2020 SmartWay Rail Carrier Partner Tool:

Technical Documentation

U.S. Version 2.0.19 (Data Year 2019)

EPA-420-B-20-023 | April 2020 | SmartWay Transport Partnership | epa.gov/smartway

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Transportation and Climate Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

EPA-420-B-20-023
April 2020

Table of Contents

List of Tables

1.0 Data Sources

The technical approach recommended for the SmartWay railroad model was developed to encourage railroad participation by providing methods to calculate emissions, fuel consumption, and comparison metrics based, to the extent possible, based on data the participating railroad companies have on hand and provide annually to the Department of Transportation's Federal Railroad Administration (FRA). For example, the approach presented uses data elements that Class 1 railway companies submit in their annual R-1 reports. Class I Railroad companies can use their most recent R-1 data for this SmartWay Tool. The relevant data reported annually to the FRA's R-1 forms include:

- Power Unit Information – Form 710
- Locomotive Unit Miles – Form 755, lines 8-14
- Railcar Miles – Form 755, line 30
- Fuel Consumption by Fuel Type and Unit Type – Form 750, lines 1-3
- Ton-Mile Data – Form 755, lines 104, 110, 113

As Class 2 and 3 railroads do not need to provide detailed information to the FRA, in order for them to participate in the SmartWay Program they need to develop and submit the required data specific for their operations. Where a Class 2 or 3 railroad company does not have all of the required information, surrogate data are provided in the Appendix B of this report that may be useful to develop some of the basic data required for the Tool.

2.0 Emission Estimation

Regardless of the locomotive class, the SmartWay Rail Tool was designed to calculate CO_2 performance metrics based on fuel consumption estimates, and NO_x and PM emissions based on tier-specific engine operation information.

In the SmartWay Rail Tool, the data for line-haul (including short line-haul and passenger rail) and yard operations are handled separately, even though many of the data elements are the same. Line-haul and yard operations are sufficiently different that they require separate emission factors associated with the different duty cycles. If operational surrogates are needed, then these should be compiled specific to either line-haul or yard operations.

The specific Rail Tool calculation outputs include:

- total mass emissions (CO_2, NO_x, PM_{10} and $PM_{2.5}$)
- g/ton-mile (gross, revenue, non-revenue)
- g/railcar-mile (just total miles)
- g/truck-equivalent-mile (just total miles)

The following presents the calculation procedures used to estimate these performance metrics.

1. **Calculating mass emissions (total grams)**
   a. CO_2 [1]
   i. Diesel fuel: grams of CO_2 = total gallons diesel (freight + passenger + switching) x 10,180 g CO_2/gallon.
   ii. Biodiesel: The Tool uses the biodiesel blend percentage to interpolate between regular diesel and 100% biodiesel fuel factors, with 100% biodiesel = 9,460 g/gallon. Therefore 20% biodiesel (B20) has a fuel factor of 10,180 – (10,180 – 9,460) x (20/100) = 10,036 g CO_2/gallon
   iii. LNG: grams of CO_2 = total gallons LNG (freight + passenger + switching) x 4,394 g CO_2/gallon.
   iv. CNG: If input in cubic feet, grams of CO_2 = total cubic feet (freight + passenger + switching) x 57.8. If CNG input is in equivalent gallons, the Tool multiplies total gallons by 7,030 g CO_2/gallon.
   v. Electric: grams of CO_2 = total kWh x 607 g CO_2/kWhr. See **Appendix C** for details.

[1] With the exception of the electricity factors, the source of the fuel-based CO_2 factors are discussed in the SmartWay Truck Tool Technical Documentation.

b. NO_x and PM

vi. Diesel - Data Input Methods 2 and 4 (inputs differentiated by line haul and switcher)

1) The Tool first calculates the proportion of hrs/units by Tier level.

a) The following provides an example for line haul units:

Table 1. Example Operation Hour Allocation by Tier Level

Tier Level	Hrs	Fraction
Non-Tier -	3,000	0.15
0	0	0
0+	1,000	0.05
1	2,000	0.1
1+	5,000	0.25
2	0	0
2+	4,000	0.2
3	5,000	0.25
4	0	0
Total	**20,000**	**1.00**

b) The Tool repeats this calculation for the switcher distribution

c) The Tool then calculates weighted average fuel factors for NO_x and PM, using the following table.[2]

Table 2. Emission Factors by Tier Level and Unit Type

Engine Tier	Unit Type	g/gal		
		NO_x	PM_{10}	$PM_{2.5}$
Non-tier	Line-Haul/Passenger	270.40	6.66	6.46
	Switcher	264.48	6.69	6.49
Tier 0	Line-Haul/Passenger	178.88	6.66	6.46
	Switcher	191.52	6.69	6.49
Tier 0 +	Line-Haul/Passenger	149.76	4.16	4.04
	Switcher	161.12	3.50	3.40

[2] EPA 2009, Emission Factors for Locomotives. https://nepis.epa.gov/Exe/ZyNET.exe/P100500B.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2006+Thru+2010&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C06thru10%5CTxt%5C00000010%5CP100500B.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL,accessed 3-23-20.

Table 2. Emission Factors by Tier Level and Unit Type

Engine Tier	Unit Type	g/gal		
		NO_x	PM_{10}	$PM_{2.5}$
Tier 1	Line-Haul/Passenger	139.36	6.66	6.46
	Switcher	150.48	6.54	6.34
Tier 1 +	Line-Haul/Passenger	139.36	4.16	4.04
	Switcher	150.48	3.50	3.40
Tier 2	Line-Haul/Passenger	102.96	3.74	3.63
	Switcher	110.96	2.89	2.80
Tier 2+	Line-Haul/Passenger	102.96	1.66	1.61
	Switcher	110.96	1.67	1.62
Tier 3	Line-Haul/Passenger	102.96	1.66	1.61
	Switcher	68.40	1.22	1.18
Tier 4	Line-Haul/Passenger	20.80	0.31	0.30
	Switcher	15.20	0.23	0.22

i) Example calculation for the weighted NO_x factor for line-haul case above:

Weighted average = 270.4 x 0.15 + 178.88 x 0.0 + 149.76 x 0.05 + 139.36 x 0.1 + 139.36 x 0.25 + 102.96 x 0.0 + 102.96 x 0.1 + 102.96 x 0.25 = **132.86 g/gal NO_x**

ii) The Tool repeats these calculations for $PM_{10/2.5}$

iii) All calculations are then repeated for switchers

2) The Tool multiplies gallons of (freight + passenger) diesel by weighted average fuel factors for line-haul/passenger category.

3) The Tool multiplies gallons of switcher diesel by weighted average fuel factors for switchers.

4) The Tool sums grams for line-haul/passenger and switchers to obtain total tons for NO_x, PM_{10} and $PM_{2.5}$.

ii. Diesel - Data Input Methods 1 and 3 (inputs NOT differentiated by line haul and switcher)

1) The Tool uses Table 2 to calculate the weighted average fuel factors[3]

[3] The factors in Table 2 are calculated by weighting the line haul/passenger and switcher values from Table 1 by the national average relative fuel consumption levels for these categories (0.925 and 0.075, respectively). National average values were obtained from 2010 R-1 reports.

Table 3. Emission Factors by Engine Tier Only

Engine Tier	g/gal		
	NO_x	PM_{10}	$PM_{2.5}$
Non-Tier	269.96	6.66	6.46
Tier 0	179.83	6.66	6.46
Tier 0+	150.61	4.11	3.99
Tier 1	140.19	6.65	6.45
Tier 1+	140.19	4.11	3.99
Tier 2	103.56	3.68	3.57
Tier 2+	103.56	1.66	1.61
Tier 3	100.37	1.63	1.58
Tier 4	20.38	0.31	0.30

2) The Tool follows the same process as for Data Input Methods 2 and 4, but there is no need to sum across unit types (step 4 above).

iii. Biodiesel –

1) Biodiesel NO_x and $PM_{10/2.5}$ emissions are calculated by applying an adjustment factor to diesel emissions. Therefore the first is to multiply the biodiesel gallons by the diesel fuel factors as described above to calculate an unadjusted estimate for grams of NO_x, PM_{10} and $PM_{2.5}$.

2) Next the Tool calculates adjustment factors based on % biodiesel blend specified – see Truck Tool Technical Documentation for references.

a) % change in emissions = $[\exp[a \times (\text{vol\% biodiesel})] - 1] \times 100\%$

Where $a = 0.0009794$ for NO_x, and $a = -0.006384$ for $PM_{10/2.5}$

b) The Tool applies the adjustment factor to the unadjusted grams of NO_x and $PM_{10/2.5}$ calculated above. In general PM emissions are somewhat lower than diesel emissions, while NO_x emissions increase slightly.

iv. LNG – [4]

1) The Tool first sums total gallons of LNG across line-haul, passenger, and switchers

2) The Tool then multiplies total gallons by 20.3 g/gal to obtain grams NO_x; and by 1.35 g/gal to obtain PM_{10}. The Tool multiplies the gallons value by 1.31 to obtain $PM_{2.5}$. See Appendix A regarding the source of these fuel-based factors.

[4] LNG, CNG, and Electricity factors do not vary with engine tier. Therefore the Tool does not calculate weighted averages based on tier level distributions, but simply uses the gallons and/or kWh amounts from the Operations screen.

v. CNG –

1) The Tool converts cubic feet of CNG to gallons if necessary with 1 standard cubic foot of CNT = 0.00823 equivalent gallons.
2) The Tool sums total gallons of CNG across line-haul, passenger, and switchers
3) The Tool multiplies total gallons by 20.3 g/gal to obtain grams NO_x; and by 1.35 g/gal to obtain PM_{10}. The Tool multiplies the gallons value by 1.31 to obtain $PM_{2.5}$. See Appendix A regarding the source of these fuel-based factors.

vi. Electricity –

1) The Tool sums total kWh of electricity across line-haul, passenger, and switchers
2) The Tool then multiplies total kWh by 0.400 to obtain grams NO_x; by 0.091 for grams PM_{10}; and by 0.037 for grams $PM_{2.5}$. See Appendix C for details.

2. **Calculate g/ton-mile for each pollutant (three types of "ton-miles")**

a. Grams per gross ton-mile: the Tool divides the grams of each pollutant (fleet total) by gross ton miles entered on Operations screen.

b. Grams per revenue ton-mile: the Tool divides the grams of each pollutant (fleet total) by revenue ton miles entered on Operations screen.[5]

c. Grams per non-revenue ton-mile: the Tool divides the grams of each pollutant (fleet total) by non-revenue ton miles entered on Operations screen.

3. **Calculate g/railcar-mile for each pollutant[6]**

a. The Tool divides the grams of each pollutant by total railcar miles entered

4. **Calculate g/truck-equivalent-mile**

a. Since rail operators do not provide railcar type/volume information, a national default value of 6,091 cubic feet per car is assumed for all carriers – see the **Shipper Tool Technical Documentation** for details.

b. Calculate the "truckload equivalents" factor (TE): divide the national average railcar volume by 3,780 cubic feet.[7]

c. g/truck-equivalent-mile = g/railcar-mile / TE, and is calculated for each pollutant.

[5] Value reported in SmartWay Public Bin Export Report.
[6] Ibid.
[7] Truck industry average freight volume is 2.78 TEU = 3,780 cubic feet (see Shipper Tool Technical Documentation).

Table 4. National Average Railcar Volume Data (Tool Defaults)

Type in Tool	Railcar Type	Cubic Feet	Source/Assumption *Key:* Norfolk Southern (NS), Union Pacific (UP), Burlington Northern Santa Fe (BNSF), CSX Transportation (CSX), Guide to Railcars (GTRC), Chicago Rail Car Leasing (CRCL), Union Tank Car Company (UTCC), U.S Department of Agriculture (USDA)
Box-Plain 50' + Box Equipped	Boxcar 50 ft and longer including equipped boxcars	7,177	Based on the average of the following boxcar types: 50ft assumed to be 5694 [reflecting the average of 5355 (NS), 5431 (UP), 5238 (CSX), 6175 (BSNF), 6269 (GTRC)]. 60ft assumed to be 6,648 [reflecting the average of 6618 (NS), 6389 (UP), 6085 (CSX), 7500 (BNSF)]. 50ft high cube assumed to be 6,304 [reflecting the average of 6339 (NS) and 6269 (CSX)]. 60 ft high cube assumed to be 6917 [reflecting the average of 7499 (NS), 6646 (CSX), and 6607 (GTRC)]. 86ft assumed to be 9999 (NS). Autoparts assumed to be 7499 (NS).
Box-Plain 40'	Boxcar 40ft	4,555	Based on estimate of 50ft boxcar volume described above. Assumed 40ft length would result in 20% reduction in volume.
Flat TOFC/COFC **Flat General Service** **Flat all other**	Flat car – all types except for multi-level	6,395	Based on the average of the following flat car types: 60ft assumed to be 6739 (BNSF). 89ft assumed to be 9372(BNSF). Coil assumed to be 3387(NS). Covered coil assumed to be 5294 [reflecting the average of 8328 (NS) and 2260 (BNSF)]. Centerbeam assumed to be 6546 [reflecting the average of 5857 (UP) and 7236 (BNSF)]. Bulkhead assumed to be 7030 (BNSF).
Flat Multi level	Multi-level flat car	13,625	Based on the average of the following multi-level flat car types: Unilevel (that carry very large cargo, such as vehicles/tractors) assumed to be 12183 (NS). Bi-level assumed to be 14381(NS). Tri-level assumed to be 14313 (based on average of 15287 (NS) and 13339 (BNSF).
	Flat Car – all types-including multi-level	7,428	Based on the average volumes of the flatcar types described above including multi-level as a single flat car type.
Gondola Plain **Gondola Equipped**	Gondola – all types Including equipped	5,190	Based on the average of the following gondola car types: 52-53ft assumed to be 2626 [based on average of 2665 (NS), 2743 (CSX), 2400 (BNSF), and 2697(CRLC)]. 60-66ft assumed to be 3372 [based on average of 3281 (NS), 3242 (CSX), 3350 (BNSF), CRCL-3670, and 3366

Table 4. National Average Railcar Volume Data (Tool Defaults)

Type in Tool	Railcar Type	Cubic Feet	Source/Assumption *Key:* Norfolk Southern (NS), Union Pacific (UP), Burlington Northern Santa Fe (BNSF), CSX Transportation (CSX), Guide to Railcars (GTRC), Chicago Rail Car Leasing (CRCL), Union Tank Car Company (UTCC), U.S Department of Agriculture (USDA)
			(GTRC)]. Municipal Waste assumed to be 7999 (NS). Woodchip assumed to be 7781[based on average of 7862 (NS) and 7700 (CRCL)]. Coal assumed to be 4170 [based on average of 3785 (NS) and 4556 (BNSF)].
Refrigerator Mechanical Refrigerated non-mechanical	Refrigerated - Mechanical /non-Mechanical	6,202	Based on the average of the following refrigerated car types: 48-72ft assumed to be 6963 [based on average of 6043 (UP) and 7883 (BNSF)]. 50ft assumed to be 5167(GTRC). 40-90 ft assumed to be 6476 [based on average of 6952 (UP) and 6000 (BNSF)].
Hopper Open Top-General Service	Open Top Hopper	4,220	Based on the average of the following open top hopper car types: 42ft assumed to be 3000 (UP). 54ft assumed to be 3700 (UP). 60ft assumed to be 5188 [based on average of 5125 (UP) and 5250 (GTRC)]. 45ft+ assumed to be 4105 [based on average of 4500 (UP) and 3710 (BNSF). Woodchip assumed to be 7075 [based on average of 7525 (NS), 5999 (UP), and 7700 (CRCL)]. Small Aggregate assumed to be 2252 [based on average of 2150 (NS), 2106 (BNSF), and 2500 (CRCL)].
Hopper Covered	Covered Top Hopper	4,188	Based on the average of the following covered top hopper car types: 45ft assumed to be 5250 (GTRC). Aggregate assumed to be 2575 [based on average of 2150 (NS) and 3000 (CRCL)]. Small Cube Gravel assumed to be 2939 [based on average of 2655 (NS), 3100 (CSX), and 3063 (BNSF). Med-Large Cube Ores and Sand assumed to be 4169 [based on average of 3750 (NS) and 4589 (BNSF)]. Jumbo assumed to be 5147 [based on average of 4875 (NS), 4462 (CSX), 5175 (BNSF), and 6075 (CRCL)]. Pressure Differential (flour) assumed to be 5050 [based on average of 5124 (NS) and 4975 (CRCL)].
Tank under 22,000 gallons	Tank Cars under 22,000 gallons	2,314	Assumes 1 gallon=0.1337 cubic foot (USDA). Based on small tank car average volume of 17304 gallons,

Table 4. National Average Railcar Volume Data (Tool Defaults)

Type in Tool	Railcar Type	Cubic Feet	Source/Assumption *Key:* Norfolk Southern (NS), Union Pacific (UP), Burlington Northern Santa Fe (BNSF), CSX Transportation (CSX), Guide to Railcars (GTRC), Chicago Rail Car Leasing (CRCL), Union Tank Car Company (UTCC), U.S Department of Agriculture (USDA)
			which is the average of the following currently manufactured tank car volume design capacities of 13470, 13710, 15100, 15960, 16410,17300,19900,20000,20590, and 20610 gallons (GTRC).
Tank over 22,000 gallons	Tank Cars over 22,000 gallons	3,857	Assumes 1 gallon=0.1337 (USDA). Based on large tank car volume of 28851 gallons, which is the average of the following currently manufactured tank car volume design capacities of 23470, 25790, 27200, 28700, 30000, 33000, and 33800 gallons (GTRC).
All other cars **Work Equip & company Freight** **No payment car-miles**	All Other Cars	5,014	Based on average volume presented above for each of the nine railcar types (all flatcars are represented by the line item that includes multi-level flatcars - 7428).

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3.0 Activity Input Validation

SmartWay has developed general validation criteria based on 2011 R-1 report data in order to perform range checks on Partner activity inputs. These range checks are simply intended to identify unreasonable data entries only. Table 4 summarizes the R-1 data used for each Class 1 Rail Line, as well as the range check values derived from the carrier-specific data. Range check values are displayed in bold.

Maximum acceptable values for fuel use, ton-miles, car-miles, and unit miles for Class 1 operators were set equal to three times the rail-line specific maximum shown in the table. Similarly, minimum acceptable values for Class 1 operators were set equal to one tenth for fuel use, ton-miles, car-miles, and unit miles. Maximum acceptable values for Class 2 and 3 operators were set at one tenth of the Class 1 maximum value.

SmartWay will re-evaluate validation ranges to make them more precise, comprehensive, and consistent as Rail Partner data is collected in the future.

Table 5. 2011 R1 Activity Data and Rail Tool Validation Ranges

Rail Line	Total Fuel Use (gallons diesel oil)	Gross ton miles total (thousands)	Revenue Freight ton miles (thousands)	Non revenue Freight ton miles (thousands)	Total freight car miles (thousands)	Total Locomotive unit miles	Locomotive Train switching unit miles	Locomotive Yard switching unit miles
BNSF	1,340,634,000	1,200,654,478	648,431,637	6,117,197	11,316,277	495,865,213	2,161,568	14,323,105
CSX	500,735,225	456,207,620	228,394,651	1,216,165	4,789,143	186,017,342	6,557,484	14,352,854
GTC	124,776,076	105,195,469	51,253,084	518,201	1,241,217	31,375,934	2,686,536	4,714,915
KCSR	64,833,378	55,889,957	30,485,863	1,338,343	628,431	23,846,725	516,654	26,504,929
NS	473,887,662	392,056,820	191,712,562	1,267,931	4,327,021	170,767,368	7,042,003	14,060,355
Soo	72,442,000	70,325,676	34,581,354	333,090	807,927	27,407,979	2,686,353	2,577,600
UP	1,117,851,152	1,072,705,764	544,397,317	5,485,720	11,012,608	424,786,444	12,635,406	19,169,964
Class 1 max	4,021,902,000	3,601,963,434	1,945,294,911	18,351,591	33,948,831	1,487,595,639	37,906,218	79,514,787
Class 1 min	6,483,338	5,588,996	3,048,586	33,309	62,843	2,384,673	51,665	257,760
Class 2/3 max	134,063,400	120,065,448	64,843,164	611,720	1,131,628	49,586,521	1,263,541	2,650,493
Class 2/3 min	> 0	> 0	> 0	> 0	> 0	> 0	> 0	> 0

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Appendix A: Locomotive Emission Factors

A-1. FUEL-BASED EMISSION FACTORS

Table A-1. Line Haul Locomotive Emission Factors (grams per gal)

Pollutant	NO_x	PM_{10}	CO_2
Diesel	270.40[2]	6.66[2]	10,180
Biodiesel (B-20)	173[1]	7.88[1]	9,460[4]
CNG			7,030[4]
LNG	20.3[3]	1.35[3]	3,865[4]

1. MARKAL data (2009)
2. EPA Locomotive Emission Factors (2009)
3. ARB Rail Yard Agreement (2007) in terms of diesel equivalents
4. 40 CFR 600.113

Table A-2. Small Line-haul Locomotive Emission Factors (grams per gal)

Small Line Haul	Emission Factor g/gal
NO_x	236.60
PM_{10}	5.82
CO_2	10,180

Uncontrolled yard locomotive emission factors were obtained from EPA's Locomotive Emission Factors (2009).

Table A-3. Yard Locomotive Emission Factors (grams per gal)

Yard	Emission Factor g/gal
NO_x	264.48
PM_{10}	6.69
CO_2	10,180

Uncontrolled yard locomotive emission factors were obtained from EPA's Locomotive Emission Factors (2009). All emission factors listed here reflect uncontrolled (i.e., pre-Tier 0) emission levels.

Appendix B: Surrogate Locomotive Data

SURROGATE DATA FOR EMISSION ESTIMATION

Data provided in the R-1 reports have been compiled and evaluated to identify useful surrogates that may help Partners gap-fill missing data. Because the data is from Class I operations, it may be biased to larger operations.

SURROGATES FOR CALCULATING FUEL CONSUMPTION

The basic approach allows for emission calculations that roughly approximate emissions using reported total annual fuel consumption. If annual fuel consumption data are unknown, surrogate data, such as locomotive population, miles traveled, annual ton-miles or TEU-miles, can be used to provide an estimate for line-haul locomotive fuel consumption, as noted in the following table.

Table B-1. Fuel Usage Surrogates

Line Haul Surrogate Data Options in Absence of Annual Fuel Usage	Number of Locomotives	Total Annual Locomotive Miles	Total Annual Ton Miles Freight Transported	Total Annual TEU mile Equivalents
Multiplication Factor for estimating Annual Fuel Usage (gal/yr)	132,800 (gal/yr*locomotive)	2.44 (gal/ locomotive miles)	0.002 (gal/ton miles freight transported)	0.053 (gal/TEU-mile Equivalents)

Values used to develop the surrogates were derived from the Bureau of Transportation Statistics 2012 National Transportation Statistics Table 4-17.

When using the basic approach to estimate yard locomotive emissions, the number of locomotives can be applied to the fuel consumption factors noted in the following equation to estimate annual fuel usage:

Yard Fuel Use (gal/yr) = 195,451 (gal/yr*yard locomotive) x Number of Yard Locomotives

SURROGATES FOR METRIC COMPARISONS

The railroad model is designed to apply calculated emissions to a variety of operational parameters. This allows the derivation of metrics that can be used as a reference point to evaluate a Partner's environmental performance relative to others.

In instances where the necessary information has not been provided, surrogate data presented in Table B-2, may be used to estimate total miles traveled or the total annual ton-miles, based on the number of active line-hail locomotives in the Partner's fleet.

Table B-2. Surrogates for Estimating Annual Miles and Ton-Miles

Metric for Which Surrogate Data is Needed	Total Annual Train Miles Traveled	Total Annual Ton Miles
Multiplication Factor for Estimating Train miles or ton-miles based on the Number of Locomotives	54,400 (miles/yr*locomotive)	63,744,000 (ton-miles/yr*locomotive)

Appendix C: Derivation of National Average g/kW-hr Emission Factors

FROM ARGONNE GREET MODEL Version 2016. http://greet.es.anl.gov/

Table C-1. Electric Generation Mix (From Annual Energy Outlook 2016)

	U.S. Mix
Residual oil	0.7%
Natural gas	32.9%
Coal	33.5%
Nuclear power	19.7%
Biomass	1.0%
Others	12.2%

Others = Hydro, Wind, Geothermal, Solar PV etc.

Electric Transmission and Distribution Loss = 8.0%

Table C-2. Power Plant Emissions: in Grams per kWh of Electricity Available at Power Plant Gate

	GREET Calculated Emission Factors By Fuel Type Plants (Stationary and Transportation)				
	4.3	0.41	0.49		0.366
PM_{10}	0.18	0.01379	0.16	2.08	0.083
$PM_{2.5}$	0.13	0.01344	0.062	0.61	0.034
CO_2	950	440	960	1,530	559
CO_2 in burnt biomass from atmosphere				-750	

Assumes no emissions from nuclear power plants or "Others"

Table C-3. Power Plant Emissions: Grams per kWh of Electricity Available at User Sites (wall outlets)

	Total delivered based on US electric generation mix
NO_x	0.40
PM_{10}	0.091
$PM_{2.5}$	0.037
CO_2	607

Total power plant gate emissions/(1-electric transmission and distribution loss)

For more information:

U. S. Environmental Protection Agency
Office of Transportation and Air Quality
1200 Pennsylvania Ave. NW
Washington, DC 20460
(734) 214-4333

www.epa.gov/transportation-air-pollution-and-climate-change

U. S. Environmental Protection Agency
National Vehicle and Fuel Emissions Laboratory
2565 Plymouth Rd.
Ann Arbor, MI 48105
(734) 214-4200

www.epa.gov/aboutepa/about-national-vehicle-and-fuel-emissions-laboratory-nvfel