Appendix I

2017 Diesel-Fueled Portable Equipment Emissions Inventory - Technical Documentation

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California Environmental Protection Agency

Air Resources Board

Mobile Source Analysis Branch
Air Quality Planning & Science Division

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1. Summary

This documentation describes the California Air Resources Board's (CARB) 2017 Portable Equipment Emissions Inventory as well as the emissions inventory model and model inputs that are used to produce the emissions inventory. This inventory covers portable diesel engines rated at 50 horsepower and greater and registered in the Portable Equipment Registration Program (PERP), which are subject to the Airborne Toxic Control Measure for Diesel Particulate Matter from Portable Engines Rated at 50 Horsepower and Greater (ATCM). The ATCM was adopted in 2004 and set emissions requirements for portable engines to reduce exposure to toxic diesel particulate matter (PM) and protect public health. The ATCM works in concert with the Portable Equipment Registration Program and the PERP Regulation to allow fleets to voluntarily register portable equipment used across California with the State rather than permitting or registering the equipment with each local air district individually. For details on the definition of 'portable equipment' subject to the regulation and registration program, visit CARB's website for portable equipment[1].

A new Portable Equipment emissions inventory model was developed in support of assessing emission impacts of proposed amendment scenarios to the ATCM. This 2017 PERP ATCM amendment process (see the associated staff report) involved (1) updating inputs to the emissions inventory including population, activity and load, (2) updating emissions modeling methodologies including no regulation scenario turnover with newly available data and (3) simulating the existing /original rule and evaluating the impacts of different amendment scenarios in support of the 2017 Portable ATCM amendments.

The new Portable Equipment model is notable in that it uses 'fleet' identification to model equipment retirement, purchasing and average ages. A fleet in this case is a group of equipment registered by a single owner/entity in PERP, which may represent all or some portion of the entity's owned equipment since PERP is a voluntary program. This registered information allows the modeling of equipment in a much higher level of specificity than other inventory models that aggregate equipment at a county or statewide level. Instead of one retirement curve for all equipment in the state, each fleet has its own characteristics that are maintained in the emissions inventory model. This methodology is only possible when CARB has access to detailed information on equipment within each fleet, which has only been possible in the off-road sectors when an industry sector is subject to mandatory reporting requirements as with portable equipment, construction and mining, and transport refrigeration units.

[1] ARB PERP: https://www.arb.ca.gov/portable/portable.htm

Table 1: Portable Diesel Engine Quick Facts

Applicability		Portable diesel engines (no motive power) Rated at 50 horsepower and Greater Used in California
Industries		Construction, Industrial, Commercial, Drilling, Equipment Rental, Energy Generation, Other
Base Year		2016
Population		30,061 in 2016
	Population:	2011-2016 PERP Registration
	Activity	2016 Survey of PERP Owners
	Load	2016 Survey of PERP Owners
	Emission Factors	2017 CARB Off-road Emission Factors
	Category Growth	2011-2016 PERP Equipment Registration Growth

a. Scenarios

Emissions were estimated from portable engines for calendar years 2011 to 2040 for 3 different scenarios: the no regulation scenario (without the PERP ATCM), the original rule scenario under the 2004 ATCM (ARB), and the amendment scenario using the proposed 2017 amendments to the ATCM. Results from the 3 scenarios are compared to quantify the net emissions benefit from the original regulation and proposed amendments. The following tables show the emission standards under the 2004 ATCM as well as the proposed 2017 amendments

Table 2: 2004 Portable ATCM – Fleet Average PM Standard

Fleet Standard Compliance Date	*Engines <175 hp (g/bhp-hr)*	*Engines 175-750 hp (g/bhp-hr)*	*Engines >750 hp (g/bhp-hr)*
2013	0.30	0.15	0.25
2017	0.18	0.08	0.08
2020	0.04	0.02	0.02

Table 3: Proposed Amendment to the 2004 ATCM - PM Fleet Average Standards

Compliance Date	*Fleet Average PM Standard (g/bhp-hr)*
1/1/2020	0.10
1/1/2023	0.06
1/1/2027	0.03

b. Emissions Results

The graphs and tables on the following pages summarize portable engine emissions of PM and NOx for the State of California, South Coast Air District, and San Joaquin Valley Air District. All scenarios (including no regulation) were updated from the previous model for portable equipment. The relative benefits of the ATCM, including the proposed 2017 amendments, are shown in Table 5.

Figure 1: Statewide Portable Equipment PM in Tons per Day

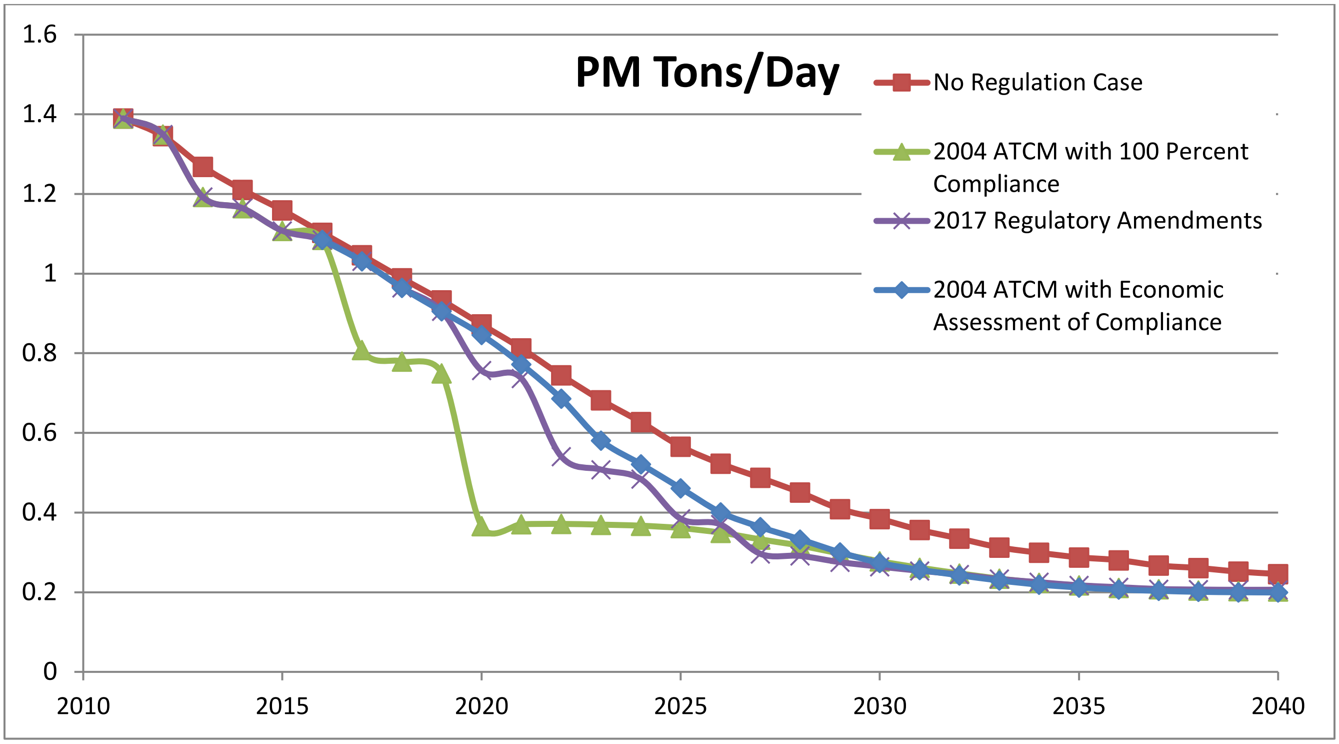


Figure 2: Statewide Portable Equipment NOx in Tons per Day

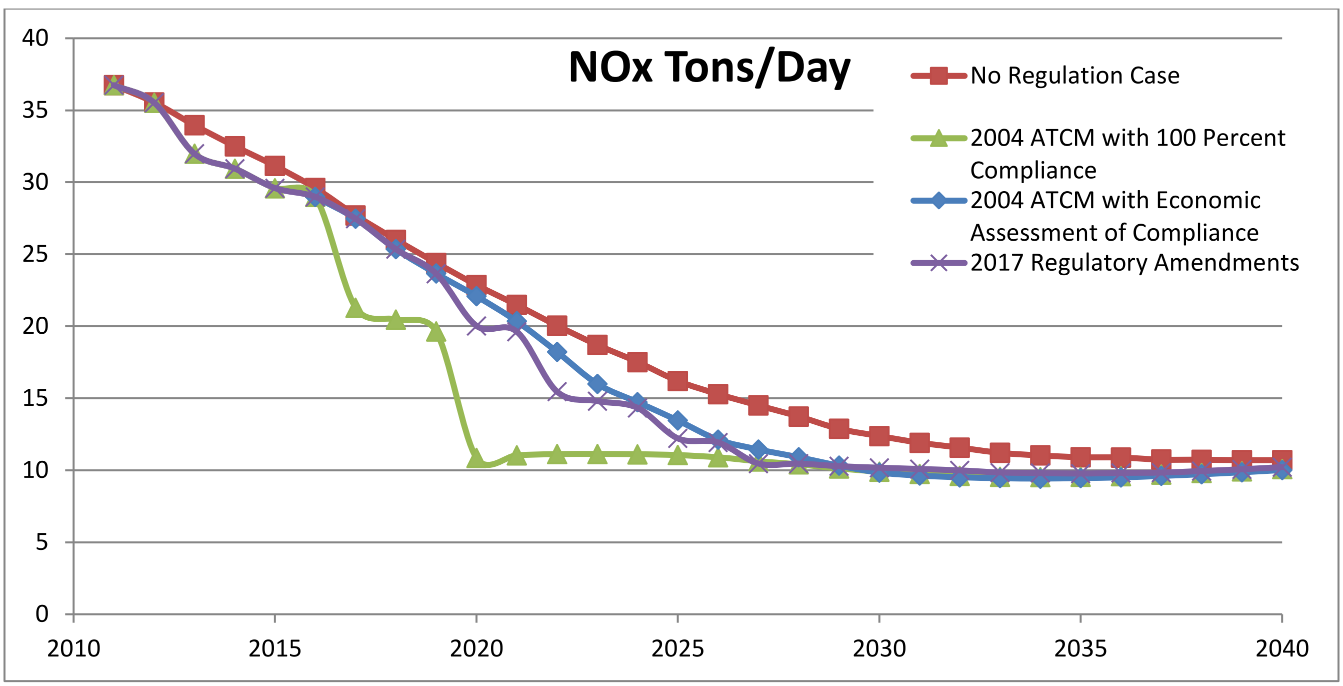


Table 4: 2017 Portable Equipment NOx and PM Emissions Inventory
(all emissions in tons per day)

	Population	No Regulation NOx	2004 ATCM NOx: with 100% Compliance	2004 ATCM NOx: with Economic Assessment of Compliance	2017 Proposal NOx
2011	31,041	36.7	36.7	36.7	36.7
2017	34,580	27.7	21.3	27.5	27.5
2023	36,490	18.7	11.1	16.0	14.8
2031	39,201	11.9	9.7	9.6	10.1
2040	42,494	10.7	10.1	10.0	10.2
	Population	**No Regulation PM**	**2004 ATCM PM: with 100% Compliance**	**2004 ATCM PM: with Economic Assessment of Compliance**	**2017 Proposal PM**
2011	31,041	1.39	1.39	1.39	1.39
2017	34,580	1.05	0.81	1.03	1.03
2023	36,490	0.68	0.37	0.58	0.51
2031	39,201	0.36	0.26	0.26	0.25
2040	42,494	0.25	0.20	0.20	0.21

2. General Emissions Inventory Methodology

This chapter provides a brief overview of the equations and input variables used by the emissions inventory model to calculate the portable equipment emissions inventory and points to associated sections of the document that provide more detail. A more detailed description of the model is provided in Appendix I-1 and the actual model is a separate package (denoted as Portable Equipment Emissions Inventory Model).

a. Emissions Calculations per Individual Piece of Equipment

Emissions are calculated for every single engine in the model using the following equation:

$$\boldsymbol{Emission\ per\ Vehicle = Activity * HP * LF * EF * FCF} \qquad \textbf{Equation 1}$$

Where:

Activity	=Number of hours per year the engine is running (hours)
HP	=Brake-horsepower of each engine (bhp)
EF	=Emission factor -adjusted for deterioration (grams/bhp-hr)
LF	=Load factor (unit-less)
FCF	=Fuel correction factor (unit-less)

b. Emissions Calculations Forecast

If one wanted to express the entirety of the modeling process and emissions calculation in a single equation, Equation 2 identifies the primary elements. Emissions are calculated for the statewide fleet by summing the emissions across each region, the fleets within each region, and the engines within each fleet. The population distribution forecast in future years is a function of the fleet turnover modeling discussed in great detail in Appendix I-1.

$$\boldsymbol{Forecasted\ Emissions =}$$

$$\boldsymbol{f(turnover\ by\ year) \sum_{i}^{m} Region \sum_{j}^{n} Fleet \sum_{k}^{o} (Engines)\ Activity * HP * LF * EF * FCF}$$

Equation 2

Where:

m ↔ i	= all the regions in the state
n ↔ j	= all the fleets in the region
o ↔ k	= all of the engines in a fleet

The remainder of this report will detail the development and methodology of each of the inputs, as well as the methodology for determining or estimating age distributions for portable diesel engines in future years.

3. Base Year Input Data

This chapter describes inputs to the base year emission equations summarized in the previous chapter.

a. Base Year Population

The 2017 portable equipment emissions inventory relies on the PERP data to establish population, horsepower and equipment categories (such as pump, generator, etc.) for portable diesel engines. A registration in PERP is voluntary. As stated earlier, portable equipment owners have the option to obtain a permit with their local air district or register in PERP. Comparisons with two major air districts in California (San Joaquin Valley AQMD and South Coast AQMD) showed that approximately 90 percent of portable equipment was registered in PERP, with the outstanding 10 percent registered with the districts (Guzzetta, 2016). Because the districts are not required to report or share any specifics of this data with CARB, the PERP registration data was used as the basis for equipment population, with an adjustment factor used to represent the remaining portable equipment in the state that is registered with local air districts. Effectively, for every active engine registered in PERP, staff assumed that 1.10 engines operate statewide.

During the PERP registration process, CARB collects information about each engine: horsepower, model year, make and model, home district, equipment description, and rental status (rental vs. non-rental). The PERP registered populations serve as the baseline population for the inventory, with a base year of 2016. Table 5 is a count of PERP-registered engines in calendar years 2011 through 2016, and Table 6 shows the distribution of PERP-registered engine populations by district for calendar year 2016.

Table 5: Population Registered in PERP by Calendar Year

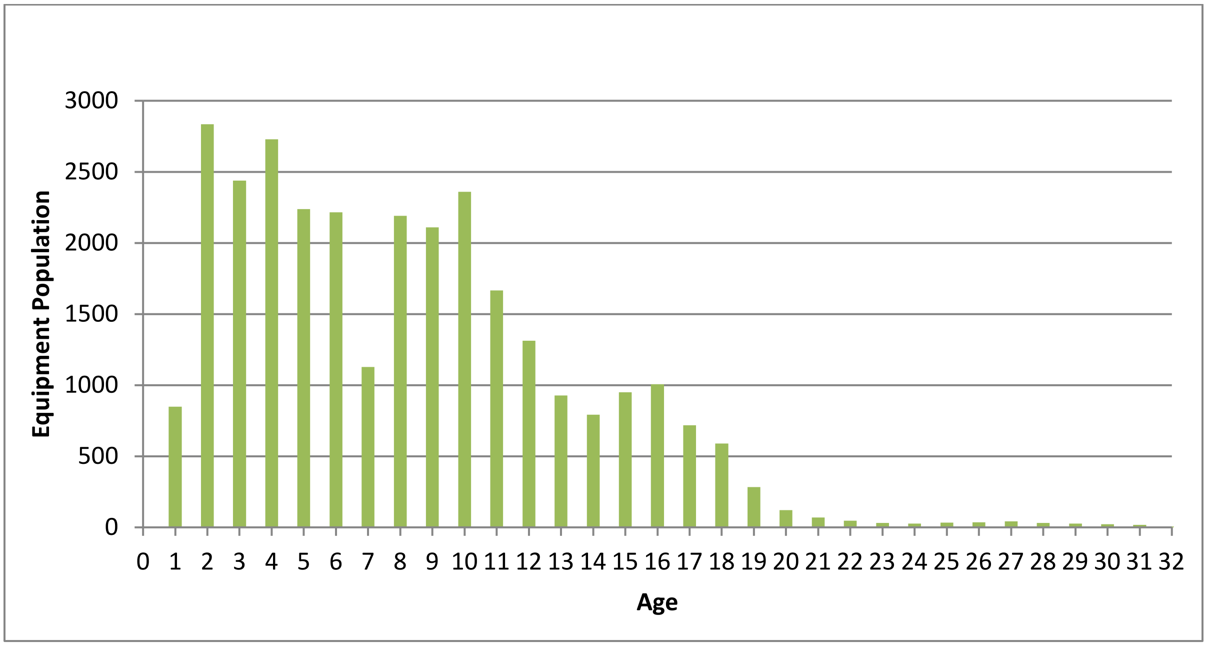
Calendar Year	Population
2011	28,219
2012	28,857
2013	28,288
2014	28,179
2015	28,837
2016	30,061

Table 6: Distribution of CY 2016 (baseline) PERP-Registered Populations by Air District

Air District	Population
South Coast Air Quality Management District	11,793
Bay Area Air Quality Management District	5,505
San Joaquin Valley Unified Air Pollution Control District	5,356
San Diego County Air Pollution Control District	1,631
Sacramento Metropolitan Air Quality Management District	1,090
Yolo-Solano Air Quality Management District	933
Imperial County Air Pollution Control District	483
Santa Barbara County Air Pollution Control District	404
Ventura County Air Pollution Control District	384
Mojave Desert Air Quality Management District	334
Placer County Air Pollution Control District	316
San Luis Obispo County Air Pollution Control District	274
Kern County Air Pollution Control District	225
Antelope Valley Air Quality Management District	202
Monterey Bay Unified Air Pollution Control District	193
Shasta County Air Quality Management District	166
El Dorado County Air Quality Management District	119
Feather River Air Quality Management District	96
Great Basin Unified Air Pollution Control District	90
Butte County Air Quality Management District	83
Northern Sonoma County Air Pollution Control District	73
Northern Sierra Air Quality Management District	68
North Coast Unified Air Quality Management District	54
Glenn County Air Pollution Control District	33
Colusa County Air Pollution Control District	32
Tehama County Air Pollution Control District	29
Lake County Air Quality Management District	22
Calaveras County Air Pollution Control District	17
Amador County Air Pollution Control District	16
Mendocino County Air Quality Management District	15
Siskiyou County Air Pollution Control District	14
Tuolumne County Air Pollution Control District	7
Modoc County Air Pollution Control District	2
Lassen County Air Pollution Control District	1
Mariposa County Air Pollution Control District	1

Below, Figure 3 shows the count of equipment by age on a statewide level, for PERP-registered equipment in calendar year 2016.

Figure 3: CY 2016 (baseline) PERP Registered Population Distribution by Engine Age



While the populations are aggregated in Figure 3, the emissions inventory model maintains individual records for each fleet and each engine. The far left bar in Figure 4a, below, illustrates that 70 percent of all fleets registered fewer than 4 engines each and make up only 10 percent of PERP-registered engines. Meanwhile, the far right bar in Figure 4a shows that very few (13; which is too small to be discernible on the chart) large companies having over 500 engine registrations each account for almost 30 percent of all engines registered in CARB's PERP database. Similarly, Figure 5b shows the distribution of fleets by the average age of engines within the fleet, with the vast majority either between 5 and 12 years of age, or 12 and 20.

Figure 4a: Distribution of Fleet Size (by engine count)

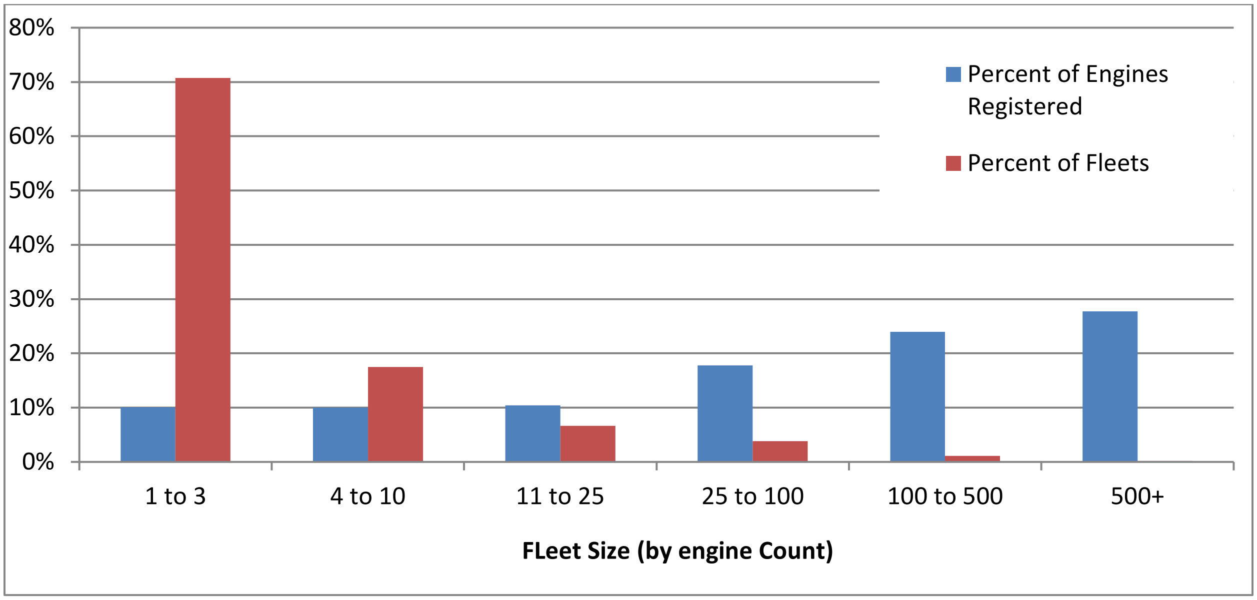
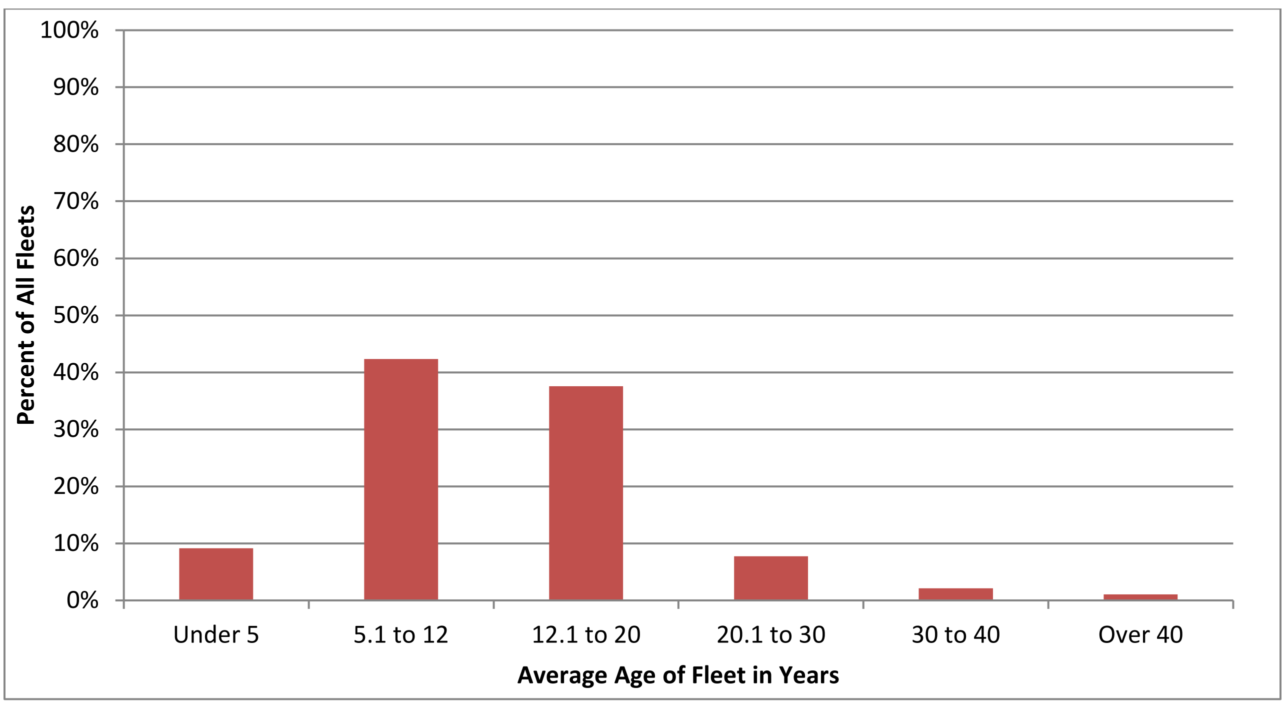


Figure 5b: Distribution of Fleets by Average Age



b. Base Year Activity

The activity of portable engines in hours of operation per year is based on a survey that was sent out in 2016 to all PERP-registered equipment owners/operators in California. Table provides a summary of relevant data collected under this survey. The survey was voluntary, and activity records were received for approximately 1,900 engines.

Table 7: Data requested in Survey of PERP Registrants

Engine Registration ID (to identify horsepower, age of engines)
Fleet ID (to define size of the fleet)
Hours of operation over a specified time period
Fuel used over the same time period
Estimated load from fleet or equipment operator

As indicated in the table above, the survey requested engine activity (hours over a specified period), and fuel used over the same period. The following chart shows the frequency distribution of annual hours of activity from the ~1900 engine activity reports.

Figure 6: Distribution of Activity Reports

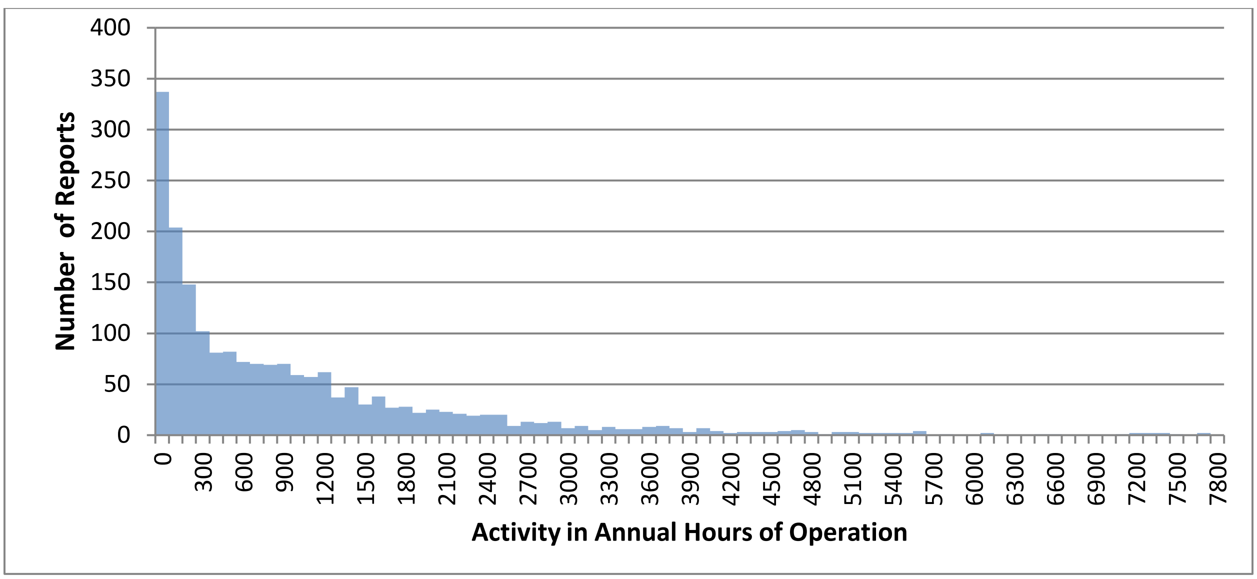


Figure 8 shows the number of reports by rental status and equipment type and Figure 9 shows the average activity for the 3 major categories of equipment use (compressors, generators, and pumps) as well as all other remaining portable equipment. Both figures break down the data into rental and non-rental usage. The average annual activity across all reported engines was approximately 842 hours annually, which is 40 percent higher than the previous estimate for portable equipment

(600 hours). Rental engine reports averaged 1290 hours annually, while non-rental engine reports averaged only 330 hours annually.

Figure 7: Number of Activity Reports by Equipment Groupings

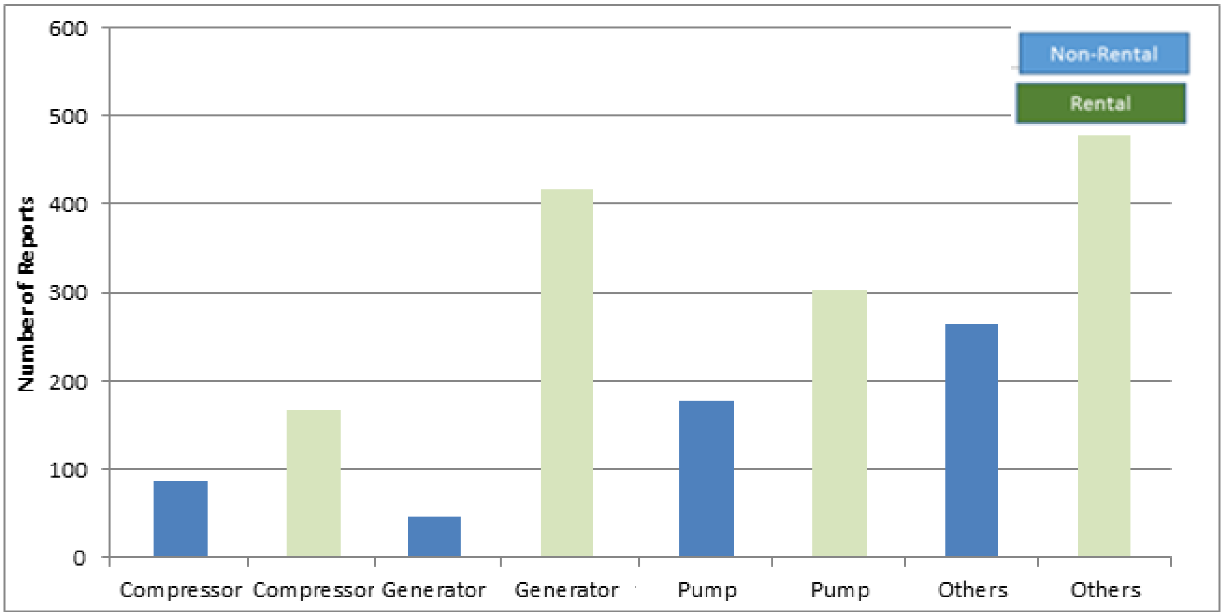
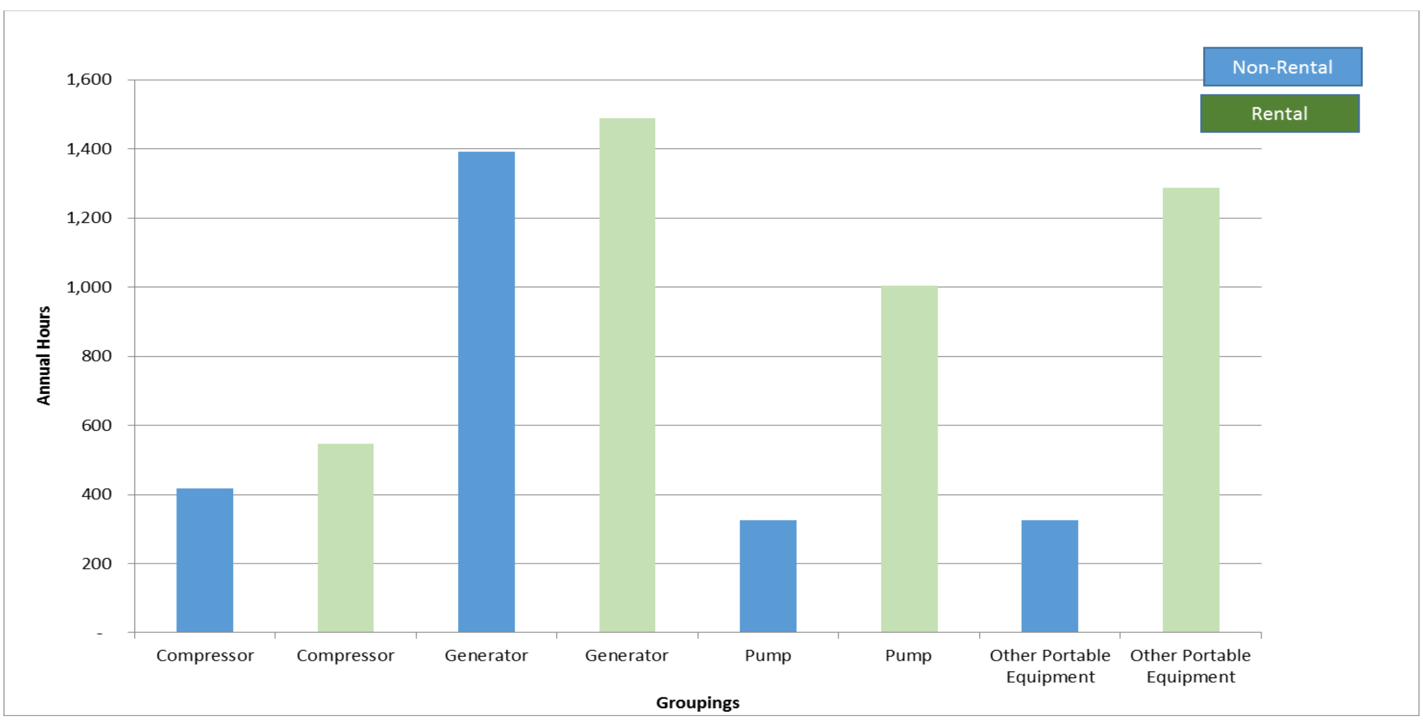


Figure 8: Average Activity by Equipment Type and Rental Status



c. Load Factor (LF)

Load is measure of how hard an engine is run on average, expressed as the percent of maximum brake-horsepower that an engine uses during running time. For example, a 100 horsepower engine that is run at 50 horsepower on average would have a load factor of 50 /100, or 0.5.

Load can be determined from measuring fuel use over a period of engine running time. Fuel use is calculated using the following equation.

$$\textbf{Fuel Used (gallons)} = \textbf{Engine Horsepower (hp)} * \textbf{Load(unitless)} * \textbf{Activity (hours)} * \textbf{Fuel Consumption Factor} \left(\frac{\textbf{gallons}}{\textbf{horsepower}*\textbf{hr}}\right)$$

Equation 3

Solving the equation above for load provides:

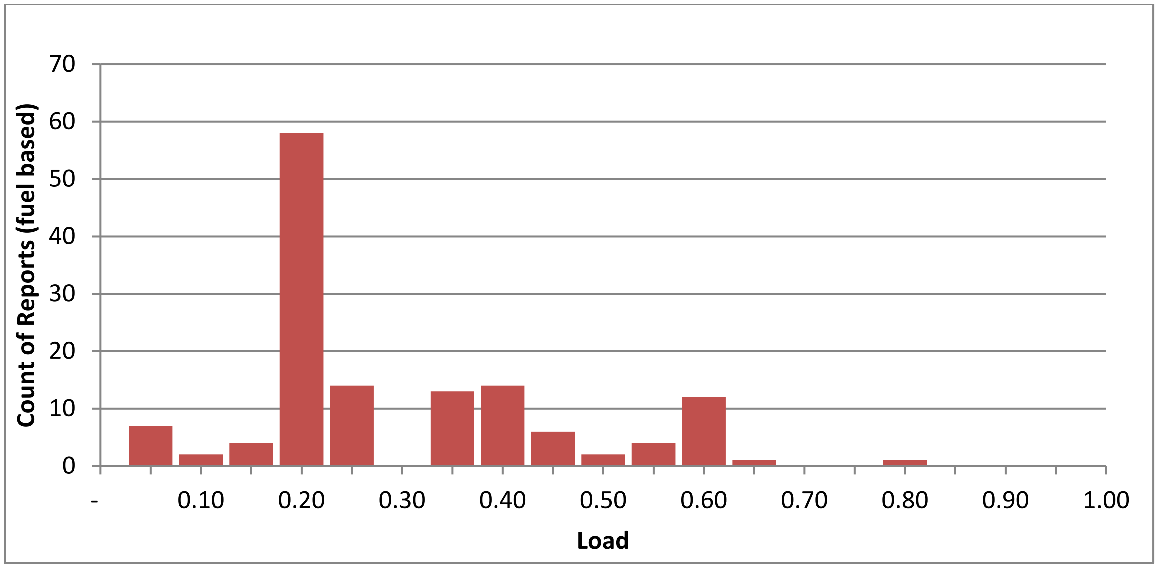
$$\textbf{Load} = \frac{\textbf{Fuel Used(gallons)}}{(\textbf{Engine Horsepower (hp)}) * \textbf{Activity (hours)} * \textbf{Fuel Consumption Factor} \left(\frac{\textbf{gallon}}{\textbf{horsepower}*\textbf{hr}}\right)}$$

Equation 4

In the survey described in the previous section, the respondents included fuel in addition to activity for 138 engines. The load factor for this inventory was calculated using these survey data, in additional the engine horsepower reported in the PERP database, and fuel consumption factors developed by the US Environmental Protection Agency (US EPA) for off-road diesel engines.

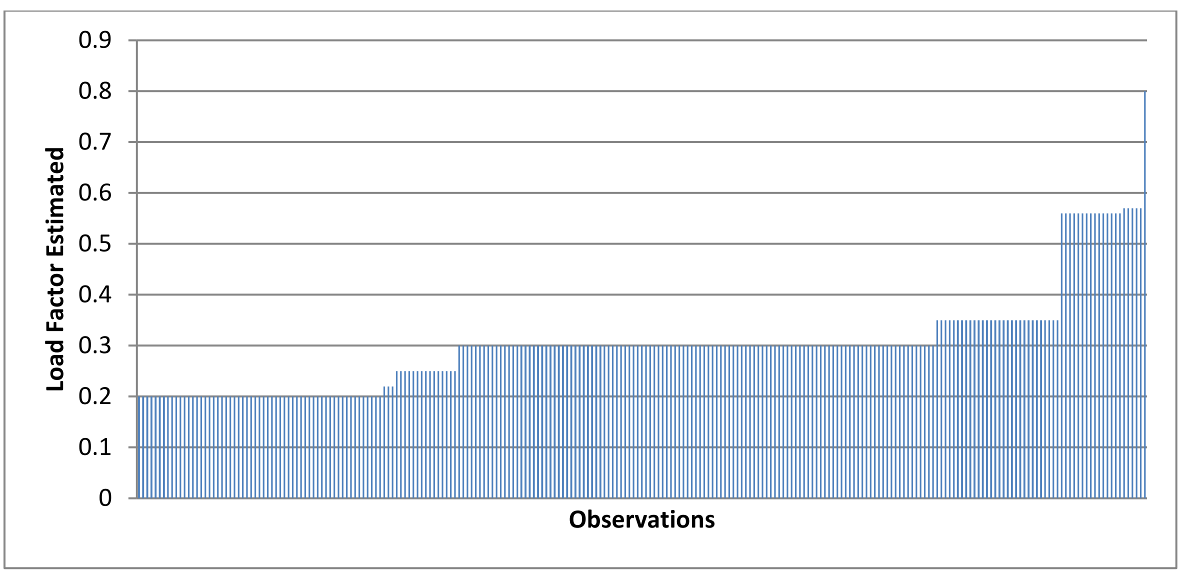
The figure below shows the distribution of load factors based on 138 survey responses that included both activity and fuel usage. They range from 0.05 up to 0.8, but average out to 0.31.

Figure 9: Load Factor Distribution from 2016 PERP Survey (fuel based)



In addition to requesting the fuel and activity in the survey, respondents were also asked to estimate the average load for their equipment. Responses were received for approximately 230 engines (the majority were not from the same respondents that had included fuel and activity), and ranged between 0.2 and 0.58. The average of all responses from the estimated load was 0.31. The figure below shows the individual responses.

Figure 10: Load Factor from 2016 Survey (Owner Estimates)



For comparison, the load factors in construction were updated in 2011, with the values shown below in Table 8. Note that, similar to the PERP category, these previous load values for this equipment were in the 0.6 to 0.7 range, and California-specific data showed that these values were an overestimate. A load factor of 0.31 for portable equipment is well within the bounds of other off-road diesel categories.

Table 8: Load Factors for Construction Equipment Based on 2011 Update

Equipment Type	Load Factor (2011 CARB Update)
Cranes	0.29
Crawler Tractors	0.43
Excavators	0.38
Graders	0.41
Paving Equipment	0.36
Rollers	0.38
Rubber Tired Loaders	0.36
Skid Steer Loaders	0.37
Tractors/Loaders/Backhoes	0.37
Aerial Lifts	0.31
Forklifts	0.20
Average	0.37

d. Emission Factors (EF)

Emission factors for off-road diesel engines were updated for this inventory and are documented online.[2]

[2] https://www.arb.ca.gov/msei/categories.htm#offroad_motor_vehicles

4. Forecasting Emissions to Future Years

Estimates of future emissions beyond the base year are made by adjusting base year estimates for population growth, activity growth, and the purchases of new equipment (i.e. turnover). Two kinds of turnover are taken into account: 1) natural turnover, which is the purchase of new equipment dictated by historical or ordinary business practices; and 2) accelerated turnover, which are purchases prompted or required by a regulation, like the 2004 ATCM and proposed rule amendments.

a. Growth in Equipment Population and Activity

The portable equipment population in California is used across an extremely wide variety of industries, including construction, industrial, commercial, drilling, equipment rental, energy generation, and many others. The broad application of these engines makes projecting equipment population growth for a specific industry both difficult and prone to significant error. Population growth surrogates for each of the 6 to 10 categories would have to be developed, and then each fleet in the PERP database assigned a specific industry sector. Because this data is not currently available, staff used the average of two statewide surrogates to model equipment population growth: the growth in the population registered in PERP from 2011 through 2011; and the growth in total horsepower registered in PERP from 2011 to 2016.

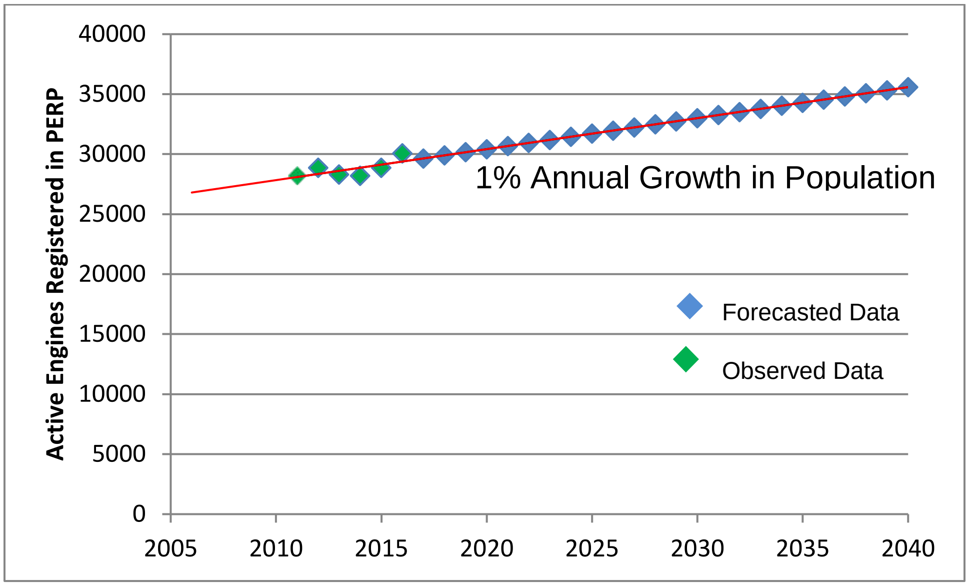
Table 9: Total Horsepower Registered in PERP by Calendar Year

Calendar Year	Total Horsepower in PERP	Year to Year Change	Total Population in PERP	Year to Year Change
2011	7,622,507	-	28234	
2012	8,134,330	6.7%	28872	2.3%
2013	8,036,142	-1.2%	28304	-2.0%
2014	8,141,098	1.3%	28186	-0.4%
2015	8,322,543	2.2%	28842	2.3%
2016	8,702,678	4.6%	30065	4.2%
	Average	2.7%	Average	1.3%
			Combined Average: 2.0% Annual Growth	

The average of these two growth rates was used as the cumulative growth for the PERP category, with approximately half apportioned to population growth, and the other half apportioned to activity growth.

Figure 11 below shows the PERP-reported population from 2011 to 2016, and the projected population using an annual growth rate of 1.0 percent beginning in 2017 (or half of the cumulative growth rate of 2.0 percent). The remaining growth is applied to the base year activity described above in section 3.b.

Figure 11: Extrapolated Growth in Population



b. Natural Turnover

The portable equipment emissions inventory model estimates future populations of equipment by simulating the turnover[3] habits observed in the real world. The analysis of annual fleet-specific changes to the equipment populations registered in PERP provide the model logic used to guide the retiring and purchasing habits in the model's population forecasting simulation. By relying heavily on real world population data, the simulation of future populations depicts scenarios based on the habits observed in the many industries within the portable equipment category.

The portable equipment model depicts more than one scenario of population forecasting: No Regulations, Original Rule, and Amendment. The No Regulation scenario depicts a case in which CARB had not adopted the standing regulation. The Original Rule depicts a scenario under the standing regulation, and the Amendment scenarios depict another under the proposed amendment. These different scenarios are modeled so that the emissions differences can be compared – the difference between the no regulation scenario emissions and the regulatory scenario (both original rule and amended rule) are the emissions benefits of the regulation.

The most defining characteristic of the portable equipment model is that it simulates future populations for each fleet in the state *individually*. A fleet in this case is

[3] Turnover: the retiring of older equipment and purchasing of new equipment over time

any group of engines reported by an individual, company, or agency in California. It often represents all equipment owned by one company or agency, although owners may split up their equipment when reporting to create multiple reporting fleets (it provides no tangible benefit or 'loophole' to comply with the regulation using multiple fleets instead of one fleet).

The model reads the characteristics of an individual fleet and then simulates a future for that fleet keeping those characteristics intact to preserve its unique equipment retiring and purchasing habits. This is done for all fleets separately. This is in contrast to methods that might read in and model all fleets in aggregate form. This fleet methodology is often referred to as a 'bottom up' methodology. A fleet model allows for more detailed simulations and results, greater quality assurance, and provides a particularly detailed assessment of regulatory and amendment scenarios.

The No Regulation turnover methodology conserves the following observed real world characteristics of an individual fleet (i.e. average age, retirement trends, purchasing trends).

This is accomplished by employing two major techniques described in the paragraphs below.

Average Age Targets: The average age target is set to the average age of a fleet in the base year[4]. The model will attempt to hold this average age as constant as possible as it forecasts populations into the future. It accomplishes this by iteratively testing the replacement of a piece of equipment and comparing the average age of the fleet before and after replacement. The model then chooses the value that results in an average age closest to the target. It does not control what the age of purchased equipment will be, but it does control when it is purchased.

Relative Purchasing Age: The relative purchasing age is the age of equipment that is typically purchased by a fleet (many fleets do not purchase brand new, age 0, equipment). This age is chosen based on the observed purchasing history for of each individual fleet within the PERP database. There are two options used for choosing the Relative Purchasing Age; based on the age range of equipment in a fleet.

(1) If the average age of a fleet is younger than the average age of California, the purchasing age of zero is chosen (brand new equipment).

[4] Base year: the beginning year of the inventory, based on real historical data from which the forecasting will begin.

(2) If the particular fleet is older than the average of California, the dispersion of ages within that fleet is used to choose the purchasing age (the standard deviation is used). Under the second option, the purchasing age of the fleet is the average age of a fleet minus the standard deviation of the ages of equipment within the fleet. For example, if the average age of a fleet was 12 years old, and the standard deviation of ages in a fleet was 8 years, the new purchases would be age 4 (or 12 minus 8).

Various other options were considered, but this methodology was the most accurate at recreating the age distribution in 2016 using the 2011 data as a starting point. Effectively, this method applied to each fleet in 2011 produced overall results that closely matched the 2016 data.

c. Accelerated Turnover

Since this model is designed to estimate the accelerated turnover effects of an amendment to an existing rule, it simulates accelerated turnover caused by both the existing rule and amendment scenarios. Under a regulation, equipment owners are likely to still go through their usual (natural) turnover habits (i.e. once a piece of equipment is unacceptably old for an operator, they are likely to replace it regardless of a regulation). Based on this assumption the model simulates No Regulation turnover first, then adds any accelerated turnover due to rule/amendment compliance needs afterwards. This is performed iteratively one year at a time. The only adjustment to the No Regulation methodology during a regulation scenario is that purchasing habits are altered to adhere to the given rule or amendment (there are minimum limits on the model year that can be purchased under the portable equipment regulation that stop operators from purchasing older equipment).

i. 2004 Portable Equipment ATCM

Under the Original Rule every fleet must meet a Fleet Average Emission Rate. This value is the average emission rate of particulate matter for all the engines in a fleet (grams/horsepower-hour). To comply with the Fleet Average Emission Rate, owners must replace higher emitting equipment with cleaner equipment (unless their fleet is already below the standard).

For fleets complying with the ATCM, compliance behavior is simulated by replacing the dirtiest equipment one at a time with newer equipment. After each replacement, the Fleet Average Emission Rate is checked so that once compliance is met there are no additional steps taken. The model uses the engine family certification results that are specific to each equipment type to calculate any fleet’s average emission rate.

The Fleet Average Emission Rate standards vary depending on the horsepower of equipment. For any given fleet, equipment within any one of the horsepower ranges below are grouped together and held to their own average standard. Effectively, a fleet containing equipment in all three horsepower ranges has three different groups of equipment all required to meet different standards. The model simulates this grouping system identically. The table below shows the emission rate requirements.

Table 10: Original Rule – PM Fleet Average Emission Rate Compliance Standards

Fleet Standard Compliance Date	*Engines <175 hp (g/bhp-hr)*	*Engines 175-750 hp (g/bhp-hr)*	*Engines >750 hp (g/bhp-hr)*
2013	0.30	0.15	0.25
2017	0.18	0.08	0.08
2020	0.04	0.02	0.02

To model compliance with the 2004 Portable Equipment ATCM, each fleet was run through an economic assessment first. The assessment went through the following steps to determine if and when a fleet was likely to comply with the 2004 ATCM.

I. Fleets at or under the fleet average targets with natural turnover comply with the ATCM without any additional cost.

II. Fleets that do not meet the fleet average standard have their cost to meet the 2020 fleet average requirements in the ATCM identified.

   a. Fleets will comply with the PERP ATCM where the following statement is true:

$$\textit{Cost of Compliance} < P(E) * [\textit{Minimum}(\$365,000 \textit{ or Fleet Value}) + \textit{Cost of Compliance}]$$

Equation 5

Where $P(E)$ is the probability of enforcement derived from annual enforcement rates observed during the implementation of the 2013 fleet average standards. Based on this experience and data, ARB has assumed enforcement resources will be limited to a statewide rate of 250 fleets per year. The probability of a non-compliant fleet being enforced upon was calculated by taking the enforcement rate of 250 and dividing it by the total number of potentially non-compliant fleets, which is 3,590, yielding a probability of enforcement, $P(E)$, equal to 6.9 percent. For example, if a fleet had a total equipment value of $1,000,000, and the cost to comply in 2020 was $200,000, the equation would be filled in as:

$$\$200{,}000 < 0.07 * [Minimum(\$365{,}000\ or\ \$1{,}000{,}000) + \$200{,}000]$$

$$\$200{,}000 < \$39{,}550$$

Because $200,000 is not less than the fleets' potential liability multiplied by their percent chance of being selected (roughly 7 percent), this fleet would not likely choose to comply with the regulation.

b. For fleets that do not comply with the regulation, the natural rate of turnover continues, but the fleet performs no additional turnover to meet the regulatory requirements.

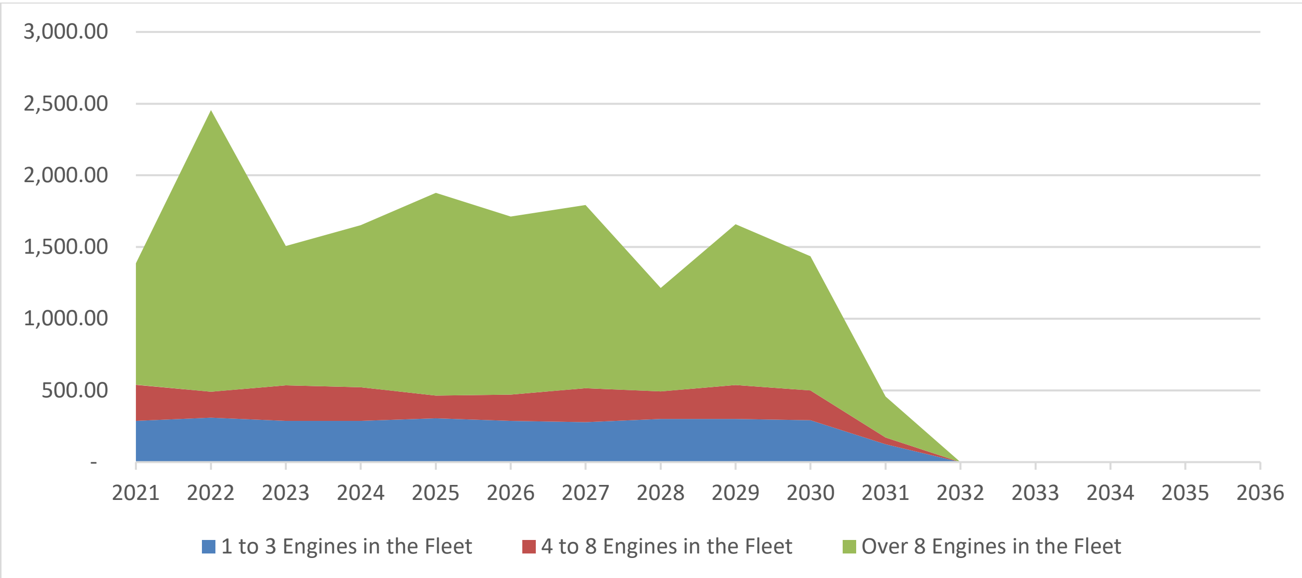
III. Among the fleets that did not comply, fleets are chosen at random every year until 250 fleets are selected that are out of compliance. This represents that average number of fleets that will likely be enforced on in future years.

a. Fleets that are selected in future years that have already come into compliance based on natural turnover are not counted toward the 250 fleets that are enforced against.
b. Fleets that are selected at random for the group of 250 fleets enforced upon again have their cost of compliance assessed again. (For some fleets, this will be lower than the 2020 cost of compliance due to natural turnover. For instance, if the fleet is enforced on in 2030, 10 years of natural turnover will bring the fleet closer to the 2020 requirements and costs will be lower than if the fleet had complied in 2020.)
c. For fleets that are enforced upon with less than 4 engines, 11 percent of the fleets with the highest total cost are assumed to move out of the portable equipment business in each year. For fleets with 4 to 8 engines, 35.5 percent of fleets with the high costs are assumed to move out of the portable equipment business in each year. Fleets with over 8 engines, all fleets are modeled as coming into compliance with the Portable Equipment ATCM, with none moving out of the portable equipment business. A more detailed explanation of the methodology used to determine how

many fleets will move out of the portable equipment business upon enforcement can be found in Appendix C. The activity (or work done) by these fleets was redistributed among remaining fleets.

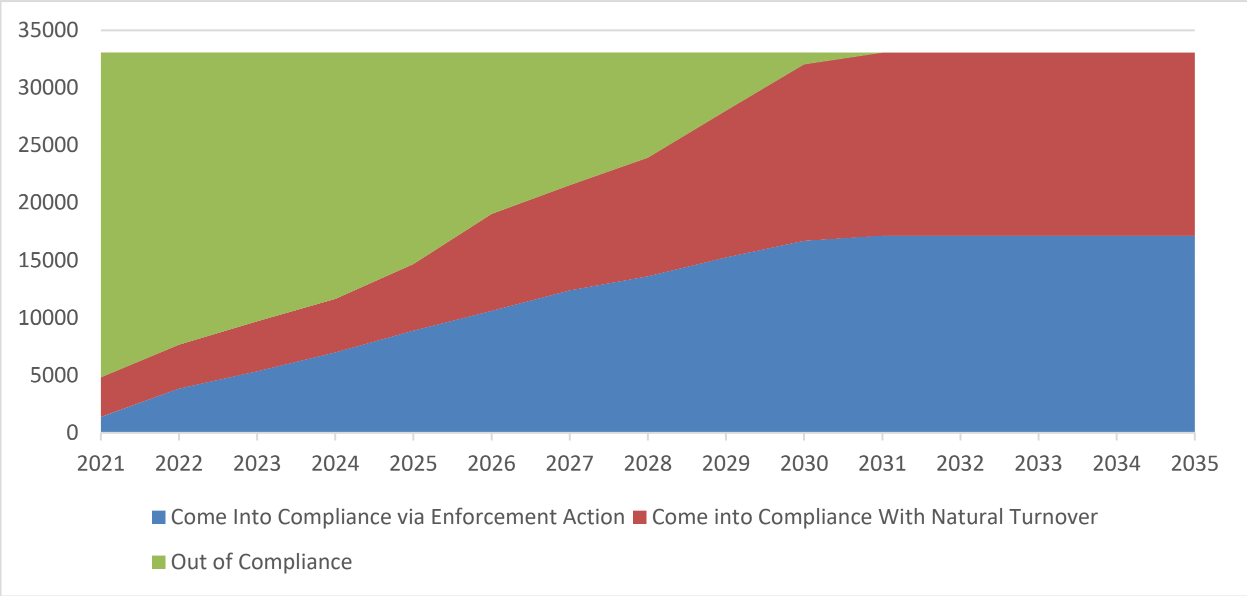
Figure 12 below shows the number of engines in the 250 fleets enforced on each year.

Figure 12: Portable Engines in Non-Compliant Fleets with Enforcement Actions



IV. By 2032, all fleets have either complied with the regulation through natural turnover, brought into compliance via enforcement action, or have moved out of the portable equipment business and/or been absorbed by other fleets. All fleets are in compliance in 2032, and natural turnover is modeled for all fleets following this date. Figure 13 shows the number of engines by compliance status over time. As shown in the figure, the majority of engines are not in compliance in 2021 and come into compliance in a mix of natural turnover or enforcement actions.

Figure 13: Portable Engines by Compliance Status



ii. 2017 Proposed Amendments to the Portable ATCM

The proposed amendment allows two optional pathways for compliance. The first is similar to the original rule and the second uses a tier drop-off approach (below). Fleets with a total horsepower (the sum of all horsepower in the fleet) greater than 750 horsepower can follow either pathway. Fleets with a total horsepower less than or equal to 750 horsepower can only comply with the tier drop-off option.

Similar to the original rule, the fleet average option under the amendment requires fleets to meet an average emission rate for their fleet. The most significant change is that the dates of compliance have been delayed significantly. Fleets are also no longer split into separate horsepower groups as can be seen in the table below.

Table 11: Proposed Fleet Average Compliance Option

Date	*Fleet PM Standard (g/bhp-hr)*
1/1/2020	0.10
1/1/2023	0.06
1/1/2027	0.03

The second pathway under the new amendments calls for a retirement of equipment according to tier by a specified date. This is often referred to as a Tier Drop-off approach. After No Regulation turnover, the model simulates this type of rule by replacing equipment by tier (equipment by tier is already loaded in the model). The following table displays the calendar years that certain tiers of equipment are no longer allowed to operate in California.

Table 12: Proposed Tier Drop-off Compliance Option

Engine Certification	Engines rated 50 to 750 bhp		Engines rated >750 bhp
	Large Fleet	Small Fleet	
Tier 1	1/1/2020	1/1/2020	1/1/2022
Tier 2 built prior to 1/1/2009	1/1/2022	1/1/2023	1/1/2025
Tier 2 built on or after 1/1/2009	NA	NA	1/1/2027
Tier 3 built prior to 1/1/2009	1/1/2025	1/1/2027	NA
Tier 3 built on or after 1/1/2009	1/1/2027	1/1/2029	NA
Tier 1, 2, and 3 flexibility engines	December 31 of the year 17 years after the date of manufacture		

Note: For more information on the Original Rule and 2017 Amendments see the 2017 Portable Equipment rulemaking activity page here: https://www.arb.ca.gov/portable/perpact/portable-activity.htm

APPENDICES

APPENDIX I-1

Appendix I-1: System Design and Portable Engine Model Population Forecasting

The following sections detail the logical flow of calculations and decision making that the portable equipment emissions model goes through to simulate a no regulation or regulatory scenario. Many of the concepts in this appendix rely on an understanding of model turnover covered in the preceding documentation. Each step will include 4 pieces of information:

- Summary explanation of the step
- Equation representing the operation performed
- A sample fleet (the same sample fleet will be shown throughout)
- Primary input tables involved

No Regulation

For the No Regulation simulation, the model will first read in the Average Age Targets and then use them to calculate the Relative Purchasing Ages[3] during the "Pre-Simulation" steps. Then it will follow a set of steps to accomplish one iteration of turnover. For simplicity, the abbreviation "AAF" is used to mean "the average age of a fleet"

1. (Pre-Simulation) – The model uses the real world portable equipment populations to calculate the average age of each individual fleet in California. The average age calculated in step 1 will have the subscript 1 denoting it as the average age of an individual fleet:

   $\mathbf{AAF_1}$ = ∑ Equipment Ages / Number of Equipment

2. (Pre-Simulation) – Relative Purchasing Ages are chosen for each fleet. If the fleet average age is less than the average of California then the purchasing age will be zero for that fleet. If the fleet average age is greater than one standard deviation less than the average is used as the purchasing age:

   <u>If:</u> (AAF_1) <= (Average age of California)

   <u>Then:</u> (Age of purchased equipment) = 0

   <u>Otherwise:</u> (Age of purchased equipment) =

   AAF_1 - (1 Standard deviation of AAF_1)

The following steps show the iterative turnover simulation process. Pre-Simulation steps are done.

3. All equipment is aged one year. The population from the previous year is loaded then increased by one year:

   New Age = Age + 1

4. Now that the equipment has aged one year it has a new average age. No replacement has taken place yet. This average age will be compared later post replacement. The population at this point is saved in case no replacement is necessary to conserve the Average Age Target. The average age calculated in step 4 will have the subscript 4 denoting it as the average age after one year has passed but no replacement has taken place yet:

   $\mathbf{AAF_4}$ = ∑ Equipment Ages / Number of Equipment

5. One piece of equipment is replaced. The model will select the oldest piece of equipment for retirement. The age of the replacement equipment was calculated in step 2. Only one piece of equipment is replaced at this point until further replacement is proved to be necessary:

   New Age = **Relative Purchasing Age** (step 2)

6. The average age is again recalculated for comparison against the average age before replacement (AAF_4). The average age calculated in step 6 will have the subscript 6 denoting it as the average age after replacement:

   $\mathbf{AAF_6}$ = ∑ Equipment Ages / Number of Equipment

7. **Decision:** If the average age after replacement is closer to the Average Age Target, the replacement is accepted; if not, the replacement is not accepted:

   If: Absolute Value (AFF_6 - AFF_1) < Absolute Value (AFF_4 - AFF_1)

   Then: New Age = Relative Purchasing Age (Step 5 is accepted)

Otherwise: New Age = Age + 1 (Step 3 is accepted)

8. **Iteration:** Steps 5 – 7 are repeated until a replacement is rejected, signaling that turnover has achieved an average age for the fleet as close as possible to the Average Age Target.

Regulation and Amendments

The following actions are taken by the model after each iteration of No Regulation turnover above, if the model is simulating a regulatory scenario. That is, after one year of No Regulation (natural turnover) the following steps are taken (compliance is checked and forced on each fleet population makeup) before the next iteration of Baseline turnover takes place. There are two compliance paths each fleet may undergo (see section 4.c.ii 2017 Proposed Amendments to the Portable ATCM), Fleet Average Emission Rates or Tier Drop-Off. Note that a given fleet will be following one of these compliance pathways, never a combination of both:

Fleet Average Emission Rates

9. The Fleet Average Emission Rate for each fleet is calculated (horsepower weighted). This will be compared to the standard for that year:

$$\sum \text{(Certification Emission Rate * Horsepower)} \ / \ \sum \text{Horsepower}$$

10. The dirtiest pieces of equipment are replaced until the fleet average emission rate for that calendar year is met:

If: Fleet Average Emission Rate > Standard

Then: New Age = 0 (one piece of equipment is tested at time)

Otherwise: Turnover is finished

Tier Drop-off

9. For fleets following the Tier Drop-off compliance pathway (see Table 12), equipment is retired based on the engine tier. The regulation specifies specific calendar years that a tier will no longer be able to operate in California:

If: Equipment Tier <= Required Tier

Then: New Age = 0

Otherwise: Turnover is finished

Parallel Amendments and Iteration

11. All fleets are still simulated separately and may follow one or the other compliance pathway. This process (including No Regulation turnover) is repeated for every year as natural turnover and the regulatory requirement change year after year.

Additional Items: Reported Years, District Reporting, and Activity Renormalization

Reported Years

The PERP registration data contains a comprehensive list of equipment registered over the years. The emissions inventory model begins its population forecasting in the most recent year (2016). However, previous years of population are available so these are appended to the forecast years (2011-2015).

District Reporting

There is portable equipment in California that is not registered in PERP because PERP is a voluntary program. This is equipment that is permitted with the Air Districts instead. A district compensation adjustment is applied to all calendar years to adjust for these pieces of equipment.

Activity Renormalization

After population growth is applied, the total activity of portable equipment in California is renormalized to follow the total activity growth expected. Due to large changes in fleet age distributions during a rule or even during No Regulation turnover the total hours of operation can stray from the expected growth and from scenario to scenario. The activity renormalizes the total hours to ensure that the total hours are consistent between scenarios.

References

The following documents are the technical, theoretical, or empirical studies, reports, or similar documents relied upon in proposing these regulatory amendments, identified as required by Government Code, section 11346.2, subdivision (b)(3).

1. Statewide Portable Equipment Registration Program. California Air Resources Board. https://www.arb.ca.gov/portable/portable.htm August 2017.

2. Guzzetta, Michael. *Branch Chief, Enforcement Division.* California Air Resources Board. December 2016.

3. U.S. EPA. Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression-Ignition. July 2010

4. California Air Resources Board. 2017 Off-Road Diesel Emission Factor Update for NOx and PM.