CMAQ EMISSIONS CALCULATOR TOOLKIT

The purpose of the Congestion Mitigation and Air Quality Improvement Program Emissions Calculator Toolkit (CMAQ Toolkit) is to provide users a standardized approach to estimating emission reductions from the implementation of a CMAQ-funded project. The CMAQ Toolkit uses emission rates for highway vehicles based on a series of project-scale and default-scale runs of the Environmental Protection Agency's (EPA) Motor Vehicle Emission Simulator (MOVES[1]) as well as other data sources. For each tool in the Toolkit, the inputs and methodology are described in user guides along with some example cases. Emission estimates from the CMAQ Toolkit are not intended to meet specific requirements for State Implementation Plans (SIPs) or transportation conformity analyses. Information regarding the development of default emission rates and guidance on incorporating user-supplied emission rates can be found in the accompanying documentation of the emissions data.

Freight Modal Shift Tool

This tool provides estimates of emission reductions for CMAQ-funded projects that shift freight activity from highways to more efficient transportation modes or projects that replace older diesel equipment with newer, more fuel efficient and cleaner models. In an intermodal transportation network, trains, trucks, ships, and aircraft are connected to provide efficiency and flexibility for consumers, carriers, and shippers. Intermodal describes an approach to planning, building, and operating the transportation system that emphasizes optimal use of transportation resources and connections between modes. An intermodal system includes both origins and destinations (e.g., ports, railyards and warehouses) and the links between them (e.g., roads, rail, or marine highways).

Emission reductions in the Freight Modal Shift tool are based on the increase in efficiency attributed to shifts to alternative transportation modes as well as any changes in fuel types or model years of the fleet. The modes modeled in this tool include highway, rail, marine highway, and battery electric/self-powered. This tool does not model air freight movements due to the small percentage of total domestic freight transported via aircraft (less than 1%).[2] Trips resulting in zero emissions, such as electric vehicles or self-powered last-mile delivery, can be modeled using the Battery Electric/Self-Powered mode.

[1] U.S. Environmental Protection Agency (EPA), https://www.epa.gov/moves.
[2] Bureau of Transportation Statistics (BTS), https://www.bts.gov/topics/freight-transportation/freight-shipments-mode.

U.S. Department of Transportation
Federal Highway Administration

This document is organized into four sections – User Guide, Tool Methodology, Examples, and Resources – to aid the user in selecting inputs and interpreting results from the emissions calculator tool. The User Guide provides direction on how to properly input values into the tool and definitions of both user inputs and tool outputs. The Tool Methodology section outlines the steps taken by the tool to calculate emission reductions, as well as any associated assumptions. The Examples section provides instructive examples of how to use the tool for different types of project analysis. The Resources section provides information on references used to develop the Freight Modal Shift tool and other tools that may be helpful to users.

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USER GUIDE

This section describes each user input and tool output, as well as error messages and key assumptions present in the tool.

User Inputs

The module contains a series of questions to guide the user in inputting information for emission reduction calculations in a step-by-step process. All inputs must be entered for each segment of freight activity chosen. A segment of freight movement in this tool consists of the transportation of freight from one node (e.g., port, railyard, warehouse, or other intermodal facility) to another. The tool allows for up to three segments. Emissions associated with the nodes, e.g., emissions from unloading equipment at the intermodal facility itself, are not accounted for in this tool.[3] Users may choose from the following mode options for each segment of freight activity before or after project implementation: long-haul truck, short-haul truck, linehaul locomotive, barge, and other battery electric/self-powered. Some inputs are specific to the mode chosen. The user-defined inputs for this tool are described in Table 1.

Table 1. User Inputs

Question	User Input	Units	Description
(1)	Project Evaluation Year	NA	Use the drop-down menu to select a year between 2018 and 2040.
(2)	Mode	NA	Use the drop-down menu to select the equipment associated with each segment.
(3)	Activity Unit	ton-miles or VMT (highway only)	Use the drop-down menu to select the activity unit. Note that the only option for linehaul locomotive and barge is ton-mile.
(4)	Annual Activity	NA	Input the annual activity associated with each segment. See the below section for more details.
(5)	Emissions Tier	NA	*Locomotive & Marine Only* Use the drop-down menu to select the emissions standard the equipment is held to. Refer to Tables A1, A2, and A3 in the Appendix for help in determining the correct emissions Tier.

[3] Users may consult the Non-Road Construction and Intermodal Equipment Tool of the CMAQ Toolkit to estimate emissions reductions associated with projects that replace or retrofit diesel nonroad engines in use at construction sites, railyards, or ports. The tool is available at: https://www.fhwa.dot.gov/environment/air_quality/cmaq/toolkit/#sect2c.

Question	User Input	Units	Description
(6)	Allocations of model years (button)	$\frac{Model\ Year\ VMT}{Total\ Fleet\ VMT}$ (All allocations must sum to 1)	Selecting this button brings the user to a separate tab to modify the model year distribution associated with the selected truck type. Input a distribution of the fleet's activity by model year. The model year cannot be later than the project evaluation year or more than 30 years prior to it. National average values are available in the tool if users do not have this information.
(7)	Fuel Type	NA	*Highway Only* Use the drop-down menu to select the fuel type (diesel, compressed natural gas (CNG), or battery electric vehicle (BEV)) associated with the selected equipment.
(7)	Commodity Density	ton/ft^3	*Highway Only* Input a custom commodity density or use the given default for mixed-use freight of 0.0095 ton/ft^3. View the "Commodity Density" tab in the tool or see Table A4 in the Appendix for more information on commodity density values.
(9)	Trailer Size	ft	*Highway Only* Use the drop-down menu to select the trailer size (28 ft, 45 ft, 48 ft, 53 ft, or Custom). If Custom is selected, enter the desired value into the cell.
(10)	After project implementation	NA	Enter information on freight movements after the project is implemented following the same directions described for questions 2-9.

Mode: The user may select from one of five mode types: Short-Haul Truck, Long-Haul Truck, Linehaul Locomotive, Barge, and Other Battery Electric/Self-Powered. If the user wishes to model emission reductions from electric barges or linehaul locomotives, the Other Battery Electric/Self-Powered mode must be selected, and activity entered in ton-miles. If the user wishes to model electric short- or long-haul trucks, the user may select either the "BEV" (battery electric vehicle) fuel type option after selecting either the short-haul or long-haul truck mode or use the Other Battery Electric/Self-Powered

mode. Note that particulate matter (PM) emissions due to brakewear or tirewear for the electric options of any mode are not included in the emissions estimates.[4]

Activity Unit: The user is expected to select ton-miles or VMT (vehicle miles traveled) for Short-Haul Truck or Long-Haul Truck modes. Linehaul Locomotive, Barge, and Other Battery Electric/Self-Powered can only be modeled using ton-miles.

Annual Activity: Total annual activity (in unit identified in Activity Unit) for a given fleet of the chosen mode per segment. For the purposes of this tool, ton-mile is defined as the distance freight is moved multiplied by the mass of that freight. For short- or long-haul trucks, a default 14.8 percent of the user input annual activity is added to activity entered as ton-miles. Activity entered as VMT is assumed to include deadhead miles.[5] To ignore deadhead mileage entirely, the user can back out the deadhead percentage assumed in the tool by dividing their ton-mile activity estimate by 1.148 before entering the activity into the tool.

Model Year: The distribution of years equipment in the fleet was manufactured. The user can access the Model Year Distribution tab by selecting the button on the tool's interface. The distribution must sum to one. Fleet age distributions change based on the evaluation year and locality, so users are encouraged to enter their own fleet activity characteristics where applicable. When the data are not available, users can choose to fill the table with the MOVES national default model year distribution.[6] When selecting national default, this tool applies MOVES national model year distributions of VMT to reflect emissions impacts of vehicle age.[7] As with MOVES, this tool will only model vehicles up to 30 years older than the project evaluation year.

Locomotive & Marine Inputs

> **Emissions Tier**: The user may select the emissions tier that corresponds to the EPA emissions standard to which their equipment is held. If the emissions tier is unknown, Tables A2, A3, and A4 in the Appendix provides guidance to help identify the appropriate Tier.

Highway Inputs

> **Fuel Type**: The user may select between Diesel, CNG (Compressed Natural Gas), and Battery/Electric.

[4] While PM emissions are estimated for trucks and other on-road vehicles from MOVES output in other CMAQ Toolkit tools, PM is omitted from this tool due to a lack of data for rail brakewear.
[5] Deadhead mileage is mileage traveled by a truck without cargo. See the Emissions Data documentation that accompanies this User Guide for more information on how deadhead miles are incorporated into the emissions calculations for trucks. The estimate of percent of total truck miles attributed to deadhead is derived from the following report: https://truckingresearch.org/wp-content/uploads/2022/08/ATRI-Operational-Cost-of-Trucking-2022.pdf.
[6] The latest version of MOVES, MOVES3.0.4 (released August 2022), was used for national inventories as well as on-road emission rates. For more information, see the Emissions Data Documentation.
[7] EPA, *Population and Activity of On-road Vehicles in MOVES3,* https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=541815

Commodity Density: The weight of the shipment in relation to the volume of the shipment. The default commodity density is 0.0095 ton/ft^3.[8]

Trailer Size: The user may select between default trailer sizes of 28, 45, 48, and 53 feet, or may enter a custom size.

Tool Outputs

Outputs of this tool include network performance and emissions reductions. For network performance, the tool outputs the total net change in annual activity as well as the net change per segment.

Emission benefits are derived from shifting annual freight activity from highways to rail or marine or from updating highway, rail, or marine fleets. In the tool output, a positive change in emissions is equivalent to an emissions reduction (benefit), while a negative value can be interpreted as an emissions increase (disbenefit). Emission reductions (i.e., benefits) are calculated for five criteria pollutants reported in kilograms per day (kg/day).

- Carbon monoxide (CO) CMAQ Emissions
- Particulate matter < 2.5 µm in diameter (PM2.5)
- Particulate matter < 10 µm in diameter (PM10)
- Nitrogen oxides (NOX)
- Volatile organic compounds (VOC)

Reductions in carbon dioxide (CO_2), carbon dioxide equivalents (CO_2e) (in kg/day) and total energy consumption (TEC) (in million BTU/day) are also provided.

Note that emission results will not automatically update. If any changes are made to the input parameters, the 'Calculate Output" button must be clicked again to calculate updated emission reductions. To return to default settings and clear the inputs, click on the 'Reset to Default Values' button at the top right of the interface.

Error Messages

Error messages that the user may encounter in this tool, the reason for the error messages, and the solutions are listed in Table 2.

Table 2. Error Messages

Error Message	Reason for Error	Solution
ERROR: Missing project evaluation year.	No input provided for project evaluation year.	Select a project evaluation year from the pull-down menu.
ERROR: Missing mode of shipment.	No input provided for the mode of shipment.	Select a mode of shipment from the pull-down menu.

[8] EPA, *Ports Emissions Inventory Guidance: Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions*, https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1014J1S.pdf

Error Message	Reason for Error	Solution
ERROR: Missing activity unit.	No input provided for the activity unit.	Select an activity unit from the pull-down menu. Note that ton-mile is the only option for linehaul locomotive and barge.
ERROR: Missing annual activity.	No input provided for estimated annual activity.	Input a whole number greater than or equal to 0.
ERROR: Invalid annual activity.	Invalid input for estimated annual activity.	Input a whole number greater than or equal to 0.
ERROR: Missing emissions tier.	No input provided for emissions tier.	Select an emissions tier from the pull-down menu. Refer to Tables A1 and A3 in the Appendix for help determining an appropriate tier.
ERROR: Please ensure that the Truck Fleet Model Year Distribution adds to 1.000 on the Model Year Distribution Tab	No input provided for fleet model year distribution or input does not add to 1.000.	Input the model year distribution of the fleet. Note that the model year can be at most 30 years before the evaluation year.
ERROR: Missing fuel type.	No input provided for fuel type.	Select a fuel type from the pull-down menu.
ERROR: Invalid commodity density.	Invalid input provided for commodity density.	Input a number greater than 0 tons per cubic foot.
ERROR: Missing trailer size.	No input provided for trailer size.	Input a number greater than 0 feet.
WARNING: The fractions in the distribution do not sum to 1. Please review allocations prior to calculating emissions.	Model year distribution is not properly allocated.	Prepare a distribution that sums to 1, within a tolerance of at least 3 significant digits (0.9999 <= sum <= 1.0001)

Click ‘Calculate Output’ to recalculate the results once errors are resolved.

Source and fuel type combinations: MOVES data has known data gaps for gasoline and CNG fueled heavy-duty trucks. No gasoline combination long-haul trucks may be modeled in MOVES (nearly all combination long-haul trucks are diesel-fueled). Gasoline combination short-haul trucks are phased out of MOVES default market share data after model year 2008 and are only available for a limited number of model years prior to 2008. The CNG fuel type is available in MOVES for combination short-haul trucks for model years 2009 and later but is not available for combination long-haul trucks. Please consult the

most recent MOVES technical report on vehicle populations and activity[9] and the latest default MOVES database[10] for further details on data gaps.

The Alternative Fuel Emission Factor Multipliers (AFLEET) Tool has adjustment factors that can be applied to conventional fuel emission rates to model alternative fuels and advanced engine technologies. This CMAQ tool utilizes AFLEET adjustment factors to fill data gaps in MOVES for CNG vehicles. For reference, the AFLEET factors are based on diesel fuel for heavy-duty vehicles. Details of how AFLEET adjustment factors were generated can be found in documentation for the GREET tool.[11] For more information on the AFLEET factors for heavy-duty vehicles specifically, please consult the GREET documentation on analyzing heavy-duty vehicle emission rates[12] and updating GREET emission factors with MOVES data[13].

Table 3 highlights which fuels have MOVES emission rates or non-zero AFLEET factors by source type. Since MOVES provides rates for CNG combination short-haul trucks for model years later than 2008, the CMAQ tool prioritizes MOVES rates over AFLEET-adjusted emission rates where the rates are available. Combinations without emissions data are denoted as 'N/A'.

Table 3 Vehicle source type-fuel type combinations in tool

Vehicle Source Type	Gasoline	Diesel	CNG	BEV
Combination Short-haul Truck	N/A	M	M: MY < 2009 A: MY > 2008	A
Combination Long-haul Truck	N/A	M	A	A

M = MOVES emission rates, A = AFLEET factors applied to MOVES conventional fuel emission rates, CNG = compressed natural gas, BEV = battery electric vehicle

Note that MOVES has data for gasoline combination short-haul trucks for model years 1988, 1989, 1992, 1993, 1995, 1997, 1999, 2001, 2002, 2003, and 2008. However, since AFLEET does not provide conversion factors for gasoline to fill in these data gaps, gasoline is excluded from the tool.

TOOL METHODOLOGY

Emissions reductions for the Freight Modal Shift tool are based on the difference between emissions from the baseline freight activity, consisting of one to three segments of freight movement, and the freight activity after project completion. Emissions reductions result from shifting activity to more efficient modes, e.g., shifting activity away from long- or short-haul trucking to rail or marine. If the user wants to model freight activity on more than three segments, the user may run the tool a second time for the remaining segments and add the results manually. For the purposes of this tool, one segment of

[9] EPA, *Population and Activity of On-road Vehicles in MOVES3,* https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1011TF8.pdf
[10] EPA, https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves
[11] DOE, *User Guide for AFLEET Tool 2020*, https://greet.es.anl.gov/publication-afleet-tool-2020-user-guide
[12] DOE, *The GREET Model Expansion for Well-to-Wheels Analysis of Heavy-Duty Vehicles,* https://greet.es.anl.gov/publication-heavy-duty
[13] DOE, *Updated Emission Factors of Air Pollutants from Vehicle Operations in GREET Using MOVES,* https://greet.es.anl.gov/publication-vehicles-13

freight movement consists of freight movement via a single mode (highway, rail, or marine) from one node (e.g., port, railyard, or intermodal facility).

Reductions may also result from updating the model year (in the case of trucks) or the emissions tier (in the case of marine or rail) since newer model years and higher emissions tiers are held to more stringent emissions standards. The tool also allows users to specify the type of fuel (diesel, CNG, or BEV) for short-haul or long-haul truck fleets which may result in emission benefits or disbenefits.

Emissions Reductions

Emission rates for locomotive or marine applications can be found in Tables A1 and A2 of the Appendix, respectively. Emission rates for the battery electric/self-powered option are assumed to be zero for all pollutants and greenhouse gases reported in this tool. Note that emission rates can be accessed within the tool by right-clicking the tab bar at the bottom of the spreadsheet tool and selecting 'Unhide' for the appropriate tab ('HighwayEmissionRates', 'RailEmissionRates', or 'MarineEmissionRates'). Additional information on the emission rates and tool calculations can be found in the Emissions Data document. For each pollutant, the change in reported CMAQ emissions (kg/day) is the difference between the emissions rate before (pre-) versus after (post-) the implementation of the freight modal shift project (Equations 1-3):

$$\Delta Emissions = Emissions_{pre} - Emissions_{post} \quad (1)$$

$$Emissions_{pre} = \sum_{i=1}^{n} E_{pre}{}_{m,n} \quad (2)$$

$$Emissions_{post} = \sum_{i=1}^{n} E_{post}{}_{m,n} \quad (3)$$

where:

$\Delta Emissions$ = total emission reductions for each pollutant in kg/day

n = each segment of freight movement as entered by the user (1 to 3 segments)

m = user input for the mode on each segment

$Emissions_{pre}{}_{m,n}$ = emissions for a given mode for each pollutant on each segment of freight movement before project implementation in kg/day

$Emissions_{post}{}_{m,n}$ = emissions for a given mode for each pollutant on each segment of freight movement after project implementation in kg/day

Equations for individual modes are included in the Emissions Data document that accompanies this User Guide.

Network Performance

The Freight Modal Shift tool also outputs the net change in annual activity[14] in ton-miles per segment and for the project overall. The total net change in activity is calculated using Equations 4-8:

$$\Delta Activity = Activity_{pre} - Activity_{post} \quad (4)$$

$$Activity_{pre} = \sum_{i=1}^{n} A_{pre_n} \quad (5)$$

$$Activity_{post} = \sum_{i=1}^{n} A_{post_n} \quad (6)$$

The change in activity for each segment is calculated with Equation 7:

$$\Delta A_n = A_{pre_n} - A_{post_n} \quad (7)$$

In the case of a segment with highway (long- or short-haul truck) activity, the user may choose to enter activity in ton-miles or VMT. If the user has opted to enter activity data in VMT, the net change in activity involves a conversion to ton-miles, as described in Equation 8:[15] Note that this conversion includes a factor accounting for assumed deadhead, or empty, miles in activity entered as VMT.

$$A_{out}\ (ton \cdot mile) = A_{in}\ (VMT) * \ d\left(\frac{ton}{ft^3}\right) * (l * CF_1)\left(\frac{ft^3}{veh}\right) * (1 - DH) \quad (8)$$

Variables for Equations 5-9 are as follows:

$\Delta Activity$ = total net change in annual activity, in ton-miles

$Activity_{pre}$ = total activity across all segments before project implementation, in ton-miles

$Activity_{post}$ = total activity across all segments after project implementation, in ton-miles

A_{pre_n} = user input for activity on each segment before project implementation, in ton-miles

A_{post_n} = user input for activity on each segment before project implementation, in ton-miles

ΔA_n = change in activity on each segment, in ton-miles

A_{in} = user input for activity for a highway mode, in VMT

A_{out} = activity after unit conversion, in ton-miles

[14] Annual activity refers to the total freight transportation movement per year for a certain mode, in either VMT or ton-miles. Note that activity in VMT accounts for the total distance of freight moved, while activity in ton-miles is a measure of the total weight and the mileage of freight moved. Activity entered in VMT is assumed to include deadhead or empty miles, while activity entered in ton-miles is assumed to exclude deadhead.

[15] More information about the conversion factors may be found in the Emissions Data document.

d = commodity density for a given segment in ton/ft^3 (0.0095 or user input)

l = trailer size for a given segment in ft (28, 45, 48, 53, or user input)

CF_1 = 68, the cross-section of the trailer in ft^2

DH = 0.148, deadhead mileage factor

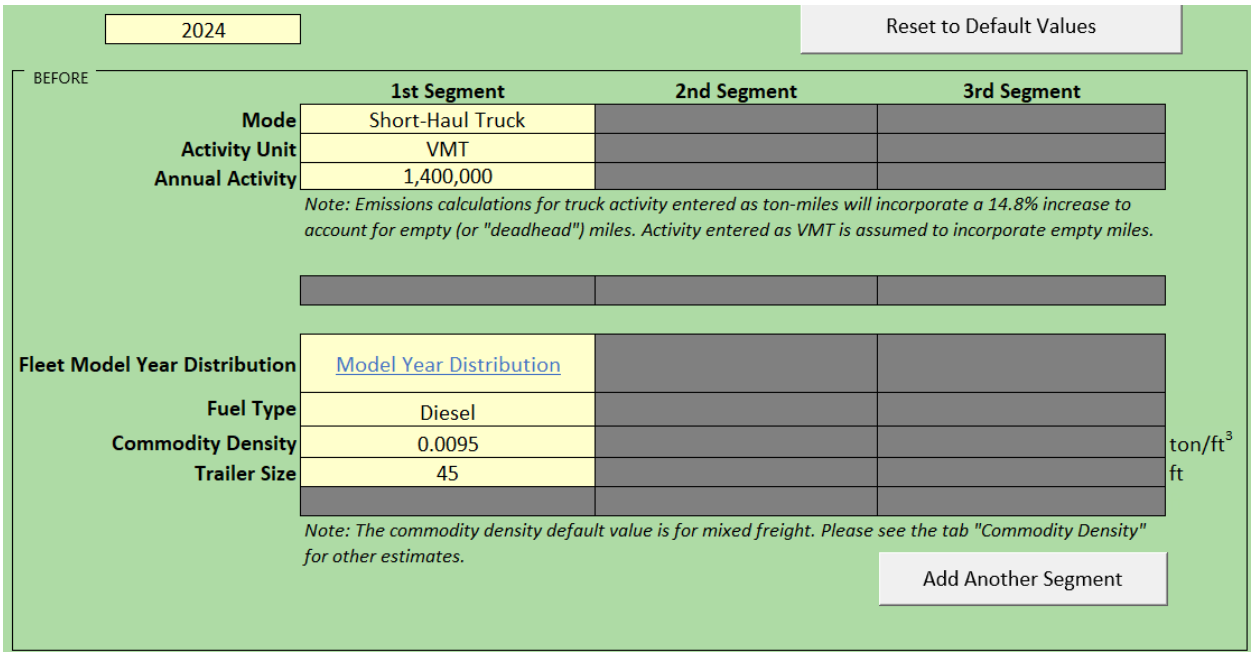
EXAMPLES

The three examples below highlight how the tool calculates emissions savings by applying user-provided activity and average fleet data for several modal shift projects.

Example 1: Highway to Marine

An intermodal facility decides to purchase a container barge to ship freight containers on a more direct route via a river rather than on a highway. Prior to the project, the company used a fleet of diesel short-haul trucks with a trailer size of 45 ft. The new barge service, consisting of Tier 2 tugboats pulling barges, will completely replace 1,400,000 VMT annually from short-haul trucks (an equivalent of 34,674,696 revenue ton-miles per year). The project will be implemented in 2024.

Before:



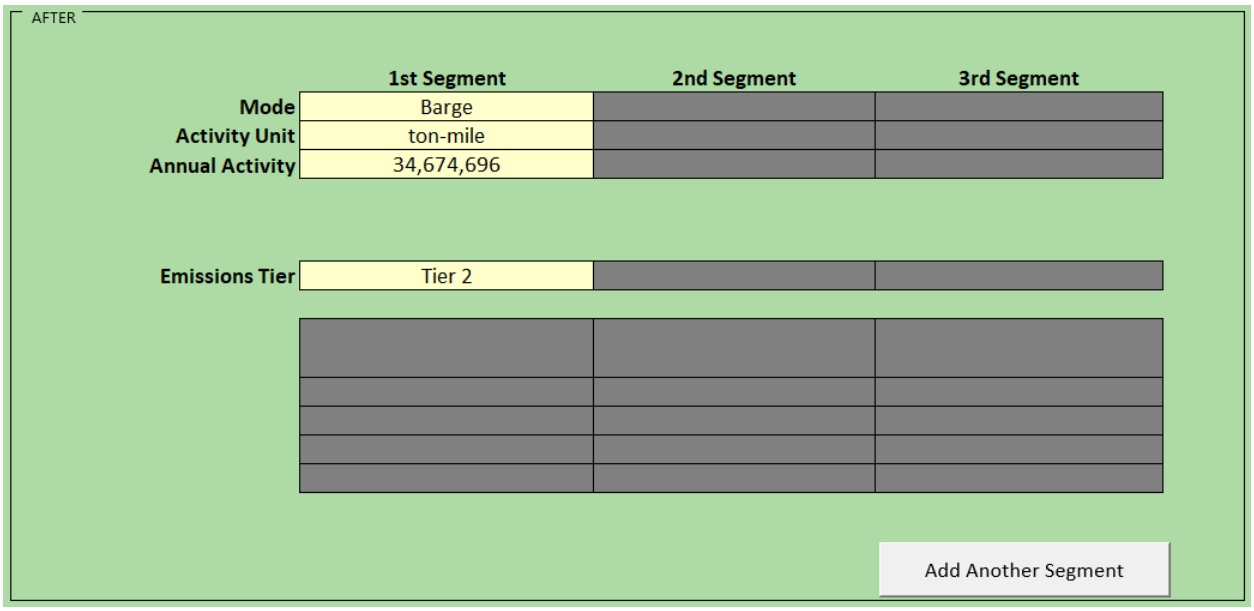
Emission Tier is not relevant to Short-haul Trucks and so will remain grayed out.

National default model year distribution values are used, as displayed in the screenshot of the “Model Year Distribution” tab.

Model Year	Age	BEFORE			AFTER		
		1st Segment	2nd Segment	3rd Segment	1st Segment	2nd Segment	3rd Segment
2024	0	0.0928					
2023	1	0.0973					
2022	2	0.1002					
2021	3	0.0940					
2020	4	0.0928					
2019	5	0.0921					
2018	6	0.0783					
2017	7	0.0626					
2016	8	0.0550					
2015	9	0.0571					
2014	10	0.0442					
2013	11	0.0336					
2012	12	0.0261					
2011	13	0.0107					
2010	14	0.0064					
2009	15	0.0070					
2008	16	0.0035					
2007	17	0.0112					
2006	18	0.0068					
2005	19	0.0060					
2004	20	0.0030					
2003	21	0.0029					
2002	22	0.0020					
2001	23	0.0029					
2000	24	0.0034					
1999	25	0.0023					
1998	26	0.0015					
1997	27	0.0012					
1996	28	0.0011					
1995	29	0.0011					
1994	30	0.0008					
SUM		1.0000					

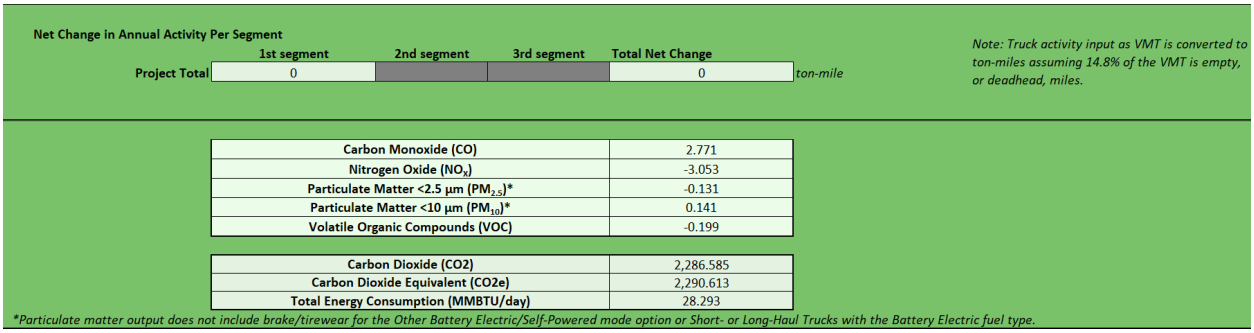
After:

If the emissions Tier of the equipment is unknown, the user could refer to Table A3 – Category 1 and 2 Marine Vessel Engine Tiers in the Appendix of this document. Tier 2 represents vessels built between 2005 and 2013.



Fleet Model Year Distribution, Fuel Type, Commodity Density and Trailer Size are not relevant to barges and so will remain grayed out.

Once inputs are entered, click the 'Calculate Output' button to estimate net change in annual activity (in ton-miles) and emission reductions for the project. The estimated emissions reductions in kg/day (TEC is in MMBTU/day) are:



Net Change in Annual Activity Per Segment (ton-miles)

1st Segment: 0

Total Net Change: 0

Emissions Reductions

CO = 2.422 kg/day

NOx = -5.196 kg/day

$PM_{2.5}$ = -0.186 kg/day

PM_{10} = 0.085 g/day

VOC = -0.312 kg/day

CO_2 = 2,026.343 kg/day

CO_2e = 2,030.372 kg/day

TEC = 24.762 MMBTU/day

Note that the total annual activity is assumed to be the same before and after project implementation to estimate the emissions benefits from implementing a barge service in place of long-haul trucking for a fixed amount of activity.

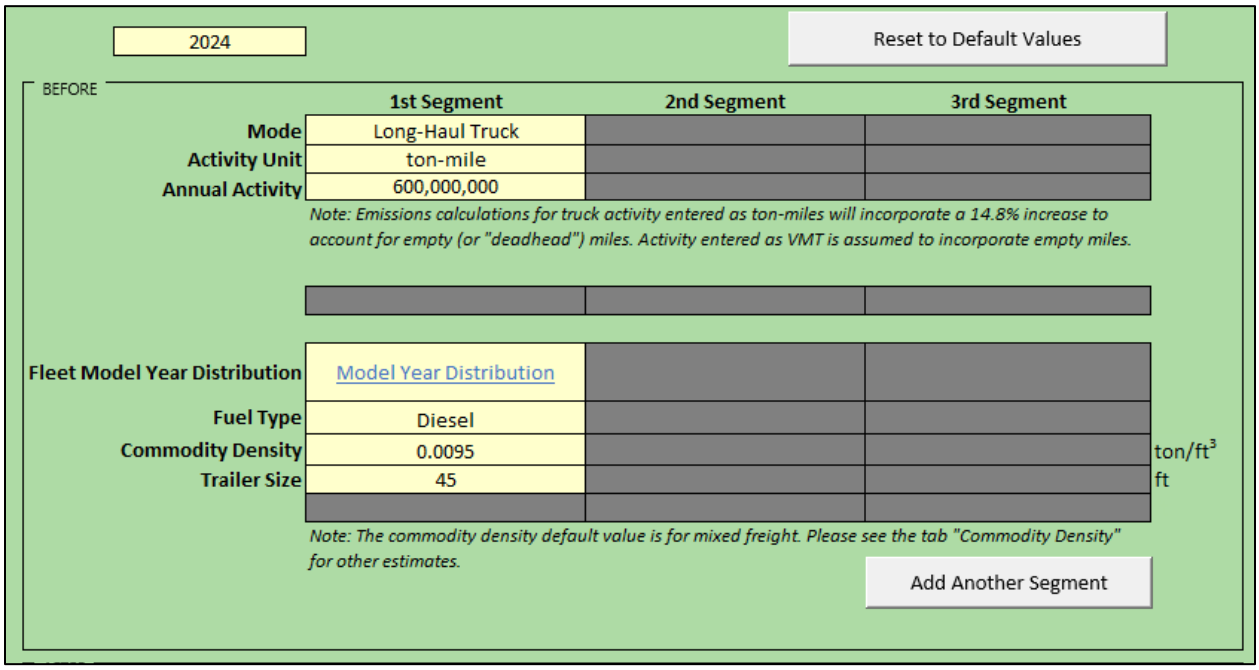
Emissions disbenefits occur for some pollutants (NO_x, $PM_{2.5}$, and VOCs) when switching from short-haul trucks to a Tier 2 barge/tugboat system due to differences in onroad diesel and the ULSD fuel used in marine vessels. While there are efficiency savings, fuel used in ships emits higher amounts of some pollutants compared with highway diesel.

Example 2: Highway to Rail

An MPO constructs a new freight rail segment in 2024 to relieve congestion in the corridor caused by truck traffic. Before the project, freight was transported on the corridor via a truck fleet compromised of diesel long-haul trucks with 45-foot trailers and had an annual activity of 600,000,000 revenue ton-miles. Two-thirds of the annual freight activity (400,000,000 ton-miles) now occurs on Tier 4 locomotives, with 200,000,000 ton-miles still transported via long-haul trucks.

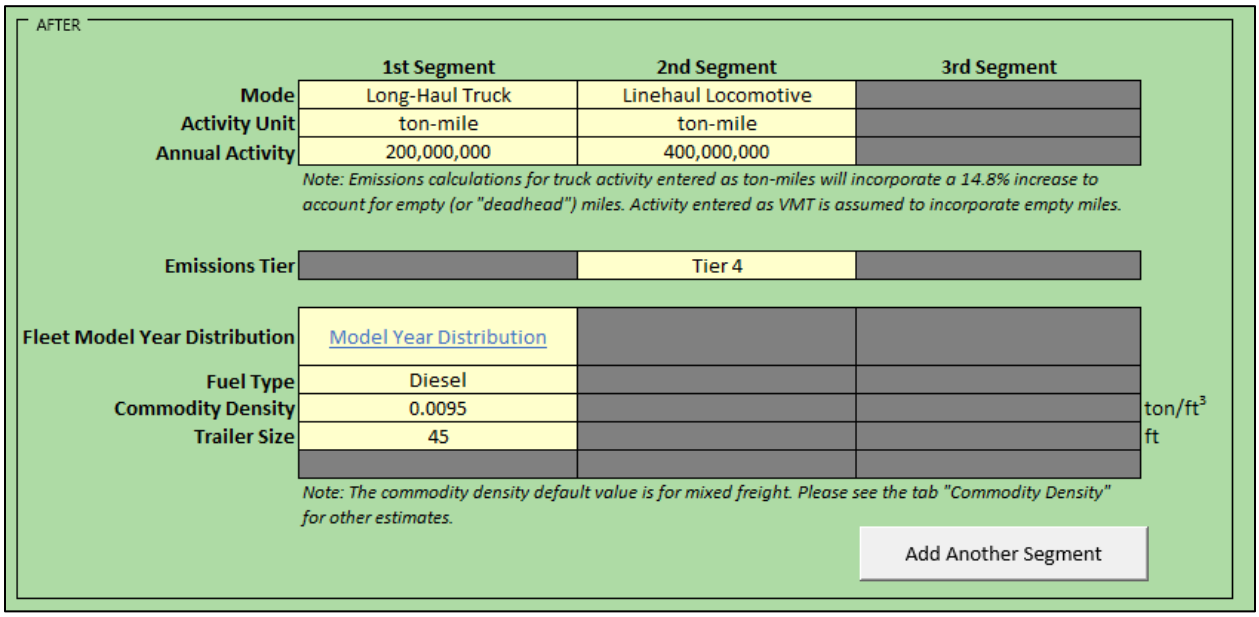
Within the tool interface, the user would select the following inputs:

Before:



Emission Tier is not relevant to Long-haul Trucks and so will remain grayed out.

After:


AFTER

	1st Segment	2nd Segment	3rd Segment	
Mode	Long-Haul Truck	Linehaul Locomotive		
Activity Unit	ton-mile	ton-mile		
Annual Activity	200,000,000	400,000,000		

Note: Emissions calculations for truck activity entered as ton-miles will incorporate a 14.8% increase to account for empty (or "deadhead") miles. Activity entered as VMT is assumed to incorporate empty miles.

Emissions Tier		Tier 4		
Fleet Model Year Distribution	Model Year Distribution			
Fuel Type	Diesel			
Commodity Density	0.0095			ton/ft^3
Trailer Size	45			ft

Note: The commodity density default value is for mixed freight. Please see the tab "Commodity Density" for other estimates.

Add Another Segment

National default model year distribution values for Segment 1, before and after project implementation, are used as displayed in the screenshot of the “Model Year Distribution” tab.

Model Year	Age	BEFORE			AFTER		
		1st Segment	2nd Segment	3rd Segment	1st Segment	2nd Segment	3rd Segment
2025	0	0.0772			0.0772		
2024	1	0.0787			0.0787		
2023	2	0.0820			0.0820		
2022	3	0.0839			0.0839		
2021	4	0.0743			0.0743		
2020	5	0.0730			0.0730		
2019	6	0.0719			0.0719		
2018	7	0.0617			0.0617		
2017	8	0.0643			0.0643		
2016	9	0.0578			0.0578		
2015	10	0.0662			0.0662		
2014	11	0.0510			0.0510		
2013	12	0.0326			0.0326		
2012	13	0.0284			0.0284		
2011	14	0.0129			0.0129		
2010	15	0.0089			0.0089		
2009	16	0.0090			0.0090		
2008	17	0.0051			0.0051		
2007	18	0.0173			0.0173		
2006	19	0.0113			0.0113		
2005	20	0.0092			0.0092		
2004	21	0.0045			0.0045		
2003	22	0.0035			0.0035		
2002	23	0.0020			0.0020		
2001	24	0.0028			0.0028		
2000	25	0.0038			0.0038		
1999	26	0.0026			0.0026		
1998	27	0.0015			0.0015		
1997	28	0.0009			0.0009		
1996	29	0.0007			0.0007		
1995	30	0.0011			0.0011		
SUM		1.0000			1.0000		

If the emissions Tier of the equipment is unknown, the user could refer to Table A1 – Locomotive Emission Tiers in the Appendix of this document. Linehaul locomotives built after 2015 fall under the Tier 4 EPA standards.

Once inputs are entered, click the 'Calculate Output' button to estimate net change in annual activity (in ton-miles) and emission reductions for the project. The estimated emissions reductions in kg/day (TEC is in MMBTU/day) are:

OUTPUT

Net Change in Annual Activity Per Segment

	1st segment	2nd segment	3rd segment	Total Net Change	
Project Total	-400,000,000	400,000,000		0	*ton-mile*

Carbon Monoxide (CO)	-21.935
Nitrogen Oxide (NO_X)	27.613
Particulate Matter <2.5 µm ($PM_{2.5}$)*	0.925
Particulate Matter <10 µm (PM_{10})*	3.293
Volatile Organic Compounds (VOC)	1.318

Carbon Dioxide (CO2)	5,847.658
Carbon Dioxide Equivalent (CO2e)	5,870.540
Total Energy Consumption (MMBTU/day)	61.128

**PM output does not include brake/tirewear for Other Battery Electric/Self-Powered mode option or Short- or Long-Haul Trucks with the BEV fuel type.*

Net Change in Annual Activity Per Segment (ton-miles)

1st Segment: -400,000,000
2nd Segment: 400,000,000
Total Net Change: 0

Emissions Reductions

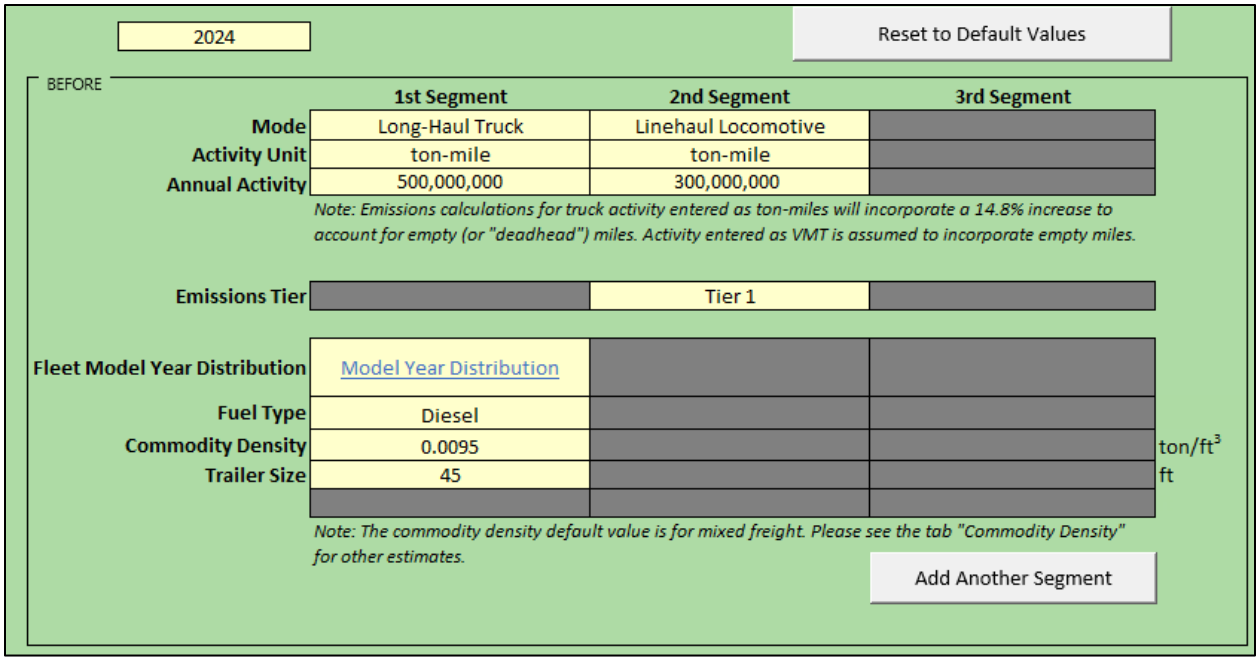
CO = -21.935 kg/day
NOx = 27.613 kg/day
$PM_{2.5}$ = 0.925 kg/day
PM_{10} = 3.293 kg/day
VOC = 1.318 kg/day
CO_2 = 5,847.658 kg/day
CO_2e = 5,870.540 kg/day
TEC = 61.128 MMBTU/day

Emissions disbenefits occur for carbon monoxide when switching from short-haul trucks to Tier 4 linehaul locomotives because the Tier 4 locomotive diesel standard is less stringent than the highway standard.

Example 3: Updating a Fleet

In 2024, an intermodal facility decides to update several of their older diesel long-haul trucks and locomotives to reduce emissions. The total annual activity of the two fleets will not change. Freight activity will occur on two segments (long-haul truck and linehaul locomotive) before and after project implementation.

Before:



2024

Reset to Default Values

BEFORE

	1st Segment	2nd Segment	3rd Segment	
Mode	Long-Haul Truck	Linehaul Locomotive		
Activity Unit	ton-mile	ton-mile		
Annual Activity	500,000,000	300,000,000		

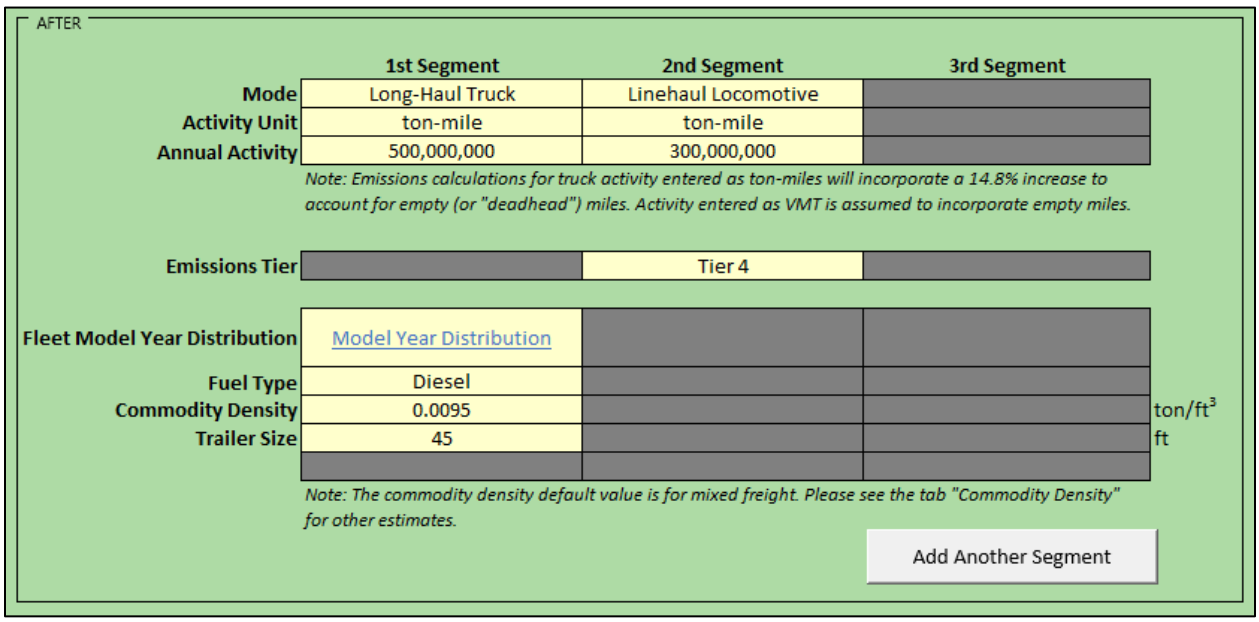
Note: Emissions calculations for truck activity entered as ton-miles will incorporate a 14.8% increase to account for empty (or "deadhead") miles. Activity entered as VMT is assumed to incorporate empty miles.

Emissions Tier		Tier 1		
Fleet Model Year Distribution	Model Year Distribution			
Fuel Type	Diesel			
Commodity Density	0.0095			ton/ft^3
Trailer Size	45			ft

Note: The commodity density default value is for mixed freight. Please see the tab "Commodity Density" for other estimates.

Add Another Segment

After:



AFTER

	1st Segment	2nd Segment	3rd Segment	
Mode	Long-Haul Truck	Linehaul Locomotive		
Activity Unit	ton-mile	ton-mile		
Annual Activity	500,000,000	300,000,000		

Note: Emissions calculations for truck activity entered as ton-miles will incorporate a 14.8% increase to account for empty (or "deadhead") miles. Activity entered as VMT is assumed to incorporate empty miles.

Emissions Tier		Tier 4		
Fleet Model Year Distribution	Model Year Distribution			
Fuel Type	Diesel			
Commodity Density	0.0095			ton/ft^3
Trailer Size	45			ft

Note: The commodity density default value is for mixed freight. Please see the tab "Commodity Density" for other estimates.

Add Another Segment

Custom model distribution allocations for Segment 1, before and after project implementation, are entered by the user. The total across all years must sum to one, as shown below.

Model Year	Age	BEFORE 1st Segment	BEFORE 2nd Segment	BEFORE 3rd Segment	AFTER 1st Segment	AFTER 2nd Segment	AFTER 3rd Segment
2024	0				0.2000		
2023	1						
2022	2				0.2500		
2021	3						
2020	4						
2019	5						
2018	6	0.2500			0.2500		
2017	7						
2016	8						
2015	9	0.1500			0.1500		
2014	10						
2013	11						
2012	12						
2011	13						
2010	14	0.1500			0.1500		
2009	15						
2008	16						
2007	17	0.1500					
2006	18						
2005	19	0.2000					
2004	20						
2003	21	0.0500					
2002	22	0.0500					
2001	23						
2000	24						
1999	25						
1998	26						
1997	27						
1996	28						
1995	29						
1994	30						
SUM		1.0000			1.0000		

Once inputs are entered, click the 'Calculate Output' button to estimate net change in annual activity (in ton-miles) and emission reductions for the project. The estimated emissions reductions in kg/day (TEC is in MMBTU/day) are:

OUTPUT

Net Change in Annual Activity Per Segment

	1st segment	2nd segment	3rd segment	Total Net Change	
Project Total	0	0		0	*ton-mile*

Carbon Monoxide (CO)	10.576
Nitrogen Oxide (NO_x)	282.357
Particulate Matter <2.5 µm ($PM_{2.5}$)*	15.684
Particulate Matter <10 µm (PM_{10})*	16.413
Volatile Organic Compounds (VOC)	22.218

Carbon Dioxide (CO2)	4,646.594
Carbon Dioxide Equivalent (CO2e)	4,650.082
Total Energy Consumption (MMBTU/day)	59.754

**PM output does not include brake/tirewear for Other Battery Electric/Self-Powered mode option or Short- or Long-Haul Trucks with the BEV fuel type.*

Net Change in Annual Activity Per Segment (ton-miles)

1st Segment: 0
2nd Segment: 0
Total Net Change: 0

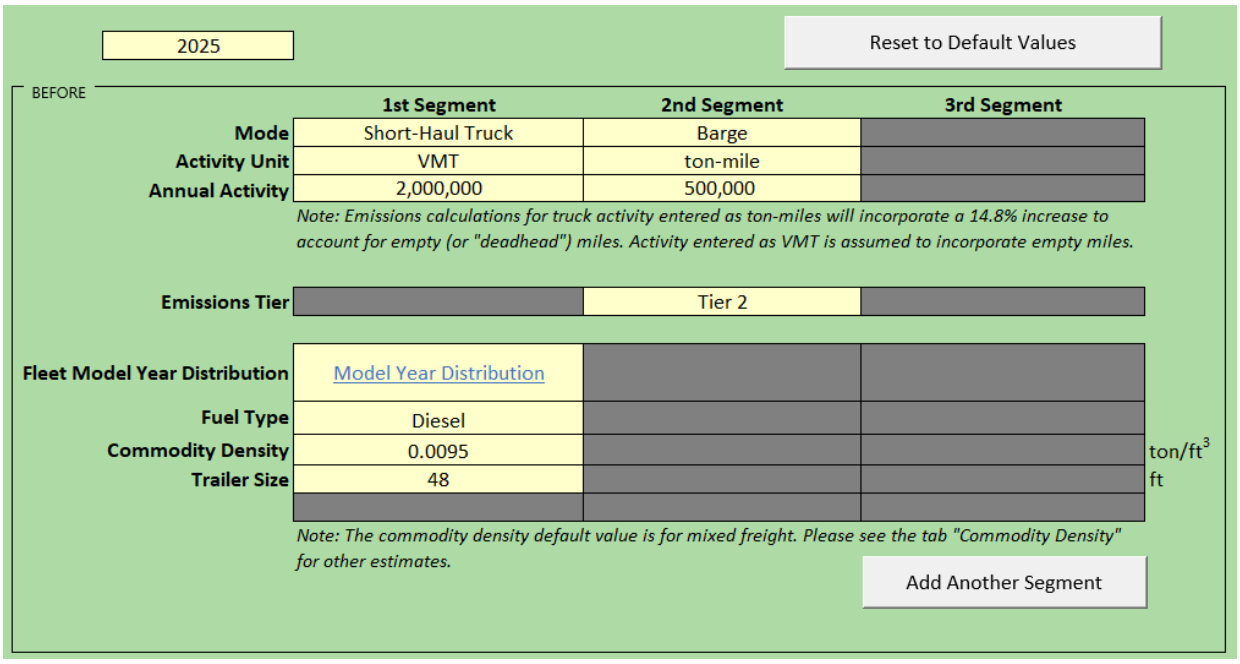
Emissions Reductions

CO = 10.576 kg/day
NOx = 282.357 kg/day
$PM_{2.5}$ = 15.684 kg/day
PM_{10} = 16.413 kg/day
VOC = 22.218 kg/day
CO_2 = 4,646.594 kg/day
CO_2e = 4,650.082 kg/day
TEC = 59.754 MMBTU/day

Example 4: Shifting to Battery Electric

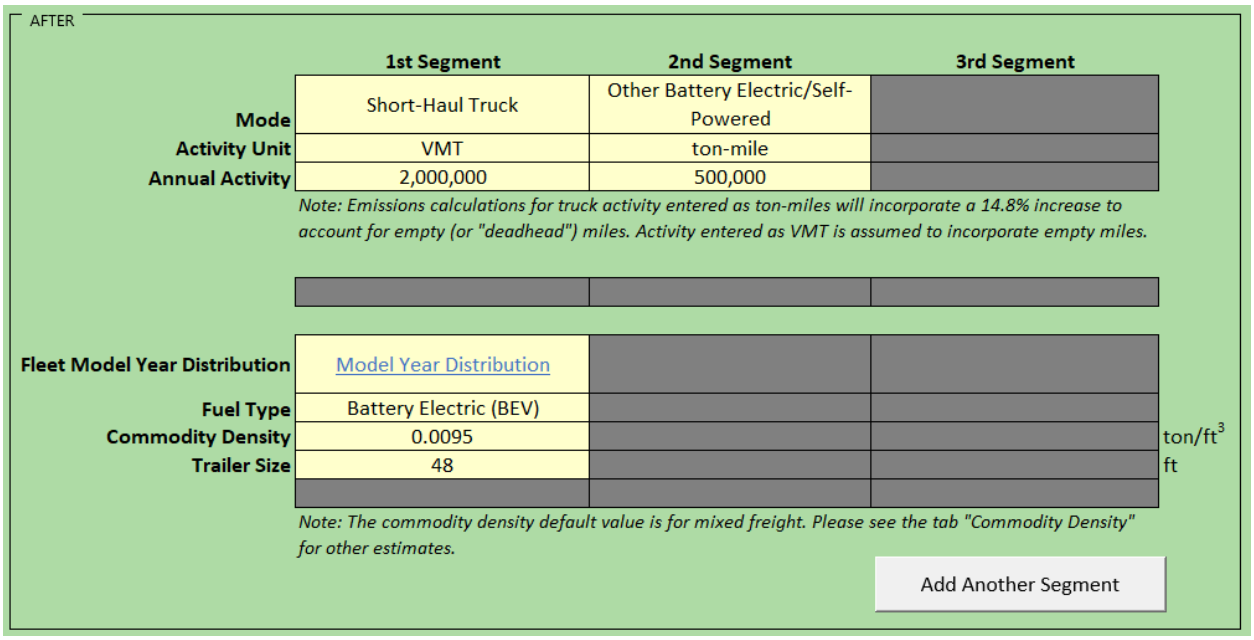
An intermodal facility will start the transition to electrification for their short-haul truck and barge fleets in 2025. The facility will replace half of their diesel truck fleet with battery electric trucks, which have an annual VMT of 2 million before and after project implementation. The facility will also pilot a battery electric self-propelled barge, which will replace 500,000 ton-miles of Tier 2 diesel barge/tugboat activity. Freight activity will occur on two segments (short-haul truck and barge) before and after project implementation.

Before:



After:

To model battery electric short-haul trucks, choose the “Short-Haul Truck” option for mode and “Battery Electric (EV)” for fuel type. To model battery electric barges, choose the “Other Battery-Electric/Self-Powered” option for mode. Note that this mode may be used to model battery electric locomotives as well.



AFTER

	1st Segment	2nd Segment	3rd Segment	
Mode	Short-Haul Truck	Other Battery Electric/Self-Powered		
Activity Unit	VMT	ton-mile		
Annual Activity	2,000,000	500,000		

Note: Emissions calculations for truck activity entered as ton-miles will incorporate a 14.8% increase to account for empty (or "deadhead") miles. Activity entered as VMT is assumed to incorporate empty miles.

Fleet Model Year Distribution	Model Year Distribution			
Fuel Type	Battery Electric (BEV)			
Commodity Density	0.0095			ton/ft^3
Trailer Size	48			ft

Note: The commodity density default value is for mixed freight. Please see the tab "Commodity Density" for other estimates.

Add Another Segment

National default model year distribution values for the truck fleet in Segment 1 are used before and after project implementation.

Model Year	Age	BEFORE 1st Segment	BEFORE 2nd Segment	BEFORE 3rd Segment	AFTER 1st Segment	AFTER 2nd Segment	AFTER 3rd Segment
2024	0	0.0928			0.0928		
2023	1	0.0973			0.0973		
2022	2	0.1002			0.1002		
2021	3	0.0940			0.0940		
2020	4	0.0928			0.0928		
2019	5	0.0921			0.0921		
2018	6	0.0783			0.0783		
2017	7	0.0626			0.0626		
2016	8	0.0550			0.0550		
2015	9	0.0571			0.0571		
2014	10	0.0442			0.0442		
2013	11	0.0336			0.0336		
2012	12	0.0261			0.0261		
2011	13	0.0107			0.0107		
2010	14	0.0064			0.0064		
2009	15	0.0070			0.0070		
2008	16	0.0035			0.0035		
2007	17	0.0112			0.0112		
2006	18	0.0068			0.0068		
2005	19	0.0060			0.0060		
2004	20	0.0030			0.0030		
2003	21	0.0029			0.0029		
2002	22	0.0020			0.0020		
2001	23	0.0029			0.0029		
2000	24	0.0034			0.0034		
1999	25	0.0023			0.0023		
1998	26	0.0015			0.0015		
1997	27	0.0012			0.0012		
1996	28	0.0011			0.0011		
1995	29	0.0011			0.0011		
1994	30	0.0008			0.0008		
SUM		1.0000			1.0000		

Once inputs are entered, click the 'Calculate Output' button to estimate net change in annual activity (in ton-miles) and emission reductions for the project. The estimated emissions reductions in kg/day (TEC is in MMBTU/day) are:

Net Change in Annual Activity Per Segment

	1st segment	2nd segment	3rd segment	Total Net Change	
Project Total	0	0		0	*ton-mile*

Note: Truck ton-miles a or deadhea

Carbon Monoxide (CO)	6.698
Nitrogen Oxide (NO_x)	12.927
Particulate Matter <2.5 µm ($PM_{2.5}$)*	0.244
Particulate Matter <10 µm (PM_{10})*	0.646
Volatile Organic Compounds (VOC)	0.610

Carbon Dioxide (CO2)	5,328.392
Carbon Dioxide Equivalent (CO2e)	5,334.072
Total Energy Consumption (MMBTU/day)	68.462

**Particulate matter output does not include brake/tirewear for the Other Battery Electric/Self-Powered mode option or Short- or Long-Haul Trucks with the Battery Electric fuel type.*

Net Change in Annual Activity Per Segment (ton-miles)

1st Segment: 0

2nd Segment: 0

Total Net Change: 0

Emissions Reductions

CO = 6.698 kg/day
NOx = 12.927 kg/day
$PM_{2.5}$ = 0.244 kg/day
PM_{10} = 0.646 kg/day
VOC = 0.610 kg/day
CO_2 = 5,328.392 kg/day
CO_2e = 5,334.072 kg/day
TEC = 68.462 MMBTU/day

Note that all emissions, including particulate matter, are assumed to be zero for all battery-electric modes, including trucks. For more information, see the Emissions Data document.

RESOURCES

Data Dictionary

The CMAQ Data Dictionary, which can be found here, is a resource available to the public to help understand terms that may be used in this tool. On the Data Dictionary webpage, select "Freight and Intermodal." If you are searching for a particular term, you can use the "Find in results" button. After clicking submit you will be shown a list of results.

MOVES

General information about the MOVES model can be found on the EPA's website. MOVES is free to download and allows users to model mobile source emissions at different scales ranging from project level to national. The website includes subpages to download the latest version, watch webinars and training sessions, and contact the developers for help.

Appendix

Table A1. Diesel (Line-haul) Locomotive Engine Tiers[16]

Year of Manufacture	Tier
Pre-1973	Uncontrolled
1973-1992	Tier 0
1973-1992	Tier 0+
1993-2004	Tier 1
1993-2004	Tier 1+
2005-2011	Tier 2
2005-2011	Tier 2+
2012-2014	Tier 3
2015+	Tier 4

Tiers with '+' are applicable only to locomotives that were originally manufactured in the corresponding Year of Manufacture range and remanufactured in 2008 or later; EPA holds these remanufactured locomotives to a higher emissions standard.

Table A2. Diesel (as ultra low sulfur diesel; ULSD) Marine Vessel Emission Factors[17]

Vessel Category	Tier*	NO_x *(g/kWh)*	PM *(g/kWh)*	VOC *(g/kWh)*	CO *(g/kWh)*
C1 or C2	Tier 0	10.2	0.26	0.30	1.61
C1 or C2	Tier 1	9.6	0.26	0.30	1.61
C1 or C2	Tier 2	5.6	0.15	0.30	0.92
C1 or C2	Tier 3	4.7	0.08	0.12	0.92
C1 or C2	Tier 4	1.3	0.03	0.12	0.92

* Refer to Table A3 for assistance in determining the appropriate Tier for barges (C1 and C2)

Table A3. Category 1 and 2 Marine Vessel Engine Tiers[18]

Cylinder Displacement Range (liters/cylinder)	Power Range (kilowatts)	Model Year Range	Engine Tier
All	0 < kW ≤ 19	Pre-2000	Uncontrolled (Tier 0)
All	19 < kW ≤ 37	Pre-1999	Uncontrolled (Tier 0)
Disp < 5	kW > 37	Pre-2004	Uncontrolled (Tier 0)
5 ≤ Disp < 30	All	Pre-2004	Uncontrolled (Tier 0)
All	0 < kW ≤ 19	2000-2004	Tier 1
All	19 < kW ≤ 37	1999-2003	Tier 1
Disp < 0.9	kW > 37	2004	Tier 1
2.5 ≤ Disp < 5	kW > 37	2004-2006	Tier 1

[16] EPA, *Emission Factors for Locomotives*, https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100500B.TXT.
[17] EPA, *Ports Emissions Inventory Guidance: Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions,* https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1014J1S.pdf
[18] Ibid.

Cylinder Displacement Range (liters/cylinder)	Power Range (kilowatts)	Model Year Range	Engine Tier
5 ≤ Disp < 30	All	2004-2006	Tier 1
All	0 < kW ≤ 19	2005-2008	Tier 2
All	19 < kW ≤ 37	2004-2008	Tier 2
Disp < 0.9	37 < kW ≤ 75	2005-2008	Tier 2
Disp < 0.9	75 < kW ≤ 600	2005-2011	Tier 2
0.9 ≤ Disp < 1.2	kW > 37	2004-2012	Tier 2
1.2 ≤ Disp < 2.5	kW > 37	2004-2013	Tier 2
2.5 ≤ Disp < 3.5	kW > 37	2007-2012	Tier 2
3.5 ≤ Disp < 5	kW > 37	2007-2011	Tier 2
5 ≤ Disp < 15	All	2007-2012	Tier 2
15 ≤ Disp < 30	All	2007-2013	Tier 2
All	0 < kW ≤ 37	2009+	Tier 3
Disp < 0.9	37 < kW ≤ 75	2009+	Tier 3
Disp < 0.9	75 < kW ≤ 600	2012+	Tier 3
0.9 ≤ Disp < 1.2	kW ≤ 600	2013+	Tier 3
1.2 ≤ Disp < 2.5	kW ≤ 600	2014+	Tier 3
2.5 ≤ Disp < 3.5	kW ≤ 600	2013+	Tier 3
3.5 ≤ Disp < 7	kW ≤ 600	2012+	Tier 3
1.2 ≤ Disp < 2.5	600 < kW ≤ 1000	2014-2017	Tier 3
2.5 ≤ Disp < 3.5	600 < kW ≤ 1000	2013-2017	Tier 3
3.5 ≤ Disp < 7	600 < kW ≤ 1000	2012-2017	Tier 3
1.2 ≤ Disp < 2.5	1000 < kW ≤ 1400	2014-2016	Tier 3
2.5 ≤ Disp < 3.5	1000 < kW ≤ 1400	2013-2016	Tier 3
3.5 ≤ Disp < 7	1000 < kW ≤ 1400	2012-2016	Tier 3
3.5 ≤ Disp < 7	kW > 1400	2012-2015	Tier 3
7 ≤ Disp < 15	kW ≤ 600	2013+	Tier 3
7 ≤ Disp < 15	600 < kW ≤ 1000	2013-2017	Tier 3
7 ≤ Disp < 15	1000 < kW ≤ 1400	2013-2016	Tier 3
7 ≤ Disp < 15	1400 < kW ≤ 2000	2013-2015	Tier 3
15 ≤ Disp < 30	1400 < kW ≤ 2000	2014-2015	Tier 3
1.2 ≤ Disp < 7	600 < kW ≤ 1000	2018+	Tier 4
1.2 ≤ Disp < 3.5	1000 < kW ≤ 1400	2017+	Tier 4
3.5 ≤ Disp < 7	1000 < kW ≤ 1400	2017+	Tier 4
3.5 ≤ Disp < 7	kW > 1400	2016+	Tier 4
7 ≤ Disp < 15	600 < kW ≤ 1000	2018+	Tier 4
7 ≤ Disp < 15	1000 < kW ≤ 1400	2017+	Tier 4
7 ≤ Disp < 15	1400 < kW ≤ 2000	2016+	Tier 4
7 ≤ Disp < 15	2000 < kW ≤ 3700	2014+	Tier 4

Cylinder Displacement Range (liters/cylinder)	Power Range (kilowatts)	Model Year Range	Engine Tier
7 ≤ Disp < 15	kW > 3700	2014-2016	Tier 4
7 ≤ Disp < 15	kW > 3700	2017+	Tier 4
15 ≤ Disp < 30	1400 < kW ≤ 2000	2016+	Tier 4
	2000 < kW ≤ 3700	2014+	Tier 4
	kW > 3700	2014-2016	Tier 4
	kW > 3700	2017+	Tier 4

Table A4. Default Commodity Density Values[19]

SCTG Code	SITC Code	Product Name	Density (ton/ft^3)
4	8	Animal feed	0.0091
7	9	Prepared foodstuffs, fats, and oils	0.0172
18	22	Fuel oils	0.0132
25	24	Raw wood	0.0113
27	25	Pulp and waste paper	0.0154
22	27	Crude materials and fertilizers	0.0290
15	32	Coal	0.0240
19	33	Petroleum products	0.0231
17	34	Gas	0.0118
20	51	Chemical elements and compounds	0.0290
20	59	Chemical materials and products	0.0163
27	64	Paper products	0.0091
12	66	Gravel and crushed stone	0.0363
31	66	Nonmetallic mineral products	0.0272
32	67	Iron and steel	0.0631
32	69	Metallic products	0.0177
26	82	Furniture	0.0032
43	88	Mixed freight	0.0095

This table is adapted from Table K.2. from the EPA's Ports Emissions Inventory Guidance and shows the average densities for 18 commodity groups, based on the Standard International Trade Classification (SITC) system of classifying commodities and listed by Standard Classification of Transported Goods (SCTG) code.

Table A5. Diesel (Line-haul) Locomotive Emission Factors[20]

Year of Manufacture	Tier	NO_X *(g/bhp-hr)*	PM *(g/bhp-hr)*	HC *(g/bhp-hr)*	CO *(g/bhp-hr)*
Pre-1973	Uncontrolled	13.00	0.32	0.48	1.28

[19] Ibid.
[20] Ibid.

1973-1992	Tier 0	8.60	0.32	0.48	1.28
1973-1992	Tier 0+	7.20	0.20	0.30	1.28
1993-2004	Tier 1	6.70	0.32	0.47	1.28
1993-2004	Tier 1+	6.70	0.20	0.29	1.28
2005-2011	Tier 2	4.95	0.18	0.26	1.28
2005-2011	Tier 2+	4.95	0.08	0.13	1.28
2012-2014	Tier 3	4.95	0.08	0.13	1.28
2015+	Tier 4	1.00	0.015	0.04	1.28

Tiers with '+' are applicable only to locomotives that were originally manufactured in the corresponding Year of Manufacture range and remanufactured in 2008 or later; EPA holds these remanufactured locomotives to a higher emissions standard.