Comments on the Non-handheld Equipment Inventories in ARB's Small Engine Initial Statement Of Reasons (ISOR)

Air Improvement Resource, Inc.

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Introduction

The California Air Resources Board has proposed new emission standards and a zero emissions requirement for small offroad engines used in California.[1] The zero emissions requirement applies to all offroad gasoline engines except those used in generators starting with model year 2024. Gasoline and diesel small off-road generators have lower exhaust and evaporative emission standards in model years 2024-2027, but all generators must meet the zero emissions requirement in model year 2028.

CARB staff developed a new small offroad engine model that it uses to update its emission inventories and develop the emission benefits of its proposal. The model is referred to as SORE2020.[2] ARB conducted a survey of small engine populations and small engine use as a part of this effort.[3] The survey included three groups – residential users, commercial users (businesses and government), and landscapers.

The Engine Manufacturers Association (EMA) and Outdoor Power Equipment Institute (OPEI) submitted comments on ARB's small engine survey on June 30, 2020.[4] EMA and OPEI contracted with AIR, Inc. to review many parts of the survey. This review uncovered many problems with the survey data. A few of these problems were addressed by ARB in the finalization of the SORE2020 model, but many problems still remain.

As a part of its comments on the ISOR, EMA is offering to meet reduced exhaust emission standards of 6 g/kw-hr for Class 1 engines and 3 g/kw-hr for Class 2 and > 825 cc engines starting with model year 2025 for Class 1, and 2026 for Class 2 and > 825 cc engines.[5] In addition, EMA is offering to meet the Class 1 standard at a durability period of 500 hours and the Class 2 and > 825 cc standard at a period of 1000 hours. These exhaust emission standards are the same as ARB's proposal for generators for model years 2024-2027. Finally, EMA is agreeing to a zero emissions standard for lawnmowers in model year 2025.

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[1] *Public Hearing to Consider Proposed Amendments to the Small Off-Road Engine Regulations: Transition to Zero Emissions, Staff Report: Initial Statement of Reasons*, State of California Air Resources Board, October 12, 2021.

[2] *2020 Emissions Model for Small Off-Road Engines – SORE2020*, California Air Resources Board, September 2020.

[3] *Survey of Small Off-Road Engines (SORE) Operating Within California: Results from Surveys with Four Statewide Populations,* May 15, 2019, Social Science Research Center (SSRC), CSU at Fullerton.

[4] Letter from Mr. Greg Knott of OPEI to ARB, June 30, 2020.

[5] EMA is also proposing that fixed mount generators installed on DMV licensed motor vehicles and trailers transition to ZEE on the date the vehicle or vehicle pulling the trailer transitions to ZEE (2035 used for modeling purposes).

AIR has now reviewed CARB's SORE2020 emissions model, and the small engine ISOR. In addition, AIR has modeled non-handheld small engine inventories for ARB's proposal, the EMA proposal, and has evaluated the effects of the different evaluations of the small engine survey data on emission inventories. Our comments on the SORE2020 model and the ISOR are as follows:

1. CARB's small engine survey was flawed, leading to a significant overestimate of the small engine inventory.
2. CARB's evaporative running loss emissions for generators and lawnmowers are overly pessimistic.
3. CARB's predictions of electric equipment penetration for non-handheld equipment for the baseline case appear to be overly conservative.
4. CARB's ZEE requirement means that many landscapers and other small engine users will purchase equipment outside of California for use in California (i.e., leakage). In addition, the high price of some new electric equipment compared to gasoline will cause fleet turnover rates to slow, reducing the benefit of ARB's proposal.
5. EMA's proposal provides significant emission reductions without the impacts of equipment leakage or slower fleet turnover.

These comments are further explained in the remainder of this document.

1. CARB's small engine survey (conducted by California State University Fullerton (CSUF)) was flawed, leading to a significant overestimate of the small engine inventory.

AIR reviewed CARB's survey data extensively, and our analysis of these data were a part of both EMA's and OPEI's comments on the survey (referenced earlier). AIR used a two-step process to examine all of the data: (1) AIR used an outlier criteria to identify potentially erroneous data, and then (2) AIR examined all identified outliers determine whether to accept or reject each piece of data.

In its review of the process AIR used, CARB staff were critical of Step 1 used by AIR. [6] However, Step 1 was never used to reject any data; instead, Step 1 was only used to identify data that was carefully reviewed in Step 2. The actual process AIR used to identify potential outliers is somewhat irrelevant; any number of processes could have been used to identify these data. Step 2 was the critical step used to determine whether the data should be accepted or rejected. AIR utilized additional information provided by respondents and publicly available data to triangulate accuracy of a given response.

One of the most critical flaws in this survey was the inability of the surveyors to adequately determine engine-on times for equipment. For example, surveyors asked respondents how long they used their equipment each day. In several cases, landscapers indicated that they used a lawnmower "all day" and in many of these cases, surveyors inputted 8 hours for "all day." Clearly, landscapers cannot leave lawnmowers on for 8 hours a day, as they must travel from location-to-location and turn off the lawnmower when it is not in use. There was no survey question that required respondents to determine the fraction of the day that their equipment was actually "on."[7] This was a very common problem, not just for lawnmowers, but for other equipment as well. Additionally, this contemplates that the maximum hours worked per day would have been 8, when the number could actually be higher.

A comparison of sample sizes and average use between our analysis of the survey data and ARB's is shown in Table 1.

[6] *2020 Emissions Model for Small Off-Road Engines – SORE2020*, California Air Resources Board, September 2020, Appendix J, page 111.

[7] ARB has commenced a survey of marine engine use, and has addressed this problem in the marine survey. Respondents are asked to provide information on the percent of time that their engines are "on" while they are boating.

Table 1. Comparison of Equipment Sample Sizes and Activity						
	Business		Residential		Vendor	
Equipment	AIR	ARB	AIR	ARB	AIR	ARB
	Sample Sizes					
Generator	76	87	103	127	77	100
Lawn Mower	62	83	278	306	354	434
Power Washer	82	99	55	68	120	146
Riding Mower	3	4	3	7	71	96
	Average Annual Use (annual hours)					
Generator	103	167	11.3	46.2	69	66
Lawn Mower	57	85	14.8	18.6	172	249
Power Washer	34	77	11.0	29.3	25.3	30.0
Riding Mower	40	147			198	258

There were many other concerns with the survey data as well which are discussed in the earlier 2020 comments by OPEI and EMA. In this section, however, we evaluated the impacts of the different analysis of the survey data on small engine inventories, both current and future. To determine the emission inventory effects of the two analyses of the survey data, we first replicated ARB's emission inventories using the "default" SORE2020 model, which ARB has made publicly available. Next, we inputted the activities shown in Table 1, and re-ran the model. Results are shown in Figure 1; "Default" means the ARB's analysis of survey data, "Survey" means AIR/OPEI/EMA analysis of survey data.

Figure 1

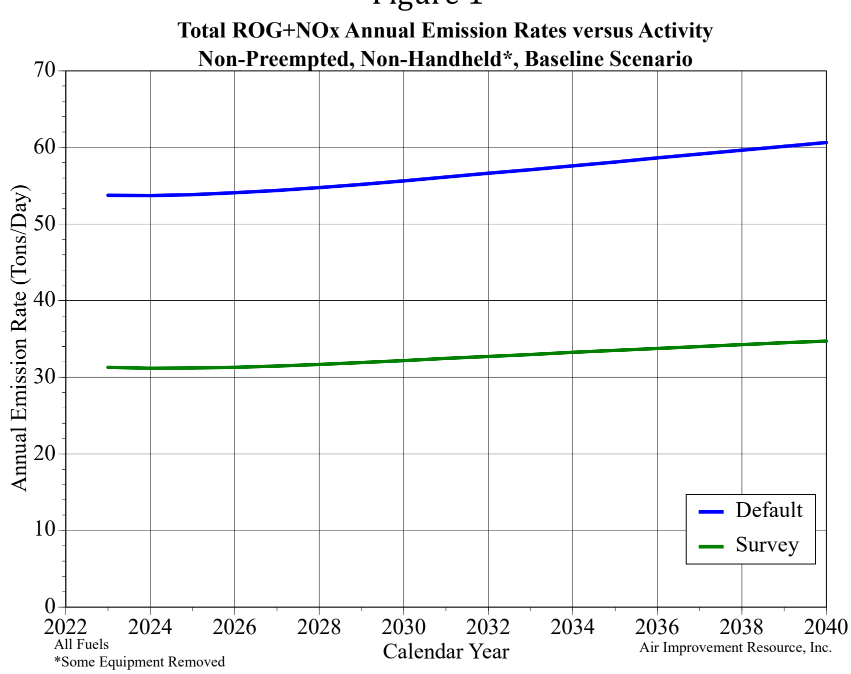
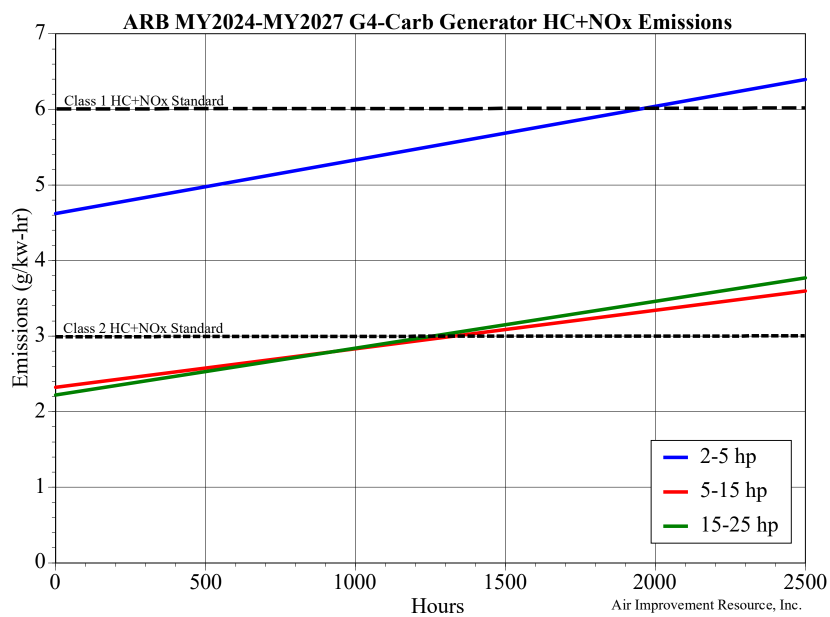


Figure 1 shows much lower small engine inventories for the more realistic activities calculated by AIR which was the main goal of the CSUF survey was to calculate a more accurate inventory of SORE emissions and modeling - than for the default ARB inventories.

2. CARB's evaporative running loss emissions for current emission standard generators and lawnmowers are overly pessimistic.

AIR reviewed the in-use emissions in the SORE2020 model and found the exhaust emissions for current standard engines to be overly pessimistic. AIR also reviewed the in-use exhaust emissions for generators certified to the 6 and 3 g/kw-hr Class 1 and Class 2 emission standards proposed for model years 2024-2027 and found these in-use emissions projections by ARB for these standards to be reasonable. The in-use ROG+NOx emissions for these standards are shown in Figure 2. Since under either the ARB or EMA proposals emission standards would change to lower levels and durability periods would be lengthened, this analysis will spend no effort to critique ARB's in-use exhaust emissions for the current Class 1 and Class 2 emission standards.

Figure 2



AIR also reviewed the in-use evaporative ROG emissions for non-handheld equipment. Evaporative emissions consist of hot soak, diurnal, resting loss, and running loss emissions. Evaporative emissions versus age for generators and lawnmowers are shown in Figures 3 and 4.

Figure 3

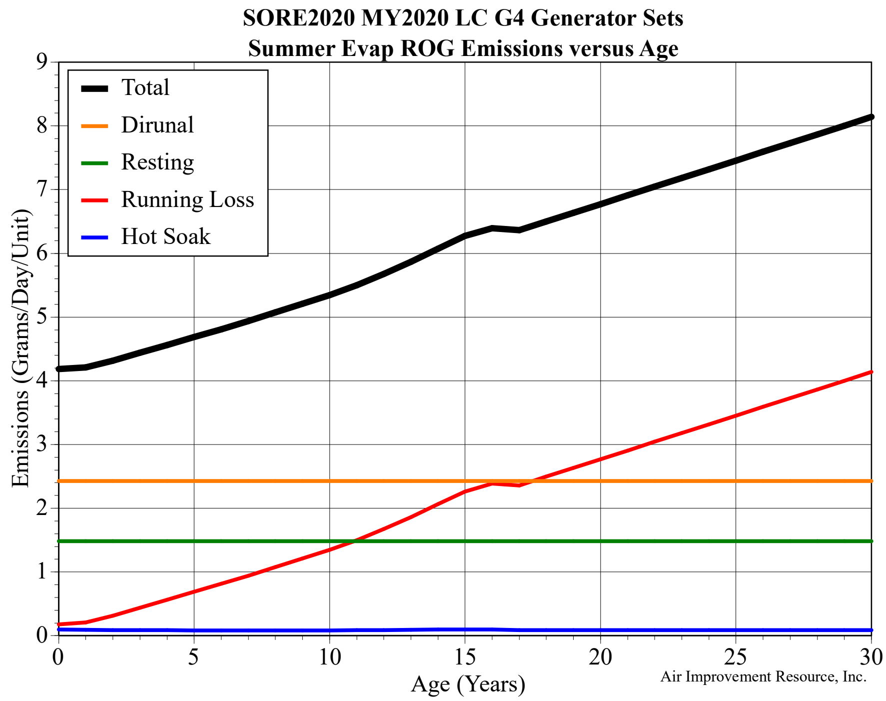


Figure 4

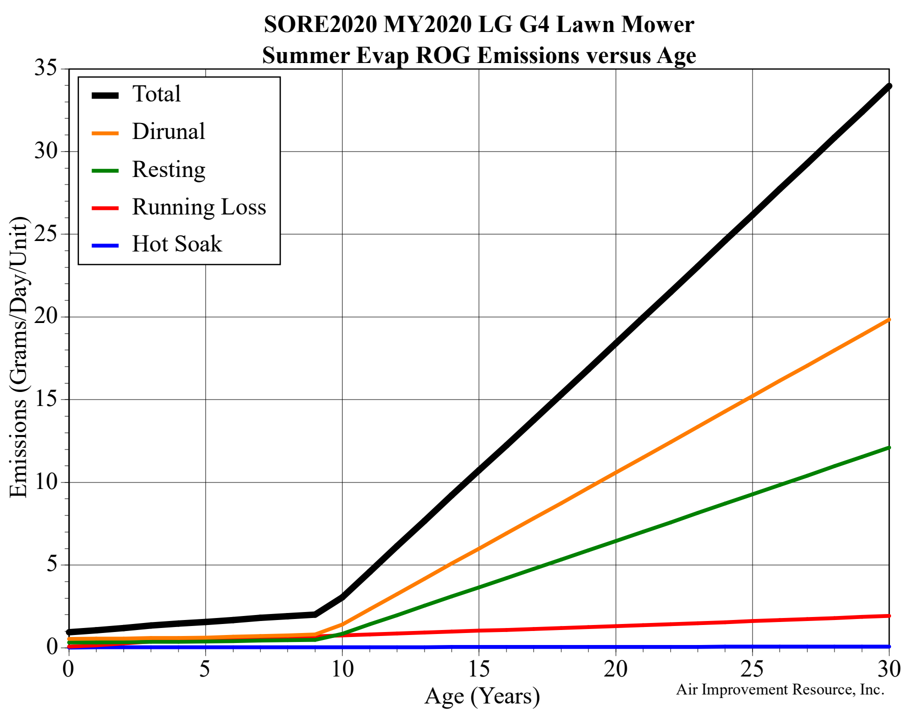


Figure 3 for generators shows a large increase in running loss emissions versus age, and the increase in running loss emissions drives total evaporative emissions higher. The other components are flat with age. Figure 4 for lawnmowers shows a large increase in diurnal and resting loss emissions for lawnmowers, which drives total emissions higher with age.

Generator Running Losses – ARB's generator running loss emissions are developed in an ARB report, and the data used come from a study by ATL.[8,9] The testing was conducted in 2002-2003, and only 2 generator engines were tested. One of these engines is over twenty-five years old, and the other is over twenty. The two engines and their tests are show in Table 2.

Table 2. Generator Tests		
Generator	Model Year	Running Loss Test Result (g)
Honda EX5500	1995	19.45
Coleman PL0545005	2002	1.80

The two running loss results are quite different. Because the higher result was a somewhat older machine, ARB assumed running loss emissions were small when the equipment is new, and high when the equipment is old. However, there are only two tests, which does not provide a robust sample size, and ARB has not tested any additional generators for running loss emissions in the last twenty years.

Generators meeting ARB Tier 3 evaporative standards have evaporative system charcoal canisters and purge systems for the canister. These systems are designed to store gasoline vapor during ambient temperature increases so that the vapor can be burned in the engine once it is started. These systems would control running losses as well. When the engine is started, if the tank temperature increases due to the engine, gasoline vapor would travel to the canister, and then continuously be purged as long as the engine is running. Thus, it is not appropriate to use the 1995 engine to represent running loss emissions for later model year generators that meet ARB MY2006+ emission standards.

We believe that it would be better to represent MY2006+ and later gasoline engines with the MY2002 Coleman, at 1.8 g/hr. The actual results could be even lower than this. Clearly, the MY1995 engine should not be used to represent generators meeting Tier 3 emission standards.

Lawnmower Diurnal and Resting Losses – Figure 5 shows steep deterioration after year 9 for lawnmower diurnal and resting losses. The OFFROAD Modeling Change Technical document referenced earlier shows that CARB based its diurnal and resting loss estimates on tests on 23 lawnmowers. They found that the emissions were highly influenced by one lawnmower - Mower23 – with emissions about ten times the average of the other 22 mowers. The mower, a 1989 model, had a liquid leak. ARB used this mower and one other old mower (Mower 20, a 1973 model)

[8] *OFFROAD Modeling Change Technical Document*, *Addition of Evaporative Emissions for Small Offroad Engines,* W. Wong, Revised, 4/21/2003.

[9] *Collection of Evaporative Emissions Data from Off-Road Equipment*, Automotive Testing Laboratory for ARB, November 24, 2003.

with lower emissions to develop its end of life emissions (at age 14) for lawnmowers in general. The estimated lawnmower emission rates developed by ARB are show in Table 3.

Table 3. ARB Estimated Lawnmower Emission Rates (g/day)			
Age	Diurnal	Resting	Total
0	2.05	1.15	3.20
7	2.72	1.53	4.25
14	8.94	5.03	13.97

At age 14, emissions are estimated to be 4.4 times the emissions at age zero. Since only 2 mowers were used to determine the emissions at 14 years, ARB is assuming that 50% of all lawnmowers are leaking at the end of life. If one assumes that at age 7, none are leaking, there is a steep increase in the leaking mower assumption between age 7 and 14, as shown in Table 4 below.

Table 4. ARB Assumed Leaking Rate for Mowers	
Age (years)	Assumed Percent Leaking (%)
7	0.00
8	7.14
9	14.28
10	21.42
11	28.56
12	35.70
13	42.84
14	50.00

ARB's comments on this assumption follow:

> The emissions estimates at fourteen years are the averages of two lawnmowers (mowers 20 and 23) one of which, mower 23, was found to have a liquid fuel leak. Because the deterioration rates beyond year seven are highly influenced by the emissions of this liquid leaker, staff surveyed a number of lawnmower repair shops and requested manufacturers input to determine how often these types of problems occur. Although it was confirmed that lawnmowers with fuel leaks are not uncommon, it was not possible to determine the incidence with accuracy. Staff found no compelling reason to exclude mower 23 from this analysis. However, by using this data at the end of equipment life, the impact is minimized because the majority of mowers (91%) are assumed to be age seven and newer at any given time. Only 0.1% of mowers are assumed to reach the age of fourteen. [10]

We have four comments on this analysis. First, is that CARB has changed equipment lifetimes in their latest model, based on the survey data, so it is likely their comments on the impact of the leaker assumption needs to be revisited. Second, if mower repair shops fix leaking lawnmowers, this means that leaking lawnmowers

[10] Technical Document, page 6 (see Reference 7).

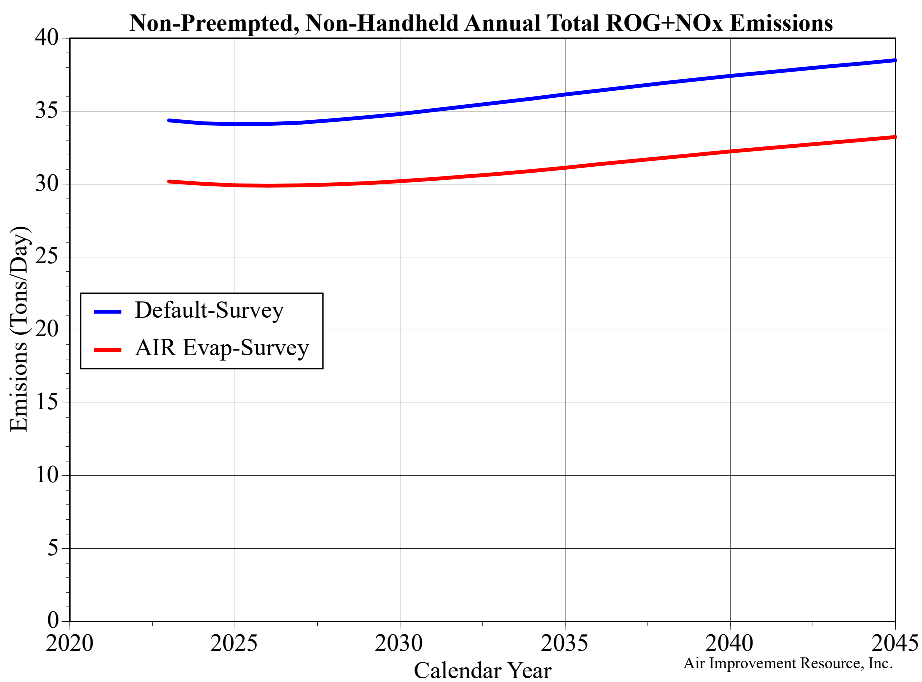
are getting fixed, so they do not stay as leaking lawnmowers as ARB is assuming. Third, it is completely unreasonable to assume a 50% leak rate at the end of life. And the fourth is that even if the percent of lawnmowers above age 7 is low, ages 7-12 or 13 still can have a large impact, even if their percent of the population is low.

The CARB assumptions for evaporative emissions and leakage rates for gasoline lawnmowers appear to be overstated and should be revisited. In our analysis, we will assume linear deterioration of diurnal and resting losses after 7 years, instead of drastically accelerating this deterioration as ARB has done.

Impacts of AIR's Evaporative Estimates on Baseline Inventories

The impact of revising these evaporative emissions for generators and lawnmowers on ROG+NOx emissions baseline emissions is shown for both the ARB Survey and AIR Survey cases in Figure 5. Updating these evaporative emissions reduces the ROG+NOx inventory from non-preempted, non-handheld equipment by about 5 tpd.

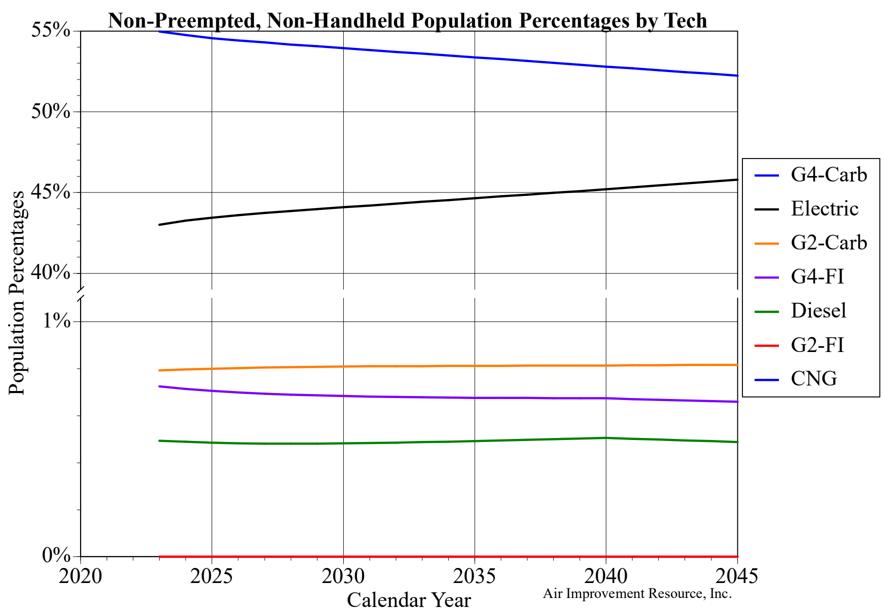
Figure 5



3. CARB's predictions of the penetration of electric equipment for the baseline case appear to be overly conservative.

Figure 6 shows the penetration of electric equipment predicted by the SORE2020 model for non-handheld, non-preempted equipment for the 2023 to 2045 calendar years. The figure shows that the current electric percentage is about 43%, with growth over the next 22 years of only about 3%. This seems to be a very conservative projection for the baseline. The lower this projection is, the more benefit ARB can claim for its SORE regulation. There is little justification for this low of an electric fraction increase for the baseline in the SRIA or the ISOR based on the information provided in the Staff Report and SRIA, industry data provided by OPEI and publicly available data.

Figure 6

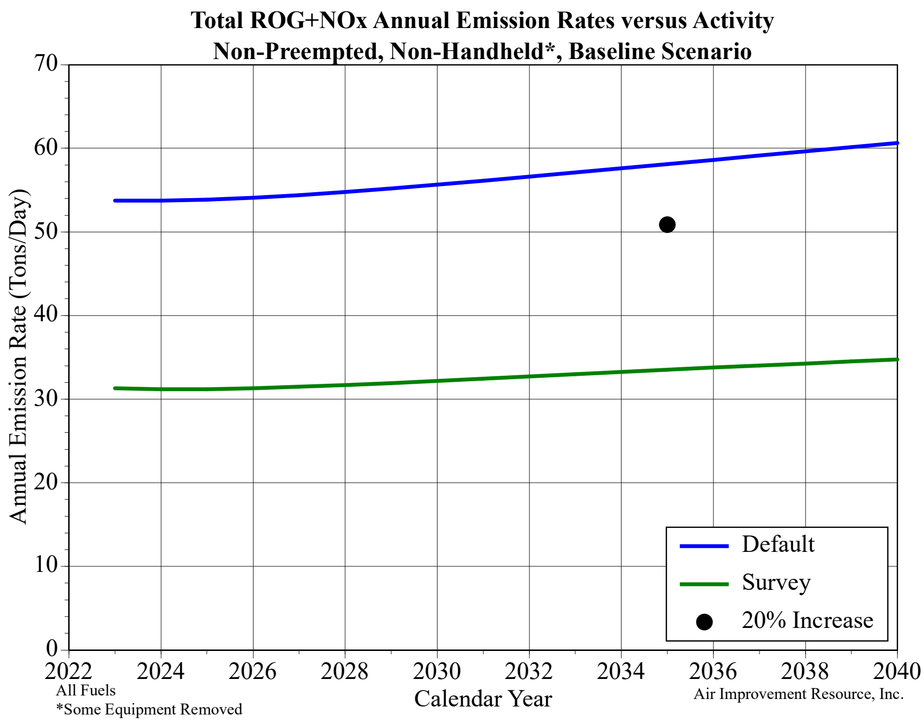


Electric equipment can be either corded or battery-powered. CARB staff do not expect much growth in corded electric equipment. However, for battery powered equipment and projected battery costs in the baseline, CARB staff cite a 2019 study by Bloomberg that indicates that battery costs will drop from $131 per kw-hr in 2021 to $70 per kw-hr in 2030. [11] CARB also indicates that some ZEE equipment would have lower cost than SORE equipment. If these projections are true, it should result in further battery-powered electrification of non-handheld equipment types under the baseline scenario.

[11] *Amendments to the Small Off-Road Engine Exhaust and Evaporative Emission Regulations, Standardized Regulatory Impact Assessment (SRIA)*, ARB, September 20, 2021, page 41.

AIR evaluated a sensitivity case where we assumed that the electrification of non-handheld equipment would grow to be 20% higher than CARB staff estimates in 2035 in the baseline case. In this modeling, we used CARB's default activity estimates. Results are shown in Figure 7. The baseline inventory for 2035 drops from about 58 tpd to 51 tpd.

Figure 7



4. ARB's proposed ZEE requirement means that many landscapers and other small engine users will purchase equipment outside of California for use in California (i.e., leakage), or simply continue to repair their existing gas powered equipment to the maximum extent possible, if they cannot find electric equipment that meets their needs or if it cannot be found at a reasonable cost.

Table VII-4 of the ISOR shows upfront and ongoing annual costs for a variety of professional-grade gasoline and electric equipment. ARB estimates the upfront cost of an electric riding mower at close to $21,000, while the gasoline version is about $11,300. For a generator, the ZEE version is $6,800, and the gasoline version is $5,300. Interestingly, a commercial ZEE lawnmower is estimated at just over $1,000, while the gasoline version is over $1,400. Despite CARB's calculated upfront savings of ZEE for a commercial lawnmower, ZEE lawnmower penetration among landscapers is very low leading one to conclude that landscapers do not equate the overall utility of a ZEE lawnmower with that of a gasoline powered unit.

If ARB's proposal takes effect, landscapers and other equipment purchasers who cannot find equipment that meets their needs in California, or cannot find it at a reasonable cost, may travel outside of California to purchase such equipment. We refer to this as "leakage." The impact of leakage on emission inventories was not modeled by CARB in the evaluation of their proposal; CARB assumed all Californians would purchase all needed equipment within the state. Furthermore, CARB assumes that there is no change in equipment turnover rates.

Based on user responses to prior rulemakings, AIR believes that landscapers in particular, and some other heavy users of equipment (residential and business) will have strong incentive to purchase some equipment out-of-state. A factor of 2x difference in the upfront cost of riding mowers (zero turn mowers, or ZTRs) is a strong incentive for that equipment type.

AIR evaluated the impacts of 50% leakage for landscapers, and 10% leakage for residential and business uses for the ARB proposal. Under this scenario, equipment purchased in other states would meet ARB "baseline" emissions instead of the emission rates of their proposal. This modeling, comparing the leakage scenario to the ARB proposal is shown in the next section.

5. EMA's Tier IV proposal provides significant emission reductions without increasing equipment leakage or slower fleet turnover.

As a part of its comments on the ISOR, EMA is offering to meet reduced exhaust emission standards of 6 g/kw-hr for Class 1 engines and 3 g/kw-hr for Class 2 and > 825 cc engines starting with model year 2025 for Class 1, and 2026 for Class 2 and > 825 cc.[12] In addition, EMA is offering to meet the Class 1 standard at a durability period of 500 hours and the Class 2 and > 825 cc standard at a period of 1000 hours. These exhaust emission standards are the same as ARB's proposal for generators for model years 2024-2027. Finally, EMA is agreeing to a zero emissions standard for lawnmowers.

The SORE2020 model was used to estimate the benefits of the EMA proposal in comparison with the ARB proposal, with some modifications. First, running loss emissions for generators and diurnal and resting loss emissions for lawnmowers (and for other equipment that utilizes evaporative emissions from these two equipment types) were modified for the ARB proposal as indicated in Section 2. Next, the AIR annual use estimates were inputted for both the ARB and EMA proposals.

For the EMA Tier IV proposal, exhaust and evaporative emissions for lawnmowers were set to zero starting with model year 2025. Exhaust emissions for all other non-handheld equipment (including fixed mount generators) were set to the same emissions estimated by CARB for generators for 2024-2027. Evaporative emissions for non-lawnmowers were unmodified, except for the modifications discussed in Section 2.

The ROG+NOx emission inventories of the EMA proposal in comparison to the ARB proposal are shown in Figure 8. This analysis uses the AIR annual use estimates discussed in Section 2. The EMA Tier IV proposal reduces ROG+NOx emissions from non- preempted, non-handheld equipment to approximately 11 tpd in 2045.

Figure 9 shows the impact of 50% landscape leakage and 10% residential/business leakage on the benefits of the ARB proposal. Purchases of equipment outside the state by landscaper, residential, and business users have a significant impact on the benefits of ARB's proposal. In addition, while not specifically modeled, slower fleet turnover would also significantly reduce the benefits of the ARB proposal.

[12] EMA is also proposing that fixed mount generators installed on DMV licensed motor vehicles and trailers transition to ZEE on the date the vehicle or vehicle pulling the trailer transitions to ZEE (2035 used for modeling purposes).

Figure 8

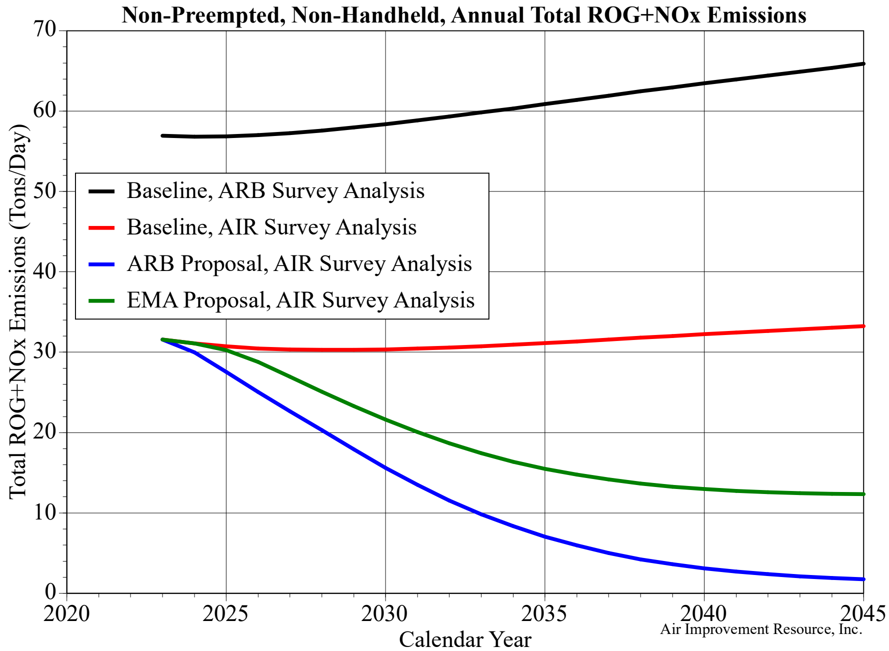
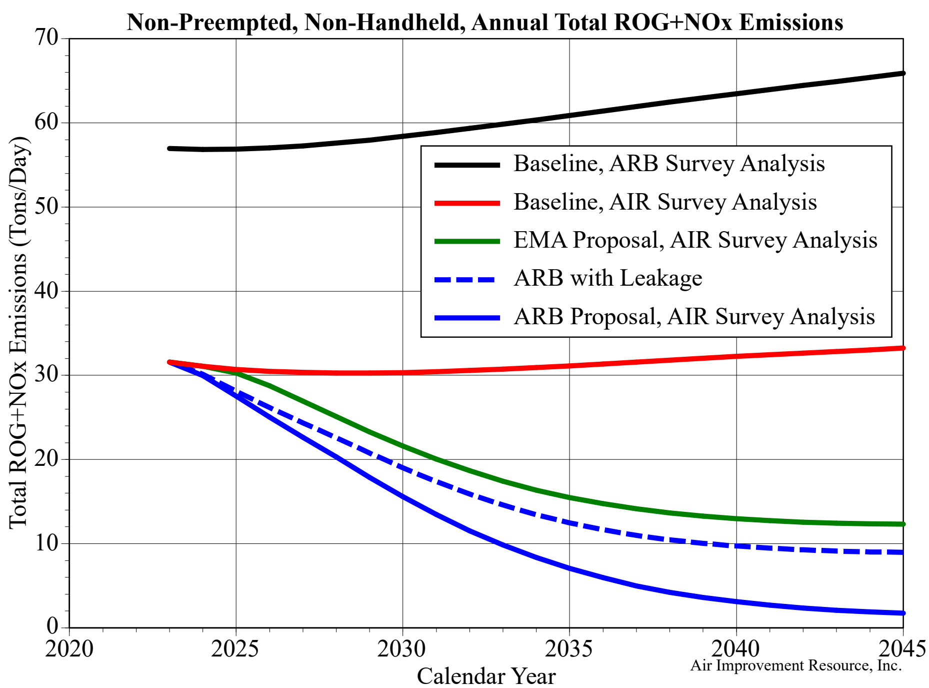


Figure 9



Conclusions

CARB's modeling of emissions benefits of their proposal significantly overstates the benefits of their proposal for the following reasons:

1. CARB's analysis of the survey data severely overstates equipment use
2. Baseline SORE exhaust and evaporative emission rates are outdated and are pessimistic
3. The baseline emission inventory does not include sufficient electrification in the future
4. The analysis does not take into account equipment leakage (purchases of equipment out of state) and slower fleet turnover due to higher prices