Eastern Research Group, Inc.

2020 National Emissions Inventory Locomotive Methodology

Prepared for:

U.S. Environmental Protection Agency

National Vehicle and Fuel Emissions Laboratory

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Ann Arbor, MI 48105

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May 19, 2022

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2020 NATIONAL EMISSIONS INVENTORY: RAIL METHODOLOGY

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Acronym List

Acronym	Definition
AAR	Association of American Railroads
ASLRRA	American Short Line and Railroad Association
BNSF	Burlington Northern Santa Fe
CH_4	methane
CN	Canadian National Railway
CO_2	Carbon Dioxide
CO	Carbon Monoxide
CPRS	Canadian Pacific Railway
CSXT	CSX Transportation
EF	Emission Factors
EIAG	Emission Inventory and Analysis Group
EIS	Emissions Inventory System
EPA	Environmental Protection Agency
ERG	Easton Research Group, Inc.
FTA	Federal Transit Administration
GIS	Geographic information system
HAP	Hazardous Air Pollutants
HC	hydrocarbon
KCS	Kansas City Southern Railroad
MBTA	Massachusetts Bay Transportation Authority
MGT	Million gross ton
NEI	National Emissions Inventory
NH_3	ammonia
N_2O	Nitrous Oxide
NO_X	Nitrogen Oxides
NS	Norfolk Southern
NTAD	National Transportation Atlas Database
NTD	National Transit Database
OAQPS	Office of Air Quality Planning and Standards
PM_{10}	Particulate matter less than 10 micrometers
$PM_{2.5}$	Particulate matter less than 2.5 micrometers
SCC	Source Classification Codes
SO_2	Sulfur Dioxide
ULSD	Ultra-low sulfur diesel
UP	Union Pacific
VOC	Volatile Organic Compounds

1. Executive Summary

The Emission Inventory and Analysis Group (EIAG) at the United States Environmental Protection Agency's (EPA) Office of Air Quality Planning and Standards (OAQPS) triennially produces the National Emission Inventory (NEI). The NEI compiles comprehensive emissions data for criteria pollutants and hazardous air pollutants (HAPs) for mobile, point, and nonpoint sources, including mobile source; aviation, marine vessels, railroads, onroad vehicles and nonroad engines. These data are needed by states, tribal, and local agencies to evaluate emissions trends in each State and to compare emission trends between geographic areas. The NEI is also used as a basis for various EPA air quality modeling and regulatory analyses. The NEI uses the Emission Inventory System (EIS) to aid in the collection and distribution of inventory information. EPA uses the data in the NEI as a starting point to prepare National Emissions Modeling Platforms that are used to prepare emissions inputs that support air quality modeling studies. These studies support both regulatory and non-regulatory analyses and often require data to be created that represent years other than NEI years, including future years.

Eastern Research Group (ERG) developed the 2020 locomotive component of the NEI for criteria air pollutants. The NEI will be used to support modeling activities, help with regulatory initiatives, state implementation programs to address concerns in nonattainment areas and address airport-related emission inquiries.

Emissions from diesel locomotives are an emerging issue in urban and regional air quality planning as other emission sectors reduce their impacts. Rail operations cover large sections of the country. Additionally, extensive freight, commuter, and intercity passenger rail operations in large urban areas may be contributing. Line haul activity and emissions are provided by county, and switch-related locomotive emissions are provided at point yard locations.

This section will include an overview of the results, trends, etc. Table 1 summarizes the national emissions totals for the 2020 inventory by source category. Locomotive emissions in all sectors declined from 2017 due in part to the impacts of the pandemic and changes in active fleet profile for both line haul and switch.

Table 1. 2020 US Locomotive Emissions by Sector

2020 Rail Sector	2020 Emissions (tons/year)									
	CH_4	CO	CO_2	N_2O	NH_3	NO_X	PM_{10}	PM_{25}	SO_2	VOC
Class I Line Haul	2,461	81,917	31,229,546	800	256	370,696	9,360	9,079	289	14,936
Class I Yard	161.21	5,605	2,045,315	52.39	16.79	40,269	1,057	1,025	18.92	2,615
Class 2/3 Line Haul	133.28	3,880.98	1,690,931	43.31	13.88	29,799	898.49	871.53	15.64	1,419.83
Commuter	76.56	2,548	971,417	24.88	7.97	12,430	332.92	322.93	8.99	528.81
Amtrak	44.60	1,484	565,872	14.50	4.64	8,653	291.52	282.78	5.24	465.08

2. BACKGROUND

In 2008, air quality planners in the eastern US formed the Eastern Technical Advisory Committee (ERTAC) for solving persistent emissions inventory issues. After four years of inventory development by the ERTAC rail group, EPA worked with ERTAC associates to transfer knowledge and discuss development of the 2020 effort. While most of the methodology is consistent with previous inventory efforts, all processing steps are included in the sections below to provide sufficient clarity for replication.

This document details the approach and data sources used for developing 2020 activity and emissions values for the locomotive sector. The 2020 version was developed by EPA using data provided by national, regional, local, and private data providers and are outlined in the sections below. The 2020 inventory includes national emissions data for five distinct components based on source classification codes (SCCs) as outlined in Table 2 below. Note that railway maintenance activities are part of the nonroad sector and are not covered in this document.

Table 2. 2020 SCCs for the Rail Sector

SCC	Sector	Description
2285002006	Railroad Equipment; Diesel	Line Haul Locomotives: Class I Operations
2285002007	Railroad Equipment; Diesel	Line Haul Locomotives: Class II / III Operations
2285002008	Railroad Equipment; Diesel	Line Haul Locomotives: Passenger Trains (Amtrak)
2285002009	Railroad Equipment; Diesel	Line Haul Locomotives: Commuter Lines
2285002010	Railroad Equipment; Diesel	Yard Locomotives (nonpoint)
28500201	Railroad Equipment; Diesel	Yard Locomotives (point)

3. CLASS I LINE HAUL INVENTORY DEVELOPMENT

3.1 Class I Line Haul Data

For the 2020 inventory, the Class I railroads granted EPA permission to use the confidential link-level line haul activity geographic information system (GIS) data layer maintained and updated annually by the Federal Railroad Administration (FRA). At the time of inventory development, 2019 million gross ton (MGT) data was the most recent and complete data available. The dataset contains three columns indicating railroad ownership and nine columns indicating trackage rights for each rail segment. While most rail links have a single owner, some links have up to six different Class 1 railroad companies operating on it. To prepare the FRA data for use in the Class I line haul calculations, all segments associated with a railroad company were extracted to identify the full network for each company. This involved iterating through each of those twelve columns to identify all segments within each railroad company's network. This process was conducted seven times, one for each Class I railroad company. This resulted in a complete inventory of rail links trafficked by each Class I railroads with a record for each link/railroad company combination.

Figure 1. 2019 Class I Line Haul Activity

EPA collected 2020 Class I line haul fuel use data from the most recent R-1 submittals from the Surface Transportation Board, summarized in Table 3.[1] Consistent with previous inventory efforts, EPA summed line haul and work train fuel usage.

Table 3. 2020 R-1 Reported Locomotive Fuel Use for Class I Railroads

Class I Railroad	Line Haul Fuel Use (gal)*
BNSF	1,137,598,007
Canadian National (CN)	96,337,392

1 Surface Transportation Board. Available at https://www.stb.gov/reports-data/economic-data/annual-report-financial-data/ Retrieved 22 June 2021.

Class I Railroad	Line Haul Fuel Use (gal)*
Canadian Pacific (CPRS)	57,664,407
CSX Transportation (CSXT)	327,917,859
Kansas City Southern (KCS)	55,763,748
Norfolk Southern (NS)	342,470,779
Union Pacific (UP)	773,476,896

* Includes work train fuel usage

The Association of American Railroads (AAR) provided national Class I locomotive tier fleet mix information that reflects engine turnover in the nation.[2] Given the impact of the pandemic in 2020, AAR provided a fleet mix that reflected active locomotives and excluded those that were held in storage. A locomotive's Tier level determines its allowable emission rates based on the year when it was built and/or re-manufactured. More accurate emission factors for each pollutant were calculated based on the percentage of the operating Class I line haul locomotives for each USEPA Tier-level category (Table 4).

Table 4. 2020 Class I Line Haul Fleet Profile by Tier

Class I Line Haul Tier Level	Locomotive Count	Percent of Fleet
Not Classified	333	2%
Tier 0 (1973-2001)	887	5%
Tier 0+ (Tier 0 rebuilds)	2,300	14%
Tier 1 (2002-2004)	119	1%
Tier 1+ (Tier 1 rebuilds)	4,288	26%
Tier 2 (2005-2011)	770	5%
Tier 2+ (Tier 2 rebuilds)	3,792	23%
Tier 3 (2012-2014)	2,422	14%
Tier 4 (2015 and later)	1,181	7%
Tier 4C (Tier 3 specifications, built after 2014)	695	4%

3.2 Calculate Class I Weighted Line Haul Emission Factors

Weighted Emission Factors (EF) per pollutant for each gallon of fuel used (grams/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 and Table 5).

2 R. Fronczak, Association of American Railroads (personal communication, May 5, 2021).

$$EF_i = \sum_{T=1}^{10}(EF_{iT} * f_T)$$ **Equation (1)**

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 5).

f_T = Ratio of the Class I locomotive fleet in Tier T total (Table 4) (unitless).

While locomotive diesel engines are certified to meet the emission standards for each Tier, actual emission rates may increase over time due to engine wear and degradation of the emissions control systems.

Emission factors for other pollutants are not Tier-specific because these pollutants are not directly regulated by USEPA's locomotive emission standards. Particulate matter less than 2.5 micrometers ($PM_{2.5}$), volatile organic carbon (VOC), sulfur dioxide (SO_2), and ammonia (NH_3) emission factors were derived from EPA guidance.[3] The 2020 SO_2 emission factor is based on the nationwide adoption of 15 parts per million ultra-low sulfur diesel fuel by the rail industry. All emission factors by Tier and 2020 fleet-weighted values are listed in Table 5.

Table 5. 2020 Line-haul Locomotive Emission Factors by Tier, AAR Fleet Mix (g/gal)

Tier	Tier Name	CH4	CO	CO_2	N_2O	NH_3	NO_X	PM_{10}	PM_{25}	SO_2	VOC
0	1973-2001	0.8	26.624	10,1500,1	0.26	0.0833	178.88	6.656	6.45632	0.0939	10.513152
0+	Tier 0 Rebuild	0.8	26.624	10,150	0.26	0.0833	149.76	4.16	4.0352	0.0939	6.57072
1	2002-2004	0.8	26.624	10,150	0.26	0.0833	139.36	6.656	6.45632	0.0939	10.294128
1+	Tier 1 Rebuild	0.8	26.624	10,150	0.26	0.0833	139.36	4.16	4.0352	0.0939	6.351696
2	2005-2011	0.8	26.624	10,150	0.26	0.0833	102.96	3.744	3.63168	0.0939	5.694624
2+	Tier 2 Rebuild	0.8	26.624	10,150	0.26	0.0833	102.96	1.664	1.61408	0.0939	2.847312
3	2012-2014	0.8	26.624	10,150	0.26	0.0833	102.96	1.664	1.61408	0.0939	2.847312
4	2015 and later	0.8	26.624	10,150	0.26	0.0833	20.8	0.312	0.30264	0.0939	0.876096
4C	Tier 3 Built after	0.8	26.624	10,150	0.26	0.0833	102.96	1.664	1.61408	0.0939	2.847312
NC	UNCONTROLLED Pre-1973	0.8	26.624	10,150	0.26	0.0833	270.4	6.656	6.45632	0.0939	10.513152
2020 Class I Line Haul Fleet-Weighted		**0.8**	**26.624**	**10,150**	**0.26**	**0.0833**	**120.5**	**3.042**	**2.95076**	**0.0939**	**4.854434**

3.3 Calculate Emissions per Link

Emissions (E_{iL}) of individual pollutants (i) per railway segment link (L) were calculated using the process described below (Equation 2):

[3] 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.

a. For each railroad segment upon which a Class I railroad operated, FRA's MGT was divided by the number of railroad companies with ownership or trackage rights on that segment. 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 in lack of other data.

b. The MGTM for each link was recalculated by multiplying the adjusted MGT by the link mileage.

c. The link-level fuel use value for each railroad was calculated by multiplying the railroad company's total fuel use by the fraction of total railroad company-specific MGTM found on that link. (Equation 2)

d. Link-level fuel use was summed and then multiplied by the weighted Class I line-haul emission factor for pollutant i to determine the emissions value for the link.

e. The Class I railroad emissions total were summed to the county level for inclusion in the USEPA's Emissions Inventory System (EIS). (Equation 3)

$$\mathrm{F}_L = \sum_{RR=1}^{N} \frac{\left(\frac{MGT_L}{N}\right) * l_L}{MGTMRR} * FRR$$ **Equation (2)**

where:

F_L	=	Fuel usage per link L (gal/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.
$MGTM_{RR}$	=	Millions of Gross Tons Miles hauled per railroad company (RR) per year.
l_L	=	Link length from the FRA database (miles).
$MTGM_{RR}$	=	Millions of Gross Ton Miles operated per railroad company.
Frr	=	Total fuel consumption for railroad company (RR) (gal).
RR	=	Railroad company.

$$E_{iL} = \sum_{FIP} \mathrm{F}_L * EF_{iRR} \ / \ 907{,}185$$ **Equation (3)**

where:

E_{iL}	=	Sum of the link level emissions of pollutant i per FIP (tons/year).
F_L	=	Fuel usage per link L (gal/year).
EF_i	=	Weighted Emission Factor for pollutant i (g/gal).
RR	=	Railroad Company.
FIP	=	County Federal Information Processing Standard.
907,185	=	g/ton conversion.

3.4 Aggregate Emissions for Inclusion into the 2020 Inventory

The final link-level emissions for each pollutant were aggregated by state/county FIPS code and then formatted for inclusion in USEPA's EIS.

4. RAIL YARD METHODOLOGY

The 2017 inventory included a dedicated effort to improve locomotive switch yard inventory. The 2020 inventory used the improvements from 2017 as a starting point for this effort (Figure 2). EPA provided railroad-specific yard data from the 2017 inventory to each Class I railroad including fuel use and engine counts for all the rail yards in their systems. Six railroad companies provided updated rail yard data: Burlington Northern Santa Fe (BNSF), Canadian Pacific Railway (CPRS), CSX Transportation (CSXT), Kansas City Southern Railroad (KCS), Norfolk Southern (NS), and Union Pacific (UP). Most railroads provided yard-specific switch engine counts and fuel use. The data received were matched to existing yard locations within USEPA's EIS. 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.

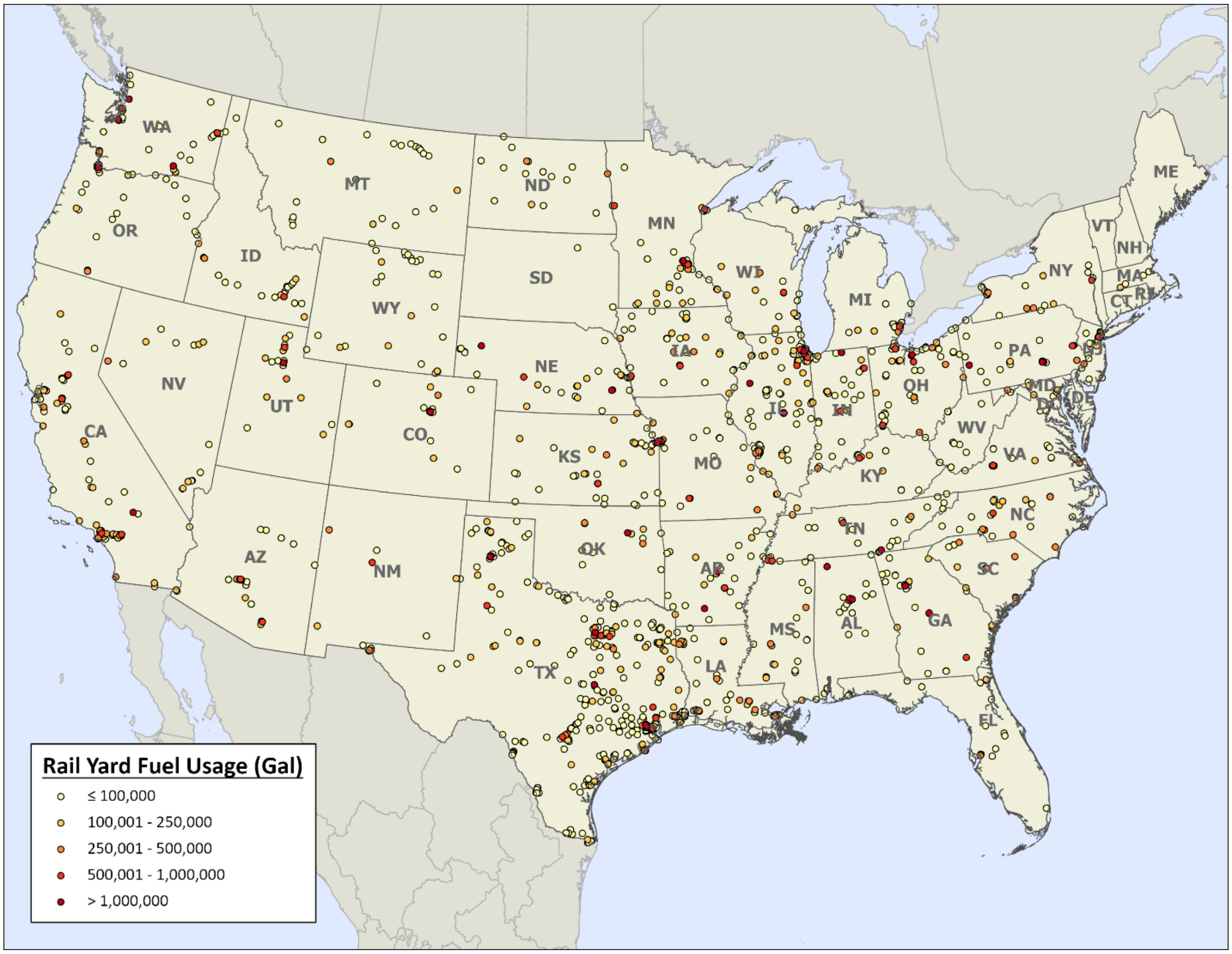

Figure 2. Rail Yard Locations in the United States

Canadian National Railway (CN) did not provide updated 2020 data; as such, the 2017 fuel data and switch engine counts were pulled forward as-is for 2020. Fuel use data for non-Class I yards (i.e., Amtrak) was not allocated to yard locations; barring a yard name or location, the switch engine fuel use could not be spatially allocated and therefore was added to line haul total fuel and processed as outlined in Class II/III line haul methodology in Section 5. NS provided data with some internal inconsistencies. After confirming with the data provider, the following assumptions were made to process the provided data accurately:

- For yard locations with fuel use but no switch engines, we assumed the fuel use is accurate and the switch engine is recorded under another location (such that both fuel and engine count are accurate).
- For yard locations with switch engines but no fuel use, we assumed the engine count is accurate and the fuel use is recorded under another location (such that both fuel and engine count are accurate).

- For yards with a site name in the 2020_Fuel (Gal) column (e.g., Calumet), we assumed that the fuel use for those yards is represented under the Calumet site. As such, we allocated fuel use from Calumet to other yards based on the number of switch engines at those yards to better represent the spatial allocation of activity.
- We used the data provided by NS with the understanding that it could be more refined than the fuel use data reported in the most recent R-1.

For the 260 yards in EIS where the yard owner was a Class II or Class III railroad or "unknown," 2017 fuel data was used. An additional 386 yards that were in the 2017 EIS with zero fuel use and not included in any of the 2020 data solicitations were not included in this effort. Table 6 summarizes the 2020-yard fuel use and switcher data for each Class I railroad.

Table 6. 2020 Class I Yard Fuel Use Data and Switch Engine Count

Railroad Company	2020 Yard Fuel Use (gal)	Switch Count
BNSF	46,495,989	483
CN	44,720	2
CPRS	894,257	72
CSXT	17,258,835	406
KCS	3,175,120	142
NS	33,295,775	530
UP	63,826,245	1,071
All Class I's	**165,035,661**	**2,708**

AAR provided ERTAC with national tier fleet mix profiles representing the entire Class I yard switching locomotive fleet. The 2020 fleet mix data was used to calculate the weighted emissions rates for the 2020 yard inventory (see Table 7).

Table 7. 2020 Class I Yard Switcher Fleet Profile

Tier	Engine Count	Percentage of Fleet
0	673	23.75%
0+	1,182	41.71%
1+	26	0.92%
2	7	0.25%
3	11	0.39%
4	23	0.81%
Not Classified	912	32.18%

5. CLASS II AND III LINE HAUL METHODOLOGY

There are approximately 630 Class II and III railroads operating in the United States.[4] Individual railroads in this sector range from small switching operations to large regional railroads that operate hundreds of miles of track. Data on Class II and III locomotive operations is publicly available from Bureau of Transportation Statistics' National Transportation Atlas Database (NTAD), along with related data including reporting mark, railroad name, route miles owned or operated, and total route miles of links.

5.1 Fleet Profile and Emission Factors

Class II and III railroads are widely dispersed across the country, often utilizing older, higher emitting locomotives than their Class I counterparts. AAR provided a national line-haul tier fleet mix profile for 2020 which reflects the trend toward older engines in this sector (Table 8). 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 9). Note that to be consistent with the 2017 inventory, the unweighted emission factors were the same as the Class I line haul due to the conservative use of the EPA's large locomotive conversion factor of 20.8 bhp-hr/gal. 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.

[4] Association of American Railroads, 2022. Industry Overview, Short Line and Regional. https://www.aar.org/railroad-101/. Accessed 19 April 2022.

Table 8. 2020 Class II/III Line Haul Fleet by Tier Level

Tier	2020 Class II/III Locomotive Count	Percent of Total Fleet
0	1,664	48%
1	31	1%
2	169	5%
3	160	5%
4	64	2%
Not Classified	1,359	39%
Total	**3,447**	**100%**

Table 9. 2020 Class II/III Line Haul Fleet-Weighted Emission Factors (grams/gal)

Pollutant	CH_4	CO	CO_2	N_2O	NH_3	NO_X	PM_{10}	PM_{25}	SO_2	VOC
Class II/III Line Haul Fleet-	0.8	26.624	10,150	0.26	0.0833	178.9	5.393	5.231	0.0939	8.523

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.

5.2 Emissions Calculations

For the 2017 inventory, ERTAC Rail contacted the American Short Line and Railroad Association (ASLRRA) and obtained a copy of their 2014 Fact Book, which contained fuel use data for 2012. ASLRRA were contacted for updated information for the 2020 inventory, but ASLRRA indicated that no newer dataset is available.

ERG researched activity data for the years 2012, 2017, and 2020 from the U.S. Energy Information Administration's Annual Energy Outlook, shown in Table 10 below.[5]

Table 10. Rail Freight Values

Rail Freight (quadrillion BTU)		
2012	**2017**	**2020**
0.43	0.52	0.44

Given that 1) the total energy use for 2012 and 2020 were very similar in magnitude and 2) the 2017 fuel use was not adjusted from the original 2012 data obtained from ASLRRA, the 2017

[5] USEIA, Annual Energy Outlook 2021. Accessed 3 Jan 2022. Available at https://www.eia.gov/outlooks/aeo/data/browser/#/?id=7-AEO2021&region=0-&cases=highmacro&start=2019&end=2021&f=A&linechart=ref2021-d113020a.5-7-AEO2021&map=&sid=ref2021-d113020a.51-7-AEO2021&sourcekey=0.

fuel use (gal) in EIS was summed to county FIP level and used to represent the spatial allocation of Class II and III rail sector activity (Figure 3).

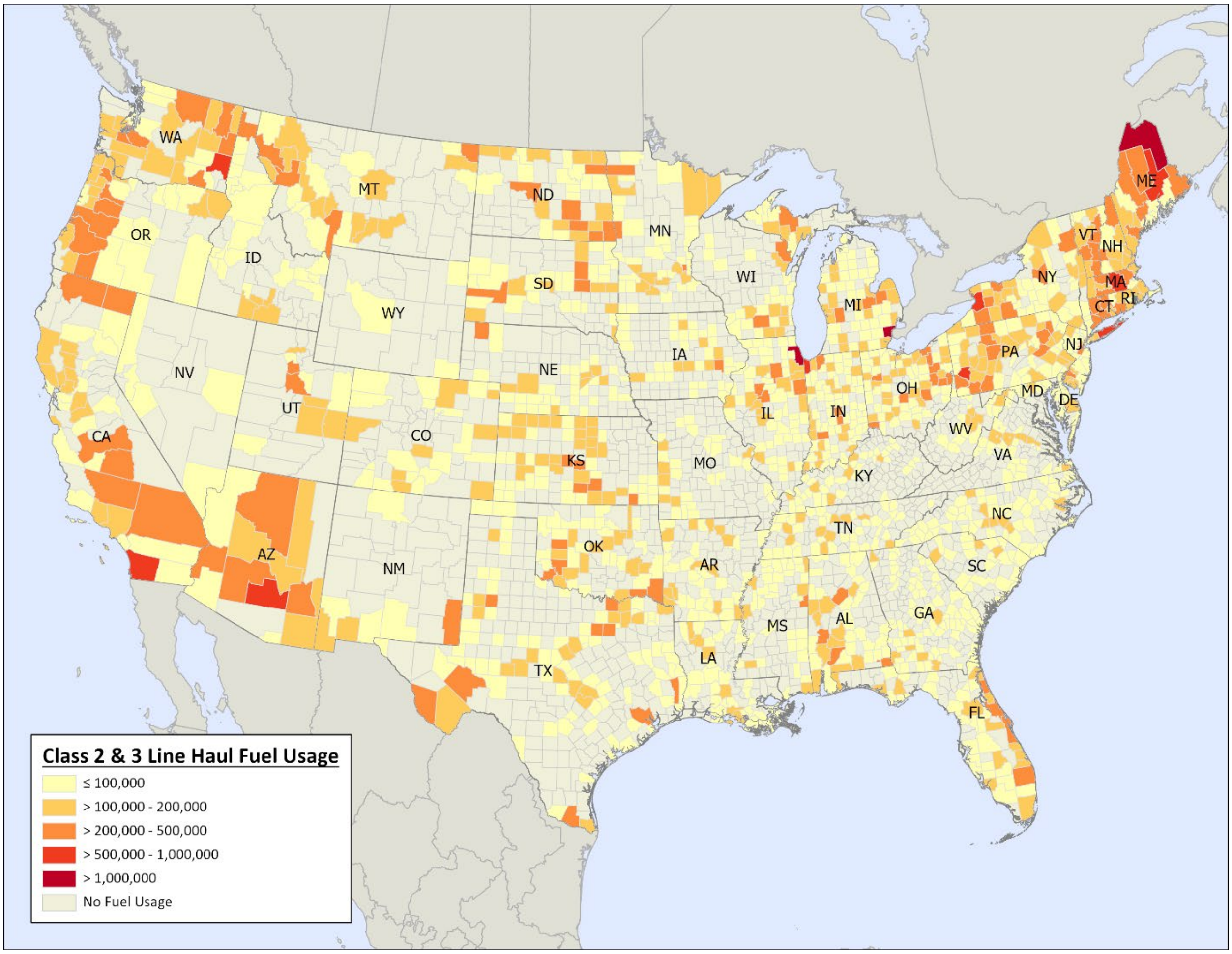

Figure 3. 2020 Class II/III Line Haul Fuel Usage (gal)

County-level fuel use was multiplied by the fleet-weighted emission factors to calculate tons of each pollutant emitted annually by county as noted in Equation 4.

$$EC = Fc * EFs/T$$ **Equation (4)**

where:

- E_C = County-level Class II & III emissions.
- F_c = County-level Class II & III fuel usage (gal).
- EFs = weighted emission factors (g/gal).
- T = 907,185 g/ton.

6. Commuter Rail Methodology

Commuter rail fuel use data was obtained from the Federal Transit Administration's (FTA) 2020 National Transit Database.[6] MBTA (Massachusetts) and Metra (Illinois) submitted their own fuel use and fleet mix data which was used in place of the NTD data. Table 11 lists the fuel use (gal) for commuter railroads in 2020 and the data source for each.

Table 11. 2020 Fuel Use by Commuter Railroad

Agency	Diesel (gal)
Altamont Corridor Express	514,210
Central Florida Commuter Rail, dba: SunRail	810,032
Central Puget Sound Regional Transit Authority, dba: Sound Transit	625,305
Connecticut Department of Transportation	1,678,569
Dallas Area Rapid Transit	1,375,987
Denver Regional Transportation District	-
Fort Worth Transportation Authority, dba: Trinity Metro	442,412
Maryland Transit Administration	3,709,703
Massachusetts Bay Transportation Authority (data provided by MBTA)	12,605,214
Metro Transit, dba: Metro Transit	213,780
Metro-North Commuter Railroad Company, dba: MTA Metro-North Railroad	5,697,351
MTA Long Island Rail Road	7,034,074
New Jersey Transit Corporation	13,166,567
North County Transit District	766,773
Northeast Illinois Regional Commuter Railroad Corporation, dba: Metra (data provided by Metra)*	18,783,969
Northern Indiana Commuter Transportation District	-
Northern New England Passenger Rail Authority	628,302
Peninsula Corridor Joint Powers Board, dba: Caltrain	3,805,923
Pennsylvania Department of Transportation	-
Regional Transportation Authority	195,054
Rio Metro Regional Transit District	-
Sonoma-Marin Area Rail Transit District	286,520
South Florida Regional Transportation Authority, dba: TRI-Rail	2,838,234
Southeastern Pennsylvania Transportation Authority	-
Southern California Regional Rail Authority, dba: Metrolink	8,293,151
Utah Transit Authority	1,921,417
Virginia Railway Express	1,430,638

[6] FTA, 2020 National Transit Database, 2020 Fuel and Energy. Accessed 21 Nov 2021. Available at https://www.transit.dot.gov/ntd/data-product/2020-fuel-and-energy.

Table 12 shows the limited fleet profiles by tier for commuter rail, for the purpose of this inventory the Class I profile was used to develop the weighted emission factors for commuter railroads noted in Table 13.

Table 12. 2020 Fleet Mix by Tier for Commuter Railroads (Percent)

Locomotive Tier	AAR	Metra	MBTA
NC	1.98%		1.69%
0	5.28%	16.67%	
0+	13.70%	65.33%	66.95%
1	0.71%	7.33%	
1+	25.54%	10.67%	
2	4.59%		3.39%
2+	22.59%		
3	14.43%		27.97%
4	7.04%		
4C	4.14%		
Total	100%	100%	100%

Table 13. 2020 Fleet-Weighted Emission Factors for Commuter Railroads

	Weighted Emission Factors (g/gal)									
	CH_4	CO	CO_2	N_2O	NH_3	NO_X	PM_{10}	PM_{25}	SO_2	VOC
AAR	0.8	26.624	10150	0.26	0.0833	120.4808	3.04202	2.95076	0.0939	4.854434
Metra	0.8	26.624	10150	0.26	0.0833	152.7423	4.75904	4.616269	0.0939	7.477479
MBTA	0.8	26.624	10150	0.26	0.0833	137.1302	3.490169	3.385464	0.0939	5.566551

Spatial distribution of commuter operations was assumed to be similar between 2017 and 2020. As such, 2017 fuel use by commuter railroad and by county was extracted from EIS. As noted in Equation 5, company/county-level values were divided by the 2017 total fuel use for each company to identify the percentage of activity represented by each county. Updated 2020 total company-level fuel use was multiplied by this percentage and the fleet-weighted emission factors to calculate tons of each pollutant emitted annually by county.

$$E_{com\text{- }FIP/RR} = F_{2017c\text{-}RR} / F_{2017RR} * F_{2020RR} * EFs / 907{,}185 \qquad \textbf{Equation (5)}$$

where:

$E_{com\text{- }FIP/RR}$ = County-level (FIP) commuter emissions per commuter line (RR) (tons).

$F_{2017c\text{-}RR}$ = County-level Commuter 2017 fuel usage per commuter line (RR) (gal).

F_{2017RR} = Total commuter 2017 fuel usage for commuter line (RR) (gal).

F_{2020RR} = Total 2020 fuel usage for commuter line (RR) (gal).

EFs = weighted commuter emission factors (g/gal).

RR = Railroad Company.

T = 907,185 g/ton.

7. Passenger Methodology (Amtrak)

For this effort, Amtrak provided updated fuel use (for the fiscal year October 2019 through September 2020) and their most recent fleet mix. Total fuel use for FY2020 was 50,576,448 gallons which included 1.56% fuel associated with switcher engines. Without yard locations to which these gallons could be allotted, the total (i.e., switch and line haul) fuel use was used in the line haul calculation.

Figure 4. Amtrak National Rail Network

As with the 2017 effort, Amtrak's reported fuel use was evenly distributed across its network based on track mileage within each county FIP. The latest Amtrak shapefile reflected both the train track as well as individual routes (Figure 5).[7] Where multiple routes pass through a single rail segment, that segment received a proportionately larger fuel allocation. For example, a portion of track that services two routes would be allocated twice the fuel as an identical length of track servicing only one route. The updated Amtrak fleet profile (Table 14) was used to create passenger-specific emission factors for the 2020 inventory (Table 15).

Table 14. 2020 Line Haul Fleet Mix by Tier for Amtrak

Locomotive Tier	Engine Count	Amtrak
NC	36	10.91%
0	217	65.76%
2+	13	3.94%
4	64	19.39%
Total	330	100%

Table 15. 2020 Amtrak Fleet-Weighted Emission Factors

Amtrak 2020 Weighted Emission Factors									
CH_4	CO	CO_2	N_2O	NH_3	NO_X	PM_{10}	PM_{25}	SO_2	VOC
0.8	26.624	10150	0.26	0.0833	155.2153	5.228994	5.072124	0.0939	8.34216

County-level fuel use was developed based on the miles of Amtrak within a county relative to the total miles of Amtrak track miles. This county level fuel usage was multiplied by the fleet-weighted emission factors to calculate tons of each pollutant emitted annually within each county as noted in Equation 6.

$$E_{at\text{-}fip} = M_{fip} / M_{at} * F_{2020at} * EFs / T$$ **Equation (6)**

where:

- $E_{at\text{-}fip}$ = County-level Amtrak emissions per commuter line.
- M_{fip} = County-level (FIP) Amtrak mileage (miles).
- M_{at} = Total Amtrak mileage (miles).
- F_{2020at} = Total 2020 Amtrak fuel usage (gal).
- EFs = weighted emission factors (g/gal).
- T = 907,185 g/ton.

8. EMISSIONS SUMMARIES

2020 emissions resulting from the methodology above are presented in Table 16.

[7] https://catalog.data.gov/dataset/amtrak-rail-lines-national.

Table 16. 2020 US Locomotive Emissions by Sector

2020 Rail Sector	2020 Emissions (tons/year)									
	CH_4	CO	CO_2	N_2O	NH_3	NO_X	PM_{10}	PM_{25}	SO_2	VOC
Class I Line Haul	2,461	81,917	31,229,546	800	256	370,696	9,360	9,079	289	14,936
Class I Yard	161.21	5,605	2,045,315	52.39	16.79	40,269	1,057	1,025	18.92	2,615
Class 2/3 Line Haul	133.28	3,880.98	1,690,931	43.31	13.88	29,799	898.49	871.53	15.64	1,419.83
Commuter	75.76	2,514	961,181	24.62	7.89	12,309	329.89	319.96	8.89	523.91
Amtrak	44.60	1,484	565,872	14.50	4.64	8,653	91.52	282.78	5.24	465.08

2020 was a unique year in locomotive activity due to the impacts of the COVID-19 pandemic. In general, activity decreased approximately 15% from 2017 according to figures from EIA's AIO. Fleet profiles also experienced significant changes, as several older line haul engines were held in storage or redeployed and newer engine purchases/rebuilds were completed and brought during this challenging time in terms of both demand and efficiency needs. For example, the 2020 Class I Fleet profile (Table 17) shows a distinct shift toward more efficient engines which impacts the weighted emission factors sufficiently to reduce overall emission factors for fuel-based pollutants by almost 17% (Table 18). Similarly, Class II/III showed an overall 10% increase in engine counts (Table 19) but still had lower emissions after emission factor weighting by the fleet makeup (Table 20).

Table 17. Class I Line Haul Fleet Profile by Tier Level for 2017 and 2020

Class I Line Haul Tier Level	Locomotive Count	2017 % of Fleet	2020 % of Fleet
Not Classified	333	5%	2%
Tier 0 (1973-2001)	887	19%	5%
Tier 0+ (Tier 0 rebuilds)	2,300	14%	14%
Tier 1 (2002-2004)	119	3%	1%
Tier 1+ (Tier 1 rebuilds)	4,288	22%	26%
Tier 2 (2005-2011)	770	12%	5%
Tier 2+ (Tier 2 rebuilds)	3,792	9%	23%
Tier 3 (2012-2014)	2,422	12%	14%
Tier 4 (2015 and later)	1,181	3%	7%
Tier 4 Credit (Tier 3 design built 2015 and after)*	695		4%

Table 18. Class I Fleet-Weighted Emission Factors

Pollutant	2017 EFs (g/gal)	2020 EF g/gal
NO_X	138.631	120.481
PM_{10}	4.117	3.042
VOC	4.772	4.855

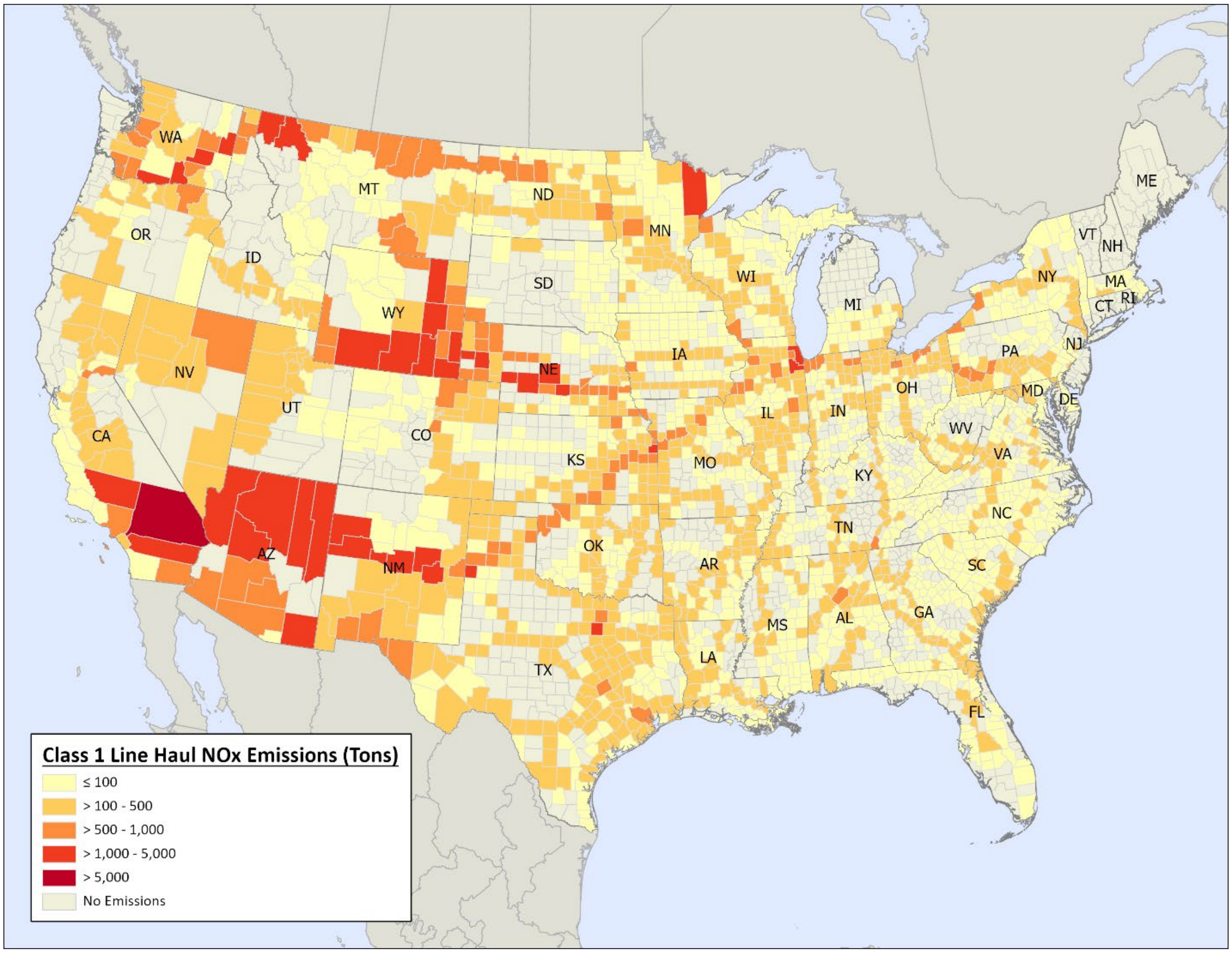

Figure 5. 2020 Class I Line Haul NO_X Emissions (tons) by County

Table 19. 2017-2020 Class II/III Fleet Profile Comparison

Class II/III Fleet Profiles				
Tier	2017 Locomotive Count	2020 Locomotive Count	2017 % of Fleet	2020 % of Fleet
0	1,379	1,664	44%	48%
1	7	31	0%	1%
2	107	169	3%	5%

Class II/III Fleet Profiles				
Tier	2017 Locomotive Count	2020 Locomotive Count	2017 % of Fleet	2020 % of Fleet
3	118	160	4%	5%
4	22	64	1%	2%
NC	1,492	1,359	48%	39%
Total	**3,125**	**3,447**	**100%**	**100%**

Table 20. Class II/III Fleet-Weighted Emission Factors for 2017 and 2020

Pollutant	2017 EFs (g/gal)	2020 EF g/gal
CO	26.624	23.296
NO_X	216.401	178.8724195
PM_{10}	6.314	5.393261387

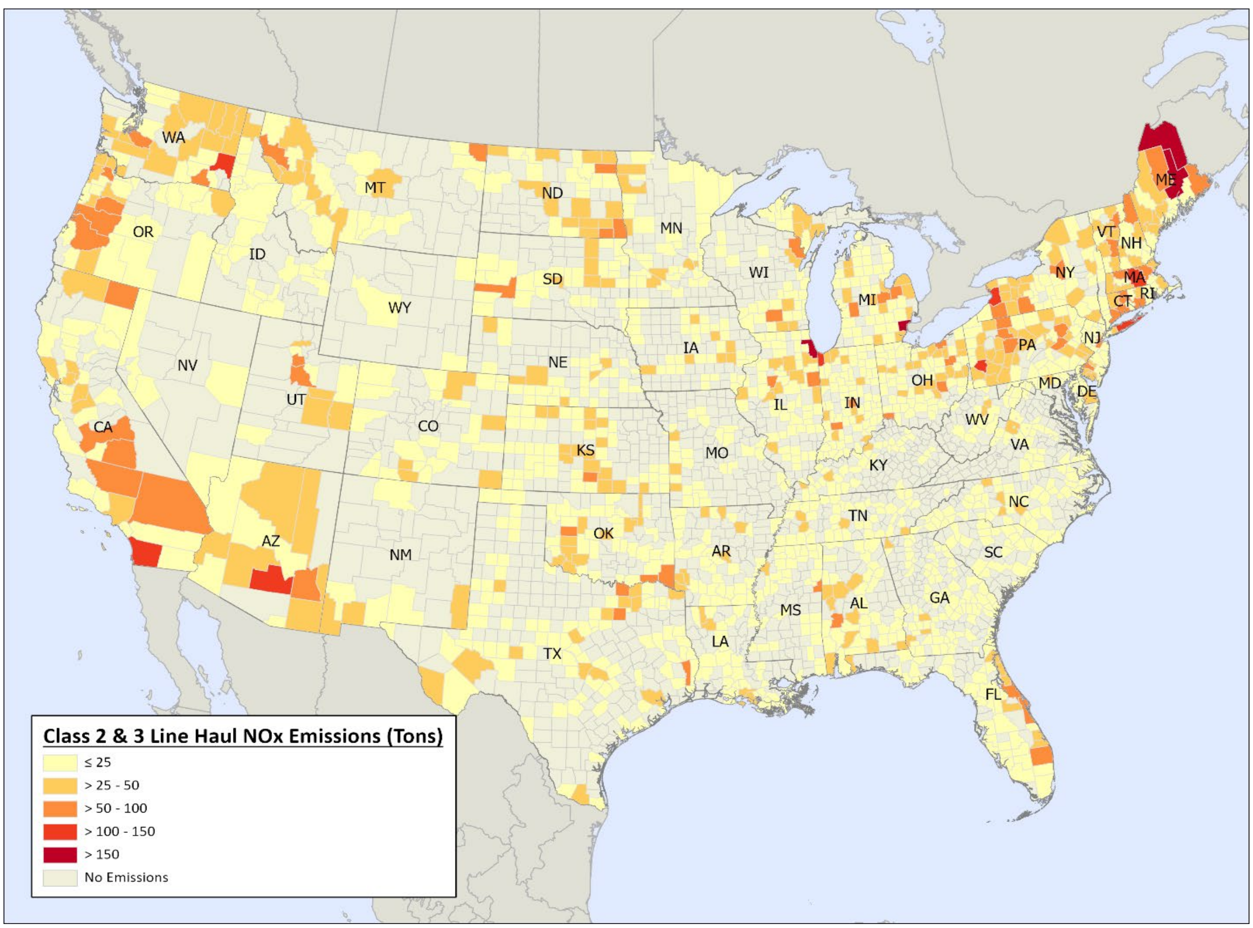

Figure 6. Class II/III Line Haul NO_X Emissions by County (tons)

For Class I yard activities, the trend is somewhat different. The change in fleet mix moves in the opposite direction, toward older technology and away from cleaner, higher Tier engines (Table 21) though declining activity is associated with lower fuel usage (Table 22).

Table 21. 2017-2020 Yard Engine Fleet Composition Comparison

Tier	2020 Locomotive Count	2017 % of Fleet	2020 % of Fleet
0	673	23.61%	23.75%
0+	1,182	25.99%	41.71%
1	0	0.00%	0.00%
1+	26	4.76%	0.92%
2	7	2.33%	0.25%
2+	0	4.64%	0.00%
3	11	10.18%	0.39%
4	23	2.47%	0.81%
NC	912	26.01%	32.18%

Table 22. 2017-2020 Switch Engine Counts and Fuel Use

	Yard Engine Count	Fuel Use (gal)
2017	2,986	223,605,320
2020	2,890	182,805,846

Finally, commuter emissions also decreased due to lower fuel usage (Table 23) which may be due to a reduction in activity and/or a changing fleet profile that could include newer more efficient engines such as noted in Tier profile for Amtrak presented in Table 24.

Table 23. Total Commuter Fuel Use (gallons)

Fuel Use	2017	2020
Commuter	96,175,602	86,823,185

Table 24. Amtrak Fleet Profile by Tier Level

Year	Uncontrolled	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4
2017	7.09%	85.43%	0	0	0	0
2020	10.9%	65.8%	4.0%	19.0	0	0

While 2020 is not a typical activity/emissions year that can be of particular use for trends and projections, these results provide valuable insight on the strengths, limitations, and flexibility of our rail infrastructure and the companies that define it. Many companies have shown unparalleled ingenuity in adjusting to unprecedented demands on the sector; and other lessons learned over the last few years may be further apparent in future industry developments and reflected in later inventory efforts.

9. LIMITATIONS AND FUTURE CONSIDERATIONS

Emission inventory development is ever evolving, such that future improvements to the locomotive component of NEI are possible through expanded availability of activity data and processing capabilities. Some potential avenues for increased accuracy include the following:

- Develop activity and emissions at the rail segment level for improved spatial accuracy. This could of particular benefit to modeling efforts to better understand how local air quality is affected by locomotive activities, including impacts within environmental justice communities.
- While fleet profiles of active locomotive engines improve emission factor refinement, current emission estimates assume equal activity by each locomotive regardless of age. More refined activity by Tier and/or engine age would bring emission factors closer to real-life fleet values.
- Similarly, studies providing additional insight on how engine efficiency changes over time could provide even more refined emission factors as determined by age instead of Tier.
- Class II and III railroads are not required to submit R-1 reports; consequently, their vital contribution to the freight network is not well-represented in publicly available data. More detailed activity information for short line and regional railroads would improve emissions estimates, particularly if track-level or local activity can be obtained.
- Switch yard emissions continue to be a weak point in emission inventory development. Yard-specific data, such as engine counts, engine age(s), hours of operation, and fuel use have improved estimates; but these data elements are not available for all yards and are particularly sparse for Class II and III and passenger rail yards.
- Amtrak operates diesel, electric, and dual-mode (diesel or electric) locomotives at varying levels and in different regions. Insight from Amtrak regarding activity levels by engine type and operations by route would improve both emission estimates and spatial representation of activity.
- Currently it is assumed that all railroad companies within a Class have the same distribution of Tier level engines. It should be noted that each rail company has different locomotive age profiles and therefore should have different fleet Tier-level profiles that reflects the investments these companies are making in efficiency and account for emission reductions associated with the use of higher Tier locomotives. For future inventories these companies should be approach for data on their fleet age/Tier level.

- HAP profiles have not been reviewed in some time. New data derived from testing and/or revised methodology could provide more accurate speciation profiles than the profile used for the last several inventory cycles.