May 6, 2020

SPECIFICATION SHEET: RAIL 2016v1 Platform

Description: Nonpoint and Point locomotive (rail) emissions, for simulating 2016 U.S. air quality

1. EXECUTIVE SUMMARY

Emissions from diesel railroad locomotives are 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. In the emissions modeling platform, locomotive emissions are found in two sectors: line haul locomotive emissions are in the rail sector, and yard locomotive emissions are part of the ptnonipm sector.

The 2016 inventory includes national emissions data for the commuter and intercity passenger rail sectors for the first time. The 2016 inventory also saw the use of Google Earth imagery to identify yard activity based on switcher counts. There are five distinct components of the 2016 Rail Inventory based on source classification codes, with Class I line-haul comprising over 80% of national rail emissions. Base year inventories were processed with the Sparse Matrix Operating Kernel Emissions (SMOKE) modeling system version 4.7. SMOKE creates emissions in a format that can be input into air quality models. National and state-level emission summaries for key pollutants are provided.

2. INTRODUCTION

This document details the approach and data sources to be used for developing 2016 emissions for the nonpoint locomotive (rail) sector. The 2016 version 1 (v1) platform uses a rail inventory developed by the Lake Michigan Air Directors Consortium (LADCO) and the State of Illinois with support from various other states.

The rail sector includes all locomotive emissionss in the NEI nonpoint data category. Table 1 summarizes the national fuel use and emissions totals for the 2016v1 inventory. The 2016v1 inventory source classification codes (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 locomotives 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 the 2016v1 platform, rail yard locomotive emissions are only in the point inventory / ptnonipm sector. Therefore, SCC 2285002010 is not present in the 2016v1 platform rail sector, except in three California counties. The California Air Resources Board (CARB) submitted rail emissions, including rail yards, for 2016v1 platform. In three counties, CARB's rail yard emissions could not be mapped to point source rail yards, and as a result, those counties' emissions were included in the rail sector.

Table 1. Summary of Rail Inventories: US Locomotive Emissions and Fuel Use for 2016*

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	3,203,595,133	489,562	14,102	21,727	332	94,020	294	22,879
Class I Yard Switching	208,604,291	40,958	1,041	2,547	21.6	6,396	19.2	2,682
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

*2016 fuel use data used for Class I railroads and Amtrak; 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.

Table 2. 2016v1 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 (nonpoint)
28500201	rail	Railroad Equipment; Diesel; Yard Locomotives (point)

3. Inventory Development Methods

Class I Line-haul Methodology

In 2008, air quality planners in the eastern US formed the Eastern Technical Advisory Committee (ERTAC) for solving persistent emissions inventory issues. This work is the fourth inventory created by the ERTAC rail group, which in this case was working as one of the 2016v1 Inventory Collaborative workgroups. For the 2016 inventory, the Class I railroads granted ERTAC Rail permission to use the confidential link-level line-haul activity GIS data layer maintained by the Federal Railroad Administration (FRA). In addition, the Association of American Railroads (AAR) provided national emission tier fleet mix information. This allowed the workgroup to calculate 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 2016 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]. Note: reference sources in this document are indicated with superscript notations such as the 1, 2, and 3 in the preceding sentence. The expanded version of each reference is provided at the end of Section 3 of this document under the heading "Rail Inventory Methodology References".

Rail Fuel Consumption Index (RFCI) is a measure of fuel use per ton mile of freight. This link-level inventory is nationwide in extent (Figure 1), 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. The Class I line-haul methodology is described in more detail in the three sections that follow.

Table 3. Class I Railroad Reported Locomotive Fuel Use Statistics for 2016

Class I Railroads	2016 R-1 Reported Locomotive Fuel Use (gal/year)		RFCI (ton-miles/gal)	Adjusted RFCI (ton-miles/gal)
	Line-Haul*	Switcher		
BNSF	1,243,366,255	40,279,454	972	904
Canadian National	102,019,995	6,570,898	1,164	1,081
Canadian Pacific	56,163,697	1,311,135	1,123	1,445
CSX Transportation	404,147,932	39,364,896	1,072	1,044
Kansas City Southern	60,634,689	3,211,538	989	995
Norfolk Southern	437,110,632	28,595,955	920	906
Union Pacific	900,151,933	85,057,080	1,042	1,095
Totals:	**3,203,595,133**	**204,390,956**	**1,006**	**993**

* Includes work trains; Adjusted RFCI values calculated from FRA gross ton-mile data as described on page 7. RFCI total is ton-mile weighted mean.

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 vary significantly between the Class I and Class II/III railroads. As can be seen in Figure 2, Class I railroad activity is highly regionalized in nature and is subject to variations in terrain across the country which can have a significant impact on fuel efficiency and overall fuel consumption.

For the 2016 inventory, the AAR provided a national line-haul Tier fleet mix profile representing the entire Class I 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).

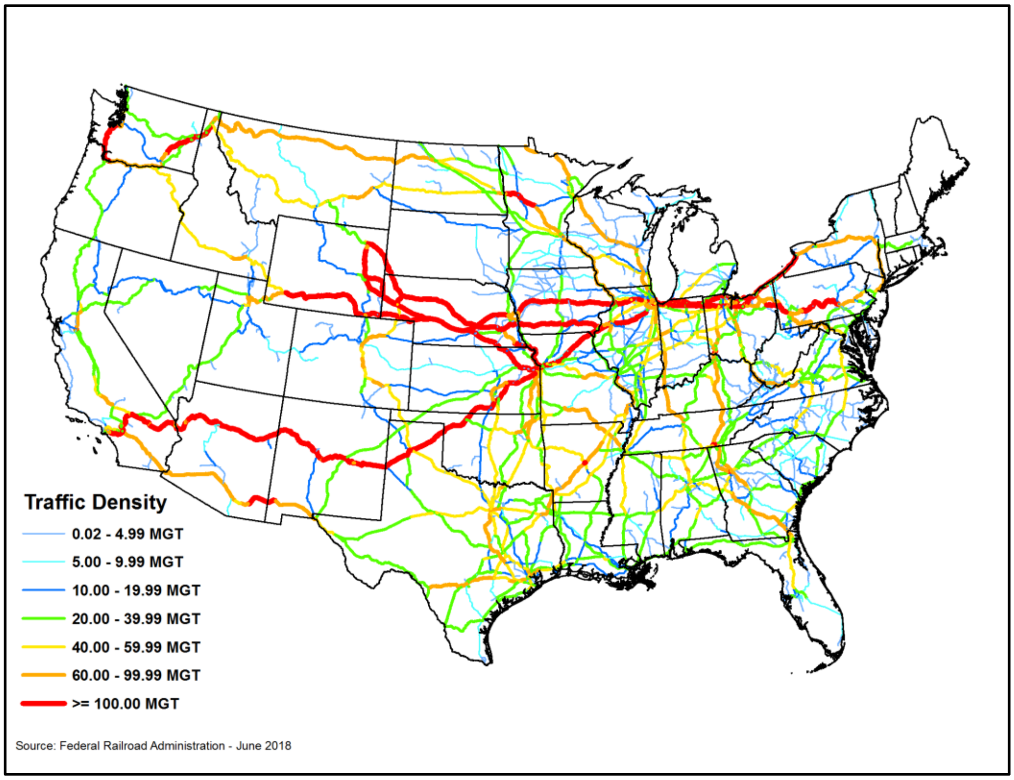

Figure 1. 2016 US Railroad Traffic Density in Millions of Gross Tons per Route Mile (MGT)[5]

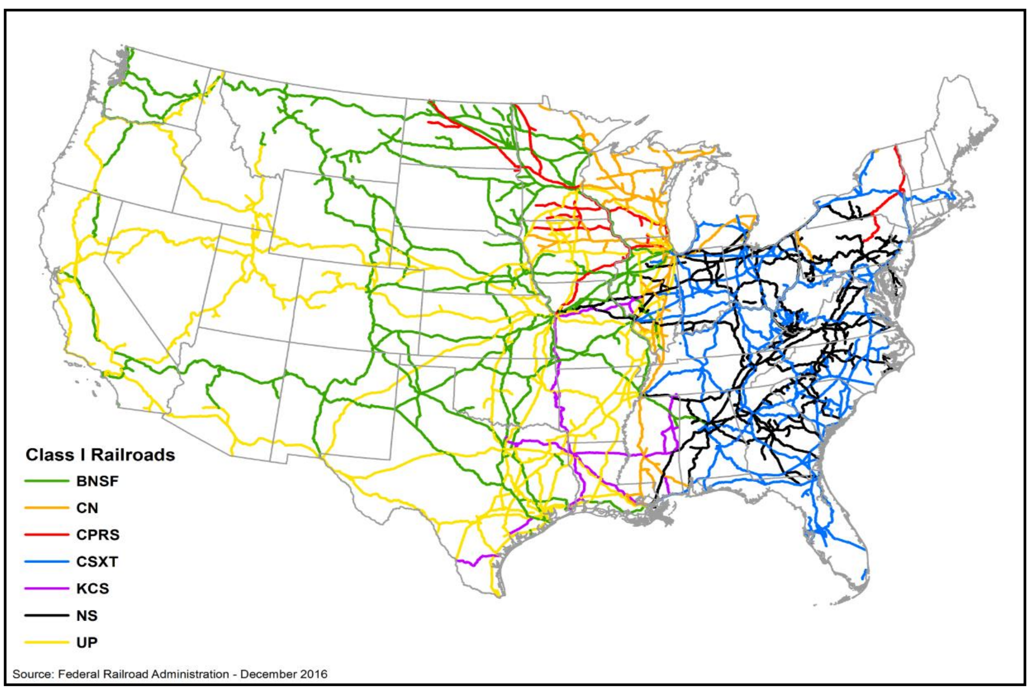

Figure 2. Class I Railroads in the United States[5]

Table 4. 2016 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)	0.047494	6.656	9.984	270.4	26.624
Tier 0 (1973-2001)	0.188077	6.656	9.984	178.88	26.624
Tier 0+ (Tier 0 rebuilds)	0.141662	4.16	6.24	149.76	26.624
Tier 1 (2002-2004)	0.029376	6.656	9.776	139.36	26.624
Tier 1+ (Tier 1 rebuilds)	0.223147	4.16	6.032	139.36	26.624
Tier 2 (2005-2011)	0.124536	3.744	5.408	102.96	26.624
Tier 2+ (Tier 2 rebuilds)	0.093607	1.664	2.704	102.96	26.624
Tier 3 (2012-2014)	0.123113	1.664	2.704	102.96	26.624
Tier 4 (2015 and later)	0.028988	0.312	0.832	20.8	26.624
2016 Weighted EF's	**1.000000**	**4.117**	**6.153**	**138.631**	**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) $$EF_i = \sum_{T=1}^{9} (EF_{iT} * f_T)$$

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 4).
- 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 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 volatile organic carbon (VOC) to (hydrocarbon) HC was assumed to be 1.053, and the emission factors used for sulfur dioxide (SO_2)and ammonia (NH_3)were 0.0939 g/gal[4] and 83.3 mg/gal[6], respectively. The 2016 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 train type mix (e.g., intermodal, unit, and manifest).

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

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 FRA gross ton-mile totals for each Class I railroad in place of the 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 R-1 reports, regardless of any problems with the FRA MGT data. This in turn enabled the workgroup to generate link-level inventories that matched the emissions totals from system-level calculations.

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

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 network)
- 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).

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

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_{iRR} = 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 2016v1 inventory

The final link-level emissions for each pollutant were aggregated by state/county FIPS code and then converted into an FF10 format text file to allow the data to be imported into the 2016v1 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 2016 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 2016 yard fuel use and switcher data for each Class I railroad. As can be seen, fuel calculation errors exist in the data for BNSF, CSX, and NS. These errors should be corrected in future inventories.

Table 6. Surface Transportation Board R-1 Fuel Use Data - 2016

Railroad	2016 R-1 Yard Fuel Use (gal)	Calculated Fuel Use (gal)	Identified Switchers	per Switcher Fuel Use (gal)
BNSF	40,279,454	40,740,317	442	92,173
CSXT	39,364,896	43,054,795	455	94,626
CN	6,570,898	6,570,898	103	63,795
KCS	3,211,538	3,211,538	176	18,247
NS	28,595,955	28,658,528	458	62,573
CPRS	1,311,135	1,311,135	70	18,731
UP	85,057,080	85,057,080	1286	66,141
All Class I's	**204,390,956**	**208,604,291**	**2,990**	**69,767**

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.

In addition to the Class I rail yards, the workgroup also calculated emission estimates for four large Class III railroad hump yards which are among the largest classification facilities in the United States. These four yards are located in Chicago (Belt Railway of Chicago-Clearing and Indiana Harbor Belt-Blue Island) and Metro-East St. Louis (Alton & Southern-Gateway and Terminal Railroad Association of St. Louis-Madison). ERTAC Rail was able to get a switcher count from Union Pacific for the Alton & Southern's Gateway Yard. Fuel use estimates for the other three yards were calculated using Google Earth switchers counts and a 2016 Class I average annual switcher fuel use of 40,731.56 gallons. This switcher fuel use average was determined by taking the 2016 R-1 yard switching fuel use total of 204,390,956 gallons and dividing it by the AAR's 2016 Class I fleet mix switcher count of 5,018 locomotives.

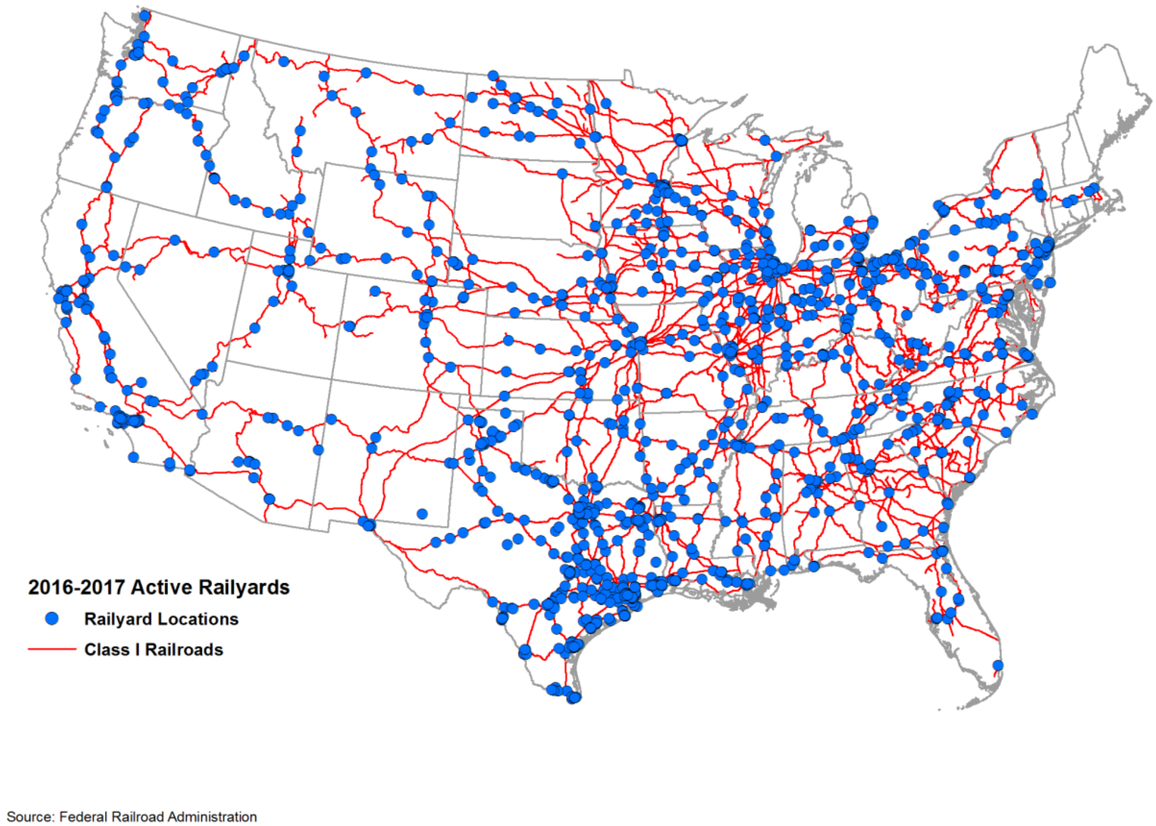

Figure 3. 2016-2017 Active Rail Yard Locations in the United States

After obtaining all the yard activity data, a spreadsheet was compiled that contained all fuel use and emissions calculations for yards. For the 2016 yard inventory, the AAR provided ERTAC Rail with national Tier fleet mix profiles representing the entire Class I yard switching locomotive fleet. The 2016 fleet mix data was used to calculate the weighted emissions rates for the 2016 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. 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. **Error! Reference source not found.** shows the spatial distribution of active yards in the 2016v1 and 2017 NEI inventories.

Class II and III Methodology

There are approximately 560 Class II and III Railroads operating in the United States, most of which 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 group'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 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 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. **Error! Reference source not found.** 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.

<u>1. Locate Class II and III Railroads</u>

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].

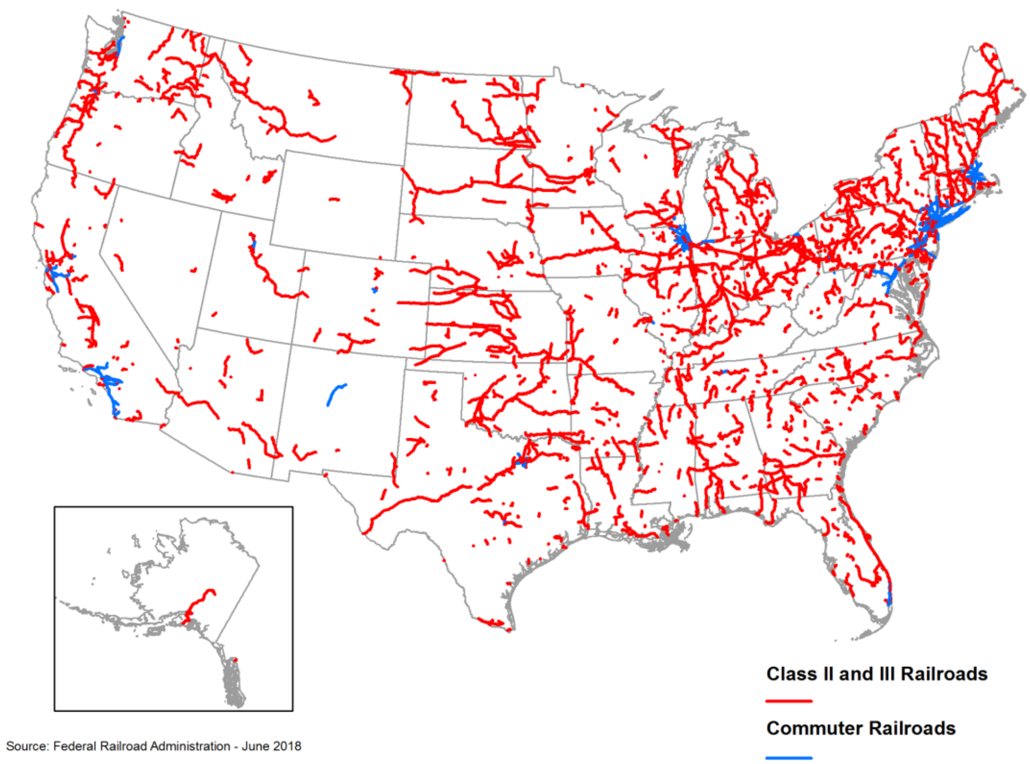

Figure 4. Class II and III Railroads in the United States[5]

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 to 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 Use (gal)
ACEX	Altamont Corridor Express	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***

FRA Code	System	Cities Served	Propulsion Type	DOT Fuel & Lube Costs	Reported/Estimated Fuel Use (gal)
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	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 and are shown in bold, underlined, italics .

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.

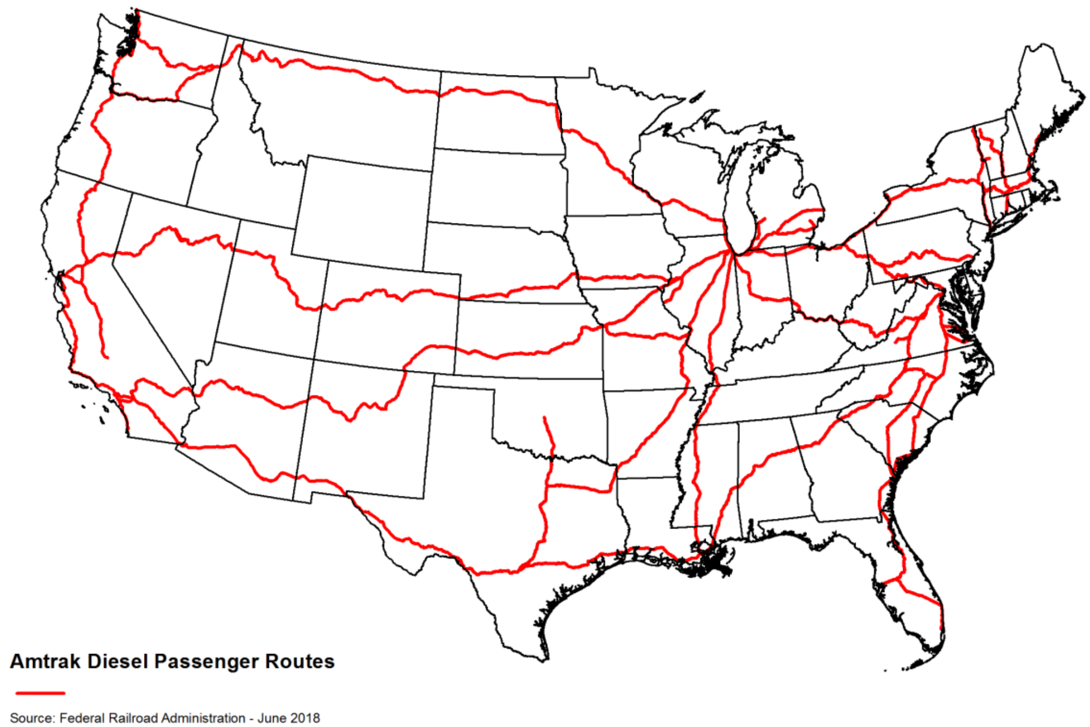

Figure 5. Amtrak Routes with Diesel-powered Passenger Trains

Amtrak also submitted company-specific fleet mix information and company-specific weighted emission factors were 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
Default Class II/III	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

Other Data Sources

The California Air Resources Board (CARB) provided rail inventories for inclusion in the 2016v1 platform. CARB's rail inventories were used in California, in place of the national dataset described above. For rail yards, the national point source rail yard dataset was used to allocate CARB-submitted rail yard emissions to point sources where possible. That is, for each California county with at least one rail yard in the national dataset, the emissions in the national rail yard dataset were adjusted so that county total rail yard emissions matched the CARB dataset. In other words, 2016v1 platform includes county total rail yard emissions from CARB, but the locations of rail yards are based on the national methodology. There are three counties with CARB-submitted rail yard emissions, but no rail yard locations in the national dataset; for those counties, the rail yard emissions were included in the rail sector using SCC 2285002010.

North Carolina separately provided passenger train (SCC 2285002008) emissions for use in the platform. We used NC's passenger train emissions instead of the corresponding emissions from the LADCO dataset.

None of these rail inventory sources included hazardous air pollutants (HAPs). For VOC speciation, the EPA preferred augmenting the inventory with HAPs and using those HAPs for integration, rather than running the sector as a no-integrate sector. So, Naphthalene, Benzene, Acetaldehyde, Formaldehyde, and Methanol (NBAFM) emissions were added to all rail inventories, including the California inventory, using the same augmentation factors as are used to augment HAPs in the NEI.

Rail Inventory Methodology References

1. STB R-1 reports. Available at: http://www.stb.dot.gov/stb/industry/econ_reports.html
2. "Revised Inventory Guidance for Locomotive Emissions"; Report No. SR2004-06-01. Prepared for Southeastern States Air Resource Managers (SESARM) by Sierra Research Inc. June 2004.
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4. "EPA Technical Highlights: Emission Factors for Locomotives", EPA Office of Transportation and Air Quality, EPA-420-F-09-025, April 2009. Available at: https://nepis.epa.gov
5. Confidential 2016 Class I railroad traffic density GIS shapefile provided by Raquel Wright of the Federal Railroad Administration.
6. "Estimating Ammonia Emissions from Anthropogenic Nonagricultural Sources", Draft Final Report. Prepared for EPA/STAPPA-ALAPCO Emission Inventory Improvement Program by E.H. Pechan & Assoc. April 2004. Supported by personal communication (5/6/2010) with Craig Harvey, US EPA, Office of Transportation and Air Quality (OTAQ), and Robert Wooten, NC DENR. Available at: http://www.epa.gov/sites/production/files/2015-08/documents/eiip_areasourcesnh3.pdf
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11. National Transit Database: Transit Operating Expenses. Available at: https://www.transit.dot.gov/ntd/data-product/2016-operating-expenses

4. ANCILLARY DATA

Spatial Allocation

Spatial allocation of rail emissions to the national 12km domain used for air quality modeling is accomplished using spatial surrogates. Spatial surrogates map county polygons to the uniformly spaced grid cells of a modeling domain. The rail sector uses spatial surrogates based on railroad density. The source of this data is an older version of the FRA database of link level activity but was simplified to protect the original FRA confidential link level activity data. Reports summarizing total emissions by spatial surrogate at the state and county level are included in the emissions modeling workgroup reports package. National emissions by spatial surrogate are provided in Table 2.

Table 12. 2016v1 rail emissions by spatial surrogate (36US3 domain; tons/year)

Srg	Description	CO	NH3	NOX	PM10	PM2.5	SO2	VOC
261	NTAD Total Railroad Density	4,657	15	33,822	1,084	1,051	16	1,626
271	NTAD Class 1 2 3 Railroad Density	98,224	307	523,394	15,528	15,063	346	24,365

Temporal Allocation

A monthly temporal profile for freight rail was developed from AAR data for the year 2016: https://www.aar.org/data-center/rail-traffic-data/, Monthly Rail Traffic Data, Total Carloads & Intermodal. The 2016 alpha platform used a similar profile based on data for the year 2014. Passenger trains use a flat monthly profile. Monthly passenger miles data are available; however, it is not known if there is a correlation between passenger miles and actual rail emissions. This is because passenger trains often operate on a fixed schedule, independent of actual passenger traffic. So, it was decided to not apply a monthly profile to passenger train emissions. All sources in the rail sector use a flat profile for both day-of-week and hour-of-day temporal allocation.

Reports summarizing total emissions according to the monthly, day-of-week, and hour-of-day temporal profile assignments are included in the emissions modeling workgroup reports package at the state and county level. A national report of emissions by monthly profile is in Table 7.

Table 7. 2016v1 rail emissions by monthly profile (tons/yr)

Profile	CO	NH3	NOX	PM10	PM2.5	SO2	VOC
262	4,657	15	33,822	1,084	1,051	16	1,626
RAILF16	98,272	307	523,776	15,540	15,074	347	24,382

Chemical Speciation

The rail sector includes speciation of PM2.5 and VOC emissions. All VOC speciation in this sector employs NBAFM integration. All rail PM2.5 emissions use speciation profile 91106 (HDDV exhaust). All rail VOC emissions use speciation profile 8774 (diesel exhaust). NO_x is speciated to HONO (0.8%), NO (90%), and NO_2 (9.2%) for all rail sources nationwide. Table 14 shows the profiles used for VOC and PM emissions

Table 14. VOC and PM Speciation Profiles.

VOC profile 8774 (entire rail sector; 100% integrate)

CB Species	NONHAPTOG	molec wt
ALDX	0.0242	42.5375
ETH	0.2484	28.0532
ETHA	0.0224	30.069
ETHY	0.0812	26.0373
IOLE	0.0293	55.207
ISOP	0.001858	68.117
KET	0.009095	18.0264
OLE	0.0977	28.1488
PAR	0.3928	14.4819
PRPA	0.027	44.0956
SOAALK	0.2064	89.3857
TERP	0.001443	136.234
TOL	0.0339	94.9032
UNR	0.001482	14.4463
XYLMN	0.0291	106.2893

PM 2.5 profile 91106 (entire rail sector)

CB Species	Mass Fraction
PCA	0.000583
PCL	0.000205
PEC	0.7712
PFE	0.000262
PK	0.000038
PMOTHR	0.004091
PNCOM	0.0439
PNO3	0.001141
POC	0.1756
PSO4	0.00295
PTI	0.000004

5. Emissions Projection Methods

Class I Line-haul Emission Projections

Fuel Use Projections

Future year fuel use values for 2020, 2023, and 2028 were based on the Energy Information Administration's 2018 Annual Energy Outlook (AEO) freight rail energy use growth rate projections for 2016 thru 2028 (see Table 15).

A correction factor was added to adjust the AEO projected fuel use for 2017 to match the actual 2017 R-1 fuel use data. The additive effect of this correction factor was carried forward for each subsequent year from 2018 thru 2028 (see Figure 6).

The modified AEO growth rates were used to calculate future year Class I line-haul fuel use totals for 2020, 2023, and 2028 (see Figure 7) The future year fuel use values ranged between 3.2 and 3.4 billion gallons, which matched up well with the long-term line-haul fuel use trend between 2005 and 2018 (see Figure 8).

Table 15. ERTAC Class I Line-haul Fuel Projections 2016-2028, based on 2018 AEO Data

Year	AEO Freight Factor	ERTAC Factor	Corrected AEO Fuel	Raw AEO Fuel
2016	1	1	**3,203,595,133**	**3,203,595,133**
2017	1.0212	1.0346	**3,314,384,605**	3,271,393,249
2018	1.0177	1.0311	*3,303,215,591*	3,260,224,235
2019	1.0092	1.0226	*3,275,939,538*	3,232,948,182
2020	1.0128	1.0262	*3,287,479,935*	3,244,488,580
2021	1.0100	1.0235	*3,278,759,301*	3,235,767,945
2022	0.9955	1.0090	*3,232,267,591*	3,189,276,235
2023	0.9969	1.0103	*3,236,531,624*	3,193,540,268
2024	1.0221	1.0355	*3,317,383,183*	3,274,391,827
2025	1.0355	1.0489	*3,360,367,382*	3,317,376,026
2026	1.0410	1.0544	*3,377,946,201*	3,334,954,845
2027	1.0419	1.0553	*3,380,697,189*	3,337,705,833
2028	1.0356	1.0490	*3,360,491,175*	3,317,499,820

Source: https://www.eia.gov/outlooks/aeo/data/browser/#/?id=45-AEO2018&sourcekey=0

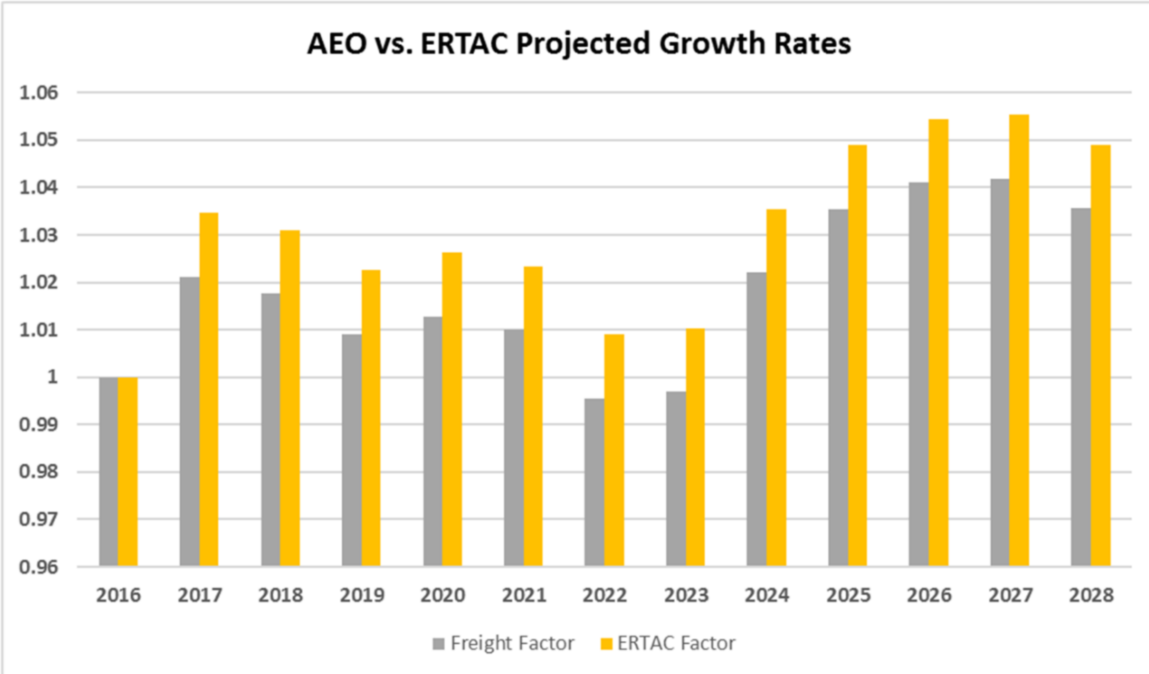

Figure 6. ERTAC Rail versus 2018 AEO Freight Rail Projected Growth Rates

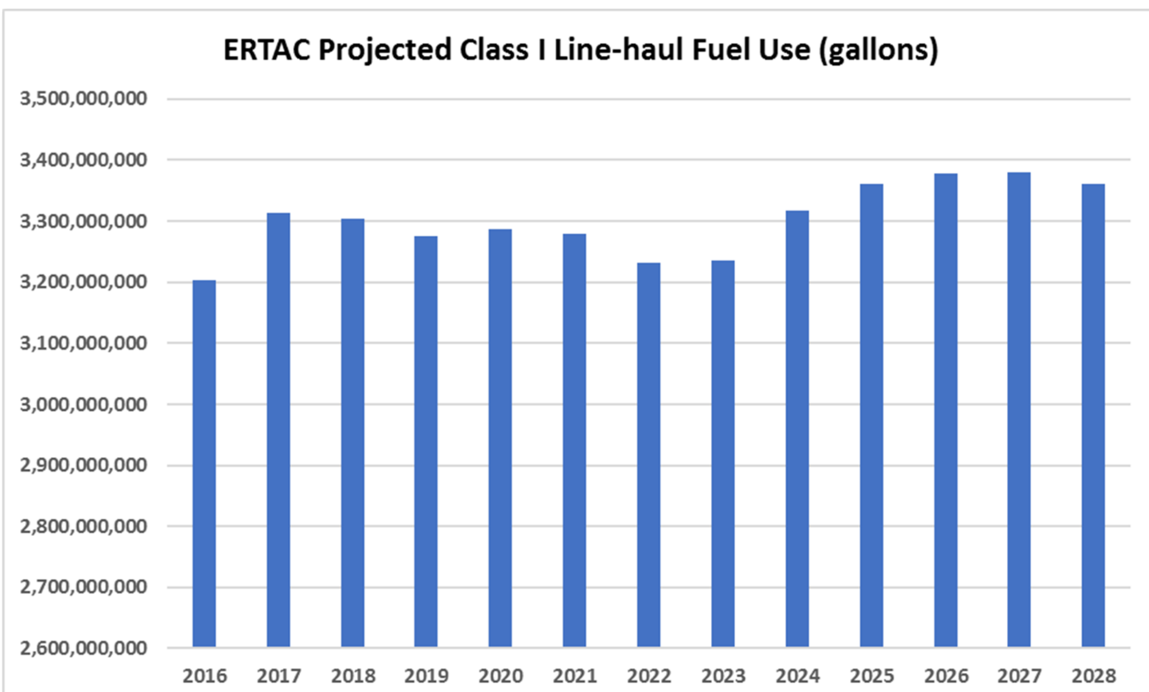

Figure 7. ERTAC Rail Projected Class I Line-haul Fuel Use 2016-2028

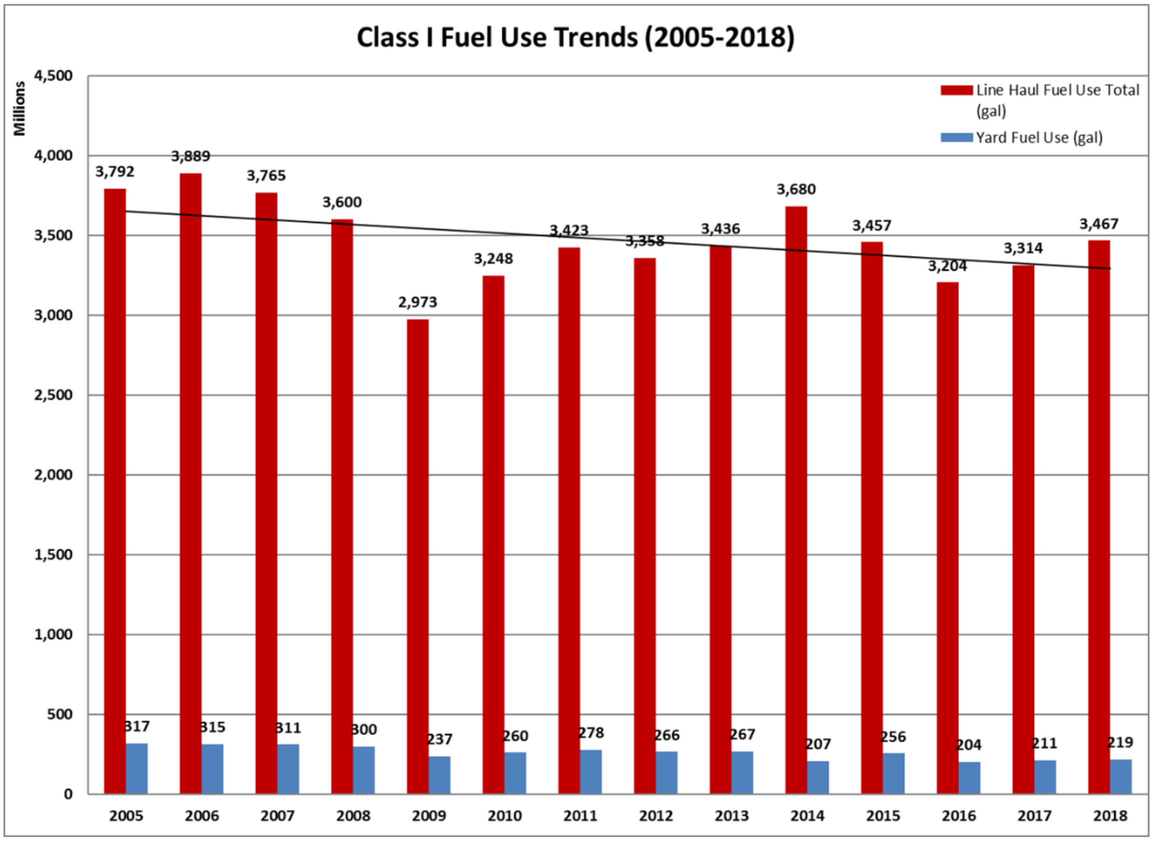

Figure 8. Class I Line-haul Fuel Use Trends 2005-2018

Emission Factor Projections

ERTAC Rail has collected historical line-haul fleet mix data for the Class I railroads via the Association of American Railroads for 2007, 2014, 2016, and 2017.

Comparison of the actual NOx, PM10, and Hydrocarbon emission factors for 2007, 2014, 2016, and 2017 with USEPA OTAQ's emission factor projections[4] shows that OTAQ's 2009 fleet turnover forecast is more aggressive (see Figures 9, 10, and 11). To correct for this, the workgroup used the historical data provided by the AAR to develop its own future year emission factor projections using Excel's Trendline function. All trendlines generated from the AAR data have R^2 values greater than 0.99.

The workgroup's future year projections better represent what is known about current and near-future industry trends – namely, reduced purchases of new Tier 4 locomotives and large rebuilding programs for 1990's-era locomotives.

Year	OTAQ NOx	ERTAC NOx	EF lbs/gallon
2006	180		
2007	175	181.5	0.400139
2008	169		
2009	165		
2010	157		
2011	149		
2012	144		
2013	139		
2014	135	150.21	0.331156
2015	129		
2016	121	138.63	0.305626
2017	114	134.77	0.297117
2018	108		
2019	103		
2020	99	123.88	0.273108
2021	94		
2022	89		
2023	84	113.33	0.249850
2024	79		
2025	74		
2026	69		
2027	65		
2028	61	97.7	0.215391
2029	57		
2030	53		
2031	49		
2032	46		
2033	43		
2034	40		
2035	37		
2036	35		
2037	33		
2038	31		

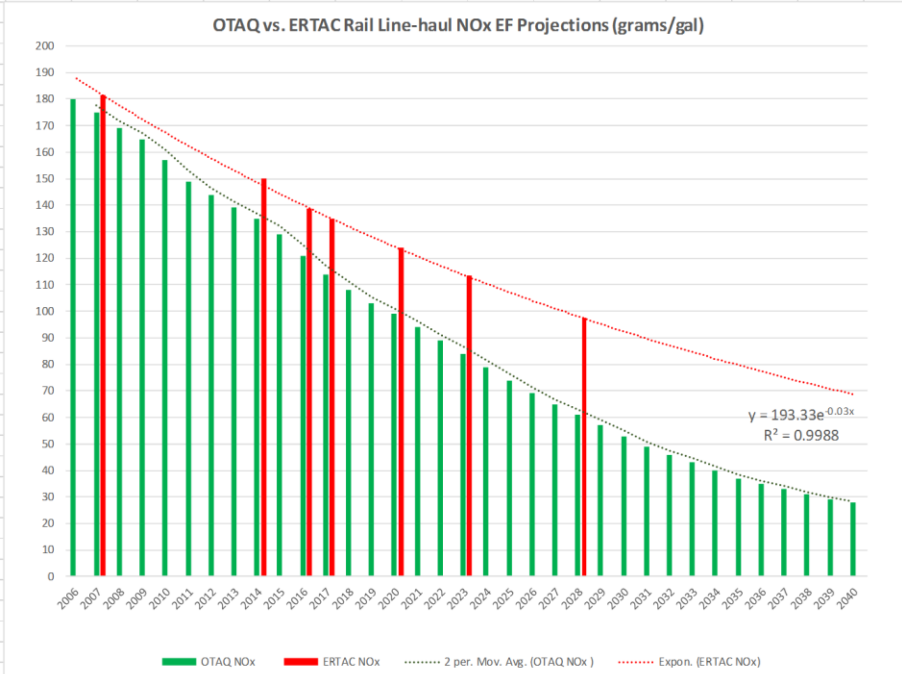

Figure 9. EPA (2009) versus ERTAC Rail NOx Emission Factor Projections

Year	OTAQ PM10	ERTAC PM10	EF lbs/gallon
2006	6.4		
2007	6.3	6.13	0.013514
2008	5.1		
2009	4.9		
2010	4.7		
2011	4.4		
2012	4.1		
2013	3.8		
2014	3.6	4.851	0.010695
2015	3.4		
2016	3.1	4.117	0.009076
2017	2.9	3.944	0.008695
2018	2.7		
2019	2.5		
2020	2.3	3.53231	0.007787
2021	2.2		
2022	2.0		
2023	1.9	3.0998	0.006834
2024	1.7		
2025	1.6		
2026	1.5		
2027	1.4		
2028	1.3	2.4934	0.005497
2029	1.1		
2030	1.0		
2031	1.0		
2032	0.9		
2033	0.8		
2034	0.7		
2035	0.7		
2036	0.6		
2037	0.6		
2038	0.5		

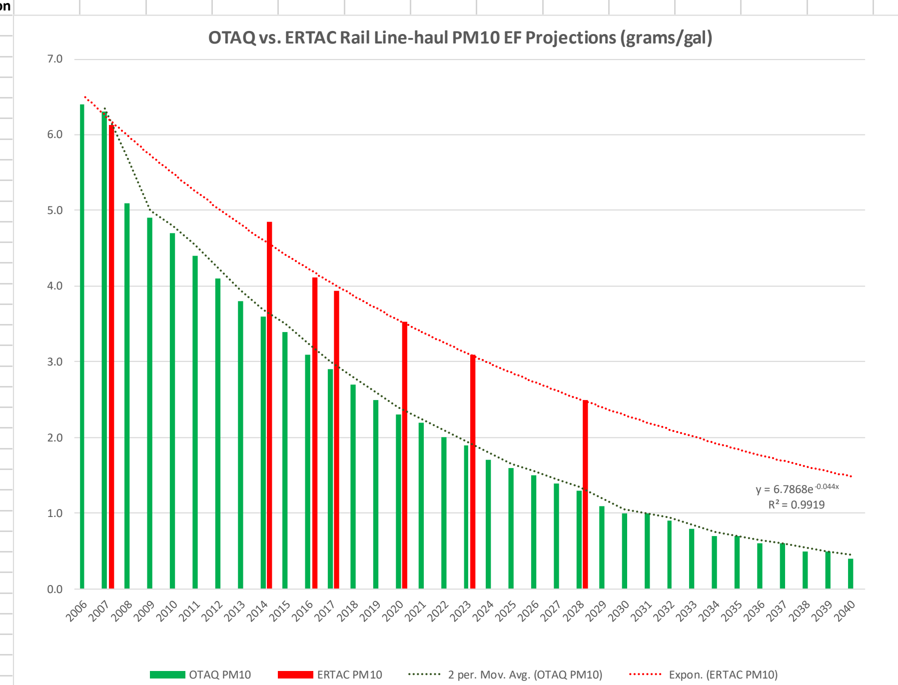

Figure 10. EPA (2009) versus ERTAC Rail PM_{10} Emission Factor Projections

Year	OTAQ HC	ERTAC HC	EF lbs/gallon
2006	9.5		
2007	9.3	9.13	0.020128
2008	9.0		
2009	8.7		
2010	8.3		
2011	7.7		
2012	7.1		
2013	6.5		
2014	6.1	7.21	0.015895
2015	5.7		
2016	5.1	6.15	0.013558
2017	4.6	5.9	0.013007
2018	4.2		
2019	3.9		
2020	3.6	5.28	0.011640
2021	3.4		
2022	3.2		
2023	3.0	4.639	0.010227
2024	2.8		
2025	2.6		
2026	2.5		
2027	2.3		
2028	2.1	3.738	0.008241
2029	2.0		
2030	1.9		
2031	1.7		
2032	1.6		
2033	1.5		
2034	1.4		
2035	1.3		
2036	1.2		
2037	1.2		
2038	1.1		

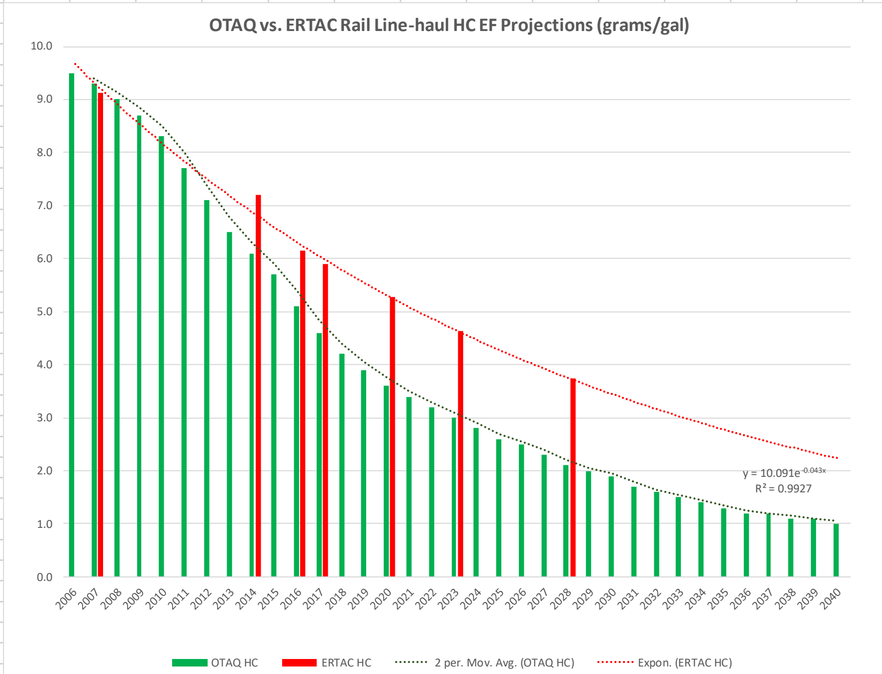

Figure 11. EPA (2009) versus ERTAC Rail HC Emission Factor Projections

Emission Projection Calculations

ERTAC Rail used the 2018 AEO fuel use projections to calculate Adjusted Rail Fuel Consumption Index (RFCI) values for each Class I railroad for 2020, 2023, and 2028 (see Table 16).

The projected fuel use data was combined with ERTAC Rail's emission factor estimates to create future year link-level emission inventories based on the MGT traffic density values contained in the FRA's 2016 shapefile.

The link-level data created for 2020, 2023, and 2028 was aggregated to create county, state, and national emissions estimates (see Table 17). The state/county-level data was provided to USEPA in FF10 format to be loaded into the 2016v1 emissions platform.

Table 16. ERTAC Projected Fuel Use Data by Class I Railroad for 2020, 2023, and 2028

Railroad	2016 Fuel Use	2016 Adj-RFCI	2020 Projected	2020 Adj-RFCI	2023 Projected	2023 Adj-RFCI	2028 Projected	2028 Adj-RFCI
BNSF	1,243,366,255	904.4703675	1,275,923,282	881.3914987	1,256,149,431	895.2660452	1,304,260,106	862.2420700
CSXT	404,147,932	1,081.463412	414,730,377	1017.1112070	408,303,018	1033.1222041	423,941,073	995.0130831
GTW (CN)	102,019,995	1,444.618538	104,691,346	1053.8683098	103,068,873	1070.4579238	107,016,423	1030.9715878
KCS	60,634,689	1,043.743840	62,222,383	969.1317287	61,258,080	984.3874501	63,604,272	948.0760241
NS	437,110,632	994.508039	448,556,192	882.4026557	441,604,611	896.2931194	458,518,121	863.2312581
Soo (CP)	56,163,697	905.508001	57,634,320	1407.7570082	56,741,122	1429.9174103	58,914,314	1377.1715730
UP	900,151,933	1,094.796364	923,722,036	1066.8610526	909,406,488	1083.6551937	944,236,866	1043.6820456
All Class I's	**3,203,595,133**	**992.470225**	**3,287,479,935**	**967.1459124**	**3,236,531,624**	**982.3703738**	**3,360,491,175**	**946.1333524**

Table 17. Comparison of ERTAC Rail Class I Line-haul Emissions 2007-2028

Inventory	CO	HC	NH3	NOx	PM10	PM2.5	SO2
2007 (2008 NEI)	110,969	37,941	347	754,433	25,477	23,439	7,836
2014 NEI	107,995	29,264	338	609,295	19,675	18,101	381
2016 v1	94,020	21,727	294	489,562	14,538	14,102	332
2017 NEI	97,272	21,560	304	492,385	14,411	13,979	343
2020 Projected	96,482	19,133	302	448,924	12,800	12,415	340
2023 Projected	94,987	16,550	297	404,329	11,059	10,728	335
2028 Projected	98,625	13,847	309	361,914	9,236	8,959	348
2016 vs 2028	4.90%	-36.27%	4.90%	-26.07%	-36.47%	-36.47%	4.90%

Class I Rail Yard Emission Projections

Class I rail yard emissions were projected using the Energy Information Administration's 2019 AEO freight rail energy use growth rate projections for 2016 to 2050. National growth rates were used, so all rail yards had identical fuel use growth rates for 2020, 2023, and 2028. Table 18 presents the growth rates used for rail yards and the other sectors of the rail inventory.

Table 18. AEO growth rates for Rail Sub-groups

Sector	2016	2020	2023	2028
Rail Yards	1.0	0.97513	0.947802	0.952483
Class II/III Railroads	1.0	0.97513	0.947802	0.952483
Commuter/Passenger	1.0	1.033858	1.071348	1.136023

The fleet mix of switching locomotives was assumed to remain constant for the entirety of the projection period. This was based on conversations with stakeholders that there are limited purchases of new switching engines nationally. In addition, widespread locomotive fleet reductions by the Class I railroads will result in a large supply of older line-haul locomotives that can be transferred over to switching service. Therefore, it was assumed that there will not be any significant changes in fleet mix for the Class I rail yard sector thru 2028. This results in a relatively flat year-to-year overall growth rate for the rail yard inventories.

Class II and III Railroad Emission Projections

Fuel use projections for the Class II and III railroad sector used the freight growth rates presented in Table 18. These rates are identical to the growth rates used for the rail yard sector. Additionally, the assumption for smaller railroads is that the fleet mix will be consistent between base and future years. This includes those elements for commuter rail that are covered in the Class II and III railroad inventories.

Commuter Rail Emission Projections

Fuel use projections for the Commuter rail sector used the Commuter/Passenger growth rates presented in Table 18. As part of the 2016 collaborative process, the committee requested company-specific fleet mix updates. ERTAC Rail was able to obtain future year fleet mix estimates for Metra, based on information related to new and rebuilt locomotive orders posted on Metra's website. This information is presented in Table 19.

Table 19. Metra Fleet Mix Projections

Tier-level	2020	2023	2028
Tier 0	0.1667	0.0667	0.0
Tier 0+	0.6533	0.6533	0.4797
Tier 1	0.0733	0.0733	0.0
Tier 1+	0.1067	0.1067	0.1824
Tier 3	n/a	0.1	0.2838
Tier 4	n/a	n/a	0.0541

Intercity Passenger Emission Projections

The Intercity Passenger sector exclusively represents Amtrak, the national passenger rail service provider. All other passenger operations (e.g., regional and tourist passenger services) are included in the Class II and III portion of the inventory. Fuel use projections for Amtrak used the Commuter/Passenger growth rates presented in Table 18. ERTAC Rail was able to obtain future year fleet mix estimates for Amtrak based on data provided directly by Amtrak and information on new locomotive orders posted on Amtrak's website. This information is presented in Table 20.

Table 20. Amtrak Fleet Mix Projections

Tier-level	2020	2023	2028
Uncontrolled	0.14	0.14	0.14
Tier 0	0.58	0.4371	0.3657
Tier 0+	0.0543	0.0543	0.0543
Tier 2	0.0286	0.0286	0.0286
Tier 3	0.0114	0.0114	0.0114
Tier 4	0.1857	0.3286	0.4

Other Data Sources

Rail emissions for future years were provided by the California Air Resources Board (CARB). These emissions are used as-is for all 2016v1 platform projections, except for the same rail yard and HAP augmentation considerations that are described at the end of Section 3 for 2016.

The North Carolina Division of Air Quality (NCDAQ) requested that instead of using the national approach for projected rail emissions, that the 2016 rail emissions in North Carolina be projected using factors provided by NCDAQ. The North Carolina projection factors for rail are shown in Table 21. Rail yard projections in North Carolina used the national approach.

Table 21. North Carolina rail projection factors

Category	Pollutant	2016-to-2023	2016-to-2028
Class I	NOx	-18.1%	-26.8%
Class I	PM	-25.8%	-38.1%
Class I	VOC	-25.3%	-37.4%
Class I	Others	+1.0%	+4.9%
Class II & III	All	+1.0%	+4.9%
Passenger	All	+7.7%	+13.2%

6. Emissions Processing Requirements

Rail emissions were processed for air quality modeling using the Sparse Matrix Operator Kernel Emissions (SMOKE[1]) modeling system. Emissions estimates enter the emissions processing steps by County and SCC code for all categories, except yards which are processed as point sources with a single discrete point identifying each yard. Because day-of-week temporalization is flat for all sources, a single representative day per month is processed. This is a 2-D sector in which all emissions are output to a single layer gridded emissions file. Emissions

[1] http://www.smoke-model.org/index.cfm

Estimates are by County and SCC code. For point source yards in the ptnonipm sector, default stack characteristics are applied to all yards to ensure that emissions end up in the lowest vertical layer of the modeled atmosphere.

7. Emissions Summaries

Table 22 compares annual, national total rail emissions for the 2016 beta platform to rail emissions from previous modeling platforms. Tables 23 and 24 show similar comparisons for state total rail NOx and VOC emissions, respectively. Table 25 shows emissions by SCC and pollutant.

Additional rail plots and maps are available online through the LADCO website[2] and the Intermountain West Data Warehouse[3].

Descriptions of the emissions platform cases shown in the tables and plots below are as follows:

2014fd = 2014NEIv2 and 2014 NATA

2016fe = 2016 alpha platform (grown from 2014NEIv2)

2016ff, 2023ff, 2028ff = 2016, 2023, and 2028 cases from 2016 beta platform

2016fh, 2023fh, 2028fh = 2016, 2023, and 2028 cases from 2016 v1 platform

Table 22. Comparison of national, 2016 annual total rail emissions (tons/yr)

Pollutant	2014fd	2016fe	2016ff	2016fh	2023ff	2023fh	2028ff	2028fh
CO	118,830	118,830	102,929	104,599	104,133	106,036	108,282	110,074
NH3	363	363	322	326	326	331	339	343
NOX	675,704	675,704	557,598	559,767	564,809	469,545	587,591	423,493
PM10	20,806	20,806	16,624	16,355	16,845	12,789	17,526	10,964
PM2.5	19,226	19,226	16,125	15,829	16,340	12,387	17,001	10,622
SO2	822	822	363	457	367	460	382	473
VOC	34,865	34,865	26,008	26,099	26,348	20,454	27,412	17,576

Table 23. Comparison of state, 2016 annual total NOx emissions (tons/yr)

State	2014fd	2016fe	2016ff	2016fh	2023ff	2023fh	2028ff	2028fh
Alabama	12,122	12,122	10,224	10,232	10,317	8,614	10,717	7,823
Alaska	976	976	382	385	385	388	400	390
Arizona	18,719	18,719	16,970	16,975	17,143	14,209	17,815	12,853

[2] https://www.ladco.org/technical/modeling-results/2016-inventory-collaborative/

[3] http://views.cira.colostate.edu/iwdw/eibrowser2016

State	2014fd	2016fe	2016ff	2016fh	2023ff	2023fh	2028ff	2028fh
Arkansas	14,443	14,443	11,355	11,361	11,460	9,539	11,905	8,641
California	43,963	43,963	27,586	29,360	28,166	21,502	29,393	15,435
Colorado	9,973	9,973	7,906	7,909	7,999	6,691	8,317	6,096
Connecticut	627	627	1,032	1,041	1,085	1,024	1,145	1,035
Delaware	248	248	250	251	252	216	262	201
District of Columbia	111	111	200	200	209	178	220	170
Florida	5,390	5,390	5,942	5,957	6,067	5,218	6,331	4,894
Georgia	14,732	14,732	12,833	12,842	12,951	10,817	13,453	9,819
Hawaii	4	4	-	-	-	-	-	-
Idaho	7,507	7,507	6,354	6,358	6,410	5,333	6,658	4,830
Illinois	33,942	33,942	33,086	33,022	33,822	28,051	35,311	25,443
Indiana	18,260	18,260	15,518	15,531	15,663	13,233	16,272	12,047
Iowa	20,173	20,173	16,580	16,585	16,728	13,810	17,375	12,449
Kansas	28,001	28,001	21,757	21,770	21,953	18,293	22,804	16,573
Kentucky	10,016	10,016	8,128	8,133	8,203	6,818	8,521	6,177
Louisiana	9,115	9,115	7,508	7,513	7,586	6,338	7,884	5,762
Maine	1,315	1,315	1,005	1,013	1,016	1,023	1,056	1,030
Maryland	2,160	2,160	2,726	2,735	2,830	2,398	2,973	2,267
Massachusetts	4,467	4,467	3,998	4,027	4,270	3,804	4,532	3,788
Michigan	5,333	5,333	4,627	4,638	4,687	4,126	4,876	3,905
Minnesota	18,239	18,239	13,781	13,789	13,917	11,581	14,461	10,493
Mississippi	6,888	6,888	5,711	5,716	5,778	4,883	6,008	4,476
Missouri	26,939	26,939	20,227	20,218	20,419	16,852	21,215	15,196
Montana	21,338	21,338	18,471	18,478	18,650	15,486	19,378	14,010
Nebraska	54,917	54,917	37,241	37,246	37,559	30,911	39,008	27,766
Nevada	5,767	5,767	4,315	4,316	4,378	3,622	4,558	3,308
New Hampshire	399	399	311	313	315	317	327	319
New Jersey	3,722	3,722	5,308	5,344	5,670	4,959	6,018	4,904
New Mexico	19,656	19,656	19,208	19,211	19,406	16,003	20,168	14,426
New York	12,409	12,409	12,737	12,776	13,085	10,979	13,687	10,338
North Carolina	6,773	6,773	5,830	5,837	5,927	5,076	6,175	4,746
North Dakota	14,890	14,890	10,798	10,805	10,903	9,134	11,329	8,310
Ohio	27,400	27,400	23,618	23,634	23,826	19,872	24,747	18,008
Oklahoma	17,624	17,624	14,349	14,358	14,471	12,049	15,029	10,906
Oregon	7,335	7,335	6,135	6,144	6,200	5,281	6,444	4,862
Pennsylvania	17,256	17,256	14,355	14,372	14,506	12,215	15,077	11,198
Rhode Island	60	60	54	54	54	55	56	55
South Carolina	4,332	4,332	4,102	4,104	4,159	3,477	4,329	3,188
South Dakota	3,762	3,762	2,621	2,627	2,642	2,289	2,744	2,122
Tennessee	11,545	11,545	9,521	9,527	9,608	7,989	9,981	7,233
Texas	49,085	49,085	46,400	46,416	46,845	38,830	48,672	35,097
Utah	5,640	5,640	5,259	5,266	5,356	4,517	5,584	4,166
Vermont	718	718	579	584	588	591	613	598
Virginia	12,841	12,841	9,815	9,821	9,956	8,265	10,363	7,540
Washington	14,357	14,357	14,766	14,777	14,946	12,552	15,545	11,471

State	2014fd	2016fe	2016ff	2016fh	2023ff	2023fh	2028ff	2028fh
West Virginia	6,941	6,941	5,808	5,811	5,875	4,900	6,108	4,454
Wisconsin	13,006	13,006	10,109	10,179	10,201	8,543	10,597	7,731
Wyoming	28,103	28,103	20,204	20,205	20,368	16,692	21,150	14,944
Puerto Rico	0	0						
Tribal Data	2,166	2,166						

Table 24. Comparison of state, 2016 annual total VOC emissions (tons/yr)

State	2014fd	2016fe	2016ff	2016fh	2023ff	2023fh	2028ff	2028fh
Alabama	601	601	476	477	481	375	499	322
Alaska	45	45	17	17	17	18	18	18
Arizona	939	939	794	795	803	619	834	527
Arkansas	721	721	530	530	535	415	556	354
California	3,431	3,431	1,284	1,365	1,311	877	1,368	707
Colorado	499	499	371	371	375	293	390	253
Connecticut	24	24	46	46	49	48	51	48
Delaware	21	21	11	12	12	10	12	9
District of Columbia	6	6	9	9	10	8	10	7
Florida	258	258	275	275	280	233	293	210
Georgia	730	730	598	598	604	471	627	404
Hawaii	0	0	-	-	-	-	-	-
Idaho	374	374	296	296	299	232	310	198
Illinois	1,695	1,695	1,565	1,562	1,602	1,239	1,673	1,052
Indiana	901	901	723	723	730	577	758	497
Iowa	1,013	1,013	774	775	781	599	812	507
Kansas	1,396	1,396	1,014	1,015	1,024	795	1,064	680
Kentucky	500	500	379	379	383	297	398	253
Louisiana	454	454	351	351	355	277	369	238
Maine	51	51	45	45	45	47	47	48
Maryland	102	102	125	125	129	107	136	98
Massachusetts	212	212	178	179	190	175	202	174
Michigan	251	251	214	214	217	185	226	170
Minnesota	912	912	643	643	650	504	675	431
Mississippi	340	340	267	267	270	215	281	187
Missouri	1,356	1,356	946	946	955	731	993	620
Montana	1,068	1,068	863	864	872	674	906	574
Nebraska	2,770	2,770	1,740	1,740	1,755	1,336	1,823	1,125
Nevada	292	292	204	204	207	160	215	139
New Hampshire	16	16	14	14	14	15	15	15
New Jersey	181	181	236	237	252	227	267	222
New Mexico	989	989	899	899	908	695	944	588
New York	601	601	585	587	601	490	629	446
North Carolina	335	335	273	273	278	222	289	200
North Dakota	740	740	504	504	509	399	529	343
Ohio	1,361	1,361	1,100	1,101	1,110	864	1,153	738

State	2014fd	2016fe	2016ff	2016fh	2023ff	2023fh	2028ff	2028fh
Oklahoma	876	876	668	669	674	523	700	446
Oregon	357	357	285	286	288	232	300	204
Pennsylvania	846	846	668	668	675	536	701	467
Rhode Island	2	2	2	2	2	3	2	3
South Carolina	216	216	193	193	196	154	204	134
South Dakota	180	180	121	121	122	101	126	89
Tennessee	575	575	444	444	448	347	465	296
Texas	2,496	2,496	2,169	2,170	2,190	1,688	2,276	1,436
Utah	280	280	245	245	249	199	260	175
Vermont	28	28	26	26	26	28	28	28
Virginia	643	643	459	460	466	363	485	313
Washington	686	686	690	690	699	551	727	477
West Virginia	347	347	271	272	275	214	286	184
Wisconsin	649	649	472	475	476	371	495	317
Wyoming	1,421	1,421	944	944	952	720	988	602
Puerto Rico	0	0						
Tribal Data	81	81						

Table 25. Rail Emissions by SCC and Pollutant

Region	Pollutant	SCC	SCC Description	2016fh
National	CO	2285002006	Line Haul Locomotives: Class I Operations	96,068
National	CO	2285002007	Line Haul Locomotives: Class II / III Operations	4,113
National	CO	2285002008	Line Haul Locomotives: Passenger Trains (Amtrak)	1,903
National	CO	2285002009	Line Haul Locomotives: Commuter Lines	2,514
National	CO	2285002010	Yard Locomotives (in rail sector)	1
National	CO	28500201	Diesel Yard Locomotives (in ptnonipm)	6,503
National	NH3	2285002006	Line Haul Locomotives: Class I Operations	301
National	NH3	2285002007	Line Haul Locomotives: Class II / III Operations	13
National	NH3	2285002008	Line Haul Locomotives: Passenger Trains (Amtrak)	5
National	NH3	2285002009	Line Haul Locomotives: Commuter Lines	8
National	NH3	2285002010	Yard Locomotives (in rail sector)	-
National	NH3	28500201	Diesel Yard Locomotives (in ptnonipm)	19
National	NOX	2285002006	Line Haul Locomotives: Class I Operations	492,999
National	NOX	2285002007	Line Haul Locomotives: Class II / III Operations	33,378
National	NOX	2285002008	Line Haul Locomotives: Passenger Trains (Amtrak)	14,188
National	NOX	2285002009	Line Haul Locomotives: Commuter Lines	19,191
National	NOX	2285002010	Yard Locomotives (in rail sector)	11
National	NOX	28500201	Diesel Yard Locomotives (in ptnonipm)	42,334
National	PM10	2285002006	Line Haul Locomotives: Class I Operations	14,350
National	PM10	2285002007	Line Haul Locomotives: Class II / III Operations	974
National	PM10	2285002008	Line Haul Locomotives: Passenger Trains (Amtrak)	460
National	PM10	2285002009	Line Haul Locomotives: Commuter Lines	571

Region	Pollutant	SCC	SCC Description	2016fh
National	PM10	2285002010	Yard Locomotives (in rail sector)	0
National	PM10	28500201	Diesel Yard Locomotives (in ptnonipm)	1,095
National	PM2.5	2285002006	Line Haul Locomotives: Class I Operations	13,889
National	PM2.5	2285002007	Line Haul Locomotives: Class II / III Operations	945
National	PM2.5	2285002008	Line Haul Locomotives: Passenger Trains (Amtrak)	443
National	PM2.5	2285002009	Line Haul Locomotives: Commuter Lines	552
National	PM2.5	2285002010	Yard Locomotives (in rail sector)	0
National	PM2.5	28500201	Diesel Yard Locomotives (in ptnonipm)	1,060
National	SO2	2285002006	Line Haul Locomotives: Class I Operations	427
National	SO2	2285002007	Line Haul Locomotives: Class II / III Operations	15
National	SO2	2285002008	Line Haul Locomotives: Passenger Trains (Amtrak)	6
National	SO2	2285002009	Line Haul Locomotives: Commuter Lines	9
National	SO2	2285002010	Yard Locomotives (in rail sector)	-
National	SO3	28500201	Diesel Yard Locomotives (in ptnonipm)	23
National	VOC	2285002006	Line Haul Locomotives: Class I Operations	22,991
National	VOC	2285002007	Line Haul Locomotives: Class II / III Operations	1,462
National	VOC	2285002008	Line Haul Locomotives: Passenger Trains (Amtrak)	762
National	VOC	2285002009	Line Haul Locomotives: Commuter Lines	885
National	VOC	2285002010	Yard Locomotives (in rail sector)	0
National	VOC	28500201	Diesel Yard Locomotives (in ptnonipm)	2,773