2017 Short line Rail Emissions Model

California Air Resources Board

Off-Road Diesel Analysis Section

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2017 Short line Emissions Model

# Background

The Short line Locomotive Emissions Inventory encompasses all short line rail traffic within the state of California. The Surface Transportation Board characterizes short line railroads as having annual operating revenue less than $36,633,120[[1]](#footnote-1) and are further classified by the Association of American Railroad as local or regional rail lines[[2]](#footnote-2). Local and regional railroads haul freight and provide switching, but report lower revenue than Class I line haul railroads and operate over a much smaller network. Some short line railroads may also offer passenger services.

Table 1.1 lists the 25 short line rail companies operating within California that form this emissions inventory. The rail companies reported the majority of the data. 2015 data was used to establish fuel consumption and 2016 data verified locomotive ID information to create an emissions model spanning 1990 – 2050.

Short line rail companies tend to be small and have no reporting obligations. Detailed recorded information is scarce. They are likely to use very old locomotive engines, with 43 years being the average age of the engines in 2016. The companies also lease and trade engines from other companies, and can struggle to stay in business. This model uses many conservative assumptions since short line companies typically do not make long-range business plans.

Table 1.1 List of California Short Line Railroads

| Arizona and California Railroad |
| --- |
| California Northern Railroad |
| Central California Traction |
| Fillmore and Western Railway |
| Lake County Railroad |
| Modesto Empire and Traction |
| Napa Valley Railroad |
| Northwestern Pacific Railroad |
| Oakland Global Rail Enterprise |
| Pacific Harbor Line  |
| Pacific Sun Railroad |
| Quincy Railroad |
| Richmond Pacific Terminal Railroad |
| Sacramento Valley Railroad |
| San Diego Imperial Valley Railroad |
| San Francisco Bay Railroad |
| San Joaquin Valley Railroad |
| Santa Cruz and Big Trees Railroad |
| Santa Cruz and Monterey Bay Railroad |
| Santa Maria Valley Railroad |
| Sierra Northern Railway |
| Stockton Terminal and Eastern Railroad |
| Trona Railway Company |
| Ventura County Railroad |
| West Isle Line Railroad |

# Data

The rail companies submitted Locomotive ID and fuel consumption data. Locomotive IDs were used to establish Model Year, Tier, and horsepower. The 2015 fuel consumption data was used for fuel projections, although it was incomplete. For those companies lacking fuel data, fuel use was estimated by comparing fuel reported by other companies with the same number of locomotives.

# Activity

Locomotive activity is based on rail company reported fuel consumption data from 2015. Three companies did not provide fuel consumption data, so their fuel was estimated by taking an average of the fuel reported by rail companies with the same number of locomotives. The model assigns fuel as a total per rail company, and not by engine.

The model assumes fuel use is constant. This can be problematic for prior year and future fuel consumption. Fuel consumption history is unavailable and short line companies typically do not have long-term business plans.

# Turnover

While the inventory reports one-third of the engines are Tier 3 or Tier 4, the model assumes no future engine turnover. According to email correspondence with Donald Norton, Director of the California Short Line Railroad Association, short line rail companies do not make long-range business plans. Without government subsidies, price can make it prohibitive to purchase replacement engines. Lack of long-term planning makes it difficult to determine model assumptions. Additionally, there are no indications that any company plans to electrify rail lines.

In establishing the backward projections, Pre-Tier engines replace new Tier 3 and Tier 4 engines. For example, if there is a 2007 engine rated with Tier 3 emissions, the model assumes (by projecting backward) it was a Pre-Tier engine prior to 2007.

# Emissions Factors

The U.S. EPA has an emission factors reference guide where it provides a generalized definition for locomotive emission factors[[3]](#footnote-3). Locomotive engines are separated according to purpose (large line-haul, small line-haul, passenger, and switcher) and tier. Although it is common to use these emission and conversion factors, they are over-simplified when it comes to building an emission inventory.

The inventory expresses emissions in terms of gram of pollutant per gallon of gasoline consumed (g/gal). U.S. EPA line-haul emission factors (Table 5.1), measured in grams per brake horsepower-hour, are multiplied by conversion factors (Table 5.2), measured in break horsepower-hour per gallon fuel. The research report titled “Development of Railroad Emission Inventory Methodologies[[4]](#footnote-4)” provides a better source for emission conversion factors for inventory modeling. These conversion factors are linked directly to the engine, thus they more accurately reflect emissions.

Table 5.1 Line-haul Emission Factors (g/bhp-hr)[[5]](#footnote-5)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **PM10** |  **HC** |  **NOx**  | **CO** |
| Pre-Tier | 0.32 | 0.48 | 13.00 | 1.28 |
| Tier 0 | 0.32 | 0.48 | 8.60 | 1.28 |
| Tier 0+ | 0.20 | 0.30 | 7.20 | 1.28 |
| Tier 1 | 0.32 | 0.47 | 6.70 | 1.28 |
| Tier 1+ | 0.20 | 0.29 | 6.70 | 1.28 |
| Tier 2 | 0.18 | 0.26 | 4.95 | 1.28 |
| Tier 2+ | 0.08 | 0.13 | 4.95 | 1.28 |
| Tier 3 | 0.08 | 0.13 | 4.95 | 1.28 |
| Tier 4 | 0.02 | 0.04 | 1.00 | 1.28 |

Table 5.2 Conversion Factors (bhp-hr/gal)

|  |  |
| --- | --- |
| Pre-Tier, Tier 0 | 15.2 |
| Tier 0+, Tier 1, Tier 1+ | 18.2 |
| Tier 2, Tier 2+, Tier 3, Tier 4 | 20.8 |

For locomotive operations, the emission factor for PM2.5 is 92% of PM10 and the emission factor for PM and PM10 are equivalent. Using factors conventional for diesel fuel, the emission factor for total organic gases (TOG) is 1.44 times the emission factor for hydrocarbons (HC), and the emission factor for reactive organic gases (ROG) is 1.21 times the emission factor for hydrocarbons (HC). The emission factor for NH3 is estimated as 0.0833 g/gal of fuel, independent of tier. CO2 is defined by U.S. EPA as 10,206 g CO2/gal of fuel.

## Sulfur Adjustment Factor

The sulfur content of diesel fuel affects PM emissions. Equation 5.1 provides the U.S. EPA equation to quantify the amount of sulfur that needs to be reduced based on the difference between the default sulfur fuel content and the episodic sulfur fuel content[[6]](#footnote-6).

Equation 5.1 U.S. EPA Sulfur adjustment equation

$$S\_{PM adj}= BSFC\*453.6\*7.0\*soxcnv\*0.01\*(soxbas- soxdsl)$$

where:

BSFC = fuel consumption (lb fuel/hp-hr)

453.6 = conversion from lb to grams

7.0 = grams PM sulfate/grams PM sulfur

soxcnv = grams PM sulfur/grams fuel sulfur consumed

0.01= conversion from percent to fraction

soxbas = default certification fuel sulfur weight percent

soxdsl = episodic fuel sulfur weight percent (specified by user)

The SOx conversion rate (soxcnv) is the amount of sulfur from the diesel fuel that gets converted to PM, specific to an engine’s certification. For engines rated below Tier 4, the SOx conversion rate is 0.02247. The SOx conversion rate for Tier 4 engines is 0.30.

The sulfur PM adjustment is subtracted from the PM emissions in Equation 5.2, which yields the corrected PM emissions.

Equation 5.2 PM adjusted emission calculation

$$PM\_{adj}=PM- S\_{PM adj}$$

## Diesel Fuel Adjustment

California has its own standards for diesel fuel. Known as CARB diesel, it is an ultra-low sulfur diesel fuel that reduces NOx emissions by 6% and PM by 14%[[7]](#footnote-7). Beginning in 2007, ARB regulation required all California locomotives to use CARB diesel with a sulfur fuel content (soxdsl) measuring no more than 500 ppm (parts per million)[[8]](#footnote-8). This was a dramatic reduction from the previous sulfur fuel content of 3000 ppm. In 2012, the sulfur content was further reduced measure less than 15 ppm.

In Equation 6.1, the term soxbas represents the diesel sulfur content that was reported based on the engine certification level. For example, in 2012, the diesel sulfur content is no more than 15ppm (soxdsl), but a Tier 2 engine (2005-2011 model year) has an engine certified for 3000 ppm (soxbas). Thus, Equation 6.1 will make adjustments to reduce the sulfur content.

## SOx Emissions

The U.S. EPA provides a formula[[9]](#footnote-9) for fuel consumption-based formula for SO2 emission in Equation 5.2. This equation makes adjustments according to the fuel’s sulfur content and the engine certification.

Equation 5.3 U.S. EPA SO2 Emission equation

$$SO\_{2}=[BSFC\* 453.6\* (1 - soxcnv) - HC] \* 0.01 \* soxdsl \* 2$$

where:

BSFC = fuel consumption (lb fuel/hp-hr)

453.6 is the conversion factor from pounds to grams

soxcnv is the fraction of fuel sulfur converted to direct PM

HC is the in-use adjusted hydrocarbon emissions in g/hp-hr

0.01 is the conversion factor from weight percent to weight fraction

soxdsl is the episodic weight percent of sulfur in nonroad diesel fuel

2 is the grams of SO2 formed from a gram of sulfur

# Results

The short line rail emission model is created from 25 rail companies, comprising commercial, switching, and recreational rail lines. Short line rail companies tend to be smaller operations, without standard methods for recording data. Also, they do not have long-term business plans, meaning there are no plans for engine replacements or fuel growth in the future. Thus, fuel is held constant and there are no plans for engine turnover or electrification.

The previous Class III model is missing, along with the date of the baseline data, background information, and model assumptions that were used. However, the results are available. Fuel consumption data from 1990 to 2030 and CEPAM pollutant data from 2000 to 2030 were available for comparison. The previous model held fuel consumption constant from 1990 to 2030, and did not distinguish by engine Tier or Air Basin.

Figure 6.1 and Figure 6.2 display statewide locomotive population and fuel consumption, and Figure 6.3 and Figure 6.4 display NOx and PM emissions, by Tier. In addition to the model forecasts, the graphs illuminate differences between the new model results and those from a previous model (the colored line), except when comparing engine population.

The average engine is 43 years old, although about one-third of engines are rated at Tier 3 or Tier 4, as seen in Figure 6.1. This is a combination of new and rebuilt Genset engines.

Figure 6.1 Statewide locomotive population, by Tier

Figure 6.2 Statewide fuel consumption (gallons per year), by Tier

Figure 6.3 Statewide NOx (tons per day), by Tier

The decreases in PM are due to both the fuel sulfur content and the introduction of cleaner engines. In 2007, the sulfur content of fuel drops from 3000 ppm to 500 ppm. Again in 2012, the sulfur content drops to 15 ppm. The emissions calculations makes these adjustments (Equation 5.1 and Equation 5.2).

Figure 6.4 Statewide PM (tons per day), by Tier

Figure 6.5 and Figure 6.6 depict NOx and PM emissions forecasts for the South Coast. There are no previous model results to be used for comparisons here. The previous model does not report any traffic in this air basin, either because this traffic was categorized as switcher traffic or the model was developed before 1998 when Pacific Harbor Line was established. The Pacific Harbor rail line produces all the emissions. They are located at the Ports of Long Beach and Los Angeles, with service beginning in 1998. Emissions decline with the introduction of cleaner Tier 3 and Tier 4 engines, and PM has additional decreases due to the lowered sulfur content of diesel fuel.

Figure 6.5 South Coast NOx (tons per day), by Tier

Figure 6.6 South Coast PM (tons per day), by Tier

In the San Joaquin Valley, Figure 6.7 and Figure 6.9 compare NOx and PM from the previous model. Figure 6.8 and Figure 6.10 are close-up graphs of NOx and PM emissions forecasts. This air basin has fewer new engines than South Coast, and contains the majority of Pre-Tier engines. Here, again, emissions begin to decline with the introduction of cleaner Tier 3 and Tier 4 engines, and PM has additional decreases due to the lowered sulfur content of diesel fuel.

Figure 6.7 San Joaquin Valley NOx (tons per day)

Figure 6.8 SJV NOx Close-up, by Tier

Figure 6.9 San Joaquin Valley PM (tons per day)

Figure 6.10 SJV PM Close-up, by Tier

1. U.S. Surface Transportation Board, https://www.stb.gov/stb/faqs.html [↑](#footnote-ref-1)
2. American Short Line and Regional Railroad Association, https://www.aslrra.org/web/About/Railroad\_Definitions/web/About/Short\_Line\_Definitions.aspx?hkey=f8f1d91d-b99a-4761-8a29-a620f42c16e1 [↑](#footnote-ref-2)
3. Emission Factors for Locomotives, EPA 420-F-09-025, U.S. EPA, April 2009. [↑](#footnote-ref-3)
4. Development of Railroad emission Inventory Methodologies, prepared for Southeastern States Air Resource Managers, Inc., by Sierra Research, Inc. June 2004. P.28. [↑](#footnote-ref-4)
5. Emission Factors for Locomotives, EPA 420-F-09-025, U.S. EPA, April 2009. [↑](#footnote-ref-5)
6. Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression-Ignition, EPA-420-R-10-018, U.S. EPA, July 2010. [↑](#footnote-ref-6)
7. Diesel Fuel Effects on Locomotive Exhaust Emissions, <https://www.arb.ca.gov/fuels/diesel/102000swri_dslemssn.pdf>, 2000. [↑](#footnote-ref-7)
8. Proposed Extension of the California Standards For Motor Vehicle Diesel Fuel to Diesel Fuel Used For Intrastate Diesel-Electric Locomotives and Harborcraft, California Air Resources Board, https://www.arb.ca.gov/regact/carblohc/rfro.pdf, 2004. [↑](#footnote-ref-8)
9. Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression-Ignition, EPA-420-R-10-018, U.S. EPA, July 2010. [↑](#footnote-ref-9)