2022 SmartWay Online Shipper Tool:

Technical Documentation

U.S. Version 1.0
(Data Year 2021)

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

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Overview

The SmartWay Shipper Tool is intended to help shippers estimate and assess their carbon, PM, and NO_x emissions associated with goods movement in the U.S. freight trucking, rail, air and barge sectors.[1] Shippers can track their freight-related emissions performance from year-to-year using the Tool and assess a range of strategies to improve the emissions performance of their freight operations, including selection of low-emissions carriers and implementation of operational strategies such as (but not limited to) packaging improvements, load optimization and logistical improvements.

The SmartWay truck, barge, air, and logistics carrier emissions performance data that EPA has included in the Tool, along with industry average Class I rail CO_2 data, will allow shippers to generate accurate emissions inventories. The data will also help shippers optimize their emissions performance by allowing them to better estimate the emissions impact of individual carriers, modal shifts, and mileage/weight reduction strategies.

[1] Future versions of the tool may help shippers evaluate the emissions performance associated with ocean going vessels.

1.0 Tool Inputs and Calculations

After shippers enter their company and contact information, they provide basic information about each company they operate, including the name and NAICS code for each of these companies. For these individual companies to show up on the SmartWay Partner list on the EPA website, shippers should submit separate Shipper Tools, one for each company.

For each company, shippers need to indicate their participation level. If they have annual mileage-related activity data by carrier (miles or ton-miles), they should select Way 3 or Way 4, and proceed to input activity data for each carrier. Otherwise, they must select the Way 2 option, which only requires them to report the portion of goods they move with SmartWay carrier partners based on money spent, weight shipped, packages shipped, or another custom metric.

If shippers select the Way 2 option, they will not be eligible for a SmartWay Excellence Award, nor will they be able to calculate an emissions inventory or develop emissions performance metrics (e.g. g/mile or g/ton-mile) for their freight operations.[2] All shippers – regardless of participation level – will be able to see the SmartWay Category-level emissions performance data for their truck and logistics carriers as well as available industry average rail emissions factors. Emissions performance data for barge and air carriers are reported on a carrier-specific basis.

After identifying and selecting their SmartWay and non-SmartWay carriers, Way 4 shippers can then identify each carrier that they use for each company and the service that the carrier provides (e.g., Inbound or Outbound hauls, International and/or Domestic service, etc.). These optional parameters serve as "tags" which allows shippers to filter their emission data as desired using the screen tools discussed below.

EMISSION INVENTORY AND PERFORMANCE METRIC CALCULATIONS

If shippers choose the Way 3 or 4 option, the Tool will calculate their total mass emissions (i.e., an emissions inventory) based on the mileage-related activity data entered for each carrier, as well as various emission performance metrics (e.g., grams/mile and grams/ton-mile – see below).

Carrier-specific emissions are first calculated either on a ton-mile basis (as ton miles x grams per ton-mile), or on a miles basis (miles x grams per mile), depending on the SmartWay Category as shown in Table 1.[3] Any modes/categories not listed have a limited data availability and their emissions are calculated using ton-miles.

[2] Shipper partners are encouraged to select the Way 3 or 4 reporting option for all their companies whenever possible. When a shipper has multiple companies the participation level chosen for the % SmartWay Value calculation must be the same for all companies in order for the Tool to calculate a Partner level % SmartWay Value.

[3] Note that the Tool does not need shippers to enter a payload or ton-mile estimate for SmartWay Categories whose emissions are based on Miles, as the payload estimate will not affect the overall emissions footprint. However, the calculated emission factors and average payload estimate are affected by the assigned payload.

Table 1. Emissions Calculation Basis by SmartWay Category

SmartWay Category	Activity Basis	D_{tm}	D_m
Refrigerated	Ton-miles	1	0
Mixed	Ton-miles	1	0
TL/Dry Van	Ton-miles	1	0
Flatbed	Miles	0	1
Moving	Miles	0	1
Dray	Miles	0	1
Non-SW Truck General	Ton-Miles	1	0
Specialized	Miles	0	1
Expedited	Miles	0	1
Auto	Miles	0	1
Tanker	Miles	0	1
Heavy/Bulk	Miles	0	1

The Shipper partner's mass emissions are calculated by summing the individual carrier emissions. Then, fleet average emission factors are calculated by dividing mass emissions by total ton-miles and total miles to obtain grams per ton-mile and grams per mile, respectively. The fleet average payload is calculated by dividing total ton-miles by total miles.

Overall, carrier emissions are calculated using the following equations, where D_{tm} and D_m are dummy variables with values of either 0 or 1, as shown in Table 1 above.

$$E_c = D_{tm} * TonMiles * gtm + D_m * Miles * gm$$

Total emissions:

$$E_{tot} = \sum_c E_c$$

Emission factors and average payload (APL):

$$gtm = \frac{E_{tot}}{\sum_c TonMiles_c}$$

$$gm = \frac{E_{tot}}{\sum_c Miles_c}$$

$$APL = \frac{\sum_c TonMiles_c}{\sum_c Miles_c}$$

The emissions inventory for each carrier/mode combination displayed on the Emissions Summary, Carrier Performance and SmartWay Category Details screens is calculated using the equations shown above. To calculate composite emissions and associated performance metrics on the Carrier Performance screens (i.e., overall g/mile and g/ton-mile performance), the Tool simply sums the emissions, miles and ton-miles for the associated group (e.g., all Inbound carriers) and divides the total emissions by total miles and ton-miles as appropriate.

TON-MILE CALCULATION

Correctly calculating Ton-Miles is critically important for the accurate determination of your carbon footprint. You can calculate your company's ton-miles as follows.

Determine the ton-miles hauled per year attributable to each carrier. A ton-mile is one ton moving one mile. DO NOT ESTIMATE TON-MILES BY SIMPLY MULTIPLYING TOTAL MILES BY TOTAL TONS - this calculation effectively assumes your entire tonnage is transported on EACH AND EVERY shipment and will clearly overstate your ton-miles.

Many companies track their ton-miles and can report them directly without further calculation. For example, shipper company systems are often set up to associate a payload with the mileage traveled on each trip by carrier and are then summed at the end of the year. If such information is not available, there are two ways to calculate ton-miles:

1. Companies can determine their average payload per carrier, multiply the average payload by the total miles per carrier, and sum the results for all carriers for the reporting year; or

2. Set Ton-miles per carrier = $\frac{\text{(total miles per carrier x total tons per carrier)}}{\text{total \# of trips per carrier}}$

NOTE: In both ton-mile calculations, empty miles are not factored in while the fuel used to drive those empty miles is factored in.

To check your estimate, divide ton-miles by miles. The result is your fleet-average payload. If this number is not reasonable, (e.g., typically between 15 and 25 tons for Class 8b trucks), please check your calculations.

CARRIER EMISSIONS PERFORMANCE DATA

The current SmartWay program provides CO_2, NO_x and PM gram per mile, and gram per ton-mile emission factors for truck, rail, logistics, air and barge freight transport providers.

SmartWay may incorporate emission factors from ocean-going vessel transport providers in the future.

TRUCK CARRIER PERFORMANCE

Truck carrier performance data utilized by the current Shipper Tool is based on 2022 Truck Partner Tool submittals for activity in 2021. Performance data includes g/mile and g/ton-mile for each truck carrier. Note that g/mile and g/ton-mile values represent midpoints for the appropriate SmartWay Category, rather than exact performance levels for a given carrier. Truck SmartWay Categories include:

- TL Dry Van
- LTL Dry Van
- Refrigerated
- Flatbed
- Tanker
- Dray
- Package
- Auto Carrier
- Expedited
- Heavy/Bulk
- Moving
- Specialized
- Mixed

Carrier fleets are placed into a SmartWay Category and ranked with other SmartWay partners' fleets in that same category based on the following rules:

1. If 75% or more of fleet's Operation is Drayage the fleet is categorized as a Drayage fleet, regardless of what is specified for fleet's Body Type.

Otherwise

1. If 75% or more of the fleet's Body Type is Moving, Heavy/Bulk, Refrigerated, Tanker, Auto Carrier, or Flatbed then the fleet is categorized as that matching body type.
2. If the sum of the fleet's Utility Body Type and Special Hauler Body Type is 75% or more, then the fleet is categorized as Specialized/Utility.
3. If 75% or more of the fleet's Body Type is Dry Van or Chassis then:
    a. If 75% or more of the fleet's Operation is Truckload then the fleet is categorized as TL/Dry Van.
    b. If 75% or more of the fleet's Operation is Less than Truckload then the fleet is categorized as LTL/Dry Van.
    c. If 75% or more of the fleet's Operation is Package then the fleet is categorized as Package.
    d. If 75% or more of the fleet's Operation is Expedited then the fleet is categorized as Expedited.
    e. If none of the above (a through d) are true, then the fleet is categorized as Mixed.
4. Otherwise, if none of the above conditions exist the fleet is categorized as a Mixed fleet.

The following provides an overview of the process used to estimate the carrier-specific performance ranges.

Truck Performance Categories

In the 2022 SmartWay Truck Tool, data is collected at the individual company fleet level. Fleets are characterized by a) business type: for-hire or private, b) operational type: truckload/expedited, less than truckload, dray, expedited, or package delivery, and c) equipment type: dry van, refrigerated van, flatbed, tanker, chassis (container), heavy/bulk, auto carrier, moving, or specialized (e.g., hopper, livestock, others.)

The possible categories are shown below.

For Hire									
	Dry Van	Reefer	Flatbed	Tanker	Chassis	Heavy/Bulk	Auto Carrier	Moving	Specialized
TL									
LTL									
Dray									
Expedited									
Package									
Private									
	Dry Van	Reefer	Flatbed	Tanker	Chassis	Heavy/Bulk	Auto Carrier	Moving	Specialized
TL									
LTL									
Dray									
Expedited									
Package									

Note that while Specialized fleets have disparate operations/equipment types and thus do not compare well, they are also unlikely to compete with one another, so it was deemed acceptable to aggregate these disparate fleets into one category.

For-hire and private fleets are combined in the SmartWay Categories. There are relatively few private fleets compared to for-hire fleets. Because owners of private fleets generally hire their own fleets exclusively, it was determined that grouping for-hire and private fleets together would not be detrimental to for-hire fleets, and the simplicity of one for-hire and private category outweighed the benefits of listing fleets separately. Grouping for-hire and private separately would have doubled the number of SmartWay Categories. Therefore, fleets can thus be categorized as shown below.

For Hire and Private									
	Dry Van	Reefer	Flatbed	Tanker	Chassis	Heavy/Bulk	Auto Carrier	Moving	Specialized
TL									
LTL									
Dray									
Expedited									
Package									

Individual fleets were then placed into SmartWay Categories. The following shows the relative number of fleets for the various category intersections, with darker shadings indicating more fleets.

	Dry Van	Reefer	Flatbed	Tanker	Chassis	Heavy/Bulk	Auto Carrier	Moving	Specialized	Mixed
TL										
LTL				-	-	-			-	
Dray			-	-		-	-	-		
Expedited		-	-	-	-		-	-	-	
Package		-	-	-	-	-	-			-
Mixed				-		-		-	-	-

SmartWay then considered combining categories with similar characteristics for simplification purposes. One prerequisite was that there needed to be a minimum number of fleets in each category. SmartWay determined that a category needed a minimum of 25 fleets to be created. It was also determined that dry van and chassis (i.e., intermodal container) groups functioned primarily as dry van transport, so these categories were combined. While most refrigerated carriers were truckload, a few less than truckload refrigerated fleets exist, so these categories were combined. Although no expedited or package refrigerated fleets were identified, these categories were also combined into one overall refrigerated category so that no operation and equipment type intersections would be left undefined. A similar situation was identified with flatbed, tanker, heavy/bulk, auto carrier, moving, and specialized fleets. All dray fleets were collapsed into one category. Any fleet that had mixed operation and/or mixed equipment was placed into a single mixed category. Finally, logistics fleets were also included and retained as unique categories.

The final performance categories for 2022 are illustrated below. The solid colors indicate how operation and equipment type assignments vary by performance category. For example, if 75% or more of a fleet's mileage is associated with reefer trucks, the fleet is assigned to the Reefer category *regardless* of the operation percentage across truckload, expedited, LTL, and package categories. However, the Reefer category assignment is overridden if the operation category is greater than or equal to 75% dray or logistics. Similar assignment rules apply to flatbed, tanker, heavy/bulk, auto carrier, moving, and specialized equipment types, as described above. Only the Dry Van/Chassis equipment category is subdivided by the truckload, expedited, LTL, and package operation categories, meaning that the 75% threshold must be met for *both* equipment and operation type in these cases. All other equipment/operation type percentage distributions are assigned to the Mixed category.

Figure 1. SmartWay Carrier Categories and Data Specificity 2021 Data Year

TRUCK	Dry Van & Chassis	Reefer	Flatbed	Tanker	Heavy & Bulk	Auto Carrier	Moving	Specialized & Utility	Mixed
Dray	Dray 5 Performance Levels								
Truckload	Truckload DryVan 5 Performance Levels	Reefer 5 Performance Levels	Flatbed 5 Performance Levels	Tanker 5 Performance Levels	Heavy & Bulk 5 Performance Levels	Auto Carrier 5 Performance Levels	Moving 5 Performance Levels	Specialized & Utility 5 Performance Levels	Mixed 5 Performance Levels Less than 75% in any category
Expedited	Expedited 5 Performance Levels								
LTL	LTL 5 Performance Levels								
Package	Package Delivery 5 Performance Levels								
Mixed	Mixed								

Rail	Single Modal Average for All Rail (No company differentiation allowed per Association of American Railroads)
Barge	Company Specific Data
Air	Company Specific Data
Logistics	10 Performance Levels
Marine	To be determined

It is possible that SmartWay will expand these categories in the future based on in-use experience or as a result of further data analysis, and/or requests from industry.

Fleets *within a SmartWay Category* have been ranked from lowest emission factor (best) to highest emission factor (worst) for each of the following metrics: CO_2 g/mile, CO_2 g/ton-mile, NO_x g/mile, NO_x g/ton-mile, PM_{10} g/mile and PM_{10} g/ton-mile. When SmartWay Categories are first established, fleets within a category are separated into ranges such that an equal number of fleets were in each range. Each range thus represents a group of emission factors. These ranges, and associated ranking "cutpoints" (transition points from one rank to the next) were then modified so that each range had an equal difference between upper and lower bounds, and the new cutpoints remained as close to the originals as possible. The new range cutpoints are displayed as numbers with significant digits appropriate to emission factors in that range. The midpoint of the range is used as the emission factor for all fleets in that range.

It would be simpler and more straightforward to use fleet-specific emission factors, however the trucking industry expressed concern that revealing exact data could be used to back-calculate mile per gallon numbers. The methodology described above prevents a determination of an exact mpg figure, while at the same time attributing an emission factor much more precisely than a modal default number. Given the large number of trucking fleets, and thus opportunity for fleets to be very close to each other in performance, SmartWay believes it is acceptable and appropriate to break truck fleets into 5 performance ranges for each SmartWay Category.[4]

The table below illustrates the ranges in the For Hire/Private Truckload/Expedited Dry Van SmartWay Category, using 2013 Truck Partner data as an example.

Table 2. Emission Factor Ranges for One Performance Category (2013 Data)

For Hire/Private Truckload/ Dry Van CO_2 g/mile						
Group ID	Fleets Per Bin	Grams Per Mile Min	Grams Per Mile Max	Grams Per Mile Avg	Grams Per Mile Midpoint	Grams Per Mile Std Dev
1	186	944	1,549	1,452	1,500	118
2	227	1,551	1,650	1,601	1,600	28
3	194	1,651	1,749	1,692	1,700	29
4	140	1,751	1,848	1,798	1,800	29
5	115	1,851	5,090	2,010	1,900	359

Similar tables have been developed for all performance SmartWay Categories. The midpoint of each performance range is the data that a shipper downloads into their SmartWay Shipper Tool to represent the emission performance of a specific fleet that is in the associated range. Once the categories and ranges have been established, the fleets of any new companies joining SmartWay will fall into one of the predefined categories/ranges for that reporting year. SmartWay expects to update the category/range structure periodically.

Performance estimates for non-SmartWay truck carriers were calculated based on the lowest performing truck partners. Since no data exist to define non-SmartWay fleets, SmartWay believes the prudent approach is to assign conservative emission factors to non-SmartWay companies. Also, this policy makes it likely that any company joining SmartWay will see better emission factors displayed than the non-SmartWay default emission factors.

The non-SmartWay performance metrics were calculated by taking a standard performance range delta (max - min) for each range within each SmartWay Category and using the delta to calculate a non-SmartWay carrier midpoint for each Category. This midpoint is the midpoint for Range 5 plus the standard range delta. For example, if the Range 5 midpoint was 10.5 and the Category's standard delta was 1, then the non-SmartWay midpoint is calculated to be 11.5.[5] Table 3 summarizes the 2021 data year performance metrics for non-SmartWay Truck Carriers.

[4] 10 ranges for logistics to adequately characterize the wide range of modal operations used.

[5] The performance metrics for the Non-SmartWay "General" Truck Category, which can be selected by shippers when a carrier's SmartWay Category is unknown, is set equal to the performance metrics for the Non-SmartWay Mixed Truck Category within the tool.

Table 3. Non-SmartWay Truck Carrier Performance Metrics (Data Year 2022)

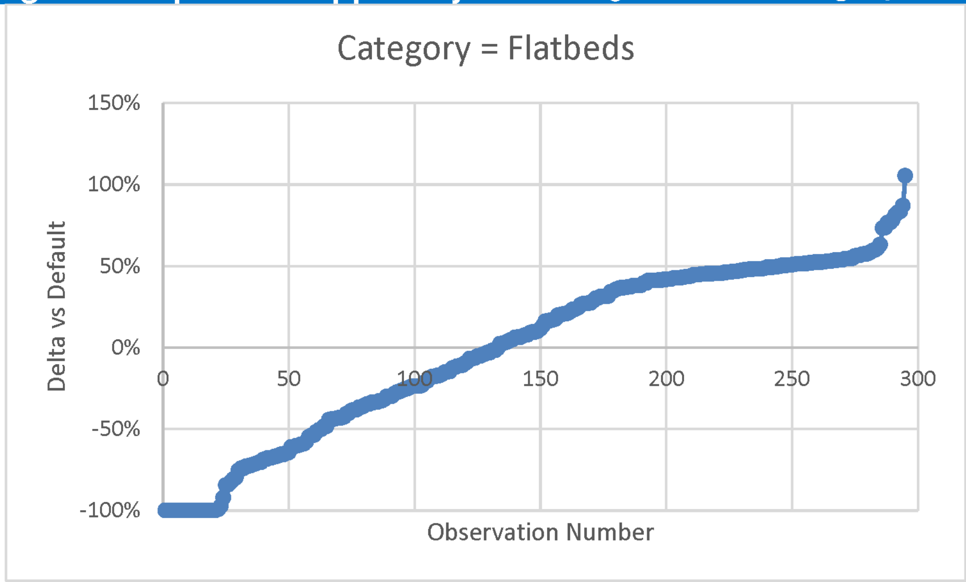
Category	CO_2 g/tmi	CO_2 g/mi	NO_x g/tmi	NO_x g/mi	PM2.5 g/tmi	PM2.5 g/mi
Auto Carrier	129	2,300	0.32	7.00	0.001	0.009
Dray	112	2,000	0.65	12.50	0.005	0.096
Expedited	980	1,825	0.63	4.80	0.008	0.017
Flatbed	99	2,060	0.235	6.50	0.002	0.013
General	100	2,015	0.29	5.60	0.002	0.028
Heavy/Bulk	83	2,540	0.185	6.50	0.001	0.010
LTL/Dry Van	192	1,730	0.425	5.15	0.003	0.013
Mixed	100	2,015	0.29	5.60	0.002	0.028
Moving	475	1,865	0.565	11.00	0.015	0.588
Package	890	1,090	1.04	2.75	0.012	0.007
Refrigerated	112	2,075	0.265	5.20	0.002	0.031
Specialized	113	2,310	0.325	7.10	0.002	0.031
TL/Dry Van	103	1,850	0.29	4.70	0.001	0.010
Tanker	80	1,950	0.215	4.90	0.002	0.012

As discussed in the Online Shipper Tool User Guide, depending upon the type of data available for a given carrier, the user may input ton-miles or miles, and rely on carrier data to back-calculate the other value. For example, providing ton-miles and average payload allows the Tool to estimate total miles, by dividing the former by the latter.

When the "Miles Only" data availability option is selected, the Shipper Tool uses a default payload saved in the carrier file for the associated SmartWay Category. Default values were determined by first plotting the range of reported payloads for all carriers within a SmartWay Category that were hired by Shipper Partners in the 2019 calendar year. The default payload value for each Category was selected to minimize the sum of the differences between each carrier's reported payload and the default value.[6] This approach effectively equalizes the areas above and below the 0% line in the plots – see Figure 2 for an example.

[6] The default payload value for the General Truck category is set equal to the average payload reported by shippers across all truck SmartWay Categories.

Figure 2. Reported Shipper Payload (2019) vs Default (15.24 tons)



LOGISTICS CARRIER PERFORMANCE

Logistic carriers have their own performance bins based on the carrier tool submittals for the most recent available calendar year.

Non-SmartWay carrier performance for the SmartWay Categories is estimated in the same way as is done for non-SmartWay Truck carriers. Table 4 summarizes the 2022 data year performance metrics for non-SmartWay Logistics Carriers.

Table 4. Non-SmartWay Logistics Carrier Performance Metrics (Data Year 2022)

Category	CO_2 g/tmi	CO_2 g/mi	NO_x g/tmi	NO_x g/mi	PM2.5 g/tmi	PM2.5 g/mi
Logistics	139	2,550	0.395	7.85	0.005	0.395

AIR AND BARGE CARRIER PERFORMANCE

Air and barge carriers have agreed to have their actual emissions results made public, and barge performance values used in the Shipper Tool are carrier-specific. The gram per mile performance values for barge carriers correspond to individual barge (nautical) miles travelled, rather than miles travelled by a string of barges or the associated tug(s).

Non-SmartWay barge carrier gram per mile and gram per ton-mile performance is set to be 25% higher than the worst performing SmartWay barge carrier.

Performance levels for non-SmartWay air freight are based on partner submittals, increasing the highest values reported by partners to provide a reasonable margin of error. These values will be reassessed as more air partner data are obtained. The performance metrics are shown in Table 5.

Table 5. Performance Metrics for Non-SmartWay Air and Barge Carriers

	CO_2/tmi	CO_2/mi	NO_x/tmi	NO_x/mi	PM/tmi	PM/mi
Short-haul Air	4,300	100,000	40	900	2	35
Long-haul Air	1,500	50,000	20	650	1	25
Barge	18.58	23,295	0.64	672	0.02	22.24

RAIL CARRIER PERFORMANCE

For Class 1 railroads, rail carrier performance data are collected and displayed in the Shipper Tool at the industry average level derived from Class 1 rail company data. Carrier performance data for Class 2 and 3 railroads are actual values calculated from their submitted tools. Gram per ton-mile factors were determined by dividing total fuel use by total ton-miles and multiplied by a rail diesel CO_2 factor (10,180 g CO_2/gal diesel fuel), from publicly available data submitted in the 2017 railroad R-1 reports to the Department of Transportation. 2017 R-1 data was also used to obtain total railcar-miles per year for all Class 1 carriers, to estimate gram per railcar-mile factors. *Industry average values are currently assumed for all rail carriers in the carrier file, regardless of SmartWay Partnership status.* Specific rail companies may have the opportunity to provide company-specific data in the future. The R-1 data and corresponding CO_2 performance data are presented in Table 6 below.

Table 6. Rail Carrier Performance Metric Calculation Inputs & Results (2017 R-1 Data)

Rail Company	Gal/Yr ('000) Sch. 750 Line 4	Freight Ton Mi/Yr ('000) Sch. 755 line 110	Railcar Mi/Yr ('000) Sch. 755 sum of lines 30, 46, 64 & 82	g CO_2/railcar mile	g CO_2/short ton mile
BNSF Railway	1,353,897	665,948,516	11,606,520	1,187	20.70
CSX Transportation	426,721	208,127,221	4,713,411	922	20.87
Grand Trunk	116,986	62,708,628	1,486,205	801	18.99
Kansas City Southern	68,873	34,582,626	724,012	968	20.27
Norfolk Southern*	458,179	201,451,969	4,383,081	1,064	23.15
Soo Line	65,299	35,244,079	745,550	892	18.86
Union Pacific	1,016,161	466,721,215	10,090,926	1,025	22.16
Total/Industry Average	3,506,116	1,674,784,254	33,749,705	980	20.72

* and combined subsidiaries

NO_x and PM emission factors for rail carriers are also based on industry averages. Please see the "Background on Illustrative (Modal Average) U.S. Truck and Rail Factors" in Appendix A for further details.

Average payloads per loaded railcar were calculated for all Class 1 carriers by dividing the value for annual ton-miles hauled by an estimate for loaded railcar-miles, based on 2008 R-1 data. The calculation uses the Total Revenue and Non-Revenue Ton-Miles as listed in the R-1 Report on line 114 of schedule 755 divided by the Total loaded Railcar-Miles (the sum of lines 30 and 64 of schedule 755) along with the factor for fuel gallons consumed for loaded freight that is created based on the percentage of loaded freight to total freight multiplied by the total diesel fuel value listed on schedule 750 Line 4. The following table summarizes the estimated average payload per railcar, by carrier.

Table 7. Rail Carrier Average Payload

Carrier	Avg Payload/Loaded Railcar (tons)
BNSF Railway	108
CSX Transportation	85
Grand Trunk	80
Kansas City Southern	91
Norfolk Southern	76
Soo Line	77
Union Pacific	91
Industry Average	93

Average railcar volumes were calculated for all carriers by first estimating an average volume for each major railcar type listed in the R-1 forms (schedule 755, lines 15-81). The assumptions used to estimate these volumes are provided in Table 8. The railcar-miles reported for each railcar type were multiplied by these average volumes to estimate annual cubic foot-miles travelled by car type for each company and for the industry average. The distribution of cubic foot-miles across car types was used as the weighting factor to estimate a single average railcar volume for each company. These values and the resulting volume estimates are presented in Table 9.

Table 8. Railcar Volume Assumptions and Sources

Railcar Type	Cubic Feet	**Source/Method** *Key:* Norfolk Southern Railroad (NS)[7], Union Pacific Railroad (UP)[8], Burlington Northern Santa Fe Railroad (BNSF)[9], CSX Transportation Railroad (CSX)[10], World Trade Press Guide to Railcars (GTRC)[11], Chicago Rail Car Leasing (CRCL)[12], Union Tank Car Company (UTCC)[13], U.S Department of Agriculture (USDA)[14]
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). Auto parts assumed to be 7499 (NS).
Boxcar 40ft	4,555	Based on estimate of 50ft boxcar volume described above. Assumed 40ft length would result in 20% reduction in volume.
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)]. Center beam assumed to be 6546 [reflecting the average of 5857 (UP) and 7236 (BNSF)]. Bulkhead assumed to be 7030 (BNSF).
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).

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14 U.S. Department of Agriculture (USDA), 1992, *Weights, Measures, and Conversion Factors for Agricultural Commodities and Their Products*, Agricultural Handbook Number 697, Economic Research Service, Washington, DC. Available at: https://www.ers.usda.gov/webdocs/publications/41880/33132_ah697_002.pdf?v=42487. Accessed 9-29-22.

Table 8. Railcar Volume Assumptions and Sources

Railcar Type	Cubic Feet	**Source/Method** ***Key:*** **Norfolk Southern Railroad (NS)[7], Union Pacific Railroad (UP)[8], Burlington Northern Santa Fe Railroad (BNSF)[9], CSX Transportation Railroad (CSX)[10], World Trade Press Guide to Railcars (GTRC)[11], Chicago Rail Car Leasing (CRCL)[12], Union Tank Car Company (UTCC)[13], U.S Department of Agriculture (USDA)[14]**
Flat Car – all types- including multi-level ***[not used in analysis, except for estimating volume of "All Other Cars"]***	7,428	Based on the average volumes of the flatcar types described above including multi-level as a single flat car type.
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 (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)].
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)].
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)].
Covered 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)].

Table 8. Railcar Volume Assumptions and Sources

Railcar Type	Cubic Feet	**Source/Method** ***Key:*** **Norfolk Southern Railroad (NS)[7], Union Pacific Railroad (UP)[8], Burlington Northern Santa Fe Railroad (BNSF)[9], CSX Transportation Railroad (CSX)[10], World Trade Press Guide to Railcars (GTRC)[11], Chicago Rail Car Leasing (CRCL)[12], Union Tank Car Company (UTCC)[13], U.S Department of Agriculture (USDA)[14]**
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, 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 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	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).

Table 9. Rail Carrier Average Volume Determination

Freight Car Types (R1 Schedule 755)	Avg. Cu Ft.	BNSF	
		Railcar Miles (x1K)	Cu Ft Miles (x1K)
Box-Plain 40-Foot	4,555	1	4,555
Box-Plain 50-Foot & Longer	7,177	9,338	67,018,826
Box-Equipped	7,177	147,226	1,056,641,002
Gondola-Plain	5,190	379,762	1,970,964,780
Gondola-Equipped	5,190	75,894	393,889,860
Hopper-Covered	4,188	758,442	3,176,355,096
Hopper-Open Top-General Service	4,220	65,077	274,624,940
Hopper-Open Top-Special Service	4,220	137,449	580,034,780
Refrigerator-Mechanical	6,202	19,272	119,524,944
Refrigerator-Non-Mechanical	6,202	32,910	204,107,820
Flat-TOFC/COFC	6,395	520,521	3,328,731,795
Flat-Multi-Level	13,625	38,624	526,252,000
Flat-General Service	6,395	357	2,283,015
Flat-All Other	6,395	71,826	459,327,270
All Other Car Types-Total	5,772	20,146	116,282,712
Average Railcar Cubic Feet			5,811

Freight Car Types (R1 Schedule 755)	CSX	
	Railcar Miles (x1K)	Cu Ft Miles (x1K)
Box-Plain 40-Foot	-	-
Box-Plain 50-Foot & Longer	6,987	50,145,699
Box-Equipped	144,631	1,038,016,687
Gondola-Plain	137,256	712,358,640
Gondola-Equipped	64,532	334,921,080
Hopper-Covered	153,315	642,083,220
Hopper-Open Top-General Service	78,412	330,898,640
Hopper-Open Top-Special Service	35,451	149,603,220
Refrigerator-Mechanical	17,117	106,159,634
Refrigerator-Non-Mechanical	11,923	73,946,446
Flat-TOFC/COFC	125,828	804,670,060
Flat-Multi-Level	29,956	408,150,500
Flat-General Service	162	1,035,990
Flat-All Other	31,913	204,083,635
All Other Car Types-Total	19,861	114,637,692
Average Railcar Cubic Feet		6,389

Freight Car Types (R1 Schedule 755)	Grand Trunk	
	Railcar Miles (x1K)	Cu Ft Miles (x1K)
Box-Plain 40-Foot	0	-
Box-Plain 50-Foot & Longer	2,119	15,208,063
Box-Equipped	66,110	474,471,470
Gondola-Plain	6,467	33,563,730
Gondola-Equipped	19,201	99,653,190
Hopper-Covered	44,239	185,272,932
Hopper-Open Top-General Service	9,114	38,461,080
Hopper-Open Top-Special Service	32,621	137,660,620
Refrigerator-Mechanical	312	1,935,024
Refrigerator-Non-Mechanical	205	1,271,410
Flat-TOFC/COFC	2,779	17,771,705
Flat-Multi-Level	4,831	65,822,375
Flat-General Service	20	127,900
Flat-All Other	31,744	203,002,880
All Other Car Types-Total	4,755	27,445,860
Average Railcar Cubic Feet		6,309

Freight Car Types (R1 Schedule 755)	Kansas City Southern	
	Railcar Miles (x1K)	Cu Ft Miles (x1K)
Box-Plain 40-Foot	0	-
Box-Plain 50-Foot & Longer	3,383	24,279,791
Box-Equipped	39,792	285,587,184
Gondola-Plain	16,628	86,299,320
Gondola-Equipped	11,150	57,868,500
Hopper-Covered	50,346	210,849,048
Hopper-Open Top-General Service	626	2,641,720
Hopper-Open Top-Special Service	943	3,979,460
Refrigerator-Mechanical	21	130,242
Refrigerator-Non-Mechanical	52	322,504
Flat-TOFC/COFC	10,736	68,656,720
Flat-Multi-Level	629	8,570,125
Flat-General Service	12	76,740
Flat-All Other	2,321	14,842,795
All Other Car Types-Total	247	1,425,684
Average Railcar Cubic Feet		5,938

Freight Car Types (R1 Schedule 755)	Norfolk Southern	
	Railcar Miles (x1K)	Cu Ft Miles (x1K)
Box-Plain 40-Foot	0	-
Box-Plain 50-Foot & Longer	7,622	54,703,094
Box-Equipped	136,745	981,418,865
Gondola-Plain	193,214	1,002,780,660
Gondola-Equipped	111,320	577,750,800
Hopper-Covered	116,848	489,359,424
Hopper-Open Top-General Service	84,557	356,830,540
Hopper-Open Top-Special Service	30,078	126,929,160
Refrigerator-Mechanical	3,512	21,781,424
Refrigerator-Non-Mechanical	5,392	33,441,184
Flat-TOFC/COFC	114,928	734,964,560
Flat-Multi-Level	20,349	277,255,125
Flat-General Service	145	927,275
Flat-All Other	24,563	157,080,385
All Other Car Types-Total	212,408	1,226,018,976
Average Railcar Cubic Feet		6,065

Freight Car Types (R1 Schedule 755)	Soo Line	
	Railcar Miles (x1K)	Cu Ft Miles (x1K)
Box-Plain 40-Foot	0	-
Box-Plain 50-Foot & Longer	725	5,203,325
Box-Equipped	17,972	128,985,044
Gondola-Plain	1,203	6,243,570
Gondola-Equipped	8,856	45,962,640
Hopper-Covered	94,146	394,283,448
Hopper-Open Top-General Service	3,077	12,984,940
Hopper-Open Top-Special Service	20	84,400
Refrigerator-Mechanical	159	986,118
Refrigerator-Non-Mechanical	742	4,601,884
Flat-TOFC/COFC	11,178	71,483,310
Flat-Multi-Level	2,973	40,507,125
Flat-General Service	12	76,740
Flat-All Other	10,068	64,384,860
All Other Car Types-Total	428	2,470,416
Average Railcar Cubic Feet		5,667

Freight Car Types (R1 Schedule 755)	Union Pacific	
	Railcar Miles (x1K)	Cu Ft Miles (x1K)
Box-Plain 40-Foot	0	-
Box-Plain 50-Foot & Longer	12,311	88,356,047
Box-Equipped	238,241	1,709,855,657
Gondola-Plain	206,370	1,071,060,300
Gondola-Equipped	91,775	476,312,250
Hopper-Covered	370,929	1,553,450,652
Hopper-Open Top-General Service	188,027	793,473,940
Hopper-Open Top-Special Service	104,969	442,969,180
Refrigerator-Mechanical	82,874	513,984,548
Refrigerator-Non-Mechanical	27,009	167,509,818
Flat-TOFC/COFC	1,026,251	6,562,875,145
Flat-Multi-Level	46,889	638,862,625
Flat-General Service	350	2,238,250
Flat-All Other	72,371	462,812,545
All Other Car Types-Total	16,769	96,790,668
Average Railcar Cubic Feet		6,248

Freight Car Types (R1 Schedule 755)	Total (for Industry Average)	
	Railcar Miles (x1K)	Cu Ft Miles (x1K)
Box-Plain 40-Foot	1	4,555
Box-Plain 50-Foot & Longer	42,485	304,914,845
Box-Equipped	790,717	5,674,975,909
Gondola-Plain	940,900	4,883,271,000
Gondola-Equipped	382,728	1,986,358,320
Hopper-Covered	1,588,265	6,651,653,820
Hopper-Open Top-General Service	428,890	1,809,915,800
Hopper-Open Top-Special Service	341,531	1,441,260,820
Refrigerator-Mechanical	123,267	764,501,934
Refrigerator-Non-Mechanical	78,233	485,201,066
Flat-TOFC/COFC	1,812,221	11,589,153,295
Flat-Multi-Level	144,251	1,965,419,875
Flat-General Service	1,058	6,765,910
Flat-All Other	244,806	1,565,534,370
All Other Car Types-Total	274,614	1,585,072,008
Industry Average Railcar Cubic Feet		6,091

Black Carbon Emissions Estimation

Air, rail, barge, and truck carrier black carbon (BC) emissions are estimated using either emission factors (e.g., grams of BC per mile for truck carriers) or by scaling from PM emission estimates (e.g., for air carriers). BC emissions are also estimated for logistics business units assuming BC emission rates scale directly with PM (e.g., tons BC = scaling factor x tons PM). Average scaling factors for logistics business units are estimated for each selected carrier's mode/SmartWay Category combination, based on the following:

- The BC/$PM_{2.5}$ ratios for air and rail carriers are constant for each mode and are the same as those used to estimate BC emissions in the SmartWay Air and Rail Tools, respectively. Estimates assume jet fuel use for air carriers, and ultra-low sulfur diesel for rail carriers.
- Factors for barge carriers are based on the average BC/PM_{10} ratio across all propulsion engine age groups and sizes in EPA's 2020 Port Emission Inventory Guidance.[15] Estimates assume ultra-low sulfur diesel fuel use.
- Factors for each Truck/SmartWay Category combination are based on average BC/$PM_{2.5}$ ratio for SmartWay truck carrier submissions for Data Year 2019.
- Factors for logistics business units are determined by calculating a weighted average of the BC/PM ratios for all other modes/SmartWay Categories. First, the ton-miles attributed to the air, rail, barge, and truck carriers selected by SmartWay logistics business units for the 2019 data year were summed by mode.[16] Then the fraction of ton-miles for each mode were applied to the BC factors for each mode to estimate a weighted average BC/PM ratio for all logistics carriers. The resulting weighting factors are as follows:

    - Air – 0.04%
    - Barge – 0.06%
    - Rail – 4.07%
    - Truck (all Categories) – 88.99%

Table 10 presents the average scaling factors used to estimate logistics business unit BC emissions. The table also presents the minimum and maximum BC/PM ratios observed in the various data sources to provide a measure of the potential variability associated a logistic business unit's carrier selections. BC estimates are particularly uncertain for truck carriers selected by logistics business units, due to the large variation in BC/PM ratios across engine model years and truck classes.

[15] See Table H-6. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P10102U0.pdf. Accessed 9-29-22.

[16] Logistics business units selected by other logistics business units were excluded to simplify the analysis. This exclusion adds an unspecified degree of uncertainty to the final BC/PM ratio estimate.

Table 10. BC/PM Ratios for Logistics Business Units

Mode/Category	Basis	Average	Min	Max	Range	Data Source/Basis
Rail	PM2.5	**0.677**	N/A	N/A	N/A	SmartWay Rail Tool
Air	PM2.5	**0.130**	N/A	N/A	N/A	SmartWay Air Tool
Barge	PM10	**0.746**	0.733	0.754	0.021	2020 EPA Port Emissions Inventory Guidance
Truck/Auto	PM2.5	**0.366**	0.088	0.760	0.671	2019 Data Year Truck Partner submissions
Truck/Dray	PM2.5	**0.442**	0.085	0.782	0.697	2019 Data Year Truck Partner submissions
Truck/Expedited	PM2.5	**0.295**	0.071	0.720	0.649	2019 Data Year Truck Partner submissions
Truck/Flatbed	PM2.5	**0.366**	0.083	0.815	0.732	2019 Data Year Truck Partner submissions
Truck/Heavy-Bulk	PM2.5	**0.335**	0.088	0.764	0.676	2019 Data Year Truck Partner submissions
Truck/LTL	PM2.5	**0.330**	0.063	0.746	0.684	2019 Data Year Truck Partner submissions
Truck/Mixed	PM2.5	**0.355**	0.077	0.785	0.708	2019 Data Year Truck Partner submissions
Truck/Moving	PM2.5	**0.361**	0.077	0.673	0.596	2019 Data Year Truck Partner submissions
Truck/Package	PM2.5	**0.162**	0.088	0.576	0.488	2019 Data Year Truck Partner submissions
Truck/Refrigerated	PM2.5	**0.330**	0.090	0.799	0.710	2019 Data Year Truck Partner submissions
Truck/Specialized	PM2.5	**0.353**	0.077	0.733	0.656	2019 Data Year Truck Partner submissions
Truck/Tanker	PM2.5	**0.330**	0.088	0.767	0.680	2019 Data Year Truck Partner submissions
Truck/TL-Dry Van	PM2.5	**0.295**	0.059	0.826	0.768	2019 Data Year Truck Partner submissions
Truck/General	PM2.5	**0.329**	0.059	0.826	0.768	Average across all SmartWay Truck Categories
MM/Surface	PM2.5	**0.503**	0.329	0.677	0.348	Average of truck and rail BC ratios
MM/Air	PM2.5	**0.230**	0.130	0.329	0.199	Average of truck and air BC ratios
Logistics	PM2.5	**0.355**	0.130	0.746	0.616	Weighted average of all category ratios

% SMARTWAY VALUE

The % SmartWay screen presents the portion of goods that shippers move with SmartWay Partners (expressed as a percentage between 0 and 100). Shippers select the basis for calculating the percentage shipped with SmartWay Partners, including the following options for Way 3 and 4 participants:

- Total annual miles (the Tool will automatically populate the % SmartWay screen with any carrier activity data that shippers entered in the freight Activity Data screen). Miles correspond to truck-miles for trucks, aircraft-miles for air, barge-miles for barge, and railcar-miles for rail;
- Total annual ton-miles (the Tool will automatically populate the % SmartWay screen with any carrier activity data that shippers entered on the freight Activity Data screen);

Note the Tool will automatically populate the % SmartWay screen with any carrier activity data entered in the Activity Data screen. In addition, the metric selected for your first company will be chosen as the basis for your other companies as well, so that a Partner-level % SmartWay Value can be calculated. The Partner-level % SmartWay Value is used to determine Excellence Award eligibility in the SmartWay program. To see your Partner-level % SmartWay Value, calculated across all companies, go to the % SmartWay Report in the Reports Menu via the Home page.

Shippers participating at the Way 2 level must characterize their carrier activity using one of the following metrics:

- Percent Spent;
- Percent Weight Shipped;
- Percent Packages Shipped;
- Other Custom Metric (as defined by Shipper).

PUBLIC DISCLOSURE REPORTS

The Shipper Tool now provides a report summarizing Scope 3 emissions for public disclosure purposes. Mass emissions are presented in metric tons for CO_2 (biogenic and non-biogenic), NO_X, and PM[17] for all carriers NOT specifically designated as "Shipper Carriers" on the Tool's Activity screen.[18] The percent of CO_2 attributable to SmartWay Carriers is also provided, again excluding any Shipper Carriers. Biogenic CO_2 emissions estimates are assumed to equal approximately 2 percent of total CO_2 emissions, as per U.S. requirements for biomass-based diesel from the EPA Renewable Fuel Standard program final volume requirements.[19]

[17] Emissions from CH_4, N_2O, HFC's, PFC's, SF_6 and NF_3 have been deemed immaterial, comprising less than 5% of overall GHG emissions and are therefore EXCLUDED for reporting purposes.

[18] "Shipper Carriers" refer to fleets directly operated by the Shippers themselves. These fleets are associated with Scope 1 emissions which are not reported in the Shipper Tool. For purposes of developing a corporate inventory using the SmartWay Shipper Tool, the relevant Scope 3 category only includes upstream transportation and distribution and therefore excludes downstream transportation and distribution as falling outside of the system boundary.

[19] As stated in the Final Rule (Table I.B.7-1 – see https://www.govinfo.gov/content/pkg/FR-2018-12-11/pdf/2018-26566.pdf, Accessed 9-29-22.), the volume requirements for biomass-based diesel in 2019 is 1.73%, rounded to equal 2% for calculation purposes. The percentage is updated annually in the Tool.

2.0 Calculator Tools

In addition to estimating a shipper's emissions inventory and performance metrics, the Shipper Tool also allows shippers to estimate the emissions impact of mileage and weight reduction strategies as well as modal shifts, if the user provides mileage-related activity data under the Way 4 option. Reductions can be estimated for retrospective actions (i.e., activities that occurred during the current reporting year) or for prospective actions (activities to be implemented in the coming year). Only actions occurring within the current reporting year satisfy the Way 4 reporting requirements.

MILE AND WEIGHT IMPROVEMENTS

The Mile & Weight Improvements screen is optional and is intended for reference purposes only. On this screen, shippers may estimate emission reduction benefits for the following options:

- Miles Removed from the System
  - Distribution center relocation
  - Retail sales relocation
  - Routing optimization
  - Cube optimization
  - Larger vehicles and/or multiple trailers
- Weight Removed from System
  - Product weight reduction
  - Package weight reduction
  - Vehicle weight reduction

For each activity selected, shippers must provide an estimate of the percentage reduction in freight activity (in miles or weight), for each mode of interest, along with a detailed text description of the strategy. The Tool assumes that total mass emissions are reduced in direct proportion with the specified mileage or weight reduction.[20] Shippers must also specify if the activity (or activities) are retrospective or prospective.

[20] This assumption should be accurate for weight reduction strategies when applied to truckload shipments that weigh out. Additional uncertainty arises in the case of LTL and package delivery shipments, where weight reductions may not result in one-to-one reductions in miles hauled. Uncertainties are even greater for non-truck modes, where the shipper commonly does not control the entire content of the container. Likewise, this assumption may not hold if shippers reduce freight by loading more products (i.e., more weight) on trucks that were previously cubing out, since the increase in payload will negatively impact the truck's fuel economy and g/mile emissions performance.

Mass emission reductions are calculated by using the appropriate mass emissions estimates from the Emissions Summary screen (based on reported activity data and associated carrier emissions performance data). The emission savings calculation differs for retrospective and prospective actions, as shown below:

$$S_R = EM \times (1 / (1 - \text{Reduction}) - 1)$$

$$S_P = EM \times \text{Reduction}$$

Where:

S_R = Retrospective Savings (tons of CO_2, NO_X, or PM)

S_P = Prospective Savings (tons of CO_2, NO_X, or PM)

EM = Mass Emissions value for current Data Year (tons of CO_2, NO_X, or PM from Emissions Summary screen)

Reduction = Reduction in total miles or weight as a result of the strategy (expressed as fraction)

Fractional reduction estimates must be documented in the Shipper Tool. An example calculation is provided below:

A shipper changes the shape of its milk cartons from round to square. As a result, the shipper can pack 20% more milk cartons per truck trailer than the rounded milk cartons. This reduces 20% of the loads associated with that product line (corresponding to the "Cube Optimization" activity selection for the "Miles removed from system" category). However, the company sells many products, and the total truckloads associated with milk shipments is 1,000 out of 50,000 overall truckloads. The efficiency gain is thus 20% x (1,000/50,000), or a 0.4% system improvement. Therefore, the shipper would enter "0.4" in the Percent Improvement column. This assumes that all loads on average travel an equivalent distance. If milk loads were significantly shorter than other loads, then a mileage-based weighting per trip would need to be applied to arrive at a percent improvement. The burden of proof on demonstrating an accurate percent reduction and modal allocation is the shipper's. The data sources and methodology should be briefly described in the Tool under Data Source/Methodology. The shipper should, at a minimum, keep detailed records electronically within the company to document the estimate upon EPA request. The shipper can also submit any documentation in electronic text format along with the Tool to its Partner Account Manager.

MODAL SHIFT IMPACTS

Overview

The Modal Shift Impacts screen in the Tool is optional and is intended for reference purposes only. Shippers should develop their carrier emissions inventories (and associated emissions factors for their companies) by inputting activity data in the Activity Data screen.

Shippers wishing to conduct scenario analyses can use the Modal Shift Impacts screen to estimate the emissions impacts associated with modal shifts by specifying the mode from which they are considering shifting their freight ("From Mode"), as well as the target mode ("To Mode"). Shippers must also specify if the modal shifts are retrospective or prospective. Shippers have several options for selecting an emissions factor for both the "From Mode" and "To Mode". First, the Tool automatically calculates and displays the average emission factors for truck, barge, air and rail modes corresponding to the carrier file values used on the Activity Data screen (corresponding to the "Shipper's Carrier Average" Emission Factor Source selection). In this case partners can also adjust their estimates of emission impacts from modal shifts by applying different filters for the "From" Mode (e.g., just considering inbound international freight). Second, partners may select illustrative industry average emission factors (discussed in the section below) from the drop-down menu (corresponding to the "Modal Average" selection). Third, the shipper can input a set of alternative emissions factors of their choice (corresponding to the "User Input" selection). In this instance the user must also provide a description of the source of the information used to develop the alternate factors (by selecting the "User Input Data Source" button).

Some modal shifts may include some form of drayage activity. To properly account for all emissions in these cases, you may need to add additional lines - the first line will be for the main leg of the trip, while a second or third may account for changes in drayage miles. Additionally, due to the location of infrastructure (roads, rail lines, etc.) the distances across the different modal shifts may not be the same; for example, the mileage for trucks will very likely be different from the mileage for rail.

Note: the emissions factors that automatically appear on the Modal Shift Impacts screen do not include all potential emissions impacts; for example, the factors do not include emissions specifically associated with drayage (i.e., short-distance trips often required to move freight from one mode to another), or operations at intermodal facilities.

While EPA has populated the Tool with illustrative modal average freight emission factors, we recommend partners use more representative emission factors to analyze scenarios whenever possible. For example, partners may wish to evaluate the emissions impact from moving freight from rail to a specific truck fleet by consulting the SmartWay Category average emissions factors associated with that truck fleet (available on the SmartWay website), or by inputting data that partners receive directly from a carrier. For better estimates of emission impacts from modal shifts, partners are encouraged to use a factor that reflects the full emissions impact (e.g., including anticipated drayage emissions) and that best represents the fleet equipment and operational type that they are most likely to work with for their unique freight movement.

While we have not provided modal average ocean-going vessel factors in the Tool, there are several external resources that partners can consult. Some selected sources for ocean-going vessel factors are presented in the following section.

To calculate the emissions impact associated with a modal shift, shippers input the activity data corresponding with their modal shift scenario expressed in a given unit (miles or ton-miles) and the Tool combines that data with a corresponding emission factor (described above) in the same unit. The Tool then displays the change in emissions in tons per year as shown in the equation below.[21]

Total Emission Impact (tons/yr) = [(Efficiency Before x "From Mode" Amount) – (Efficiency After x "To Mode" Amount)] x g to tons conversion factor[22]

If the shipper is evaluating a mode shift between truck and rail or barge, and if the available activity units are in miles rather than ton-miles, then the activity data entered must be expressed in terms of railcar-miles or barge-miles, as appropriate to be consistent with the g/mile factors included in the carrier file. Determination of railcar and barge-miles for any particular container/commodity type and route should be made in consultation with carriers or logistics service providers in order to account for volume differences compared to truck carriers.

If you need to convert truck-miles to railcar and/or barge-mile equivalents for your assessment, a railcar-to-truck equivalency factor can be calculated by first identifying the average cargo volume for a given rail carrier (see Table 9 above). These volumes estimates should be weighted by the miles associated with each rail carrier to estimate a single weighted-average railcar volume for the carrier company in question. Similarly, weighted average volumes can also be calculated for the different truck carriers associated with the given shipping company. (Company-specific volume data is contained within the carrier file for SmartWay truck carriers.) The weighting calculations should involve all carriers used by the company if no filters are selected on the Modal Shift Impacts screen (only relevant for the "From" mode). Otherwise, the weighted average calculation should only be performed for the filtered subset (e.g., inbound domestic truck carriers).

Once the weighted average volumes are determined for both rail and truck modes, you can calculate the ratio of the average railcar volume to the average truck volume (R). Using industry average volume estimates as described in Appendix B, we estimate R to equal approximately 1.41, meaning that the average railcar has 1.41 times the volume of an average truck trailer/container. Next, you can convert your truck-equivalent mile estimates to railcar equivalent miles by dividing truck miles by the ratio R.[23] Enter the corresponding railcar-mile activity estimate in the "Amounts" column.

The same process is used to convert truck-miles to barge-mile equivalents, although national average barge volume information was not identified for this analysis. In this case volume estimates may be used for specific barge carriers from the carrier file. In addition, the value for truck miles should also be divided by 1.15 to convert from statute to nautical miles.[24]

[21] The emission calculations are the same for retrospective and prospective shifts, assuming the mode-specific emission factors for the prior year are equal those for the current data year.

[22] 1.1023×10^{-6} short tons/gram

[23] Any route mileage differences must be adjusted for separately.

[24] Barge performance values are expressed in grams per nautical mile, to be consistent with barge carrier reporting practices.

BACKGROUND ON ILLUSTRATIVE U.S. MODAL AVERAGE FACTORS

Modal Average performance metrics were estimated for rail and truck modes (both gram per mile and gram per ton-mile), as well as for barge and air modes (gram per ton-mile only) in order to estimate emission impacts using the Modal Shift Impacts screen. We developed the truck g/mile factors for CO_2, NO_x, and $PM_{2.5}$[25] using EPA's 2014b version of the Motor Vehicle Emissions Simulator model (MOVES2014b). The model was run at the national level for calendar year 2019, with emissions estimated and summed across the diesel short-haul single unit, short-haul combination unit, long-haul single unit, and long-haul combination unit truck categories.[26,27] MOVES does not contain ton-mile data, so we divided the MOVES-based mass emission estimates by national freight truck ton-mile estimates from the Bureau of Transportation Statistics (BTS) to obtain the truck g/ton-mile factors.[28] The most recent BTS ton-mile data were for 2017, so estimates for 2019 were based on a linear interpolation of the 2012 and 2017 values.

Table 11 presents the illustrative freight truck emissions factors in the tool and Table 12 presents the key underlying data. (Note that the modal average factors calculated for truck carriers were assumed valid for logistics carriers as well.)

Table 11. U.S. Freight Truck Industry Average Factors Used in Modal Shift

Units	CO_2	NO_x	$PM_{2.5}$
gram/short ton-mile	210	0.744	0.027
gram/mile	1,578	5.586	0.199

Table 12. Underlying Data for Freight Truck Industry Average Factors (2019)

CO_2 (grams)	436,853,902,968,783
NO_x (grams)	1,547,043,757,414
$PM_{2.5}$ (grams)	55,183,809,776
Miles	276,927,898,414
short ton-miles	2,078,299,600,000

SmartWay developed the freight rail g CO_2/ton-mile and g CO_2/mile factors using the 2017 data summarized in Table 6 above. SmartWay then developed the freight rail NO_x and PM g/mile and g/ton-mile factors as described in Appendix A.

The modal average barge emissions factors presented in Table 13 are from a study prepared by the Texas Transportation Institute (TTI) for the U.S. Maritime Administration[29] and reflect inland waterway towing

[25] Corresponding PM_{10} emission factors were estimated assuming $PM_{2.5}$ values were 97% of PM_{10} values, based on MOVES model outputs for diesel fueled trucks.

[26] These four truck categories are coded as 52, 53, 61, and 62 in the MOVES model, respectively.

[27] EPA's MOVES model and accompanying resources, including technical documentation, are available at: https://www.epa.gov/moves. Accessed 9-29-22.

[28] Bureau of Transportation Statistics, U.S. Ton-Miles of Freight, https://www.bts.gov/us-ton-miles-freight Accessed 9-29-22.

[29] U.S. Maritime Administration and the National Waterways Foundation (U.S. MARAD), amended January 2017. *A Modal Comparison of Domestic Freight Transportation Effects on the General Public*. Prepared by Center for Ports & Waterways, Texas Transportation Institute, Table 10. Available at: http://www.nationalwaterwaysfoundation.org/documents/Final%20TTI%20Report%202001-2014%20Approved.pdf, Accessed 9-290-22.

operations in the U.S. We converted the PM_{10} factor in the TTI study into $PM_{2.5}$ by assuming 95% of PM_{10} is $PM_{2.5}$, which we determined was a good approximation of the share of overall PM_{10} emissions represented by particulate matter that is 2.5 micrometers in diameter or smaller.

Table 13. Modal Average Barge Emission Factors

	CO_2	NO_X	$PM_{2.5}$
gram/short ton-mile	17.48	0.4691	0.0111

Estimates of average g/mi performance metrics were not identified for barge carriers.

Modal average estimates for air freight are based on EDMS outputs, presented in Table 14 below.

Table 14. Modal Average Performance Metric Estimates for Air Carriers

	g/mi			g/ton mi		
Mode	CO_2	NO_X	PM	CO_2	NO_X	PM
Short Haul Air	96,998	878.37	5.743	4,236	38.134	0.251
Long Haul Air	33,448	301.13	1.98	1,461	13.15	0.086

OUTSIDE SOURCES OF OCEAN-GOING MARINE EMISSION FACTORS

There are many sources of marine emission factors available in research literature and other GHG estimation tools. For reference, we have included below the g CO_2/ton-mile marine factors from the Business for Social Responsibility's (BSR) Clean Cargo Tool as well as factors from a study prepared for the International Maritime Organization (IMO).[30]

Note that the factors from BSR and IMO are published in units of kg CO_2/metric ton-km, so we converted this data into g CO_2/ton-mile by first multiplying by 1,000 (to convert from kilograms to grams), then multiplying by 0.9072 (to convert from metric tonnes to short tons), and then multiplying by 1.609 (to convert from kilometers to miles) to prepare the tables below.

BSR developed average 2009 marine emission factors for various shipping corridors, as well as global defaults that are applicable outside those corridors, based on surveys from marine carriers. The BSR marine factors in Table 15 below are from the "Emission Factors & Distances" tab in their tool.

[30] Buhaug, et al. for the International Maritime Organization (IMO), 2009. Second IMO GHG Study 2009, International Maritime Organization (IMO), London, UK, April 2009. Available at: https://www.imo.org/en/OurWork/Environment/Pages/Greenhouse-Gas-Study-2009.aspx, Accessed 9-29-22.

Table 15. BSR Marine Emission Factors (g CO_2/short ton-mile)

Ship_general	International	13.0678
Ship_Barge	International	29.1937
Ship_Feeder	International	29.1937
Ship_inland_Germany	Germany	41.5280
Ship_inland_China	China	35.0578
Ship_Asia-Africa	Asia--Africa	11.9227
Ship_Asia-South America (EC/WC)	Asia--South America (EC/WC)	13.1897
Ship_Asia-Oceania	Asia--Oceania	13.4028
Ship_Asia-North Europe	Asia--North Europe	10.8586
Ship_Asia-Mediterranean	Asia--Mediterranean	12.1358
Ship_Asia-North America EC	Asia--North America EC	12.9854
Ship_Asia-North America WC	Asia--North America WC	12.0818
Ship_Asia-Middle East/India	Asia--Middle East/India	13.5459
Ship_North Europe-North America EC	North Europe--North America EC (incl. Gulf)	14.1823
Ship_North Europe-North America WC	North Europe--North America WC	13.0642
Ship_Mediterranean-North America EC	Mediterranean--North America EC (incl. Gulf)	12.6788
Ship_Mediterranean-North America WC	Mediterranean--North America WC	10.1433
Ship_Europe (North & Med)-Middle East/India	Europe (North & Med)--Middle East/India	13.4276
Ship_Europe (North & Med)-Africa	Europe (North & Med)--Africa	15.8361
Ship_Europe (North & Med)-Oceania (via Suez / via Panama)	Europe (North & Med)--Oceania (via Suez / via Panama)	14.4056
Ship_Europe (North & Med)-Latin America/South America	Europe (North & Med)--Latin America/South America	12.6146
Ship_North America-Africa	North America--Africa	17.4549
Ship_North America EC-Middle East/India	North America EC--Middle East/India	12.8788
Ship_North America-South America (EC/WC)	North America--South America (EC/WC)	13.4379
Ship_North America-Oceania	North America--Oceania	15.0552
Ship_South America (EC/WC)-Africa	South America (EC/WC)--Africa	11.7432
Ship_Intra-Americas (Caribbean)	Intra-Americas (Caribbean)	15.9222
Ship_Intra-Asia	Intra-Asia	15.2012
Ship_Intra-Europe	Intra-Europe	17.1790

The marine factors in the IMO study reflect commonly-used equipment sizes and types. The factors in Table 16 below come from Table 9.1 4 in the IMO study.

Table 16. IMO Marine Emission Factors

TYPE	SIZE	AVERAGE CARGO CAPACITY (metric tonne)	Average yearly capacity utilization	Average service speed (knots)	Transport work per ship (tonne NM)	Loaded efficiency (g of CO_2/ ton mile)	Total efficiency (g of CO_2/ton mile)
Crude oil tanker	2000,000+dwt	295,237	48%	15.4	14,197,046,742	2.34	4.23
Crude oil tanker	120,000-199,99 dwt	151,734	48%	15	7,024,437,504	3.21	6.42
Crude oil tanker	80,000-119,999 dwt	103,403	48%	14.7	4,417,734,613	4.38	8.61
Crude oil tanker	60,000-79,999 dwt	66,261	48%	14.6	2,629,911,081	6.28	10.95
Crude oil tanker	10,000-59,999 dwt	38,631	48%	14.5	1,519,025,926	7.59	13.28
Crude oil tanker	0-9,999 dwt	3668	48%	12.1	91,086,398	30.22	48.61
Products tanker	60,000+ dwt	101,000	55%	15.3	3,491,449,962	4.82	8.32
Products tanker	20,000-59,999 dwt	40,000	55%	14.8	1,333,683,350	10.51	15.03
Products tanker	10,000-19,999 dwt	15,000	50%	14.1	464,013,471	16.49	27.30
Products tanker	5,000-9,999 dwt	7,000	45%	12.8	170,712,388	21.60	42.62
Products tanker	0-49,999 dwt	1,800	45%	11	37,598,072	38.68	65.69
Chemical tanker	20,000 + dwt	32,200	64%	14.7	1,831,868,715	8.32	12.26
Chemical tanker	10,000-19,999 dwt	15,000	64%	14.5	820,375,271	10.66	15.76
Chemical tanker	5,000-9,999 dwt	7,000	64%	14.5	382,700,554	15.62	22.04
Chemical tanker	0-4,999 dwt	1,800	64%	14.5	72,147,958	27.15	32.41
LPG tanker	50,000 + m^3	46,656	48%	16.6	2,411,297,106	7.59	13.14
LPG tanker	0-49,999 m^3	3,120	48%	14	89,631,360	39.41	63.50
LNG tanker	200,00 + m^3	97,520	48%	19.6	5,672,338,333	7.88	13.58
LNG tanker	0-199,999 m^3	62,100	48%	19.6	3,797,321,655	12.26	21.17
Bulk carrier	200,000 +dwt	227,000	50%	14.4	10,901,043,017	2.19	3.65
Bulk carrier	100,000-199,999 dwt	163,000	50%	14.4	7,763,260,284	2.63	4.38
Bulk carrier	60,000-99,999 dwt	74,000	55%	14.4	3,821,361,703	3.94	5.98
Bulk carrier	35,000-59,999 dwt	45,000	55%	14.4	2,243,075,236	5.55	8.32
Bulk carrier	10,000-34,999 dwt	26,000	55%	14.3	1,268,561,872	7.74	11.53
Bulk carrier	0-9,999 dwt	2,400	60%	11	68,226,787	33.43	42.62
General cargo	10,000 + dwt	15,000	60%	15.4	866,510,887	11.09	17.37
General cargo	5,000-9,999 dwt	6,957	60%	13.4	365,344,150	14.74	23.06
General cargo	0-4,999 dwt	2,545	60%	11.7	76,645,792	15.91	20.29
General cargo	10,000+ dwt, 100+ TEU	18,000	60%	15.4	961,054,062	12.55	16.06
General cargo	5,000-9,999 dwt, 100+TEU	7,000	60%	13.4	243,599,799	20.14	25.54

Table 16. IMO Marine Emission Factors

TYPE	SIZE	AVERAGE CARGO CAPACITY (metric tonne)	Average yearly capacity utilization	Average service speed (knots)	Transport work per ship (tonne NM)	Loaded efficiency (g of CO_2/ ton mile)	Total efficiency (g of CO_2/ton mile)
General cargo	0-4,999 dwt, dwt+TEU	4,000	60%	11.7	120,938,043	22.63	28.90
Refrigerated cargo	All	6,400	50%	20	392,981,809	18.83	18.83
Container	8000+TEU	68,600	70%	25.1	6,968,284,047	16.20	18.25
Container	5,000-7,999 TEU	40,355	70%	25.3	4,233,489,679	22.19	24.23
Container	3,000-4,999 TEU	28,784	70%	23.3	2,280,323,533	22.19	24.23
Container	2,000-2,999 TEU	16,800	70%	20.9	1,480,205,694	26.71	29.19
Container	1,000-1,999 TEU	7,000	70%	19	578,339,367	42.91	46.86
Container	0-999 TEU	3,500	70%	17	179,809,363	48.61	52.99
Vehicle	4000 +ceu	7,908	70%	19.4	732,581,677	36.78	46.71
Vehicle	0-3999 ceu	2,808	70%	17.7	226,545,399	68.90	84.08
Ro-Ro	2,000 + lm	5,154	70%	19.4	368,202,021	66.12	72.25
Ro-Ro	0-1,999 lm	1432	70%	13.2	57,201,146	80.57	88.02

Note: “Loaded efficiency” is the theoretical maximum efficiency when the ship is fully loaded at service speed/85% load. Since engine load at the fully loaded condition is higher than the average including ballast and other voyages, the difference between the columns “loaded efficiency” and “total efficiency cannot be explained by differences in utilization only.

3.0 Shipper Payloads and Data Validation

The Shipper Tool contains data validation checks designed to identify missing and potentially erroneous data. At this time the only validation involves payload checks and total ton-mile checks, on the Activity Data screen.

PAYLOAD VALIDATION

Payload validation cutpoints were set with the intention of identifying those payloads that are somewhat outside typical industry values (yellow flag warnings) and those that are far outside industry averages (red flag warnings). The payload check only apples to Data Availability selections a, b, and c where payloads are either entered by the user, or calculated based on other inputs. Checks are applied at the carrier (row) level.

Payload checks are specific to the truck carrier fleet's SmartWay Category, which is available for each carrier category from the Carrier File. Note that payload Ranges 1 (very low) and 5 (very high) are colored red on the Activity screen and require explanations before proceeding. Ranges 2 (low) and (high) 4 are colored yellow, and explanations are optional.

Reported Shipper payloads were compiled for each shipper carrier for the 2017 – 2018 reporting years. The data was broken down for each SmartWay carrier category. Next, for every category a histogram was developed, and the distribution of the data was reviewed. By adjusting the size of the bins outliers were identified and the histograms adjusted to exclude those points. In most cases specific cutpoints were then selected for each SmartWay Category to represent 5, 10, 90, and 95 percentiles. (Certain highly skewed distributions such as that for package carriers did not define low end cutpoints). The resulting cutpoints used to establish the "red" and "yellow" validation ranges are provided below.

Table 17. Shipper Payload Validation Ranges

Carrier Category	low red	low yellow	high yellow	high red
Dray	N/A	2.39	22.31	24.40
Expedited	N/A	N/A	11.45	19.23
Specialized	4.37	8.57	25.79	28.79
LTL	N/A	N/A	6.50	12.70
Auto Carrier	12.00	14.67	18.20	19.22
Heavy Bulk	9.16	11.82	25.85	34.08
TL	3.39	5.51	21.60	22.05
Moving	N/A	N/A	19.25	23.46
Flatbed	4.23	5.94	23.81	24.86
Mixed	N/A	N/A	21.71	22.41

Table 17. Shipper Payload Validation Ranges

Carrier Category	low red	low yellow	high yellow	high red
General[31]	N/A	N/A	21.00	28.00
Package	N/A	N/A	1.20	1.63
Tanker	13.60	18.27	26.58	35.08
Reefer	1.64	4.39	21.00	21.85
Logistics	**N/A**	1.51	22.31	24.00

Barge carrier payloads are flagged for verification if their density is greater than 0.6 tons per cubic foot or less than 0.003 tons per cubic foot, consistent with the payload validation used in the Barge Tool.

TON-MILE VALIDATION

2011 Logistics Partner data was evaluated to establish absolute upper bounds for ton-mile inputs. The ton-mile validation applies at the carrier (row) and total fleet (summation of rows) level, with the same values applied to both. The maximum allowable ton-mile value was set to twice the observed maximum value in the 2011 data set: 209,207,446,000 ton-miles.

[31] Based on all SmartWay Carrier Categories combined.

Appendix A - Background on Industry Average U.S. Rail Factors

Industry average freight rail grams per mile and grams per ton-mile factors were developed using data released in August of 2019 for EPA's 2017 National Emission Inventory (NEI).[32] The factors were developed using emission estimates specifically for Class I (line-haul and yard switching) locomotives. These data were then divided by railcar-mile and ton-mile data for 2017 Class I rail carriers to obtain the corresponding performance metrics. Table A-1 presents the industry average freight rail emissions factors used in the Tool.

Table A-1. U.S. Freight Rail Industry Average Factors (2017)

Performance Metric	CO_2	NO_x	PM_{10}	$PM_{2.5}$
gram/short ton-mile	20.72	0.2897	0.0085	0.0082
gram/railcar mile	980	14.38	0.418	0.405

Note that NO_x and PM emission factors are not available at the carrier level for the rail mode. Accordingly, the industry average emission factors are assumed to apply equally for all rail carriers.

[32] Emissions Modeling Platform Collaborative, Specification Sheet: Rail 2017 National Emissions Inventory, August 2019 – Table 1.

Appendix B - Calculation of Truck-Equivalent Mileage Factors for Rail

Truck-equivalent can be converted into railcar-miles, so that partners can more readily estimate emissions impacts from shifting freight between truck and rail modes, by estimating the average volume capacity of Class I railcars and dividing it by an average freight truck volume capacity. This results in a rough estimate that does not take into consideration the utilized volume of railcars or the comparative freight truck, but we determined that this was the best available data and method to estimate modal average railcar-equivalent miles.

To estimate the average volume capacity of railcars, we multiplied the railcar miles reported by each company for each railcar type in their respective 2008 R-1 reports (lines 15-81) by the volume-per-railcar assumptions in Table 8 to obtain total Class I TEU-miles. We then divided the total railcar TEU-miles by the total railcar-miles to estimate the average railcar volume capacity. We then divided this average railcar volume capacity (3.92 TEUs) by the average freight truck volume capacity that we developed for the truck g/TEU-mile factor discussed above (2.78 TEUs) to develop the conversion factor - 1.41 railcar-miles-to-truck-miles. In the absence of more specific data, this factor can be used to convert truck miles to railcar miles for use on the Modal Shift screen of the Shipper Tool. Note that no equivalent information was identified for the estimation of industry-average barge or air volumes.

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