August 19, 2019

SPECIFICATION SHEET: RAIL 2017 National Emissions Inventory

Description: Nonpoint and Point locomotive (rail) emissions for the 2017 National Emissions Inventory (NEI).

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1. EXECUTIVE SUMMARY

Emissions from diesel railroad locomotives is an emerging issue in urban and regional air quality planning as other emission sectors reduce their impacts. Rail freight operations cover large sections of the country. Additionally, extensive freight, commuter, and intercity passenger rail operations are located in many large urban areas.

There are five distinct components of the 2017 Rail Inventory. The Class I line-haul and Class I yard switching categories were updated using reported 2017 fuel use data, while the data for the remaining rail sectors are based on the information collected for the Collaborative's 2016v1 rail inventory. Table 1 describes the fuel use and emissions totals in more detail below.

Table 1. Summary of ERTAC Rail Inventories: US Locomotive Fuel Use and Emissions for 2017*

Rail Sector	Fuel Use (gal/year)	Emissions (tons/year)						
		NO_x	$PM_{2.5}$	HC	SO_2	CO	NH_3	VOC
Class I Line-Haul	3,314,384,605	492,385	13,979	21,560	343	97,272	304	22,703
Class I Yard Switching	212,092,987	42,462	1,079	2,641	22.4	6,630	19.9	2,781
Non-Class I Yard Switching	11,197,442	2,199	56	137	1.2	343	1.0	144
Class II and III Railroads	151,131,705	36,002	1,019	1,576	15.6	4,435	13.9	1,660
Commuter Railroads	96,175,600	21,388	625	965	9.95	2,823	8.8	1,016
Amtrak	60,545,490	12,226	419	615	6.3	1,777	5.6	648

*2017 fuel use data used for Class I railroads; 2012 estimated and 2017 reported fuel use data used for Class II/III railroads; 2016 estimated and 2016/2017 reported fuel use data used for the Commuter railroads; 2016 reported fuel use data used for Amtrak.

2. INTRODUCTION

This document details the methodology and data sources used for developing the 2017 emission estimates for the nonpoint locomotive (rail) sector. This inventory was developed by LADCO and the State of Illinois, with support from various other states, using the Collaborative's 2016v1 rail inventory as a starting point.

The rail sector includes all locomotives in the NEI nonpoint data category. SCCs are shown in Table 2. This sector excludes railway maintenance activities. Railway maintenance emissions are included in the nonroad sector. The point source yard locomotive emissions are included in the ptnonipm sector. In 2014NEIv2, rail yard locomotive emissions were present in both the nonpoint (rail sector) and point (ptnonipm sector) inventories. For 2017 NEI, rail yard locomotive emissions are only in the point inventory/ptnonipm sector. Therefore, SCC 2285002010 is not present in the 2017NEIv1 rail sector.

Table 2. 2017NEIv2 SCCs for the Rail Sector

SCC	Sector	Description: Mobile Sources prefix for all
2285002006	rail	Railroad Equipment; Diesel; Line Haul Locomotives: Class I Operations
2285002007	rail	Railroad Equipment; Diesel; Line Haul Locomotives: Class II / III Operations
2285002008	rail	Railroad Equipment; Diesel; Line Haul Locomotives: Passenger Trains (Amtrak)
2285002009	rail	Railroad Equipment; Diesel; Line Haul Locomotives: Commuter Lines
2285002010	rail	Railroad Equipment; Diesel; Yard Locomotives
28500201	rail	Internal Combustion Engines Railroad Equipment Diesel Yard (point)

3. INVENTORY DEVELOPMENT METHODS

Class I Line-haul Methodology

For the 2017 rail inventory, the Class I railroads granted ERTAC Rail permission to use the 2016 confidential line-haul activity GIS shapefile maintained by the Federal Railroad Administration (FRA). Class I line-haul activity data was coded into the FRA shapefile at the link-level in units of Millions of Gross Tons per Route Mile (MGT). The 2016 MGT data was reused for the 2017 inventory because FRA's 2017 data would not be available until well after the submittal deadline for version 1 of the 2017 NEI (Figure 1). It is assumed that the relative distribution of MGT traffic density values for 2017 closely matched that for 2016.

Adjusted Rail Fuel Consumption Index (RFCI) values, as described below, were used allocate each Class I railroad's 2017 R-1 fuel use to the shapefile's links based on FRA's 2016 Gross Ton-Mile totals. The Association of American Railroads (AAR) provided ERTAC Rail with updated locomotive fleet mix information for 2017. This allowed ERTAC Rail to calculate 2017 weighted emission factors for each pollutant based on the percentage of the Class I line-haul locomotives in each USEPA Tier level category. These two datasets, along with 2017 Class I line-haul fuel use data reported to the Surface Transportation Board[1] (Table 3), were used to create a link-level Class I emissions inventory, based on a methodology recommended by Sierra Research[2,3]. This link-level inventory is nationwide in extent (Figure 4), but it can be aggregated at either the state or county level. It can also be converted into other formats for use in photochemical and dispersion air quality models.

Table 3. Class I Railroad R-1 Report Line-haul Activity Statistics for 2017[1]

Class I Railroads	2017 R-1 Report Line-haul Gross Ton-Mile and Fuel Use Activity Data		RFCI (ton-miles/gal)	Adjusted RFCI (2016 FRA ton-miles/gal)
	Gross Ton-Miles	Fuel Use (gal)*		
BNSF	1,270,332,339,000	1,322,859,935	960.29	850.1186738
Canadian National	130,733,042,000	110,554,757	1,182.52	997.975075
Canadian Pacific	68,787,636,000	64,373,234	1,068.58	1,260.385922
CSX Transportation	428,879,185,000	392,481,373	1,092.74	1,074.769259
Kansas City Southern	67,085,372,000	66,461,739	1,009.38	907.314292
Norfolk Southern	415,580,691,000	430,036,855	966.38	920.402914
Union Pacific	981,451,930,000	927,616,712	1,058.04	1,062.381747
Totals:	**3,362,850,195,000**	**3,314,384,605**	**1,014.62**	**959.295061**

* Includes work trains; Adjusted RFCI values calculated from FRA gross ton-mile data as described on page 7. The RFCI and Adjusted RFCI totals are ton-mile weighted means.

The Class I line-haul methodology is described in more detail in the three sections listed below.

1. Calculate Class I-Specific Emission Factors

USEPA provides annual default emission factors for locomotives based on operating patterns ("duty cycles") and the estimated nationwide fleet mixes for both switcher and line-haul locomotives[4].   However, Tier-level fleet mixes differ significantly between the Class I and Class II and III railroads. For the 2017 inventory, the AAR provided ERTAC Rail with a national line-haul Tier fleet mix profile representing the entire Class I line-haul locomotive fleet. A locomotive's Tier level determines its allowable emission rates based on the year when it was built and/or re-manufactured. The national fleet mix data was then used to calculate weighted average in-use emissions factors for the line-haul locomotives operated by the Class I railroads (Table 4).
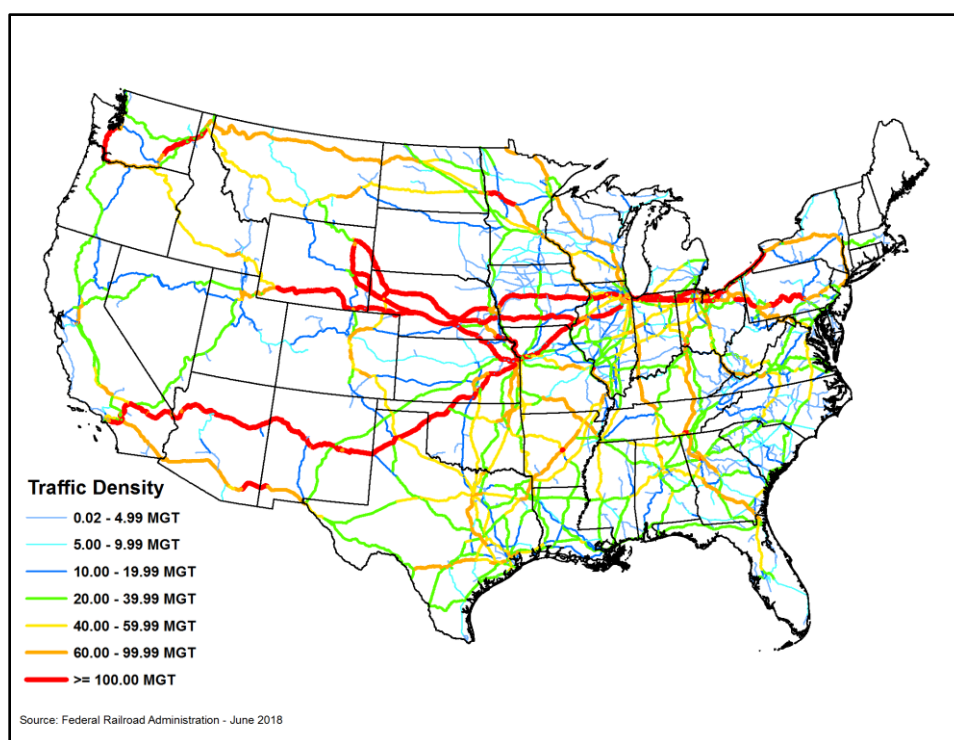

Figure 1. 2016 US Railroad Traffic Density in Millions of Gross Tons per Route Mile (MGT)[5]
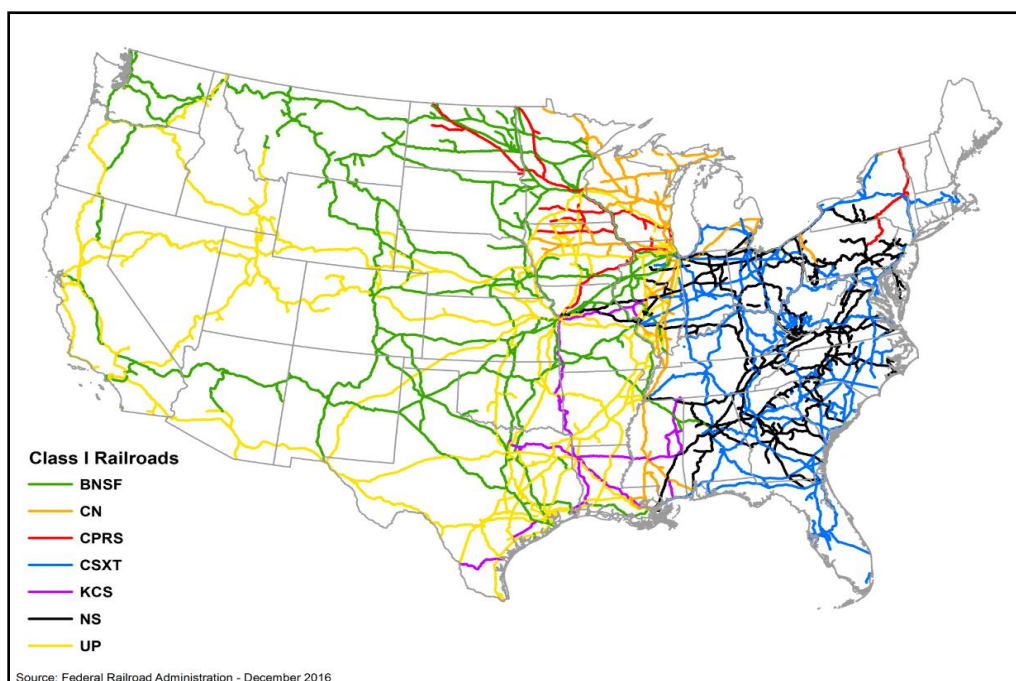
Figure 2. Class I Railroads in the United States[5]

Table 4. 2017 Line-haul Locomotive Emission Factors by Tier, AAR Fleet Mix (grams/gal)[4]

Tier Level	AAR Fleet Mix Ratio	PM$_{10}$	HC	NO$_x$	CO
Uncontrolled (pre-1973)	0.035628	6.656	9.984	270.4	26.624
Tier 0 (1973-2001)	0.170656	6.656	9.984	178.88	26.624
Tier 0+ (Tier 0 rebuilds)	0.151779	4.16	6.24	149.76	26.624
Tier 1 (2002-2004)	0.018282	6.656	9.776	139.36	26.624
Tier 1+ (Tier 1 rebuilds)	0.243995	4.16	6.032	139.36	26.624
Tier 2 (2005-2011)	0.112198	3.744	5.408	102.96	26.624
Tier 2+ (Tier 2 rebuilds)	0.098125	1.664	2.704	102.96	26.624
Tier 3 (2012-2014)	0.123549	1.664	2.704	102.96	26.624
Tier 4 (2015 and later)	0.045789	0.312	0.832	20.8	26.624
2017 Weighted EF's	**1.000000**	**3.944**	**5.901**	**134.770**	**26.624**

Based on values in EPA Technical Highlights: Emission Factors for Locomotives, EPA Office of Transportation and Air Quality, EPA-420-F-09-025, April 2009.

Weighted Emission Factors (EF) per pollutant for each gallon of fuel used (grams/gal or lbs/gal) were calculated for the US Class I locomotive fleet based on the percentage of line-haul locomotives certified at each regulated Tier level (Equation 1; Table 4).

Equation (1) $\quad EF_i = \sum_{T=1}^{9}(EF_{iT} * f_T)$

where:

EF_i	=	Weighted Emission Factor for pollutant i for Class I locomotive fleet (g/gal).
EF_{iT}	=	Emission Factor for pollutant i for locomotives in Tier T (g/gal) (Table LH3).
f_T	=	Percentage of the Class I locomotive fleet in Tier T expressed as a ratio.

While actual engine emissions will vary within Tier level categories, the approach described above likely provides reasonable emission estimates, as locomotive diesel engines are certified to meet or exceed the emission standards for each Tier. It should be noted that actual emission rates may increase over time due to engine wear and degradation of the emissions control systems. In addition, locomotives may be operated in a manner that differs significantly from the conditions used to derive line-haul duty-cycle estimates.

Emission factors for other pollutants are not Tier-specific because these pollutants are not directly regulated by USEPA's locomotive emission standards. $PM_{2.5}$ was assumed to be 97% of PM_{10}[4], the ratio of VOC to HC was assumed to be 1.053, and the emission factors used for SO_2 and NH_3 were 0.093888 g/gal[4] and 83.3 mg/gal[6], respectively. The SO_2 emission factor is based on the nationwide adoption of 15 ppm ultra-low sulfur diesel (ULSD) fuel by the rail industry. Greenhouse gases (GHGs) were estimated using the emission factors shown in Table 5. Note that non-road engine and fuel specific information is sparse for these conversions and that locomotive and marine engines are not subject to general non-road fuel or engine standards.

Table 5. EPA Greenhouse Gas Emission Factors for Locomotive Diesel Fuel (grams/gal)[7]

	CO_2	N_2O	CH_4
Locomotive diesel	1.015E4	0.26	0.80

2. Calculate Class I Railroad-Specific Rail Fuel Consumption Index Values

Railroad Fuel Consumption Index (RFCI) values were calculated for each Class I railroad using the system-wide line-haul fuel consumption (FC) and gross ton-mile (GTM) data reported in their annual R-1 reports submitted to the Surface Transportation Board[1] (Equation 2). These values represent the average number of gross ton-miles produced per gallon of diesel fuel burned by each Class I railroad for a given year. RFCI values vary between Class I railroads

depending on factors such as average locomotive fuel efficiency, severity of grades, and differences in operational practices related to train speed, train tonnage, and traffic mix.

Equation (2) $\quad RFCI_{RR} = \dfrac{GTM_{RR}}{FC_{RR}}$

where:

$RFCI_{RR}$ =   Railroad Fuel Consumption Index (gross ton-miles/gal) per RR.

GTM_{RR} =   Gross Ton-Miles (GTM), annual system-wide gross ton miles of freight transported per RR. (R-1 Report Schedule 755, Line 104)

FC_{RR} =   Annual system-wide fuel consumption by line-haul and work trains per RR (gal). (R-1 Report Schedule 750, Lines 1 and 6).

Due to the complexities involved with coding traffic density MGT data onto the FRA's GIS network, there are discrepancies between the R-1 report GTM totals and the GTM totals obtained from the FRA's GIS data layer for each Class I railroad. These GTM discrepancies in turn cause problems in matching ERTAC Rail's aggregated link-level fuel use estimates for each Class I railroad with their R-1 line-haul fuel use totals. To address this problem, adjusted RFCI values were calculated using the 2016 FRA gross ton-mile totals for each Class I railroad in place of the 2017 R-1 GTM data (Equation 2a). This change ensured that each Class I railroad's line-haul fuel use total matched what was recorded in their 2017 R-1 reports, regardless of any problems with the FRA MGT data. This in turn enabled ERTAC Rail to generate link-level inventories that matched the emissions totals from system-level calculations.

Equation (2a) $\quad RFCI_{RRA} = \dfrac{GTM_{RR-FRA}}{FC_{RR}}$

where:

$RFCI_{RRA}$ =   Adjusted Railroad Fuel Consumption Index (gross ton-miles/gal) per Class I railroad RR.

GTM_{RR-FRA} =   Gross Ton-Miles (GTM), annual system-wide gross ton-miles of freight transported per RR. (FRA 2016 GIS shapefile)

FC_{RR} =   Annual system-wide fuel consumption by line-haul and work trains per RR (gal). (2017 R-1 Reports - Schedule 750, Lines 1 and 6).

3. Calculate Emissions per Link

Emissions of pollutant i per link L (E_{iL}) were calculated using the four-part process described below (Equation 3):

a) The number of gross-ton miles (GTM) for each Class I railroad operating on link L was determined by converting the MGT value to gross tons, dividing the gross tonnage value by the number of Class I railroads operating on the link, then multiplying this final value by the link length in miles.

b) The gross ton-mile value for each railroad operating on the link was then divided by the adjusted RFCI value for that railroad to calculate the number of gallons of diesel fuel used by that railroad on the link.

c) The link-level fuel use value for each railroad was then multiplied by the nationwide Class I line-haul emission factor for pollutant i to determine that railroad's emissions value for the link.

d) The Class I railroad emissions total for the link was calculated by summing all the individual railroad pollutant emission values.

It is important to note that this approach splits the line-haul MGT activity data on each link evenly between all the Class I railroads operating on a specific link. No data is provided in the FRA GIS data layer to apportion MGT traffic density values between multiple railroads operating on the same link.

Equation (3) $$E_{iL} = \sum_{RR=1}^{N} \frac{\left(\dfrac{MGT_L * 10^6}{N} \right) * l_L}{RFCI_{RRA}} * EF_{iRR}$$

where:

E_{iL}	=	Emissions of pollutant i per link L (tons/year).
N	=	Number of Class I railroads operating on link L.
MGT_L	=	Millions of Gross Tons hauled per link per year from the FRA database (10^6 tons/yr)[9].
l_L	=	Link length from the FRA database (miles).
EF_i	=	Weighted Emission Factor for pollutant i per railroad RR (Equation 1; tons/gal).
$RFCI_{RRA}$	=	Adjusted Railroad Fuel Consumption Index per railroad RR (Equation 2a; gross ton-miles/gal).

4. Aggregate Emissions for inclusion into the 2017 NEI

The final link-level emissions for each pollutant were aggregated by state/county FIPS code and then converted into FF10 format text file to allow the data to be imported into the NEI database by USEPA.

Rail Yard Methodology

Early in the project, the group identified that the past methods for locating and calculating activity at yards was flawed. The older method looked at MGT data at locations that were identified as yard links. Later, data showed that the older method resulted in activity at yards that were inactive (i.e., false positives) and missed important yards (i.e., false negatives) that were not identified in the FRA data. It was agreed that past methods needed a significant overhaul to create an acceptable inventory.

The first step was to request that all of the Class I railroads supply fuel use and/or yard switcher locomotive counts for all of the rail yards on their systems. Three railroads provided complete rail yard datasets: BNSF, UP, and KCS. CSX provided switcher counts for its 14 largest rail yards. This reported activity data was matched to existing yard locations and data stored in USEPA's Emissions Inventory System (EIS) database. All existing EIS yards that had activity data assigned for prior years, but no reported activity data for 2016 were zeroed out. New yard data records were generated for reported locations that were not found in EIS. Special care was made to ensure that the new yards added to EIS did not duplicate existing data records. Data for non-Class I yards was carried forward from the 2014 NEI.

Since the railroads only supplied switcher counts, average fuel use per switcher values were calculated for each railroad. This was done by dividing each company's 2017 R-1 yard fuel use total by the number of switchers reported for each railroad[1]. These values were then used to allocate fuel use to each yard based on the number of switchers reported for that location. Table 6 summarizes the 2017 yard fuel use and switcher data for each Class I railroad.

Table 6. Surface Transportation Board R-1 Fuel Use Data - 2017

Railroad	2017 Yard Fuel Use (gal)	Identified Switchers	Per Switcher Fuel Use (gal)
BNSF	43,946,592	437	100,564
CSXT	38,404,906	416.0631579	92,305
CN	6,893,180	103	66,924
KCS	3,143,526	176	17,860
NS	30,730,245	457	67,243
CPRS	1,267,536	70	18,108
UP	87,707,002	1,286	68,201
All Class I's	**212,092,987**	**2,945**	**61,601**

Three railroads did not supply yard specific activity data: CN, CP, and NS. In addition, CSX did not supply a complete set of yard activity data for all of their railroad. After lengthy

discussions, the inventory developers agreed to look at the yards for these four companies with Google Earth and tabulate the number of switchers visible in the aerial photographic imagery. Training materials were produced to help reviewers recognize the different kinds of switching locomotives and slugs. A slug is a locomotive without a diesel engine that generates traction using electrical power from a companion "mother" locomotive. It was important to properly identify slugs so that the final switcher counts for each yard were not artificially inflated. Both CSX and NS have extensive fleets of slugs used in both line-haul and yard switching service, so it was critical that this issue was addressed. A follow up document with more detailed methodologies will act as a companion to this document so future developers can use these methods to identify yard switching activity.

LADCO, Illinois, and Michigan worked together over a series of calls to identify all of the Canadian National and Canadian Pacific yards since these two railroads primarily operate in the LADCO region and adjacent states. For CSX and NS, LADCO solicited assistance from the ERTAC Rail committee. Volunteers were found from Massachusetts, North Carolina, and South Carolina and they reviewed most of the CSX and NS yards in the eastern United States. Training calls and a well-defined data structure ensured that an accurate representation of these two companies' yard activities was collected.

Table 7. 2016 Yard Switcher Emission Factors by Tier, AAR Fleet Mix (grams/gal)[4]

Tier Level	AAR Fleet Mix Ratio	PM_{10}	HC	NO_x	CO
Uncontrolled (pre-1973)	0.2601	6.688	15.352	264.48	27.816
Tier 0 (1973-2001)	0.2361	6.688	15.352	191.52	27.816
Tier 0+ (Tier 0 rebuilds)	0.2599	3.496	8.664	161.12	27.816
Tier 1 (2002-2004)	0.0000	6.536	15.352	150.48	27.816
Tier 1+ (Tier 1 rebuilds)	0.0476	3.496	8.664	150.48	27.816
Tier 2 (2005-2011)	0.0233	2.888	7.752	110.96	27.816
Tier 2+ (Tier 2 rebuilds)	0.0464	1.672	3.952	110.96	27.816
Tier 3 (2012-2014)	0.1018	1.216	3.952	68.4	27.816
Tier 4 (2015 and later)	0.0247	0.228	1.216	15.2	27.816
2016 Weighted EF's	**0.9999**	**4.668**	**11.078**	**178.1195**	**27.813**

Based on values in EPA Technical Highlights: Emission Factors for Locomotives, EPA Office of Transportation and Air Quality, EPA-420-F-09-025, April 2009. AAR fleet mix ratios did not add up to 1.0000, which caused a small error for the CO weighted emission factor as shown above.

After obtaining all of the yard activity data, a spreadsheet was completed that contained all fuel use and emissions calculations for yards. For the 2016 and 2017 yard inventories, the AAR provided ERTAC Rail with national Tier fleet mix profiles representing the entire Class I yard

switching locomotive fleet. After reviewing this data, serious inconsistencies were found in the 2017 fleet mix data. As a result, the 2016 fleet mix data was used to calculate the weighted emissions rates for the 2017 yard inventory (see Table 7). Final emissions calculations were then exported from the spreadsheet to an FF10 file for export to SMOKE and the NEI as necessary. Additional comment fields and action flags were added to help NEI and modeling integrators understand the source of data changes from the 2014 emissions inventory. These flags included: coordinate updates, yard name updates, owner updates, yards permanently closed, duplicate entries, and yards not operated by a Class I railroad. All of the emissions calculations and activity data can be found in the emission calculation sheets available with this documentation. Figure 3 shows the spatial distribution of active yards in the 2016v1 and 2017 NEI inventories.
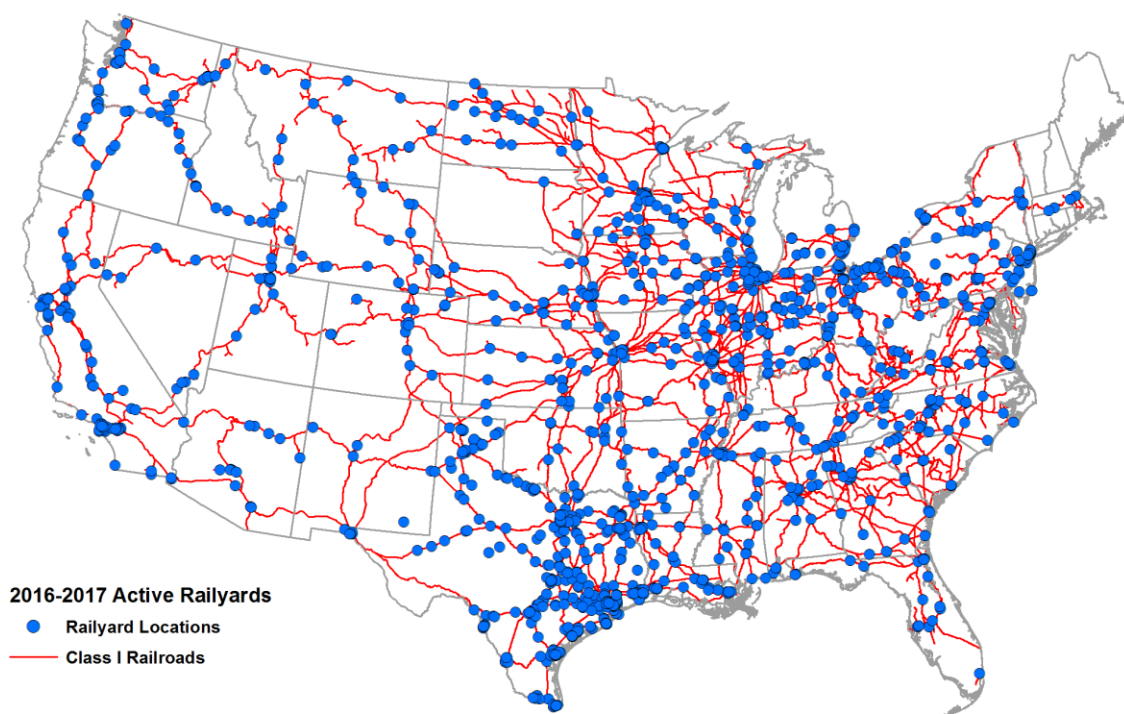
Source: Federal Railroad Administration

Figure 3. 2016-2017 Active Rail Yard Locations in the United States

Class II and III Methodology

There are approximately 560 Class II and III Railroads operating in the United States, most of whom are members of the American Short Line and Regional Railroad Association (ASLRRA)[8]. While there is a lot information about individual Class II and III railroads available online, a significant amount of effort would be required to convert this data into a usable format for the creation of emission inventories. In addition, the Class II and III rail sector has been in a constant state of flux ever since the railroad industry was deregulated under the Staggers Act in 1980. Some states have conducted independent surveys of their Class II and III railroads and produced emission estimates, but no national level emissions inventory existed for this sector of the railroad industry prior to ERTAC Rail's work for the 2008 NEI[9].

Class II and III railroad activities account for nearly 4% of the total locomotive fuel use in the combined ERTAC Rail emission inventories and for approximately 35% of the industry's national freight rail track mileage[5]. These railroads are widely dispersed across the country and often utilize older, higher emitting locomotives than their Class I counterparts. Class II and III railroads provide transportation services to a wide range of industries. Individual railroads in this sector range from small switching operations serving a single industrial plant to large regional railroads that operate hundreds of miles of track.

The ERTAC Rail Class II and III inventory contains a comprehensive nationwide GIS database of locations where short line and regional railroads operate. It also provides a comprehensive spatial allocation of Class II and III locomotive emissions based on the nationwide Class II and III fuel use data reported by the ASLRRA. Figure 4 shows the distribution of Class II and III railroads and commuter railroads across the country. This inventory will be useful for regional and local modeling, helps identify where Class II and III railroads may need to be better characterized, and provides a strong foundation for the future development of a more accurate nationwide short line and regional railroad emissions inventory. The data sources, calculations, and assumptions used to develop the Class II and III inventory are described below.

1. Locate Class II and III Railroads

Identification and correct placement of Class II and III railroads was an important first step, requiring a comprehensive electronic dataset. The FRA GIS data layer used for the Class I inventories also identifies links owned or operated by specific short line or regional railroads using reporting mark identification codes. A complete list of reporting marks is included with the inventory. The locations of these links, along with related data including reporting mark, railroad name, number of links, route miles owned or operated, and total route miles of links, were extracted by ERTAC Rail. While the FRA GIS data layer contains confidential data for the

Class I railroads, the spatial location of Class II and III links and related attribute data are public information. This data is available online as part of Bureau of Transportation Statistics' National Transportation Atlas Database (NTAD)[10].
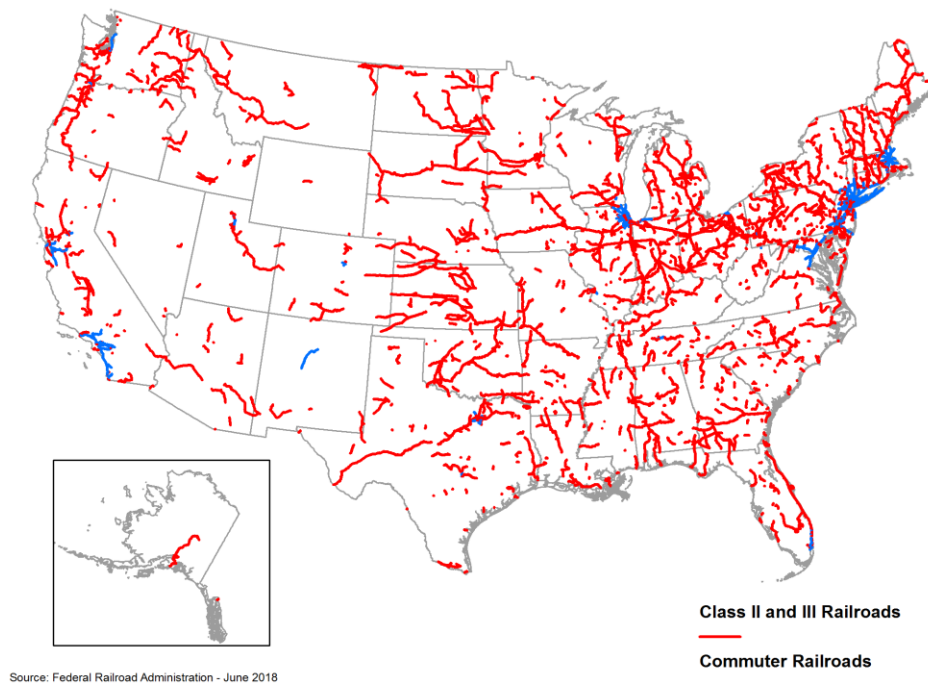

Figure 4. Class II and III Railroads in the United States[5]

2. Select/Calculate Emission Factors

While some Class II and III railroads have purchased brand new locomotives in recent years, most of the locomotives in this sector served for decades in Class I fleets before being sold to a Class II or III railroad. As a result, a large portion of the Class II and III locomotive fleet consists of uncontrolled locomotives built before 1973. To better characterize this rail sector, ERTAC Rail requested that the AAR, through its Railinc subsidiary, provide a national line-haul Tier fleet mix profile for 2016. The national fleet mix data was then used to calculate weighted average in-use emissions factors for the locomotives operated by the Class II and III railroads (Table 8).

Table 8. Class II and III Emission Factors based on a Conversion Factor of 20.8 bhp-hr/gal

Tier Level	Railinc Fleet Mix Ratio	PM_{10}	HC	NO_x	CO
Uncontrolled (pre-1973)	0.484296	6.656	9.984	270.4	26.624
Tier 0 (1973-2001)	0.432286	6.656	9.984	178.88	26.624
Tier 0+ (Tier 0 rebuilds)	0.000000	4.16	6.24	149.76	26.624
Tier 1 (2002-2004)	0.002364	6.656	9.776	139.36	26.624
Tier 1+ (Tier 1 rebuilds)	0.000000	4.16	6.032	139.36	26.624
Tier 2 (2005-2011)	0.034786	3.744	5.408	102.96	26.624
Tier 2+ (Tier 2 rebuilds)	0.000000	1.664	2.704	102.96	26.624
Tier 3 (2012-2014)	0.039514	1.664	2.704	102.96	26.624
Tier 4 (2015 and later)	0.006754	0.312	0.832	20.8	26.624
2016 Weighted EF's	**1.000000**	**6.314**	**9.475**	**216.401**	**26.624**

Based on values in EPA Technical Highlights: Emission Factors for Locomotives, EPA Office of Transportation and Air Quality, EPA-420-F-09-025, April 2009.

Emission factors for $PM_{2.5}$, SO_2, NH_3, VOC, and GHGs were calculated in the same manner as those used for Class I line-haul inventory described above.

3. Calculate Emissions

The ASLRRA collects fuel use data from the Class II and III railroads every two years. ERTAC Rail contacted the ASLRRA and obtained a copy of their 2014 Fact Book[8], which contains fuel use data for 2012. The FRA GIS data layer was used determine the total number of route miles operated by short line and regional railroads in 2016. In addition, railroad-specific fuel use data were provided by Delaware, Maryland, Michigan, New Jersey and the Indiana Harbor Belt Railroad. These datasets were combined to calculate a national average Fuel Use Factor (FUF) for all Class II and III railroads (Equation 4).

Equation (4) $$FUF = \frac{FuelUse_{ASLRRA}}{RouteMiles_{FRA}} = \frac{151,131,705\, gal}{51,379\, miles} = 2,941.5\, \frac{gal}{mile}$$

The Fuel Use Factor of 2,941.5 gallons per mile was multiplied by the number of route miles operated by each Class II and III railroad in each county in the US as coded in the FRA GIS data layer. These county-level fuel use estimates by railroad were then multiplied by the pollutant emission factors to calculate the number of tons of each pollutant emitted by railroad by

county by year. These railroad/county-specific emissions data were then aggregated to produce county, state, and national emission estimates for the entire Class II and III rail sector.

Further modifications were made to the estimates to reflect actual fuel use data collected for specific Class II and III railroads, including entries of '0' for railroads known to have ceased operation. Special coding was implemented in the calculation spreadsheet to balance and renormalize fuel use when company-specific fuel use was added to the calculations. When company-specific fuel was added but it was expected that that company's fuel use was likely not in the ASLRRA's survey, then that company's fuel use was not subtracted from the original total of 148 million gallons[8]. This generally was the case with the large commuter railroads which are not part of ASLRRA. Route mileage for these railroads also needed to be deducted from the grand total of Class II and III route-miles to make the equations above balance. Unfortunately, a small logic error in the fuel use and route mile normalization calculations caused the final Class II and III fuel use to be overestimated by approximately 2 percent. This yielded a final national fuel use total of 151,131,507 gallons versus the ASLRRA's reported fuel use total of 148,000,000 gallons. This problem will be corrected in a future version of the Class II and III inventory.

Commuter Rail Methodology

Commuter rail emissions were calculated in the same way as the Class II and III railroads. The primary difference is that the fuel use estimates were based on data collected by the Federal Transit Administration (FTA) for the National Transit Database[11]. Table 9 lists the commuter railroads reviewed by the FTA and their reported fuel and lube costs. Based on 2016 data collected for Metra, it was assumed that diesel fuel accounted for 95% of the FTA fuel and lube cost totals. 2016 fuel use was then estimated for each of the commuter railroads by multiplying the fuel and lube cost total by 0.95, then dividing the result by Metra's average diesel fuel cost of $1.93/gallon. These fuel use estimates were replaced with reported fuel use statistics for MARC (Maryland), MBTA (Massachusetts), Metra (Illinois), and NJT (New Jersey).

Table 9. Expenditures and Fuel Use for Commuter Rail.

FRA Code	System	Cities Served	Propulsion Type	DOT Fuel & Lube Costs	Reported/Estimated Fuel
ACEX	Altamont Corridor Express (ACE)	San Jose / Stockton	Diesel	$889,828	437,998.24
CMRX	Capital MetroRail	Austin	Diesel	No data	n/a
DART	A-Train	Denton	Diesel	$0	0.00
DRTD	Denver RTD: A&B Lines	Denver	Electric	$0	0.00
JPBX	Caltrain	San Francisco / San Jose	Diesel	$7,002,612	3,446,881.55
LI	MTA Long Island Rail Road	New York	Electric and Diesel	$13,072,158	6,434,481.92
MARC	MARC Train	Baltimore / Washington, D.C.	Diesel and Electric	$4,648,060	***4,235,297.57***
MBTA	MBTA Commuter Rail	Boston / Worcester / Providence	Diesel	$37,653,001	***12,142,826.00***
MNCW	MTA Metro-North Railroad	New York / Yonkers / Stamford	Electric and Diesel	$13,714,839	6,750,827.49
NICD	NICTD South Shore Line	Chicago / South Bend	Electric	$181,264	0.00
NIRC	Metra	Chicago	Diesel and Electric	$52,460,705	***25,757,673.57***
NJT	New Jersey Transit	New York / Newark / Trenton / Philadelphia	Electric and Diesel	$38,400,031	***16,991,164.00***
NMRX	New Mexico Rail Runner Express	Albuquerque / Santa Fe	Diesel	$1,597,302	786,236.74
CFCR	SunRail	Orlando	Diesel	$856,202	421,446.58
MNRX	Northstar Line	Minneapolis	Diesel	$708,855	348,918.26
Not Coded	SMART	San Rafael-Santa Rosa (Opened 2017)	Diesel	n/a	0.00
NRTX	Music City Star	Nashville	Diesel	$456,099	224,504.69
SCAX	Metrolink	Los Angeles / San Bernardino	Diesel	$19,245,255	9,473,052.98
SDNR	NCTD Coaster	San Diego / Oceanside	Diesel	$1,489,990	733,414.77
SDRX	Sounder Commuter Rail	Seattle / Tacoma	Diesel	$1,868,019	919,491.22
SEPA	SEPTA Regional Rail	Philadelphia	Electric	$483,965	0.00
SLE	Shore Line East	New Haven	Diesel	No data	n/a
TCCX	Tri-Rail	Miami / Fort Lauderdale / West Palm Beach	Diesel	$5,166,685	2,543,186.92
TREX	Trinity Railway Express	Dallas / Fort Worth	Diesel	No data	n/a
UTF	UTA FrontRunner	Salt Lake City / Provo	Diesel	$4,044,265	1,990,700.39
VREX	Virginia Railway Express	Washington, D.C.	Diesel	$3,125,912	1,538,661.35
WSTX	Westside Express Service	Beaverton	Diesel	No data	n/a

*Reported fuel use values were used for MARC, MBTA, Metra, and New Jersey Transit.

Fuel use for the commuter railroads was assumed to be separate from the 2012 ASLRRA national fuel use total. Additional code was written into the spreadsheets to segregate the commuter railroads from the Class II and III railroads so that the appropriate SCC codes could be entered into the emissions calculation sheet. The spreadsheets were also modified to generate FF10 county-level inventories for all of the commuter railroads in the country.

Intercity Passenger Methodology (Amtrak)

2016 marked the first time that a nationwide intercity passenger rail emissions inventory was created for Amtrak. The calculation methodology mimics that used for the Class II and III and commuter railroads with a few modifications. Since link-level activity data for Amtrak was unavailable, the default assumption was made to evenly distribute Amtrak's 2016 reported fuel use across all of it diesel-powered route-miles (Figure 5). Participating states were instructed that they could alter the fuel use distribution within their jurisdictions by analyzing Amtrak's 2016 national timetable and calculating passenger train-miles for each affected route. Illinois and Connecticut chose to do this and were able to derive activity-based fuel use numbers for their states based on Amtrak's 2016 reported average fuel use of 2.2 gallons per passenger train-mile. In addition, Connecticut provided supplemental data for selected counties in Massachusetts, New Hampshire, and Vermont.

Amtrak Diesel Passenger Routes

Source: Federal Railroad Administration - June 2018

Figure 5. Amtrak Routes with Diesel-powered Passenger Trains

Amtrak also submitted company-specific fleet mix information and company-specific weighted emission factors was derived. Amtrak's emission rates were 25% lower than the default Class II and III and commuter railroad emission rate. The default and company-specific fleet mix values for non-Class I railroads are listed in Table 10. The resultant weighted emission factors in lbs/gallon are listed in Table 11.

Table 10. Fleet Mix Fractions for Default and Company-specific Locomotive Fleets

OWNER	UNCONTROLLED	TIER 0	TIER 0+	TIER 1	TIER 1+	TIER 2	TIER 2+	TIER 3	TIER 4
Class2/3	0.484296	0.432286	0.0000	0.002364	0.0000	0.034786	0.0000	0.039514	0.006754
Amtrak	0.070900	0.85430	0.0748	0.00000	0.0000	0.00000	0.0000	0.00000	0.00000
CSAO	0.3419	0.3759	0.2024	0.0000	0.0003	0.0345	0.0030	0.0421	0.0000
METRA	0.0460	0.2810	0.4970	0.1760	0.0000	0.0000	0.0000	0.0000	0.0000

Table 11. Default and Company-specific Weighted Emission Rates (lbs/gallon)

EF Group	Weighted CO EF	Weighted VOC EF	Weighted NOx EF	Weighted PM10 EF	Weighted PM25 EF	Weighted NH3 EF	Weighted SO2 EF
default	0.058696	0.021996	0.477082	0.013921	0.013504	0.000184	0.000207
UNCONT	0.058696	0.023178	0.596130	0.014674	0.014234	0.000184	0.000207
Amtrak	0.058696	0.022527	0.403866	0.014262	0.013834	0.000184	0.000207
CSAO	0.058702	0.020289	0.437043	0.012842	0.012457	0.000184	0.000207
METRA	0.058696	0.018773	0.356403	0.011939	0.011581	0.000184	0.000207

Rail Inventory Methodology References

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