parties to solicit input. Staff has also reviewed several incentive programs that have been conducted successfully in local areas within California. This report will provide a summary of the available data, the potential of different strategies to increase the use and consumer buyer choice of electric small off-road equipment, and the associated implementation issues.

2. BACKGROUND

Small off-road spark-ignition engines (SORE) run on gasoline or an alternative fuel such as liquefied petroleum gas (LPG) or compressed natural gas (CNG), and are rated at or below 19 kW (25 horsepower). The vast majority of these engines use gasoline. Small off-road engines are used to power a broad range of lawn and garden equipment including lawn mowers, leaf blowers, and lawn tractors, as well as generators and small industrial equipment. Exhaust and evaporative emissions from off-road equipment are a significant source of HC emissions in California. Exhaust emissions are also a source of NOx. Small engine emissions (exhaust and evaporative) contribute to the State's current ozone and particulate matter air quality problems. Nonpreempt[1] small off-road engines and equipment will emit 89 tons per day of HC+NOx into California's air in 2010. This is equivalent to the amount of emissions emitted from 3.2 million cars (ARB's OFFROAD Model).

1 The federal Clean Air Act Amendments of 1990 preempt California control of emissions from new engines used in farm and construction equipment under 175 horsepower. Engines that do not fall under this preemption are termed "nonpreempt."

3. EMISSIONS INVENTORY

This section provides an overview of the emissions impact of small off-road mobile sources. Small off-road engines include both handheld equipment (such as string trimmers and chain saws) and nonhandheld equipment (such as lawn mowers and generators, as well as, industrial equipment).

Figures 1 and 2 illustrate the total statewide SORE population and HC+NOx exhaust emissions inventory, respectively for 2000, 2010 and 2020 (ARB's OFFROAD Model). It should be noted that the population shown in Figure 1 also includes the estimated population of electric equipment. Since the implementation of exhaust emission standards for small engines, substantial reductions have been observed in the small engine emissions inventory. The emissions contribution from small engines will continue to decline over the next decade as a result of the current regulations.

Figure 1
SORE Equipment Statewide Population
Handheld vs. Non-Handheld
including electric equipment

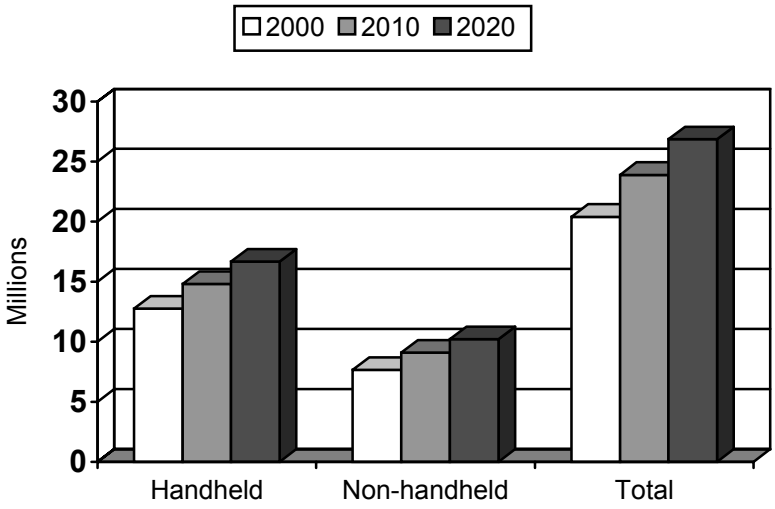
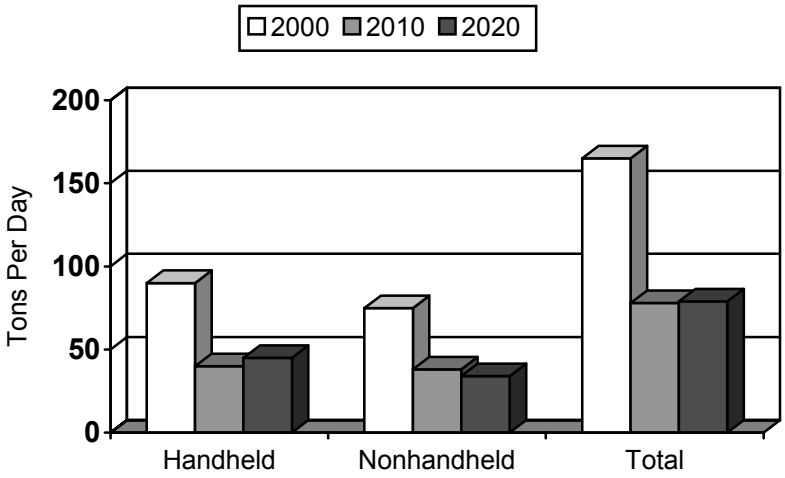


Figure 2
SORE Exhaust Emissions Inventory
Handheld vs. Non-Handheld
Statewide HC+NOx



Small off-road equipment is operated by residential and commercial users. Residential users operate lawn and garden equipment from once a week to once a month. Residential users will typically purchase equipment based on cost, weight, ease of use or portability, and assurance that equipment power is sufficient to complete small to medium-sized gardening tasks.

Commercial users operate lawn and garden equipment almost every day. They will typically purchase equipment based on whether it has enough power to complete large gardening tasks in a timely manner, projected equipment life, portability, reliability, cost, and weight.

Most of the electric equipment in the current market is better suited for residential users. Electric equipment can handle most residential gardening needs and is competitively priced with residential gasoline counterparts. Residential lot sizes are generally small enough (one-third acre or less) to be able to use battery-operated or cordless electric equipment (Black & Decker). Corded electric equipment can be used as long as the yard does not extend beyond 100 feet of an electrical outlet (TORO). However, staff believes that most electric equipment does not provide enough power, portability (for corded units), or length of use (for cordless units) for widespread commercial applications ("Assessment of Alternative Technology for Small Engine Products"). Our current inventory does not include any commercial electric equipment.

Figures 3 and 4 illustrate the relative population and emissions inventory fractions for residential and commercial equipment (ARB's OFFROAD Model). As shown, for the year 2000, residential equipment represents approximately 90 percent of the population, but only 32 percent of the HC+NOx emissions. Commercial equipment is used more often, and thus, more pollutants are emitted. The electric equipment, while included in the population, does not add any emissions to the inventory.

Figure 3
SORE Equipment Statewide Population
Residential vs. Commercial
including electric equipment

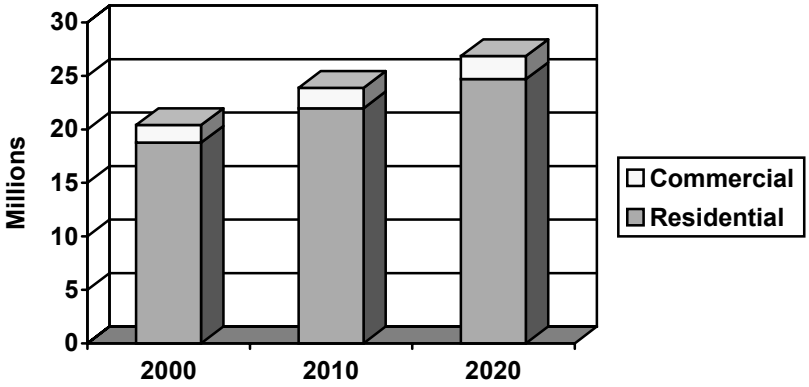


Figure 4
SORE HC+NOx Statewide Exhaust Emissions Inventory
Residential vs. Commercial

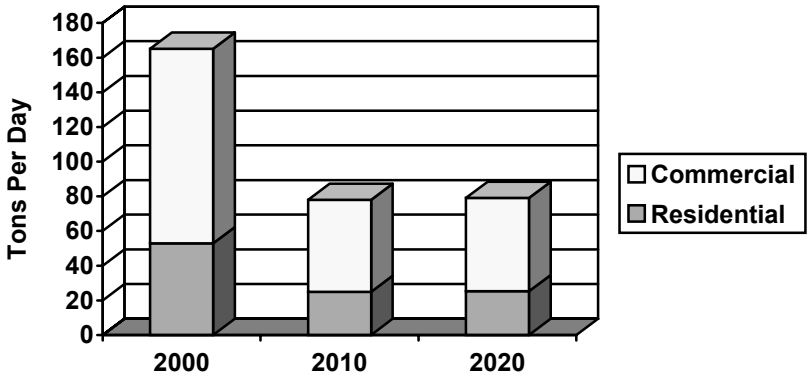
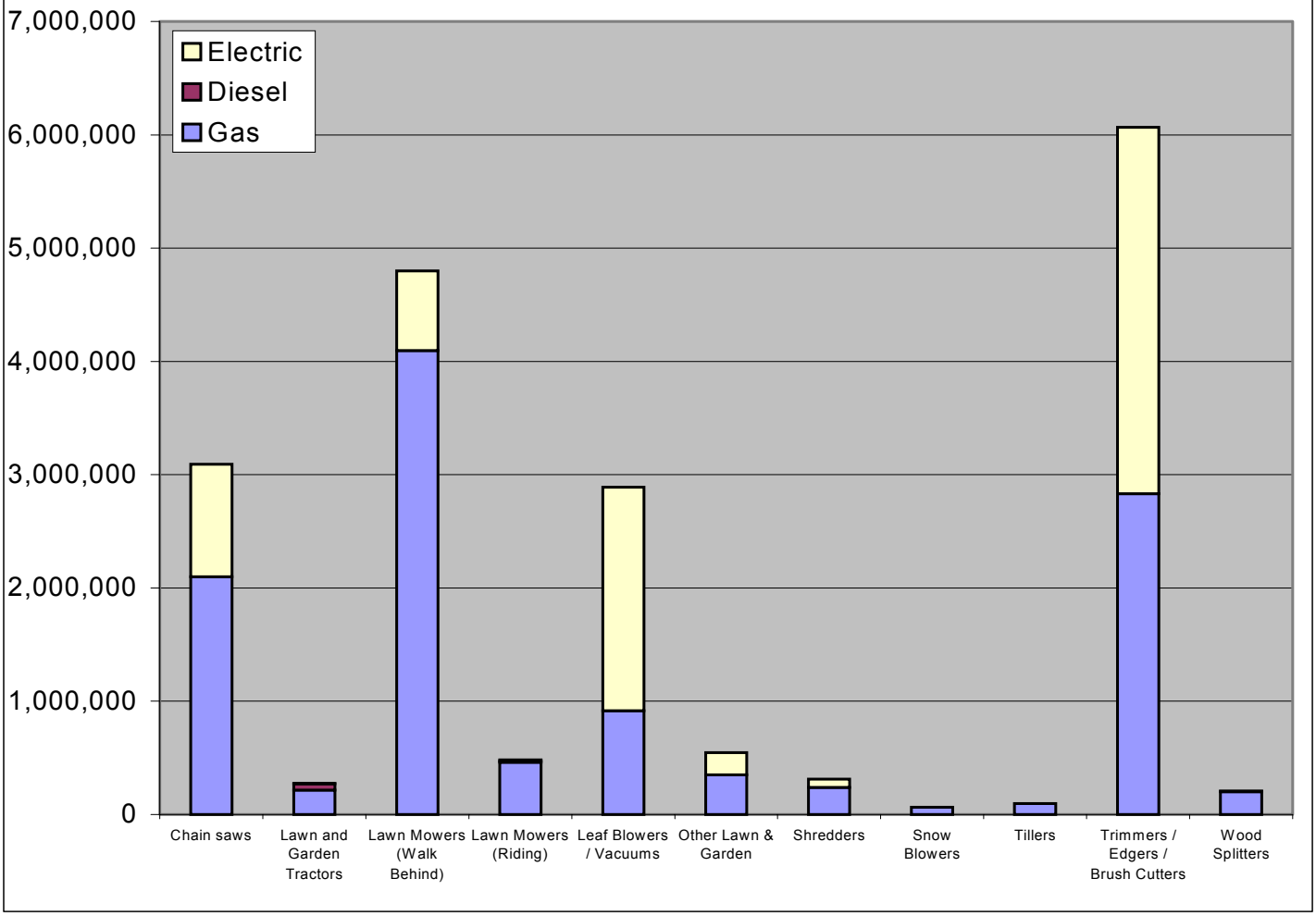


Figure 5 shows the statewide residential population breakdown of electric, diesel, and gasoline lawn and garden equipment for the calendar year 2000 based on the results from a lawn and garden survey ARB staff conducted during 2001-2002 (ARB's Lawn and Garden Survey). Most notably, Figure 5 shows that almost 70 percent of the leaf blowers and vacuums are electric; more than 50 percent of the trimmers, edgers, and brush cutters are electric; 30 percent of the chain saws are electric; and 15 percent of the lawn mowers are electric. Overall, almost 40 percent of the residential lawn and garden equipment is electrified. Staff believes the percentage of electric equipment would be increased if further improvements are made to the weight (battery), performance, and cost (primarily for lawn mowers) of electrics. A small additional shift toward electric equipment will occur in 2007 when gasoline-powered equipment will experience a modest price increase due to the implementation of the more stringent 2007 emission standards.

Figure 5
Residential Lawn and Garden Equipment Population
Statewide - Calendar Year 2000



3.1. Small Off-Road Engines

3.1.1. Current Emission Standards

At the September 2003 hearing, the Board adopted amendments to the regulations to include, starting in 2007, more stringent exhaust emission standards and new evaporative emission control requirements for small off-road equipment and engines less than or equal to 19 kW. The current and recently adopted exhaust emission standards are shown in Attachment 1.

The exhaust emission standards for engines above 80 cubic centimeters (cc) in displacement are based on the use of a catalyst and provide an additional 40 to 50 percent reduction in engine out exhaust emissions from the previously adopted HC+NOx emission standards. This size engine is generally used in nonhandheld equipment such as lawn mowers and generators. Implementation for these catalyst-based standards will begin with the 2007 model year for engines between 80 and 225 cc, and with the 2008 model year for engines 225 cc and above. A more stringent standard for handheld engines less than 50 cc was also adopted to align with the federal emission standards, beginning with the 2005 model year.

3.1.2. Optional Standards

To encourage the use of engines that go beyond the mandatory emission standards, the Board adopted optional low exhaust emission standards for small engines. These standards are presented in Table 1. These standards represent a reduction of 50 percent below the current levels for HC+NOx. Engines certified to these voluntary standards would not be eligible to participate in the corporate averaging programs allowed in the small

Table 1
"Blue Sky Series" Engine Emission Standards
grams per kilowatt-hour
[grams per brake horsepower-hour]

Model Year	Displacement	HC+NOx	CO[2]	PM[3]
2005 and later	< 50 cc	25 [18.5]	536 [400]	2.0 [1.5]
2005 and later	≥50 to ≤ 80 cc	36 [26.9]	536 [400]	2.0 [1.5]
2007 and later	>80 - <225 cc	5.0 [3]	549 [410]	N/A
2008 and later	≥225 cc	4.0 [2.3]	549 [410]	N/A

2 Carbon Monoxide.
3 The particulate matter (PM) standard is applicable to all two-stroke engines.

engine exhaust emission regulations. However, they would be classified as "Blue Sky Series" engines. Electric equipment can also be classified and labeled as "Blue Sky" under this option.

3.1.3. Electric Alternatives

Many types of handheld equipment have electric-powered counterparts. Staff inspection of retail stores and web sites shows that electric-powered handheld equipment is readily available for the residential user's market, including blowers, trimmers, and chain saws. However, most of the electric units currently available are

Table 2
Features and Specifications for Currently Available Electric Equipment[4]

Equipment Type	Cordless (Running Time Per Charge)	Corded	Features	
			Electric Equipment	Gasoline-Powered Equipment
String trimmer	Y (45 min)	Y	Cutting path: 7"-17" Weight: 2.8-11 lb	Cutting path: 15"-24" Weight: 7.3-22.7 lb
Hedge trimmer	Y (35 min)	Y	Blade length: 6"-22" Weight: 4.5-10.1 lb	Blade length: 17"-40" Weight: 10.1-15 lb
Non-backpack blower	Y (10 min)	Y	Air volume: 78-405 cfm Air speed:110-225 mph Weight: 4-8.1 lb	Air volume: 300-405 cfm[5] Air speed: 130-200 mph[6] Weight: 7-20 lb
Backpack blower	N	N	N/A	Air volume: 295-1,200 cfm Air speed: 150-220 mph Weight: 13.2-25.3 lb
Chain saw	Y (93 pieces of 1-3/4" hard wood)	Y	Bar length: 7"-20" Weight: 5.5-10.8 lb	Bar length: 10"-72" Weight: 6.5-23.2 lb
Tiller	Y	N	Tilling depth: 10" Weight: 11-21 lb	Tilling depth: 10"-20" Weight: 28.8-275 lb
Walk-behind Mower	Y (2 hr / 1/2-acre)	Y	Cutting path: up to 22" Weight: 29-223 lb	Cutting path: 20"-48" Self-propelled Weight: 56-284 lb
Riding mower & Tractor	Y (5 hr)	N	Lead-acid battery: 6×6V Top speed: 4.75 mph Weight: 760-830 lb	Top speed: 7.5 mph Weight: 358-1300 lb

4 Based on internet survey. Web sites noted in References.
5 Cubic feet per minute.
6 Miles per hour.

the small, lower weight and lower cost units. Table 2 compares features and specifications of various types of electric equipment currently available today, compared to typical gasoline-powered units. Table 3 shows a price comparison between typical electric and gasoline-powered equipment.

Table 3
Price Ranges for Typical Electric and Gasoline-Powered Equipment[7]

Equipment Type	Electric	Gasoline
Blower	$12 - $180	$50 - $320
Backpack Blower	No electric	$230 - $530
Chain Saw	$40 - $270	$98 - $1,370
Edger	$33 - $100	$200 - $400
Hedge Trimmer	$25 - $180	$140 - $500
Lawn Mower	$150 - $428	$110 - $1,200
Trimmer / Brush Cutter	$20 - $145	$55 - $700

- Handheld Equipment
  Residential gasoline handheld equipment tends to have smaller displacement engines (less than 27 cc) and be lighter (less than ten pounds) than commercial gasoline-powered equipment (2002 Handheld Internet Survey). Electric models compete well with lower end residential gasoline models because, as shown in Tables 2 and 3, the cutting paths and other measures of capacity are nearly equal and prices are competitive. Also shown in Table 2, cordless or battery-operated units provide ample operating time for most residential users. However, cordless models tend to be heavier than corded units because of the extra weight of the battery (typically eight pounds per horsepower – "Assessment of Alternative Technology for Small Engine Products").

  Commercial backpack blowers are not likely candidates for electrification because they require larger engines to provide high air volume and air speed. Commercial chain saws that are preempt from our control (not shown in Table 2) also need powerful engines to cut through large timber in a reasonable amount of time.

- Nonhandheld Equipment
  Currently, the electric lawn mower is estimated to account for about 15 percent of the California residential lawn mower market (ARB's OFFROAD Model). Corded lawn mowers draw power from a 110-volt alternating current (AC) electric outlet with a long extension cord. As shown in Table 2, the power available typically provides enough power for a cutting path up to 19 inches, thus its use is primarily limited to smaller-sized lots. Battery-powered lawn mowers tend to have added weight of about 40 pounds due to the battery, and battery size is limited ("Assessment of Alternative Technology for Small Engine Products"). Although premium gasoline lawn mowers have similar or greater unit weights, they may be easier to push than

7 Based on internet survey.

the battery-powered lawn mowers because they are self-propelled. Also, operation time is limited between recharges for battery-powered units. For residential users, the 45-60 minute operation time should be adequate for lot sizes less than one-third of an acre (Black & Decker). For commercial users, limited operation time is problematic. It should also be noted from Table 3 that unlike the other electric equipment listed, the starting price point for electric lawn mowers is higher than it is for the gasoline lawn mowers. This may be one reason for the low electric penetration in the current lawn mower market.

Figure 6 - Lawn Mower Continuous Run-Time Comparison

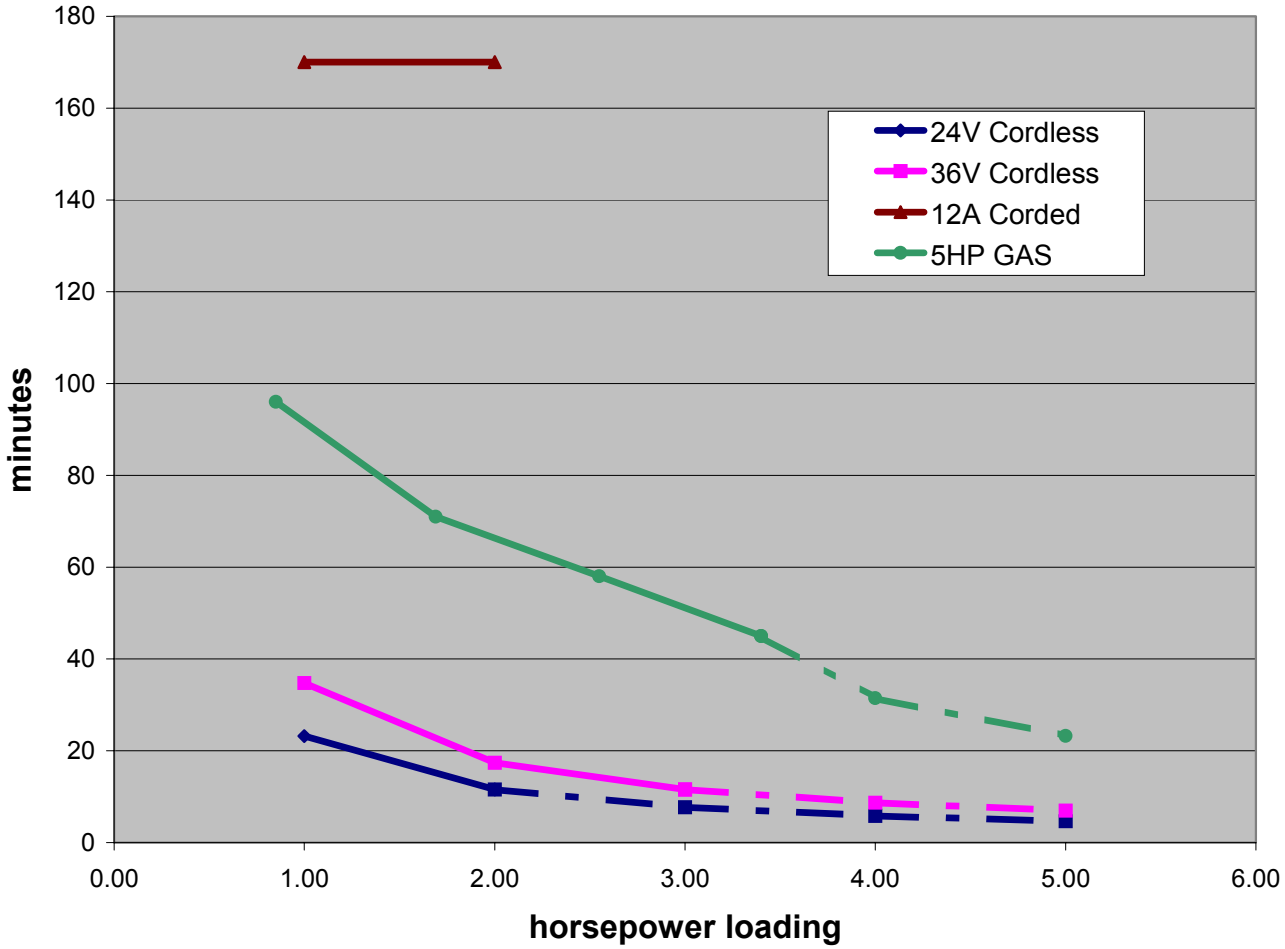


Figure 6 above compares the calculated continuous run-times for the different lawn mower technologies presently available. Three electric lawn mowers, two cordless and one corded, are contrasted against a typical five horsepower gasoline lawn mower. Figure 6 illustrates the number of minutes, theoretically, each lawn mower type could be used if operated continuously at the indicated horsepower loading. Non-continuous real-world use of the lawn mowers would likely result in longer intervals of operation between refueling and recharging than indicated in this graph, but these run-times could

vary considerably from application to application, thereby adding uncertainty to the comparison. For this reason, continuous operation was chosen as the best reference for comparing the performance of the different lawn mower technologies. ARB test data were used to determine the run-times for the gasoline lawn mower, but data for the electric lawn mowers were not readily available to staff. Run-times for the electric lawn mowers were estimated by assuming ideal efficiencies from power sources (batteries and AC outlets) transferring power to the lawn mowers' electric motors, neglecting line losses, friction, and air resistance. The resulting operating intervals indicated in the graph are therefore slightly longer than they would be if the losses were taken into consideration. The methodology is discussed further in Attachment 2.

The most significant conclusion from Figure 6 is that presently available cordless lawn mowers significantly lag behind gasoline and corded lawn mowers in how long they can be expected to operate before recharging is necessary. Battery improvements may extend the run-time of cordless lawn mowers in the future, but parity with gasoline lawn mowers is not yet foreseeable. The gasoline lawn mower in this comparison ran approximately two to three times longer than the cordless lawn mowers. Another important illustration from Figure 6 is the disparity in maximum power between the electric and gasoline lawn mowers. Corded lawn mowers will likely never be able to produce more than two horsepower and present technology cordless electric lawn mowers are limited to three horsepower output under ideal circumstances. Still, these power ratings are adequate for many residential applications involving smaller, regularly maintained lawns, but probably insufficient for the majority of commercial applications.

Some manufacturers believe there are additional safety concerns with operating electric equipment versus gasoline equipment. Battery-powered equipment is always "on" and may be easily started by children. While corded equipment is only "on" when plugged in, there is always a potential danger of electrical shock. It could also be argued that electric products are safer than gasoline equipment in that there is no risk of explosion or fire from a gasoline spill and no risk of burns typically associated with a hot exhaust system. Staff has not found any definitive data to indicate that electric equipment is more "dangerous" than gasoline equipment. General safety precautions must be used when operating any kind of equipment or machinery.

Electric equipment will continue to be a viable option for residential usage. Staff believes that a demographic shift towards smaller residential lots could result in an increase in the use of electric equipment. It is also likely that the proportion of the residential electric equipment population could be increased through consumer information programs and incentives.

Virtually no electric equipment is readily available for commercial users of lawn and garden equipment because of the demands for greater mobility than afforded by corded equipment and greater length of operation than provided by battery-powered units. However, technology improvements and paradigm shifts may increase the availability and usage of battery-powered units by commercial users. As evidenced by the current domination of battery-powered drills and other small construction equipment by

professionals, the technology and versatility has transformed from the use of corded equipment to the use of battery-powered equipment with multiple battery packs.

In addition, rechargeable batteries designed for electric golf carts may be used in some nonhandheld equipment, such as garden tractors and riding mowers. The Electric Tractor Corporation (ETC) produces the Electric Ox that can mow, tow, grade and push snow. ETC states on their web site that the Electric Ox can "work all day long without a charge in most towing applications and run up to five continuous hours when mowing" using six 8 volt deep-cycle lead-acid batteries (charged fully overnight). Early models used six standard lead-acid golf-cart batteries that allowed up to four hours on a single charge.

Furthermore, many types of lawn and garden equipment, such as edgers and trimmers, are not used in every yard or every day. Commercial users operate this equipment about 170 hours per year or three hours per week (ARB's OFFROAD Model). Battery-powered units may be able to meet these needs.

4. APPROACHES FOR INCREASING ELECTRIC SALES

The following section will discuss several electrification strategies that have been suggested. These strategies have been categorized as either regulatory/mandatory in nature, voluntary, or a combination of both. A summary of the available data, the potential of these different strategies to increase sales of electric small off-road equipment, the associated implementation issues, and staff's conclusions will also be provided. For illustrative purposes, residential lawn mowers will be used as the equipment type to more easily compare the emission benefits of each strategy.

4.1. Fleet Average Standard

One strategy would be to adopt a regulatory requirement that small engine equipment standards be set at near zero. The expected change to the industry would be an increased penetration of electric equipment offered for sale in California. The regulations would be set to allow a manufacturer to average the emissions from its gasoline and electric engine/equipment for compliance with the lower near zero emission standards. Alternatively, like the on-road cars and trucks, the near zero standard could cause manufacturers to develop very low emission technologies to comply instead of increasing electric products. Staff has not evaluated the feasibility and cost of such technologies, but expects that manufacturers would follow the least expensive pathway available to them. As with low emission vehicles, trading would also be allowed between manufacturers subject to the rule.

As shown in Table 4, there are currently 17 engine manufacturers that produce only gasoline engines/equipment and five engine manufacturers that produce both gasoline and electric engines/equipment. Black and Decker is the only manufacturer that produces all electric equipment. Any new emission standard set so low as to force every manufacturer to have electrics will impact the majority of the industry. It is important to note that some of

these manufacturers currently produce electric residential lawn mowers for the European market. These manufacturers could expand their production of electric lawn mowers to California.

Lead-time would be needed for manufacturers to develop new electric product lines for California. Staff does not have the data to estimate the cost of electric research and development (R&D) at this time. Manufacturers are currently expending R&D money and efforts to meet the more stringent 2005 and 2007 exhaust and evaporative emission standards adopted by the Board in September 2003, and would undoubtedly oppose another more stringent set of standards. Alternatively, given the cost of product development, some of the manufacturers may abandon the California market. If they do, the product lines of the six manufacturers with electric models may not be adequate to cover all existing equipment demands for residential and commercial users.

Table 4
Manufacturers with Small Engines Certified in California

No Electric[8]	Some Electric	All Electric
Briggs & Stratton	Andreas Stihl	Black and Decker
Daihatsu Motor Company	Electrolux Home Products	
Homelite Consumer Products	Husqvarna	
Honda Motor Company	MTD Southwest	
Kawasaki Heavy Industries	Solo Inc.	
Kioritz-Echo		
Kohler		
Komatsu		
Kubota		
Lister-Petter		
Maruyama		
Robin		
Onan		
Shindaiwa		
Tanaka		
Tecumseh		
Westerbeke		

A fleet average emissions standard strategy may be applied to the entire small engine category or to certain segments. For comparison purposes with the other potential strategies, the staff's analysis is based on the impact on residential lawn mowers only. Staff estimates that if a fleet average emissions standard were set low enough to require an additional ten percent of the new residential lawn mower sales to be electric (i.e., increase from 15 to 25 percent) beginning in 2007, a 0.2 and a 0.7 tons per day HC+NOx emissions benefit could be achieved by 2010 and 2020, respectively. This represents a one percent reduction from a baseline residential lawn mower emission inventory (HC+NOx exhaust

8 Some manufacturers who do not produce electric lawn mowers in California, like Briggs & Stratton and Honda, currently offer electric models in Europe.

and evaporative emissions) of 20.9 tons per day in 2010 and a six percent reduction from a baseline of 11.9 tons per day in 2020. This is a small emissions benefit. If the residential lawn mower fleet was completely "turned over" such that an additional ten percent of the 2020 emissions inventory was electric, the maximum emissions benefit would be 1.2 tons per day HC+NOx.

If residential owners purchased corded electric lawn mowers compared to the lowest priced gasoline lawn mowers, this strategy could be cost-effective at $4 per pound of HC+NOx reduced over the lifetime of the lawn mower. If the market demanded the purchase of cordless electric lawn mowers compared to the average price of a gasoline lawn mower, the cost-effectiveness would increase to $16 per pound of HC+NOx reduced.

These emission benefits can only be realized if consumers actually buy new electric lawn mowers to replace gasoline lawn mowers. The new electric lawn mowers would need to be competitively priced (refer to Table 3), as powerful as its gasoline counterparts, and easy to use. It is possible that some consumers are simply averse to buying electric equipment because of the preconception that it is not going to do as good a job as gasoline-powered equipment. The Toro Company once produced electric corded lawn mowers in the United States, but has reportedly ceased production due to poor sales (Toro). Toro also manufactures other electric lawn and garden equipment, such as string and hedge trimmers, blower/vacuums, and snowthrowers. If a lower fleet average emissions standard that included electrics were proposed for residential lawn mowers, it is likely that incentives may be needed to encourage consumers to purchase the electric lawn mowers. Additionally, the advantages of electric lawn mowers would need to be promoted to help boost consumer confidence.

4.2. Zero Emission Mandate

Environmental groups and the South Coast Air Quality Management District (SCAQMD) support a strategy to require a portion of new sales of lawn and garden equipment to be electric.

While a fleet average standard strategy discussed above would be the responsibility of the engine manufacturer, staff envisions that a zero emission mandate strategy would be the responsibility of the equipment manufacturer. Equipment manufacturers are generally in a position to decide whether a gasoline-powered engine or an electric motor is installed in their equipment. Equipment manufacturers currently decide how their products are "packaged" and how many they will produce depending on the market. Staff believes that for those manufacturers who produce engines and install them in their own equipment, i.e. an integrated manufacturer, and already have electric product lines, a zero emission mandate would be a less onerous requirement. Those manufacturers who only produce equipment would need to either buy electric motors from other manufacturers or produce their own electric motors. They would also likely need to redesign some of their equipment to allow for the installation of the electric motor.

As shown in Table 5, there are currently 21 equipment manufacturers that produce only gasoline engine powered equipment and 12 equipment manufacturers that produce both gasoline and electric powered equipment. Black and Decker is the only manufacturer that produces all electric equipment. As discussed in section 4.1, a fleet average standard strategy could force some manufacturers to abandon the California market. The same could be said for a zero emission mandate strategy. Additionally, consumer incentive and acceptance issues would still exist.

Table 5
Small Engine Equipment Manufacturers

No Electric	Some Electric	All Electric
Ariens Co.	American Honda Motor Co.	Black and Decker
Bush Hog L.L.C.	Echo, Inc.	
Dixon Industries	Electrolux Home Products	
Deere & Co.	Husqvarna Forest & Garden	
Exmark Manf. Co.	Makita USA, Inc.	
Hoffco, Inc.	Minuteman Parker	
Homelite Consumer Products	MTD Products Inc.	
Kawasaki Motors Corp., USA	Stihl, Inc.	
Kubota Tractor Corp.	Textron Golf, Turf & Specialty Products	
Murray, Inc.	Tennant Co.	
New Holland North America Inc.	The Toro Co.	
Redmax	Wolf Garten of North America L.P.	
Robin America		
Scag Power Equipment, Inc.		
Simplicity Manufacturing Inc.		
Shindaiwa, Inc.		
Snapper, Inc.		
Solo, Inc.		
Tanaka Power Equipment		
Woods Equipment Co.		
Yamaha Motor Corp.		

As discussed in section 3 and shown in Figure 5, three of the four major residential equipment categories already have sizeable electric market penetration. Residential lawn mowers are the second largest engine category and have only about 15 percent electrified. Thus, if a zero emission mandate strategy was pursued, it makes the most sense to focus it just on residential lawn mowers to increase their electrification levels to be on par with chain saws, blowers and trimmers. If a zero emission mandate required that an additional ten percent of new residential lawn mower sales in California were electric beginning in 2007, an emissions benefit of 0.2 tons per day HC+NOx would result by 2010 and 0.7 tons per day HC+NOx would result by 2020. Similar to the fleet average standard discussed above, this represents a one percent and a six percent

reduction by 2010 and 2020, respectively. The cost-effectiveness of a zero emission mandate would be similar to a fleet average standard strategy with a range of $4 to $16 per pound of HC+NOx reduced over a residential lawn mower lifetime of 12 years.

Other suggestions from stakeholders included establishing an emissions credits program for manufacturers to be credited for going beyond a percent electric requirement or for early introduction of electrics. Additionally, a quarterly or annual reporting requirement for manufacturers would help properly account for the electric equipment being produced. These and other issues would need to be discussed and resolved through the regulatory process.

4.3. Electric Requirement for Residential Equipment

Environmental groups and SCAQMD have suggested, as part of their 2003 State Implementation Plan, that 30 percent[9] of new residential lawn and garden equipment sold in California be required to be electric. SCAQMD has suggested that this approach could be met with regulatory or voluntary means such as through incentives.

The residential and commercial markets for lawn and garden equipment are not distinct. It would be extremely difficult to enforce a mandatory residential-only electric purchase requirement due to crossover buying of equipment between residential and commercial users. The burden of compliance would fall on the retailers to ensure that only commercial businesses purchase gasoline mowers. Comparing the current electric residential lawn and garden population with SCAQMD's proposed 30 percent requirement, as shown earlier in Figure 5, the overall residential lawn and garden equipment category is already almost 40 percent electric with some categories well over 50 percent. Natural penetration of electric equipment into the lawn and garden market seems to have already met the proposed requirement of 30 percent. Therefore, there would be no additional benefit associated with this requirement. Residential lawn mowers, which are currently 15 percent electric, could benefit from additional resources and incentive funding to increase its electric percentage. The benefits of incentives and trade-in programs are discussed in Section 4.7.

4.4. Scrap Program

SCAQMD has also suggested a control measure to require manufacturers to retire or scrap a percentage of lawn and garden equipment based on a manufacturer's sales numbers in California. This would help turn over the small off-road equipment fleet sooner and introduce lower emission engines/equipment faster. If a scrap ratio was stringent enough to require one percent of the existing residential gasoline lawn mowers to be scrapped, about 46,000 units would need to be retired by 2010. Assuming the scrap program started in 2007, approximately 15,000 units would be scrapped each of

9 The 30 percent requirement is based on SCAQMD staff's estimate that at least 50 percent of residential lawn and garden equipment would have electric counterparts by 2010. Assuming that 50 percent of the residential equipment can be electrified and by applying a 60 percent electrification requirement, an overall 30 percent of the existing residential lawn and garden equipment would be replaced with electric models.

the three years preceding 2010. In 2010, it is estimated that about 386,000 new residential gasoline lawn mowers will be sold in California (ARB's OFFROAD Model). That would mean that for every 25 new residential lawn mowers sold, one old residential lawn mower would need to be scrapped. Manufacturers would estimate the actual number of mowers to be scrapped based on their estimated sales at the time of certification. If the manufacturer offered a $100 voucher toward the purchase of a new electric lawn mower to acquire each old lawn mower, then the total cost to the manufacturers would be $4.6 million by 2010. If the manufacturers chose to pass on the entire cost to the consumers, this could add $4 to the price of each new residential lawn mower sold in California. The tons per day HC+NOx benefit would be 1.1 in 2010. The cost-effectiveness for this example would be $9 per pound of HC+NOx reduced.

A manufacturer-run scrap program would require a quarterly or annual reporting requirement to ensure accurate counts are made of lawn and garden equipment sold in California. Because there is no registration program for small off-road equipment, tracking down potential equipment to be scrapped may be difficult. The turnover ratio would also need to take into account natural growth in the market, which could be affected if this program were made a condition for a manufacturer to do business in California.

4.5. Residential Weekend Usage Restriction

This potential measure would restrict the residential use of gasoline-powered lawn and garden equipment on weekend days, which represent 96 percent of the exhaust and evaporative emissions from residential lawn mowers. Alternatively, the restriction could be limited to weekend days for which an ozone exceedance is predicted. A weekend usage restriction for gasoline lawn mowers may also encourage residents to purchase electric lawn mowers rather than be inconvenienced by having to mow the lawn on a weekday. The restriction would be specific only to weekend days because the use of lawn and garden equipment on weekend days is primarily residential (i.e., not lawn care companies). Broadening this measure to include weekdays could put a burden on lawn care companies whose livelihoods are dependent upon being able to operate lawn and garden equipment.

To assess the impact of a weekend usage restriction, we assumed that at a minimum compliance would be double (i.e., 16 percent) that achieved by the "Spare the Air" program discussed in the following section, to as high as 50 percent. If this level of compliance were achieved by using electric mowers on weekends, the benefits would be 3.2-10.1 tons per day HC+NOx by 2010 and 1.8-5.7 tons per day HC+NOx by 2020[10.]

If all residents shifted their mowing from weekends to weekdays (i.e., without purchasing/using electric mowers), there would be no benefit and no cost. If some residents chose to purchase corded electric lawn mowers to mow their lawns on

10 For every ten percent of California residents that would use electric lawn mowers instead of their current gasoline lawn mowers on summer weekends, the emissions benefits would be 2.02 and 1.14 tons per day HC+NOx in 2010 and 2020, respectively.

weekends, the cost-effectiveness of this strategy would be $14 per pound of HC+NOx reduced over 12 years. If residents purchased cordless electric lawn mowers instead of using their gasoline lawn mowers, the cost-effectiveness would be high at $39 per pound of HC+NOx reduced.

This measure could be adopted as a mandatory requirement. However, it may be more appropriate if it were a voluntary measure because it would be difficult to enforce a mandatory program.

4.6. Consumer Awareness and Information Programs

Electric lawn and garden product line sales can be increased through "clean air" marketing and ad campaigning. For example, the Bay Area Air Quality Management District (BAAQMD) has a "Spare the Air" program. Spare the Air is a voluntary, summertime program that notifies residents in advance of Spare the Air days when air quality is forecast to reach unhealthy levels. The district notifies the public via television, radio, newspaper, and at participating work sites. When a Spare the Air day has been called, residents are asked to reduce or avoid activities that may contribute to air pollution for the following 24 hours. Promoting the use of electrics through a Spare the Air program can be a good way to keep the public informed about cleaner alternatives.

Based on a 1998 survey (Tools of Change) conducted by the BAAQMD to determine the effectiveness of their Spare the Air program, about eight percent of the residents reduced their use of gasoline-powered garden equipment on Spare the Air days. If consumer reduced usage patterns influenced by the Spare the Air program remained constant at eight percent and was in effect statewide, 1.7 and 0.95 tons per day of HC+NOx could be reduced throughout the state on Spare the Air days in 2010 and 2020, respectively. This represents an eight percent reduction in residential lawn mower emissions. If the costs of a statewide program were similar to the BAAQMD program, the cost-effectiveness would range from $10 to $18 per pound of HC+NOx emissions reduced in 2010 and 2020, respectively.

A statewide Spare the Air program could be expanded to further encourage residents to reduce their use of gasoline equipment on non-peak ozone days and use electric equipment on a regular basis. This would help provide additional reductions, similar to the approaches discussed in the previous two sections (although it would be a voluntary measure). However, citizens are less likely to comply on a non-urgency basis.

4.7. Incentive/Rebate/Trade-in Programs

Incentive programs provide partial funding to consumers to purchase electric products. While, in general, these programs are not limited to any particular equipment type, they have primarily targeted lawn mowers. This is most likely because the opening price point of electric lawn mowers is typically higher than gasoline lawn mowers (as shown in Table 3). Thus, cost seems to be an issue with regard to lawn mowers. As an example of these programs, many local districts have sponsored "trade-in events" where a

consumer can trade-in their old gasoline lawn mower and receive a voucher for a certain dollar amount that can be used to purchase a new electric lawn mower. The use of these vouchers are often times combined with an additional manufacturer rebate which can significantly discount the price of a new electric lawn mower. Vouchers have been offered for $100 and more. These trade-in events have been popular and successful with high participation from local residents.

While popular, the overall emissions benefit from incentive programs compared to the total emissions impact of the small off-road category is generally small due to limited funding. As an example, the Sacramento Metropolitan Air Quality Management District (AQMD) has been conducting annual trade-in events for the last several years. Their "Mow Down Air Pollution Program" has sold over 6,000 electric lawn mowers since the program began in 1997. The Sacramento Metropolitan AQMD has estimated that they have reduced approximately 68 total tons of HC+NOx emissions from this program between 1997 and 2003. The total cost of the program through 2003 is $1.1 million, which includes the cost of the vouchers of $772,000 and marketing costs of $335,000. The average voucher cost was $116 per electric lawn mower sold and the cost-effectiveness per pound was approximately $8 of HC+NOx.

As previously mentioned, electric lawn mowers currently represent 15 percent of the residential lawn mower population. If incentives were used to increase the electric residential lawn mower population by another one percent by 2010, about 46,000 lawn mowers would need to be traded-in. Currently, districts are offering up to $100 vouchers for corded electric lawn mowers and up to $200 vouchers for cordless electric lawn mowers. These vouchers discount the price of a new electric lawn mower to be comparable with the price of a new gasoline lawn mower. Therefore, $9.2 million would be needed to replace 46,000 gasoline lawn mowers with cordless electric lawn mowers or $4.6 million with corded electric lawn mowers in 2010. The lifetime emissions benefit would be 253 tons HC+NOx. This amounts to a 1.1 tons per day HC+NOx benefit by 2010. In this example, the cost-effectiveness would range from $9 to $18 per pound of HC+NOx, well above the Carl Moyer Program NOx limit of $6.80. However, incentives can be a useful public relations tool to make consumers more aware of cleaner alternatives, which they may choose to purchase without incentives.

Districts primarily get their funding from mitigation fees, individual city sponsors, and state matching funds. An additional source of funds could be created, if under a regulatory requirement such as the zero emission mandate, equipment manufacturers were allowed the option of contributing to a statewide "incentive fund" for future trade-in programs in lieu of meeting a portion of the zero emission requirement. New legislation would need to be proposed in order for this to be possible. Other new funding sources might include an "indirect source mitigation fee" that the San Joaquin Valley Air Pollution Control District is working to establish with new housing developers. The funds from this fee would be used to reduce emissions from new sources that would result from the development of that area. Other ways to make electric lawn mowers more attractive to consumers might be to provide tax breaks or offer energy efficiency rebates.

For new housing, the San Joaquin Valley Air Pollution Control District is also trying to work with housing developments to require outdoor electric outlets to make it easier for powering electric lawn and garden equipment. It has been suggested that outlets be placed strategically around the outside of the house so that electric equipment can be used anywhere in the yard with a 50 foot extension cord. This type of building requirement could be incorporated into new housing requirements in other nonattainment areas or throughout the state. Although building code requirements are outside the scope of the ARB's authority, staff believes this is a good idea that deserves further investigation by local government.

5. SUMMARY OF ISSUES AND POTENTIAL

Overall, it would not make sense to switch over the entire lawn and garden category to electric only. The potential for significantly increasing electrification in various portions of the category depends on the ability of electric models to compete with current gasoline-powered equipment.

- Electric equipment currently available is designed for residential applications. Corded or cordless electric units could replace certain handheld equipment designed for residential users such as string trimmers, hedge trimmers, edgers, small chain saws, and blowers, at the same or lower cost. In addition, electric nonhandheld equipment (lawn mowers) can be an ideal alternative to gasoline-powered equipment for residential applications with smaller sized lots, but they cost more.

- Electric equipment in the residential lawn and garden market is already sizeable (ARB's OFFROAD Model), representing from 15 percent of lawn mowers to 50 percent or more of trimmers and blowers. Improved battery technology provides reasonable promise for further increases in electrification of lawn and garden equipment in the future. The rechargeable batteries designed for electric golf carts may be used in some nonhandheld equipment, such as garden tractors and riding mowers.

- Increased availability of incentive funds could further increase the amount of electric equipment sold especially for product lines such as the residential lawn mower which are currently more expensive to purchase than their gasoline counterparts. As emission standards become more stringent, the price differences may decrease due to gasoline-powered equipment requiring additional emission controls.

- Commercial users typically require more power than current electric models offer. Electric equipment could not perform adequately in commercial uses, which typically require greater mobility than afforded by corded equipment and greater operating time than provided by current battery-powered units. Commercial use accounts for about two thirds of the current small engine emissions.

Staff has preliminarily assessed the strategies outlined in this report and ranked them according to their potential feasibility and cost effectiveness in Table 6.

- Staff ranked mandatory residential electric and usage restriction requirements as low feasibility primarily because enforcement would be very difficult. However, these strategies may have potential as voluntary measures.

- A lower new engine fleet average emission standard that would likely require production of additional electric equipment was ranked as medium feasibility. ARB has the authority to adopt a lower fleet average emissions standard for small off-road engines. As shown in Table 6, the emissions benefit of this strategy would be relatively small. In addition, many equipment manufacturers currently produce no electric models, thus substantial lead time would be required to allow them to develop equipment to remain competitive in the California market.

- A manufacturer scrap program was also ranked as medium feasibility. As a mandatory requirement, there is no registration program for small off-road equipment so tracking down older lawn and garden equipment with the potential for being scrapped each year may be difficult. If manufacturers chose to pass on the cost to the consumer, prices of gasoline equipment in California would increase.

- It is also feasible to require equipment manufacturers to produce and sell a minimum percentage of electric small off-road equipment. However, because the electric penetration of handheld equipment is already relatively high (and market forces will likely increase this penetration in the future), it would be prudent to only pursue a zero emission mandate with lawn mowers. This requirement could be supplemented with incentive money to encourage consumers to buy electric lawn mowers, thus increasing the market demand for electric equipment. This would likely be a costly measure overall with a small emissions benefit.

Table 6
Feasibility and Cost-Effectiveness of Potential Control Measures

Potential Control Measure	2010 HC+NOx Benefit (tpd)[11]	Cost-Effectiveness $ per lb. HC+NOx	Feasibility			Comment
			Low	Medium	High	
Lower Fleet Average Standard Including Electrics	0.2	$4-$16		X		Regulatory requirement ensures a mix of electric equipment in the fleet average, but lead time required for research and development of new electric products for many companies. Small emissions benefit.
Zero Emission Equipment Manufacturer Mandate	0.2	$4-$16		X		Regulatory requirement ensures a minimum percentage of electric equipment. Small emissions benefit. Lead time required for manufacturers to develop electric equipment.
Residential Electric Requirement	0	$0	X			Market shift to electric already happening. Can be met through voluntary programs (see Consumer Awareness).
Manufacturer Scrap Program	1.1	$9		X		Prices of gasoline-powered equipment could increase and thus be higher in California than in other states.
Residential Usage Restriction	3.2-10.1	$14-$39	X			Difficult to enforce if a mandatory program. Possible voluntary program (see Consumer Awareness).
Consumer Awareness Spare the Air	1.7	$10-$18			X	Highly visible. Already happening in many districts.
Incentive Programs	1.1	$9-$18			X	Highly visible. Only limited by funding.

11 Statewide 2010 HC+NOx tons per day emissions benefit compared to the statewide summer average inventory of 20.9 tons per day.

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- Staff believes that it is feasible to increase electrification of residential lawn mowers with increased incentive funding. Currently, incentive programs are not very cost-effective at $9-18 per pound, but they can be useful for public relations purposes to make electric lawn mowers more attractive. Thus, modest programs that receive lots of publicity would make the most sense.

- Consumer awareness programs are a good way to keep consumers informed about what they can do to help reduce emissions. The BAAQMD's "Spare the Air" Program cost approximately one million dollars for the year 2000. The cost of their program was funded by a grant given to the Metropolitan Transportation Commission by the federal Department of Transportation. This grant allowed BAAQMD to purchase more airtime for radio and television advertising to improve program recognition. Consumer awareness programs could be expanded to not only encourage consumers to avoid using gasoline-powered equipment on "Spare the Air" days, but to also encourage them to consider purchasing electric equipment instead of gasoline-powered equipment. This could be an alternative to requiring residents to restrict their use of gasoline equipment on weekends or requiring residents to purchase electric equipment. If a program like this were expanded statewide, the costs would likely be higher with eight percent of residents choosing not to use their gasoline-powered equipment on peak ozone days. The emission benefits for this program would be relatively small and expensive.

6. CONCLUSION

- Electric residential equipment is already cheaper than gasoline-powered equipment for all of the major equipment categories, except for residential lawn mowers.

- The residential electric equipment market has already expanded to reflect this. It is most evident in the trimmer, blower, and chain saw residential equipment categories, where electric equipment penetration ranges from 30 to 70 percent.

- Only 15 percent of residential lawn mowers are electric because of limited performance and higher cost (battery electrics). Programs to turn over the market to electric have been tried and are popular, however they are expensive and only marginally cost-effective.

- The commercial equipment market is not electric because current electric equipment cannot meet the demands of the commercial user.

- The most effective way at this time to increase the purchase and use of electric equipment is to "get the word out." Specifically, the public needs to know that not only is electric equipment good for the environment, many types of electric equipment perform equally as well as gasoline equipment in a residential

environment and are less costly to buy. One means to achieve this is to use strategies such as “Spare the Air” campaigns to bring the message to the public. This is a program that staff can initiate. However, additional funds would be necessary to expand the program statewide.

7. MEETINGS

The following is a list of those who contributed ideas for the development of this report:

American Lung Association - Bonnie Holmes-Gen
Black & Decker – David Olsen
CA Electric Transportation Coalition - Dave Modisette
Natural Resources Defense Council - Diane Bailey
Outdoor Power Equipment Institute
San Joaquin Valley Air Pollution Control District - Tom Jordan
SCAQMD- Zorik Pirveysian
Southern California Edison - Dean Taylor
TORO - Ron Lloyd
Union of Concerned Scientists - Don Anair

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Sacramento Air Quality Management District, Mowdown Air Pollution,
http://www.airquality.org/mobile/mowdown/mowdowngeneral.shtml

Tools of Change, Case Studies, Spare the Air,
http://www.toolsofchange.com/English/CaseStudies/default.asp?ID=81

Electric Tractors, Mowers, Blowers, Tillers, etc.
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Electric Tractor Corporation
http://www.electrictractor.com/html/multi_prod.shtml

ATTACHMENT 1

Exhaust Emission Standards for Spark-Ignition Engines
grams per brake horsepower-hour
[grams per kilowatt-hour]

Model Year	Engine Class	Durability Periods (hours)	Hydrocarbon plus Oxides of Nitrogen[2]	Carbon Monoxide	Particulate
2000-2001[5]	0-65 cc, inclusive	50/125/300	54 [72]	400 [536]	1.5[4] [2.0]
	>65 cc - <225 cc	NA	12.0 [16.1]	350 [467]	
	≥225 cc	NA	10.0 [13.4]	350 [467]	
2002-2004[5]	0-65 cc, inclusive	50/125/300	54 [72]	400 [536]	1.5[4] [2.0]
	>65 cc - <225 cc Horizontal-Shaft Engine	125/250/500	12.0 [16.1]	410 [549]	
	>65 cc - <225 cc Vertical-Shaft Engine	NA	12.0 [16.1]	350 [467]	
	≥225 cc	125/250/500	9.0 [12.0]	410 [549]	

Exhaust Emission Standards for Spark-Ignition Engines
grams per kilowatt-hour

Model Year	Displacement Category	Option	Durability Periods (hours)	Hydrocarbon plus Oxides of Nitrogen[2][6]	Carbon Monoxide	Particulate
2005 and subsequent	<50 cc		50/125/300	50	536	2.0[4]
	50-80 cc, inclusive		50/125/300	72	536	2.0[4]
2005	>80 cc - <225 cc	Horizontal-shaft Engine	125/250/500	16.1	549	
		Vertical-shaft Engine	NA	16.1	467	
	≥225 cc		125/250/500	12.1	549	
2006	>80 cc - <225 cc		125/250/500	16.1	549	
	≥ 225 cc		125/250/500	12.1	549	
2007[7]	>80 cc - <225 cc	Option A	125/250/500	8.0	549	
		Option B	125/250/500	10.0	549	
	≥ 225 cc		125/250/500	12.1	549	
2008 and subsequent [7]	>80 cc - <225 cc	Option A	125/250/500	8.0	549	
		Option B	125/250/500	10.0	549	
	≥ 225 cc	Option A	125/250/500/1000	6.0	549	
		Option B	125/250/500/1000	8.0	549	

(1) “Class I” means small off-road engines greater than 65 cc to less than 225 cc in displacement.
“Class II” means small off-road engines greater than or equal to 225 cc in displacement.
“Class III” means small off-road engines less than 20 cc in displacement.
“Class IV” means small off-road engines 20 cc to less than 50 cc in displacement.
“Class V” means small off-road engines greater than or equal to 50 cc to 65 cc in displacement.

(2) The Executive Officer may allow gaseous-fueled (i.e., propane, natural gas) engine families, that satisfy the requirements of the regulations, to certify to either the hydrocarbon plus oxides of nitrogen or hydrocarbon emission standard, as applicable, on the basis of the non-methane hydrocarbon (NMHC) portion of the total hydrocarbon emissions.

(3) Applicable to all diesel-cycle engines.

(4) Applicable to all two-stroke engines.

(5) Engines used exclusively in snowthrowers and ice augers need not certify to or comply with the HC and NO_x standards or the crankcase requirements at the option of the manufacturer.

(6) Engines used exclusively to power products which are used exclusively in wintertime, such as snowthrowers and ice augers, at the option of the engine manufacturer, need not certify to or comply with standards regulating emissions of $HC+NO_x$ or $NMHC+NO_x$, as applicable. If the manufacturer exercises the option to certify to standards regulating such emissions, such engines must meet such standards. If the engine is to be used in any equipment or vehicle other than an exclusively wintertime product such as a snowthrower or ice auger, it must be certified to the applicable standard regulating emissions of $HC+NO_x$ or $NMHC+NO_x$ as applicable.

(7) Engine families that comply with the Option A may comply with any of the evaporative emission standards, as noted in Title 13, California Code of Regulations, Sections 2754 or 2754.1 or 2751(b). Engine families that comply with the Option B may only comply with the evaporative emission standards, as noted in Title 13, California Code of Regulations, Section 2754.1 or 2751(b).

ATTACHMENT 2

Methodology for Estimating Electric Lawn Mower Run-Times

The methodology for estimating electric lawn mower run-times is based on calculating the current draw from the battery, or AC outlet, necessary to generate the desired power. For the cordless lawn mowers, battery packs consisting of four and six 6 Volt 12 Amp-Hour sealed lead-acid batteries were assumed to be the energy sources for the 24 Volt and 36 Volt lawn mowers typical in the industry. Five power points from one to five horsepower were chosen where current flow could be established by dividing power output by system voltage. For example, the 24 Volt cordless lawn mower would be required to pull about 31 Amps (= Power / System Voltage = 750 Watts / 24 Volts) at one horsepower and about 62 Amps at two horsepower. Higher current draws are possible in surges, but not for continuous operation without overheating the motor and damaging the batteries. Although Figure 6 shows cordless lawn mower run-times corresponding to three, four, and five horsepower outputs (dashed line where current is more than 65 Amps), 24 Volt systems would likely be limited to continuous operation at less than two horsepower output and 36 Volt systems to less than three horsepower only. Run-times are calculated by dividing the Amp-Hour capacity of the battery pack (12 Ah) by the electric current required to generate the desired power.

A similar approach is used to analyze the corded electric lawn mower. A 12 Amp corded lawn mower was chosen for this comparison because it operates at nearly the maximum amount of current that can safely be drawn through a residential circuit breaker using a 100 foot 14 gauge extension cord. Using the same power calculations as before, the maximum power output from a 12 Amp corded electric lawn mower is about two horsepower (Voltage * Current = 120 Volts AC * 12 Amps AC). Run-times for corded electric lawn mowers are unlimited, but the maximum available power output of two horsepower may be inadequate for some lawn care applications. The 170-minute run-time shown in Figure 6 for the corded lawn mower is for the purpose of comparison and should not be concluded to be a maximum value.

The run-times for the five horsepower gasoline lawn mower were determined by measuring fuel flow rate at several horsepower levels. Using the nominal fill capacity of the tank, the run-times were determined mathematically by calculating how long it would take to empty the tank at the measured fuel flow rates for each horsepower indicated. The dashed portion of this line from approximately three and a half to five horsepower has been extrapolated using polynomial regression since the available data did not include these ranges. The lawn mower used was powered by a Honda GVC160 engine and had a 1.16 quart fuel tank. Obviously a larger tank would have extended the run-time estimations for this lawn mower.