OFFROAD Modeling Change Technical Memo

SUBJECT: Addition of Evaporative Emissions for Small Off-Road Engines

LEAD: Walter Wong

Summary

The OFFROAD model is used to estimate the contributions of emissions of various equipment types to the overall off-road emissions inventory. With the exception of gas cans, the OFFROAD model does not currently account for evaporative hydrocarbons. This is primarily due to the lack of test data.

In support of pending regulation, however, Air Resources Board (ARB or Board) staff has performed a number of evaporative tests of small off-road equipment. In addition, a research project performed by the Automotive Testing Laboratories (ATL) for the ARB entitled "Collection of Evaporative Emissions Data from Off-Road Equipment", has recently been completed. It is the information from these projects that serve as the basis for the proposed modification to the off-road emissions inventory.

This change is estimated to result in an increase in the off-road evaporative emissions inventory of 32.9 tons per day of reactive organic gases (ROG), statewide in 2010. By the year 2020, the evaporative emissions inventory is estimated to increase to 36.1 tons per day, statewide.

Regulations for the control of evaporative emission from the SORE category are estimated to result in a 32 percent reduction in ROG from this category, statewide in 2010 and a 68 percent reduction by the year 2020.

Background

Small off-road engines (SORE) are less than 25 horsepower and are used in equipment that falls into several of the OFFROAD categories. Small off-road engines are used in handheld (HH) and non-handheld (NHH), preempted (P) and non-preempted (NP) equipment in the following categories: Light Commercial, Agricultural, Logging, Airport Ground Support and Transport Refrigeration Units. However, the majority is used in the Lawn and Garden Equipment category. A full listing of SORE equipment can be found in Appendix A. Table 1 (below) rank orders the top ten SORE equipment types according to the percentage of the overall SORE population.

Table 1. Top Ten SORE Equipment Types by Population (2000)

Equipment	Category	Population	% of SORE
Lawn Mowers	Lawn & Garden	2,513,937	44.7
Trimmers/Edgers/Brush Cutters	Lawn & Garden	8,631,88	15.4
Chainsaws	Lawn & Garden	601,336	10.7
Leaf Blowers/Vacuums	Lawn & Garden	408,593	7.3
Tillers	Lawn & Garden	281,444	5.0
Generator Sets	Light Commercial	258,639	4.6
Snow blowers	Lawn & Garden	97,662	1.7
Front Mowers	Lawn & Garden	85,476	1.5
Wood Splitters	Lawn & Garden	72,789	1.3
Pumps	Light Commercial	59,681	1.1

The exhaust emissions inventory for small off-road engines was last presented and approved by the Board in 1998. Several characteristics of the SORE inventory presented at that time, including equipment population and activity, are common to both the exhaust and evaporative emission inventories.

Methodology

The evaporative emissions inventory is segregated into four distinct processes:

1. **Diurnal** emissions occur when rising ambient temperatures cause fuel evaporation from engines and gas tanks throughout the day.

2. **Hot soaks** are evaporative losses that occur immediately after the engine is turned off. The cause of evaporation is the heat of the engine.

3. **Running losses** are evaporative emissions that occur while the equipment is being operated.

4. **Resting loses**, like diurnal emissions, occur while the equipment is not being used. Unlike diurnal events, the ambient temperature is either stable or declining during a resting loss event. These losses are mainly due to the permeation of hydrocarbon molecules through plastic and rubber equipment components.

The basic equations for estimating the evaporative emissions are displayed below:

Diurnal/Resting (tpd) = Population * Emission Rate * Temp/RVP Correction

Hot Soak (tpd) = Population * Percent Usage * Emission Rate * RVP Correction

Running Loss (tpd) = Population * Percent Usage * Activity * Emission Rate * RVP Correction

Where **tpd** is Tons per day, **Population** is equipment and age specific, **Emission Rate** is expressed in grams per hour for running loss, grams per event for hot soaks, and grams per day for diurnal and resting losses, **Percent Usage** is the percent of the equipment population in use in a given period, **Activity** is equipment usage in hours per day, **RVP** is the Reid Vapor Pressure of the fuel and the **Temp/RVP Correction** is a multiplicative correction factor to adjust the basic emission rate with respect to standardized test conditions.

<u>Population and Activity</u>

The population and activity estimates used in this analysis were obtained from; the Booz-Allen Hamilton (BAH) report entitled "Off-Road Mobile Equipment Emission Inventory Estimate", the Power System Research (PSR) database of manufacturer's factory production and surveys, and input provided by small off-road equipment manufacturers and their consultants.

The population growth rates were obtained from the California State University, Fullerton (CSUF) study entitled "A Study to Develop Projected Activity for Non-Road Mobile Categories in California, 1970-2020". In this study, growth in the equipment population is linked to number of households.

The estimates of population and activity used in this analysis are the same as those presented to, and approved by the Board in 1998. A more detailed discussion of the development of these estimates can be found in ARB Mailout #98-04 (http://www.arb.ca.gov/msei/off-road/pubs.htm).

<u>Emission Rates</u>

Evaporative emissions are quantified by placing the equipment within a sealed enclosure (a shed) and measuring the concentration of hydrocarbons emitted over a predetermined period of time.

The baseline testing for diurnal and resting loss emissions was performed using California Phase 2 gasoline with an RVP of 7.0, over a 24 hour period using an episodic summertime temperature profile. This temperature excursion from a low of 65^{o}F to a high of 105^{o}F, is the same as that used to certify on-road motor vehicles.

Hot Soak emissions were measured after operating each piece of equipment for 15 minutes after which the equipment was placed in a shed at a constant temperature of 95^{o}F. The resulting evaporative emissions were monitored minute by minute for three hours.

In order to measure running loss emissions, the equipment must be operated (according to the specific equipment type) within the shed enclosure. Exhaust emissions must be routed outside of the shed in order to ensure that only evaporative hydrocarbons are measured.

Table 2 lists the number of pieces of equipment tested by the ARB and their contractors.

Table 2. Equipment Tested for Baseline Emissions

Equipment Type	Diurnal	Resting Loss	Hot Soak	Running Loss
Lawnmower	23	23	23	4
Trimmer/Edger	8	8	8	1
Leaf blower	3	3	3	0
Chainsaw	3	3	3	0
Tractor	4	4	3	0
Tiller	1	1	1	0
Generator	4	4	3	2
ATV *	4	4	4	2
Forklift *	2	2	2	2

*Although all terrain vehicles (ATVs) and forklifts are not included in the SORE category, these data were used as surrogates for some SORE equipment types that were not tested.

Because lawnmowers dominate the SORE category, lawnmowers were tested more often than any other equipment type. For simplicity, the discussion of the evaporative emissions inventory development will focus primarily on lawnmowers.

Basic Emission Rates

Diurnal and Resting Losses

The Basic Emission Rate (BER) consists of two parts: a zero hour and a deterioration rate. The zero hour emission rate is the emissions of the equipment when it is brand new. The deterioration rate is the rate at which emissions increase due to usage and is modeled as a function of the age of the equipment.

Table 3 segregates the lawnmower test fleet into three strata by age, namely “new”, “used” and “old” equipment. New lawnmowers were those purchased by ARB or their contractors that had not been previously operated in customer service. These test results were averaged to estimate the zero hour emission rate of lawnmowers.

The used lawnmowers were randomly obtained from customer service and are assumed to be representative of the in-use lawnmower fleet. The test results of these mowers were averaged to establish a deterioration factor. Finally, the emission rates of the old lawnmowers were averaged to estimate the emission of lawnmowers at the end of their lives.

Table 3. Evaporative Emissions Test Results

ID	Manufacturer	Year	Strata	Diurnal (g/day)	Resting (g/day)	Total (g/day)
Mower1	Lawn Boy	01	New	1.32	0.74	2.06
Mower2	Craftsman	01	New	1.40	0.79	2.19
Mower3	Craftsman	01	New	1.44	0.81	2.25
Mower4	Yard Machine	01	New	1.46	0.82	2.28
Mower5	Yard Machine	01	New	1.57	0.88	2.45
Mower6	Yard Machine	01	New	1.57	0.88	2.45
Mower7	Honda	01	New	1.60	0.90	2.50
Mower8	Honda	00	New	2.03	1.14	3.17
Mower9	Scott’s	01	New	2.27	1.27	3.54
Mower10	Toro	99	New	3.55	2.00	5.55
Mower11	Murray	01	New	5.61	3.16	8.77
Mower12	Briggs & Stratton	01	New	1.82	1.03	2.85
Mower13	Briggs & Stratton	01	New	1.65	0.93	2.58
Mower14	Tecumseh	01	New	2.08	1.17	3.25
Mower15	Tecumseh	01	New	2.26	1.27	3.53
Mower16	Honda	01	New	1.62	0.91	2.53
Mower17	Honda	01	New	1.60	0.90	2.50
Mower18	Toro	90	Used	1.47	0.83	2.30
Mower19	Sears	94	Used	2.27	1.27	3.54
Mower20	Builders Best	73	Old	2.52	1.42	3.94
Mower21	Murray	?	Used	2.64	1.48	4.12
Mower22	Murray	99	Used	4.52	2.54	7.06
Mower23	Toro	89	Old	15.35	8.64	23.99

“?” The Model Year of equipment could not be determined

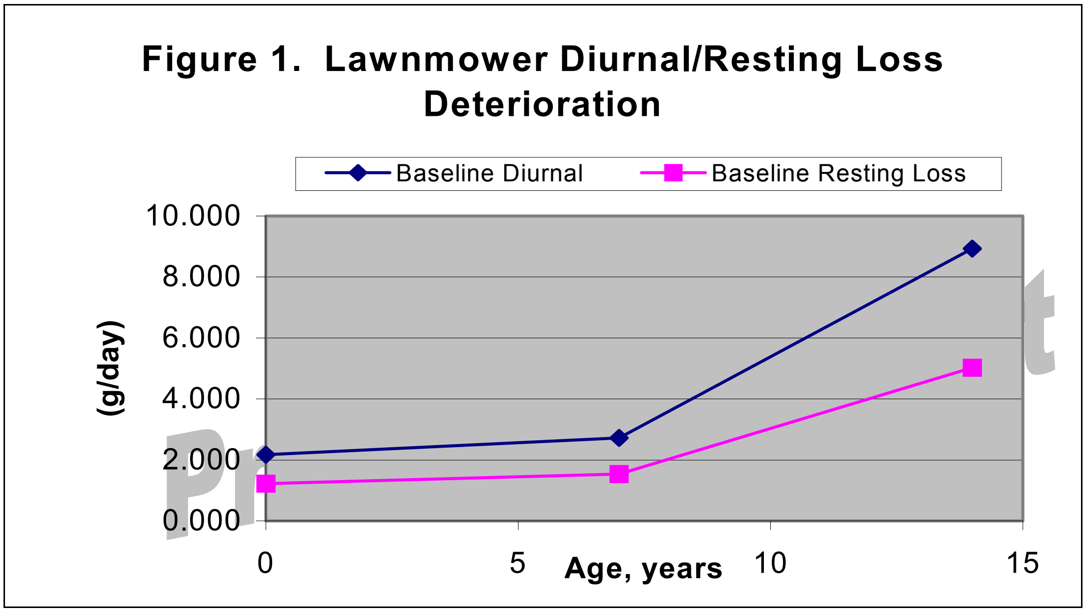
Useful Life is defined as the age at which fifty percent of the originally sold equipment population still exists. For lawnmowers, this is assumed to be seven years, however, some equipment is assumed to remain in use for as long as twice the defined useful life.

Therefore, the test data was used to establish three emission points in the life of the lawnmower fleet; “new” for year zero, “used” for the useful life definition of seven years, and “old” for the end of equipment life which for lawnmowers is fourteen years. Linear deterioration was assumed between each point (See Table 4).

Table 4. Estimated Lawnmower Emission Rates

Age	Diurnal (g/day)	Resting Loss (g/day)
0	2.05	1.15
7	2.72	1.53
14	8.94	5.03

Figure 1 graphically displays the proposed lawnmower emission and deterioration rates for diurnal and resting losses.

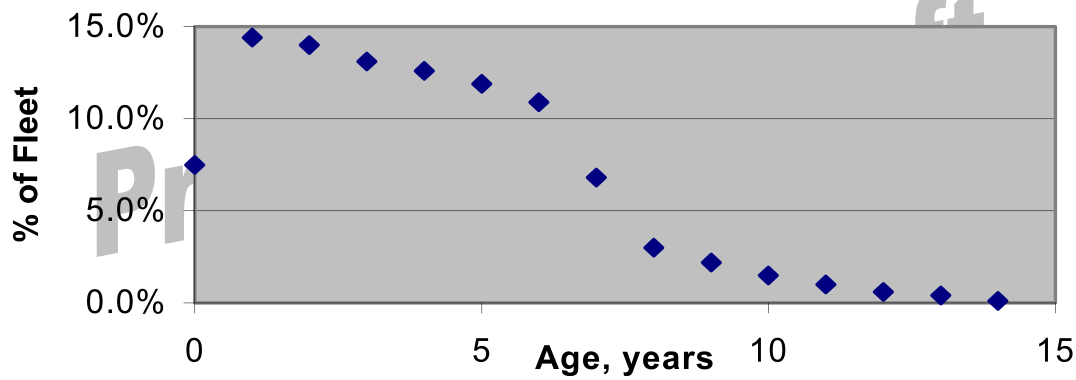


Liquid Leakers

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 manufacturer's 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 or newer at any given time. Only 0.1% of mowers are assumed to reach the age of fourteen (See Figure 2).

Figure 2. Lawnmower Population Distribution by Age



Basic Emission Rates for Other Equipment Types

The emission factors for chainsaws, tractors and ATVs were estimated in the same manner described above for lawnmowers given that a clear pattern of deterioration between new and used equipment could be discerned.

In cases where deterioration could not be discerned because of the lack of data or high variability in test results, straight averages of the emission rates were used across all years. Table 5 lists the estimated zero hour (ZHR), useful life (UL), and end of life (END), diurnal and resting loss evaporative emission rates for all tested equipment types.

Table 5. Basic Evaporative Emission Rates (grams/day)

Equipment Type	Diurnal	Resting Loss

	ZHR	UL	END	ZHR	UL	END
Chainsaw	0.44	0.49	0.54	0.21	0.23	0.25
Lawnmower	2.05	2.72	8.94	1.15	1.53	5.03
Tractor	5.93	8.33	10.73	3.33	4.69	6.05
ATV	8.14	10.3	12.51	2.43	3.06	3.68
Trimmer/Edger	0.63	0.63	0.63	0.30	0.30	0.30
Leaf blower	1.07	1.07	1.07	0.51	0.51	0.51
Tiller	2.89	2.89	2.89	1.24	1.24	1.24
Generator/Welder	12.04	12.04	12.04	2.29	2.29	2.29
Forklift	30.61	30.61	30.61	5.40	5.40	5.40

Hot Soak and Running Losses

Table 6 (below) displays the hot soak and running loss evaporative emissions results for the fleet of tested lawnmowers. The same methodology used in establishing the basic emission rates for diurnal and resting losses was used to derive the hot soak estimates. Again, where data permitted, both a zero hour and deterioration rate were established, otherwise a straight average of all data by equipment type was used (See Table 7).

Table 6. Hot Soak and Running Loss Test Data

ID	Manufacturer	Year	Strata	Hot Soak (g/event)	Running (g/hr)
Mower1	Lawn Boy	01	New	0.41	
Mower2	Craftsman	01	New	0.58	
Mower3	Craftsman	01	New	0.55	
Mower4	Yard Machine	01	New	0.41	
Mower5	Yard Machine	01	New	0.61	
Mower6	Yard Machine	01	New	0.63	
Mower7	Honda	01	New	0.48	
Mower8	Honda	00	New	0.89	0.81
Mower9	Scott’s	01	New	0.58	2.60
Mower10	Toro	99	New	0.72	
Mower11	Murray	01	New	2.18	
Mower12	Briggs & Stratton	01	New	0.52	
Mower13	Briggs & Stratton	01	New	0.67	
Mower14	Tecumseh	01	New	0.70	
Mower15	Tecumseh	01	New	0.75	
Mower16	Honda	01	New	0.47	
Mower17	Honda	01	New	0.39	
Mower18	Toro	90	Used	1.56	
Mower19	Sears	94	Used	1.06	27.03
Mower20	Builders Best	73	Old	0.87	
Mower21	Murray	?	Used	0.70	
Mower22	Murray	99	Used	1.00	
Mower23	Toro	89	Old	2.88	12.10

"?" The Model Year of equipment could not be determined

Table 7. Hot Soak and Running Loss Basic Emission Rates

Equipment Type	Hot Soak			Running Loss		
	New	Used	Old	New	Used	Old
Chainsaw	0.12	0.34	0.56			
Lawnmower	0.68	1.08	1.88	1.7	15.0	28.2
Tractor	1.23	2.09	2.95			
ATV	2.40	3.60	4.80	11.3	11.3	11.3
Trimmer/Edger	0.29	0.29	0.29	0.58	0.58	0.58
Leaf blower	0.15	0.15	0.15			
Tiller	0.57	0.57	0.57			
Generator/Welder	3.24	3.24	3.24	1.80	19.5	37.1
Forklift	10.5	10.5	10.5	4.61	4.61	4.61

The difficulty associated with measuring running losses resulted in few pieces of equipment being tested. Separate running loss rates were established for lawnmowers, ATVs, trimmers, generators, and forklifts. No deterioration rates were estimated for running losses with the exception of lawnmowers and generators.

For lawnmowers, two emission rates were created. A new engine rate was established by averaging the test results of mowers 8 and 9. A used rate was established by averaging the test results of mowers 19 and 23. The used rate represents the average emissions of a nine year old mower, the average age of mowers 19 and 23.

Because the SORE category includes more equipment types than those tested, staff used the test results (including ATVs and forklifts) in order to estimate the emissions for other equipment in the SORE category. The emission rate assignment was based upon engine size, equipment characteristics, and usage. The mapping strategy is included in Appendix B.

In ARB's research project, two forklifts, a 1995 Komatsu and a 1987 Toyota were tested. The initial test of the Toyota revealed an extremely high running loss emission rate of 195 grams per hour. This rate can be directly compared to the Komatsu that had an emission rate of 2 grams per hour.

The problem with the Toyota's engine was diagnosed and repaired and upon retest, the emissions were reduced to 7 grams per hour. Staff chose to use the lower emission rate in establishing the emission factor for forklifts given that this result seemed to better typify the emissions of these engines.

RVP/Temperature Correction Factors

In order to account for spatial, temporal, and seasonal variations in ambient temperature and dispensed fuel properties, correction factors for RVP and temperature needed to be developed. To determine the magnitude of the effects of these parameters, a subset of the SORE equipment was tested using different temperature profiles and fuels (See Table 8).

Table 8. Temperature / RVP Test Results

	Summertime (65-105F) 7.0 RVP	Summertime (65-105F) 9.5 RVP	Average (50-90F) 9.5 RVP	Wintertime (48-69F) 7.0 RVP
Equipment	**Diurnal (Grams per Day)**			
Mower 3	1.44			0.41
Mower 8	2.03	2.66	1.50	
	Resting Loss (Grams per Day)			
Mower 3	0.81			0.43
Mower 8	1.14	1.37	1.13	

In analyzing this data for temperature effects, the measured emissions given a specific fuel formulation were evaluated each hour in terms of the change in emissions as a function of the change in temperature. For RVP, the emission results over a set diurnal temperature profile were compared across fuel types.

Each hour's emissions were normalized dividing by the emissions obtained under standard conditions (7 RVP, 65^{o}F to 105^{o}F) to obtain the percent change. Finally, a general linear model was used to find the variables that best fit the data. The resulting statistical analysis indicated that a multi-variable polynomial equation was best for both a diurnal and resting loss correction factor (See below).

Diurnal/Resting Loss Temperature/RVP Correction Factor =
(A) hr + (B) RVP + (C) Temp + (D) dtemp + (E) temp*dtemp + (F) temp*hr + (G) temp*rvp + (H) dtemp*hr + (I) dtemp*rvp + intercept

Where: **hr** is the duration of the soak in hours
RVP is the Reid Vapor Pressure of the fuel
temp is the starting temperature
dtemp is the change in temperature

Table 9 shows the Temperature/RVP correction factors that result from the use of the statewide annual average, summer and winter temperature profiles from the EMFAC on-road emissions inventory model.

Table 9. Temperature/RVP Correction Factors

Profile	Diurnal	Resting Loss
Summer Average	0.55	0.80
Winter Average	0.30	0.74

Annual Average	0.45	0.78

Estimated Baseline Inventory for Lawnmowers

Using the basic emission rates and correction factors described above, the baseline inventory for lawnmower was calculated. The results are shown in Table 10 below.

Table 10. Statewide Lawnmower Evaporative Emissions Inventory (Tons per Day – Annual Average)

Year	Pop	Hot soak	Diurnal	Resting	Running	Total
1999	2472640	1.19	3.21	3.13	3.10	10.63
2010	2789569	1.38	3.74	3.65	3.61	12.38
2020	3263809	1.57	4.24	4.13	4.04	13.98

Proposed Regulatory Action

The Board will soon consider taking action to control evaporative emissions from equipment in the SORE category. This regulation, if adopted, would require compliance either in terms of a percent reduction from uncontrolled emission levels or with a set gram per day diurnal + resting loss standard throughout the useful life of the equipment (See Table 11).

Table 11. Proposed Diurnal + Resting Loss Evaporative Standards

Equipment Type	Reduction	Standard	Implementation
Handheld	30%		2005
Non Handheld Class I (65-225cc)		1.0 grams/day	2006 Lawnmower 2007 Other
Non Handheld Class II (>225cc)		2.0 grams/day	2008

In estimating the potential benefits of such a standard for lawnmowers, staff adjusted the basic evaporative emission rates in the following manner:

1. Assuming compliance with a 1.0 gram standard in use (for example), the seven year, or "used", emission rates for diurnal and resting loss were lowered, proportionately, until the resulting sum was equal to 1.0 gram.

2. Manufacturers routinely allow for deterioration in emissions during the useful life of the equipment. This "compliance margin" is designed to assure that the standards are not exceeded in-use. Assuming a compliance margin of twenty

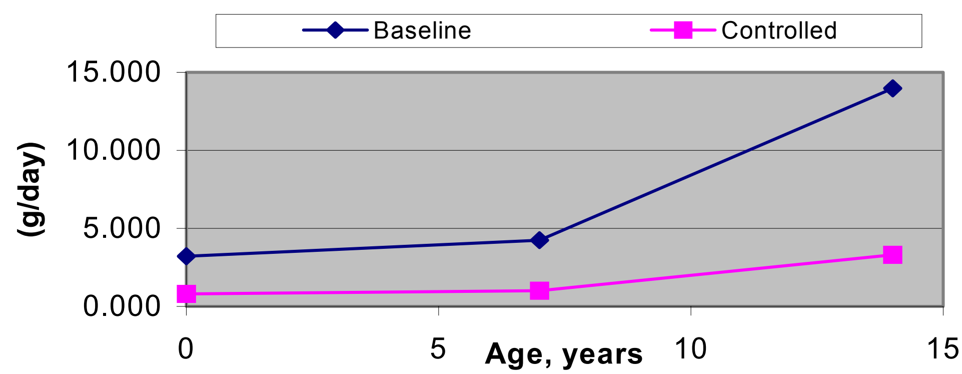
percent, the zero hour emission rate was set at 0.8 gram per day of diurnal + resting loss.

3. Assuming that beyond the useful life of the equipment, deterioration in the fleet will be equivalent to that in the uncontrolled fleet, the baseline assumption of deterioration was used to establish the "old" or end of life emission rate. Linear deterioration was assumed between emission rate.

4. Although not specified directly, based on testing of prototype equipment, a 70% reduction in hot soak emissions and a 50% reduction in running losses are anticipated for equipment complying with the proposed standards. These reductions were applied to the basic emission rates in order to estimate the benefits of control.

A comparison of baseline emission rates for lawnmowers and those modeled to comply with a 1.0 gram per day standard are displayed in Figure 3 below for diurnal + resting loss. For other pieces of equipment required to meet the 1.0 or 2.0 gram per day standard, a revised zero hour and deterioration rate was calculated using the same methodology as outlined for lawnmowers.

Figure 3. Lawnmower Diurnal + Resting Loss



Using the revised emission rates as described above, an alternative inventory can be calculated and compared to the baseline to estimate the benefits of the proposed regulation. This analysis is displayed for various equipment types in Tables 12 and 13 for calendar years 2010 and 2020, for various areas of the state in Table 14 and for the overall inventory in Table 15.

Table 12. Baseline and Controlled Evaporative Inventory Estimates (Tons per Day – Annual Average in 2010)

Scenario	Pop	Hot soak	Diurnal	Resting	Running	Total
	Baseline					
Lawnmower	2879569	1.38	3.74	3.65	3.61	12.38
Chainsaw	688119	0.09	0.16	0.13	0.13	0.51
Trimmer	988730	0.16	0.31	0.26	0.10	0.83
	Controlled					
Lawnmower		0.90	2.28	2.22	2.70	8.10
Chainsaw		0.07	0.14	0.11	0.09	0.41
Trimmer		0.12	0.26	0.22	0.08	0.68
	Percent Reduction					
Lawnmower		35%	39%	39%	25%	35%
Chainsaw		22%	13%	15%	31%	20%
Trimmer		25%	16%	15%	20%	18%

Table 13. Baseline and Controlled Evaporative Inventory Estimates (Tons per Day – Annual Average in 2020)

Scenario	Pop	Hot soak	Diurnal	Resting	Running	Total
	Baseline					
Lawnmower	3263808	1.57	4.24	4.13	4.09	14.03
Chainsaw	779318	0.11	0.18	0.15	0.14	0.58
Trimmer	1120663	0.18	0.35	0.29	0.12	0.94
	Controlled					
Lawnmower		0.47	1.29	1.26	2.05	5.07
Chainsaw		0.05	0.13	0.10	0.07	0.35
Trimmer		0.09	0.25	0.20	0.06	0.60
	Percent Reduction					
Lawnmower		70%	70%	69%	50%	64%
Chainsaw		55%	28%	33%	50%	40%
Trimmer		50%	29%	31%	50%	36%

Table 14. Baseline and Controlled Evaporative Emissions for Various areas of the State (Annual Average - Tons per Day)

	Year 2000	Year 2010		
Area	**Baseline**	**Baseline**	**Controlled**	**% Diff**
Santa Barbara Co	**0.30**	**0.34**	**0.23**	**32%**
South Coast AB	**11.72**	**13.25**	**9.02**	**32%**
San Francisco AB	**4.97**	**5.62**	**3.84**	**32%**
San Joaquin AB	**2.38**	**2.69**	**1.84**	**32%**
Sacramento AB	**1.99**	**2.25**	**1.54**	**32%**

Table 15. Baseline and Controlled Evaporative Inventory Estimates (Tons per Day – Annual Average)

Scenario	Pop	Hot soak	Diurnal	Resting	Running	Total
	Year 1999					
Baseline	5529142	5.26	8.83	5.50	7.52	27.11
	Year 2010					
Baseline	6417962	6.02	10.16	6.38	8.66	31.22
Controlled		3.94	6.78	4.29	6.50	21.51
Reduction		2.08	3.38	2.09	2.16	9.71
% Reduction		35%	35%	35%	25%	31%
	Year 2020					
Baseline	7209465	6.51	11.13	7.14	9.51	34.29
Controlled		2.02	3.07	2.58	4.76	12.43
Reduction		4.49	8.06	4.56	4.75	21.86
% Reduction		69%	72%	64%	50%	64%

<u>Modeling Change</u>

The test results for equipment types other than lawnmowers are displayed in Table 16.

Table 16. Evaporative Emission Test Results for Other Equipment

ID	Manufacturer	Year	Strata	Diurnal (g/day)	Resting (g/day)	Hot Soak (g/event)	Running (g/hour)
Chainsaw1	Husqvarna	2001	New	0.24	0.11	0.10	
Chainsaw2	Echo	2001	New	0.64	0.30	0.15	
Chainsaw3	McCulloch	1989	Used	0.54	0.25	0.56	
Leafblower1	Shindaiwa	2001	New	1.21	0.57	0.11	
Leafblower2	Stihl	2001	New	1.16	0.55	0.22	
Leafblower3	Echo	2001	New	0.85	0.40	0.11	
Tiller	Maxim		Used	2.89	1.24	0.57	
Tractor1	Murray	2001	New	3.81	2.14	1.25	
Tractor2	Snapper	2001	New	4.57	2.57	1.22	
Tractor3	Toro		Used	8.33	4.69	2.09	
Tractor4	Toro	2001	New	9.40	5.29	N/A	
Trimmer1	Power Trim	2001	New	0.92	0.43	1.20	
Trimmer2	Echo	2001	New	0.46	0.22	0.07	
Trimmer3	Honda	2001	New	0.49	0.23	0.07	
Trimmer4	Echo	2001	New	0.62	0.29	0.08	
Trimmer4	Ryobi		Used	0.55	0.26	0.13	
Trimmer5	Stihl	1999	New	0.73	0.35	0.17	
Trimmer5	McCulloch		Used	0.36	0.17	0.40	
Trimmer6	Makita	1999	Used	0.92	0.43	0.23	0.58

Generator1	Honda	1995	Used	6.79	1.29	4.64	19.45
Generator2	Coleman	2001	New	12.63	2.41	2.72	1.80
Generator3	Tsurumi		Used	6.21	1.18	2.36	
Generator4	Coleman		Used	22.54	4.29	N/A	
ATV1	Honda	1983	Used	13.13	3.85	2.24	
ATV2	Yamaha	2001	New	12.21	3.58	2.64	21.35
ATV3	Suzuki	2001	New	4.14	1.22	2.16	1.25
ATV4	Kawasaki	1988	Used	11.90	3.50	4.96	
Forklift1	Komatsu	1995	Used	40.19	7.90	13.54	1.83
Forklift2	Toyota	1987	Used	21.03	3.71	7.43	7.39 *

* This engine was originally tested at 195.4 g/hour. However, the engine was malfunctioning and was repaired. The retest result was used in the analysis.

The model will be modified to accept evaporative emission rates for all four processes for each gasoline-powered equipment type. The emission rates will take the form of a zero hour rate, and one or more deterioration rates as a function of equipment age.

In equation form, the baseline emission factors are:

Emission Rate = [ZHR+DR1*Age] where Age<=Useful Life
Emission Rate = [ZHR + DR1*Age+DR2*(Age-UL)] where Age > Useful Life

ZHR = Zero Hour Rate or Intercept
DRx = Deterioration Rate (1 or 2)
Age = Age of the Equipment in years (Calendar Year – Model Year)
UL = Useful Life (years)

Table 17. Basic Emission Rates for Diurnal and Resting Loss (grams/day)

	Diurnal			Resting Loss			
Equipment Type	**ZHR**	**DR1**	**DR2**	**ZHR**	**DR1**	**DR2**	**Useful Life**
Chainsaw	0.44	0.010	0.010	0.21	0.004	0.004	5
Lawnmower	2.05	0.096	0.889	1.15	0.054	0.500	7
Tractor	5.93	0.343	0.343	3.33	0.194	0.194	7
ATV	8.14	0.360	0.360	2.43	0.105	0.105	6
Trimmer/Edger	0.63	0.000	0.000	0.30	0.000	0.000	5
Leaf blower	1.07	0.000	0.000	0.51	0.000	0.000	5
Tiller	2.89	0.000	0.000	1.24	0.000	0.000	7
Generator/Welder	12.04	0.000	0.000	2.29	0.000	0.000	12
Forklift	30.61	0.000	0.000	5.40	0.000	0.000	7

Table 18. Basic Emission Rates for Host Soak and Running Loss

	Hot Soak (g/event)			Running Loss (g/hr)		
Equipment Type	**ZHR**	**DR1**	**DR2**	**ZHR**	**DR1**	**DR2**
Chainsaw	0.12	0.044	0.044	0.58	0.000	0.000
Lawnmower	0.65	0.071	0.071	1.71	1.894	1.894
Tractor	1.23	0.123	0.123	1.71	1.894	1.894
ATV	2.40	0.200	0.200	11.3	0.000	0.000
Trimmer/Edger	0.29	0.000	0.000	0.58	0.000	0.000
Leaf blower	0.15	0.000	0.000	0.58	0.000	0.000
Tiller	0.57	0.000	0.000	1.71	1.894	1.894
Generator/Welder	3.24	0.000	0.000	1.80	1.470	1.470
Forklift	10.5	0.000	0.000	4.61	0.000	0.000

For running losses, lawnmower emission rates will be used as a surrogate for tractors and tillers. The emissions of trimmers will be used as a surrogate for chainsaws and leaf blowers.

Evaporative emissions will be calculated each hour in order to account for the percentage of equipment that is either in-use or idle, and the change in ambient temperature. Regional and seasonal variations will be reflected through changes in activity and the use of Temperature/RVP correction factors.

The Temperature/RVP correction factor equation is:

Diurnal/Resting Loss Temperature/RVP Correction Factor =
(A) hr + (B) RVP + (C) Temp + (D) dtemp + (E) temp*dtemp + (F) temp*hr + (G) temp*rvp + (H) dtemp*hr + (I) dtemp*rvp + intercept

Temperature/RVP correction factor coefficients for both diurnal and resting losses are shown below.

Variable	Diurnal Coefficients	Resting Loss Coefficients
A	-0.0832099	0.032988944
B	-0.007304156	0.041684179
C	-8.10117E-05	0.005296275
D	-0.025853192	0.06209003
E	0.000175569	-0.000459595
F	0.001980283	0.000596396
G	1.47497E-05	-0.000500966
H	0.001471629	0.000804361
I	0.001715214	-0.002281295
intercept	0.05201313	-0.40806693

Because no tests were performed beyond 105°F, 105°F will be used for all ambient temperatures in excess of 105°F. At the lower extremes of the temperature range, the equation may produce a negative estimate of emissions. In this instance, zero emissions will be assumed.

During engine operation and immediately after, the heat of the engine is the dominant factor with respect to vapor generation. Therefore, running loss and hot soak emission will be corrected only for variation in RVP.

Test of the same equipment using different fuel formulations was used to determine the affect of RVP. The results were normalized to standard conditions (7.0 RVP) to derive a dimensionless multiplier to the basic emission rates. Because insufficient information exists to derive a separate RVP correction factor for running losses, the hot soak factor will be applied.

RVP correction factor equation for hot soak and running losses =
0.3045749(RVP) – 1.1320242 / 0.3045749(7.0) – 1.1320242

The population by equipment type and the usage estimates remain unchanged.

Appendix A

SORE EQUIPMENT BY CATEGORY

Lawn and Garden Equipment

1. Trimmers / Edgers / Brush Cutters
2. Lawn Mowers
3. Leaf Blowers
4. Rear Engine Riding Mowers
5. Front Mowers
6. Chainsaws < 5 HP
7. Shredders < 5 HP
8. Tillers < 5 HP
9. Lawn and Garden Tractors
10. Wood Splitters
11. Snow Blowers
12. Chippers / Stump Grinders
13. Commercial Turf Equipment
14. Other Lawn and Garden Equipment

Light Commercial Equipment

1. Generator Sets
2. Pumps
3. Air Compressors
4. Welding Machines
5. Pressure Washers

Agricultural Equipment

1. 2-Wheel Tractors
2. Agricultural Tractors
3. Agricultural Mowers
4. Combines
5. Sprayers
6. Balers
7. Tillers > 5 HP
8. Swathers
9. Hydro Power Units
10. Other Agricultural Equipment

Logging Equipment

1. Chain Saws > 5 HP
2. Shredders > 5 HP
3. Log Skidders
4. Fellers / Bunchers

Appendix A

SORE EQUIPMENT BY CATEGORY
(contiuned)

Airport Ground Support Equipment

1. Airplane Tow Tractors
2. Baggage / Cargo Tow Tractors
3. Ground Power Units
4. Start Units
5. Deicing Units
6. Load Lifting and Handling
7. Service Utility Carts
8. Pressure Washers

Transport Refrigeration Units

1. Small Units <25 HP
2. Large Units >25 HP

APPENDIX B

Equipment	Surrogate
Asphalt Pavers	Forklift
Tampers/Rammers	Forklift
Plate Compactors	Forklift
Rollers	Forklift
Paving Equipment	Forklift
Surfacing Equipment	Forklift
Signal Boards	Forklift
Trenchers	Forklift
Bore/Drill Rigs	Forklift
Concrete/Industrial Saws	Forklift
Cement and Mortar Mixers	Forklift
Crushing/Process Equipment	Forklift
Skid Steer Loaders	Forklift
Dumpers/Tenders	Forklift
Aerial Lifts	Forklift
Forklifts	Forklift
Sweepers/Scrubbers	Forklift
Other General Industrial Equipment	Forklift
Lawn Mowers	Lawnmower
Tillers	Tiller
Chainsaws <=5 HP	Chainsaw
Trimmers/Edgers/Brush Cutters	Trimmer
Leaf Blowers/Vacuums	Leaf blower
Snow blowers	Leaf blower
Rear Engine Riding Mowers	Tractor
Front Mowers	Tractor
Shredders <=5 HP	Chainsaw
Lawn & Garden Tractors	Tractor
Wood Splitters	Lawnmower
Chippers/Stump Grinders	Lawnmower
Commercial Turf Equipment	Tractor
Other Lawn & Garden Equipment	Lawnmower
2-Wheel Tractors	ATV
Agricultural Mowers	ATV
Sprayers	ATV
Tillers >5 HP	ATV
Hydro Power Units	Generator
Other Agricultural Equipment	ATV
Generator Sets	Generator
Pumps	Generator
Air Compressors	Generator
Welders	Generator
Pressure Washers	Generator
Chainsaws >5 HP	Chainsaw
Shredders >5 HP	Chainsaw
Cart	Forklift
Lavatory Cart	Forklift
Transport Refrigeration Units	Generator