2022 Military and Industrial Locomotive Emission Inventory

Air Quality Planning and Science Division
Mobile Source Analysis Branch
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CALIFORNIA
AIR RESOURCES BOARD

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Executive Summary

Military and Industrial (M&I) locomotives are a subcategory of locomotives comprised of 39 private companies, 4 military rail groups, with a total of 85 locomotives. The M&I locomotive operators include both the military and businesses that use locomotives typically to move their own products or equipment within and around their facility. As of 2022, M&I locomotive categories are responsible for about 0.7 percent of total NOx emissions from the entire locomotive sector in California. These fleets typically consist of smaller, older switchers and medium horsepower (2,301 to 3,999 hp) locomotives operating within the boundaries of a granary, plant, or industrial facility. Due to the lack of regulations for fleet turnover, most industrial and military locomotive fleets are far older than other locomotive subcategories. Currently, the average age of industrial locomotives in CA is around 50 years, and Military locomotives are approximately 66 years old on average. This is the first emission inventory for M&I locomotives in California, and this inventory will continue to be improved and updated in the future.

CARB staff developed the military and industrial locomotive emission inventory with the following assumptions.

- The locomotive emission characteristics are similar to the Class I switcher's emission factor.
- The subject categories will maintain the annual activity with a zero activity growth rate assumption.
- Annual fuel consumption of individual locomotives has a significant relationship with their ages. As the locomotives get older, their fuel consumption and activity will decrease over time, based on the base year data.

Figure 1 presents the forecasted locomotive activity of the subject categories. These two locomotive categories have almost no fleet turnover and do not appear to be moving towards a cleaner or zero-emission fleet. It shows the increasing importance of M&I locomotive emissions over time, as other categories move towards cleaner engines and operations.

Figure 1. Military and Industrial Locomotive NOx emissions of BAU scenario in tons per day
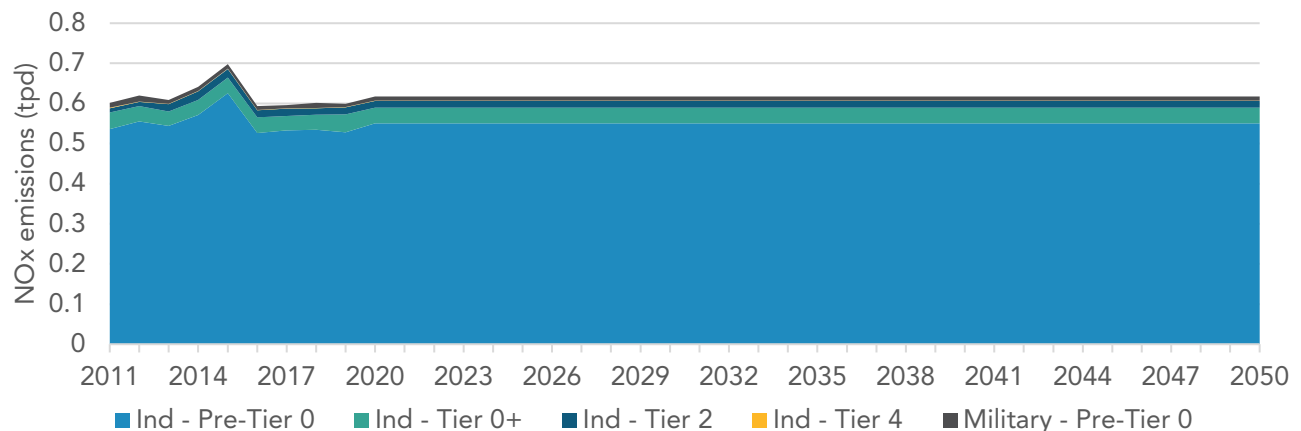
Inventory Inputs and Methodology

Military and Industrial Locomotive Population and Activity Data

CARB staff has worked with the industry to track and record the total population and fuel consumption of military and industrial locomotives in California from 2011 to 2019. This data includes Locomotive ID, annual diesel consumption, Tier, age, engine model and make information of the 43 operators (39 industrial and 4 military rail operators).

The Tier of an engine is based on the model year of the locomotive. Engine standards for locomotives began in 2001. Engines produced before that time are referred to as Tier 0. Table 1 shows the model year and emission standards for switcher locomotive engines.

Table 1: Tier Emission Standards for Locomotives (g/bhp-hr)

Tier	MY	CO	NOx	PM
Tier 01	2001 and Previous	8	11.8	0.26
Tier 1	2002-2004	2.5	11	0.26
Tier 2	2005-2010	2.4	8.1	0.13
Tier 3	2011-2014	2.4	5.0	0.1
Tier 4	2015 or later	2.4	1.3	0.03

Figure 2 and Table 2 show the base year Tier distribution of the two sub locomotive categories, split into their Tier category and type (industrial (INDU) or military (MIL)).

Figure 2. Tier Distribution of Military and Industrial Locomotive Inventory in California

Mil - Pre-Tier 0 15%
Indu - Tier 4 4%
Indu - Tier 2 8%
Indu - Tier 0+ 6%
Indu - Pre-Tier 0 67%

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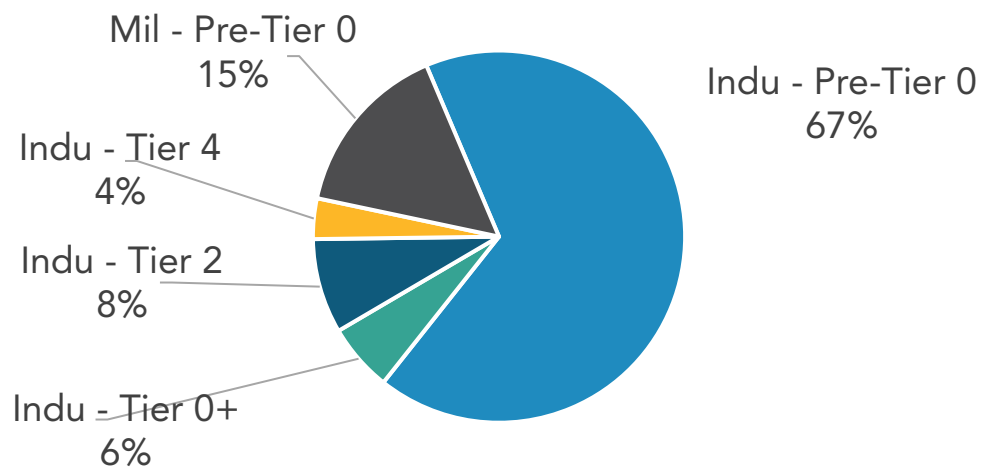
1 These standards apply when the locomotive is remanufactured. No standards were in place when the locomotive engine was initially developed.

Table 2. Number of Military and Industrial Locomotives in CA

| Tier	Count
Industrial - Pre-Tier 0	57
Industrial - Tier 0+	5
Industrial - Tier 2	7
Industrial - Tier 4	3
Military - Pre-Tier 0	13
Total	85

Missing Activity Values

The M&I locomotive operators are not mandated to report their locomotive activity. Due to the lack of data reporting or recordkeeping rules, the inventory input data has missing values for activity for four military and ten industrial locomotives.

Missing Activity for Military Locomotives

For the military locomotive inventory, CARB staff replaced missing values with the median value of the given annual fuel consumptions. The military inventory has only nine samples, which means the sample size is too small to test whether the data follows a Gaussian distribution. A histogram of the fuel consumption data shows a multimodal distribution in Figure 87. The average fuel consumption, 1,200 gallons per year (gpy), may not be the best measure representing the general activity level as a few high activity cases influence them. Thus, the missing values were replaced with the median value, 650 gpy (highlighted below).

Figure 3. Histogram of Fuel Consumption in Military Locomotive Inventory
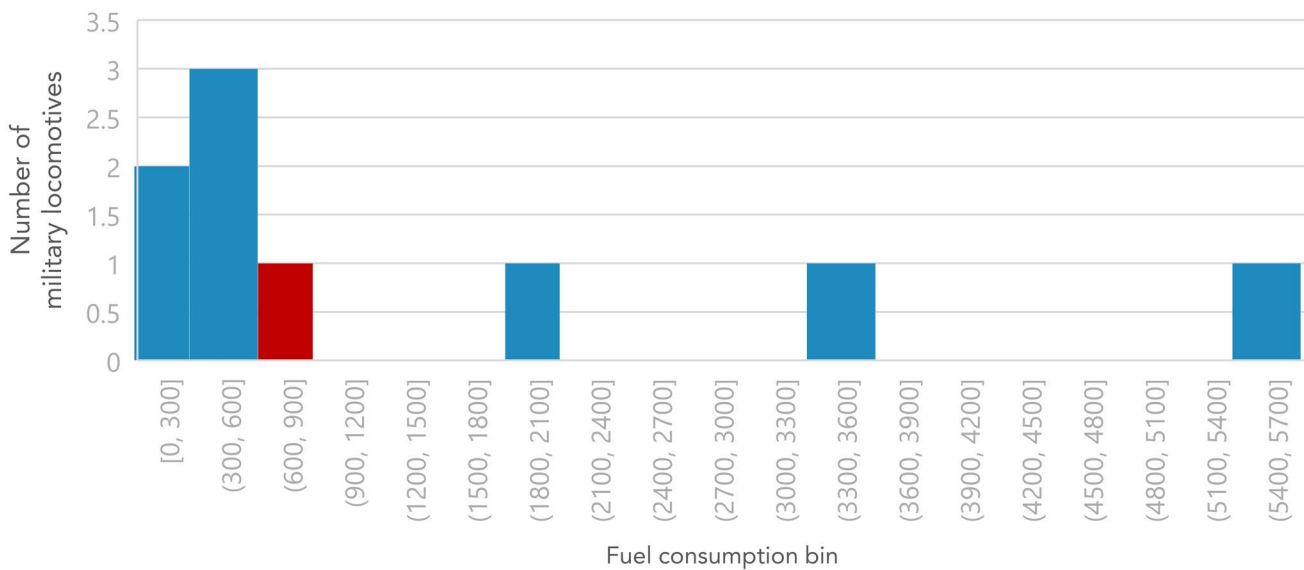
Missing Activity for Industrial Locomotives

To treat the missing activity data, CARB staff developed a model that estimates annual fuel consumption based on the observed relationship between locomotive age and annual fuel consumption. The main assumptions of the model are:

- Activity accrual rate usually decreases as a locomotive gets older
- The two locomotive categories' fleet mix and activity will not significantly change in the near future

A 6th order polynomial function provided the best fit with the highest R-square value compared to the other approaches considered, such as linear, logarithmic, and moving average. Figure 4 shows observed and estimated fuel consumptions by age bin.

Figure 4. Observed and Estimated Fuel Consumption
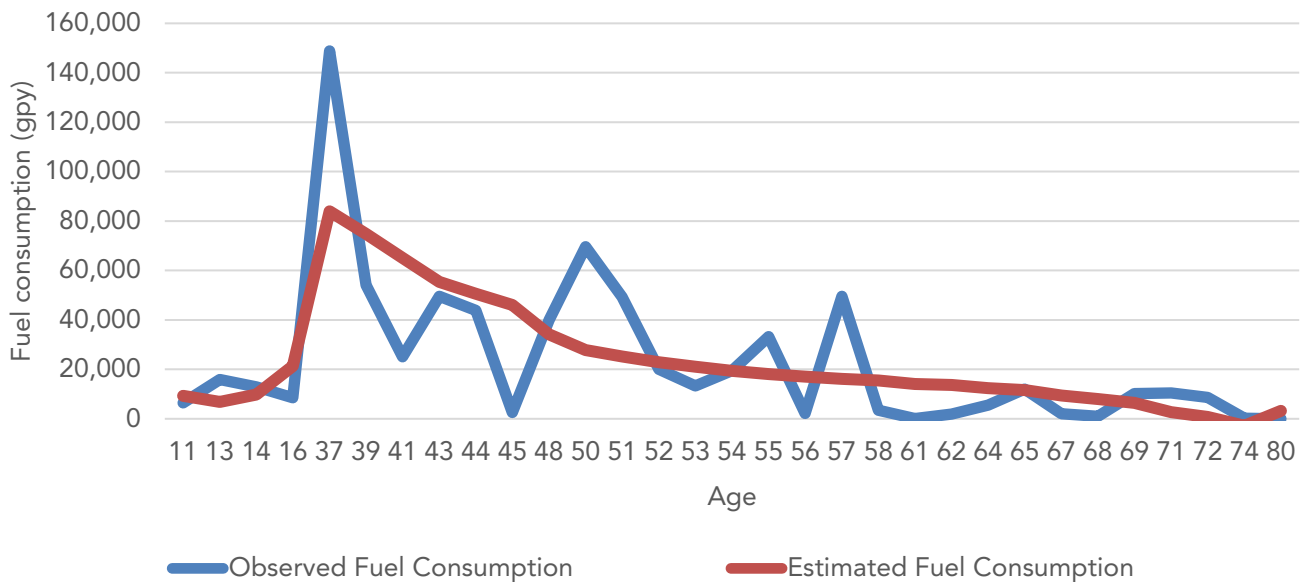
CARB staff replaced missing values with the median fuel consumption for the locomotive cases without model year and fuel usage data because of limited data availability. As shown in Figure 5, the distribution of fuel consumption is highly skewed to the left, suggesting that the average is not the best statistic to represent the whole shape of the fuel usage distribution. Average fuel consumption, 11,000 gpy, could result in overestimated annual fuel usage; therefore, this inventory used a median value, 6,200 gpy (highlighted in red), for missing values.

Figure 5. Histogram of Fuel Consumption in Industrial Locomotive Inventory
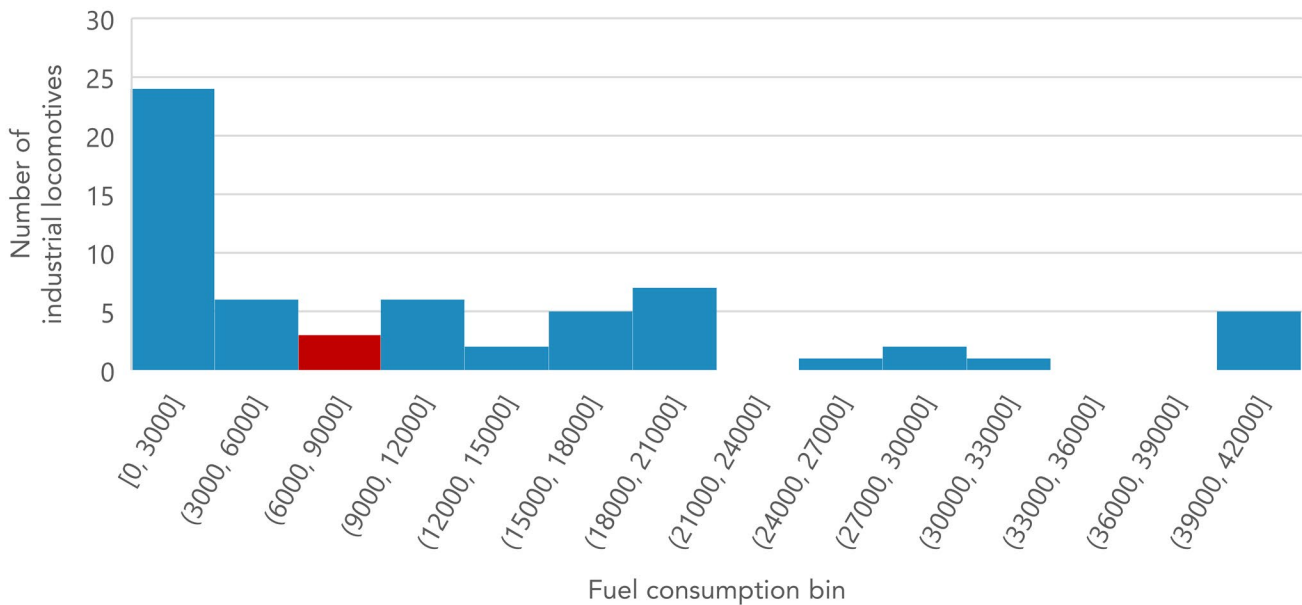
For a similar reason, the estimated fuel consumptions are set to be under the median value. If the fitted function yields a higher fuel consumption value than the median, the missing value was set to the median value.

Emission Factors

The updated emissions inventory model uses the Class I switcher emission factors, by Tier, published by U.S. Environmental Protection Agency (US EPA)[2] as shown in Table 3. This table shows that Tier 4 engines offer significantly lower NOx and diesel PM emission rates than older Tiers.

These values differ from the emissions standards for switcher engines, which set limits. The emission factors represent real-world engine emissions based on testing and certification values.

Table 3. U.S. EPA Switcher Emission Factors for NOx and PM10 in g/bhp-hr

Tier	PM10	NOx
Pre-Tier 0	0.44	17.4
Tier 0	0.44	12.6
Tier 0+	0.23	10.6
Tier 1	0.43	9.9

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2 Emission Factors for Locomotives, United States EPA, December 1997, available at:
https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P1001Z8C.TXT

Tier	PM10	NOx
Tier 1+	0.23	9.9
Tier 2	0.19	7.3
Tier 2+	0.11	7.3
Tier 3	0.08	4.5
Tier 4	0.015	1

Tier Distribution of Locomotives in Source Data

Figure 6 shows the megawatts-hours (MWhs) distribution of military and industrial locomotive Tier groups in California from 2011 to 2019. Military locomotive inventory solely consists of pre-Tier 0 units, while most industrial locomotives are also pre-Tier 0s. Both locomotive inventories have had insignificant fleet turnover between 2011 and 2019.

Figure 6. Megawatt-hours (MWhrs) Distribution of Military and Industrial Locomotive Inventory

Legend:
- Ind - Pre-Tier 0
- Ind - Tier 0+
- Ind - Tier 2
- Ind - Tier 4
- Ind - Tier 2 (Genset)
- Ind - Pre-Tier 0 (Unknown)
- Mil - Pre-Tier 0
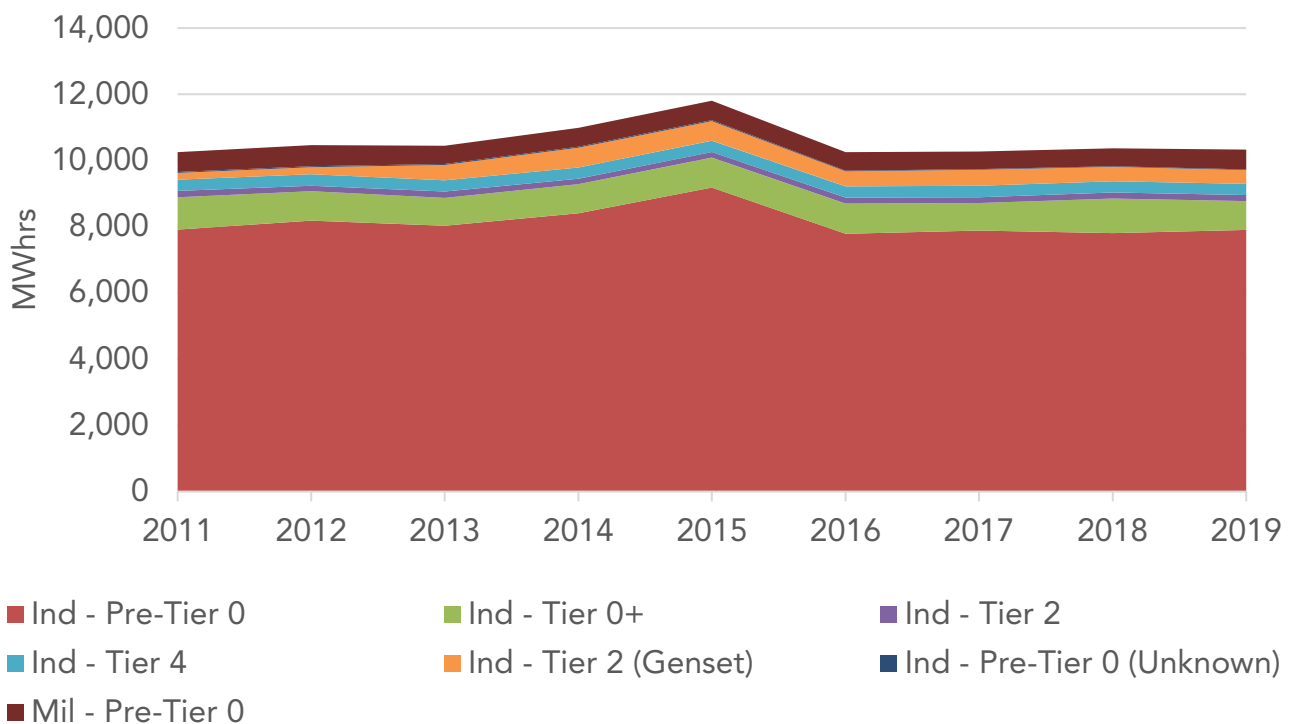
Locomotive Activity Forecast

Activity Growth

Most industrial and military locomotive fleets are significantly smaller than other locomotive categories, and their activities usually focus on operations within facility boundaries.

According to the given inventory data, the average number of industrial locomotives per fleet is 1.85. In addition, M&I locomotive inventory has shown a consistent total activity level and number of operating locomotives over a decade. Therefore, CARB staff assumes that these categories' total number and activity will remain the same in the future, and the activity growth rates are set to zero.

Emissions Results

Table 4 and Table 5 shows statewide NOx and PM projections of of the BAU scenario. Figure 8 and Figure 9 present NOx and PM emissions in tons per day, respectively.
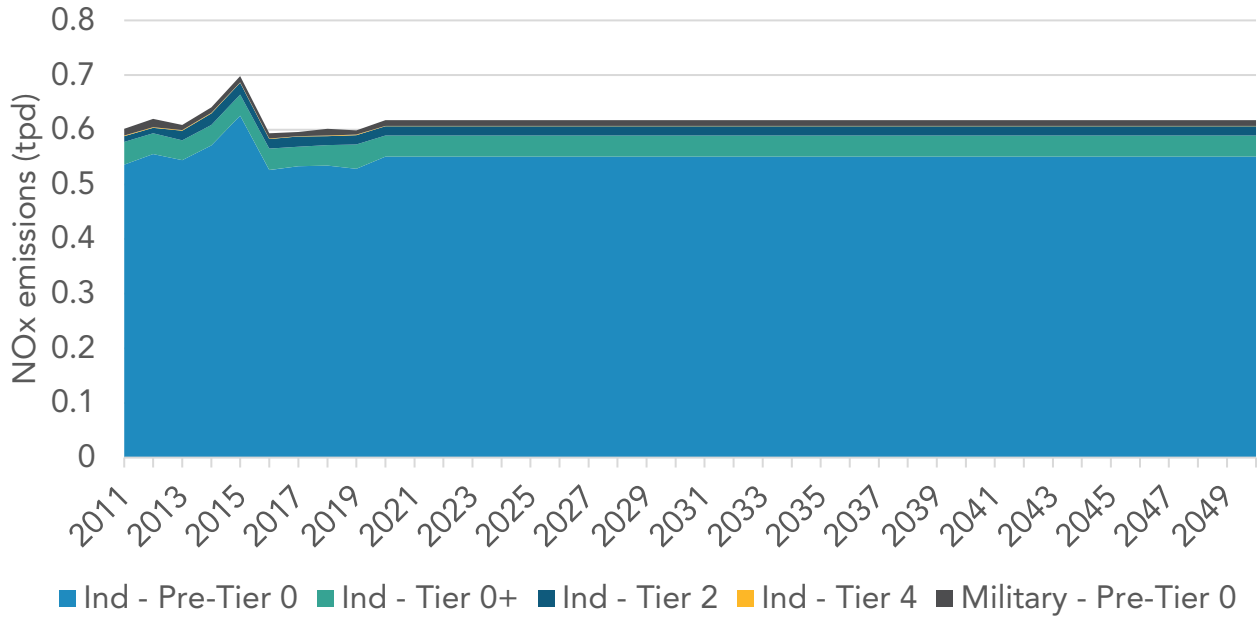
Table 4: Statewide Industrial Locomotive NOx, PM, and CO2 Emissions (tpd)

Year	PM	NOx	CO2
2011	0.0147	0.59	23.17
2012	0.0151	0.60	23.51
2013	0.0150	0.60	23.61
2014	0.0158	0.63	24.86
2015	0.0172	0.69	26.77
2016	0.0146	0.58	23.31
2017	0.0148	0.59	23.44
2018	0.0148	0.59	23.42
2019	0.0148	0.59	23.68
2020-2050	0.0152	0.61	23.98

Table 5: Statewide Military Locomotive NOx and PM Emissions (tpd)

Year	PM	NOx	CO2
2011	0.0003	0.0124	0.48
2012	0.0004	0.0151	0.58
2013	0.0002	0.0092	0.36
2014	0.0003	0.0104	0.40
2015	0.0003	0.0115	0.44
2016	0.0002	0.0094	0.36
2017	0.0002	0.0077	0.30
2018	0.0003	0.0127	0.49
2019	0.0002	0.0078	0.30
2020-2050	0.0003	0.0107	0.41

Figure 7: Military and Industrial Locomotive NOx emissions by Tier

Legend: ■ Ind - Pre-Tier 0 ■ Ind - Tier 0+ ■ Ind - Tier 2 ■ Ind - Tier 4 ■ Military - Pre-Tier 0

Figure 8: Military and Industrial PM emissions by Tier

Legend: ■ Ind - Pre-Tier 0 ■ Ind - Tier 0+ ■ Ind - Tier 2 ■ Ind - Tier 4 ■ Military - Pre-Tier 0