California Air Resources Board

Truck vs. Train Methodology

September 23, 2020

Table of Contents

Section A. Introduction 1
Section B. Detailed Methodology 1
1. Scenarios and Assumptions 1
2. Truck Methodology 3
3. Train Methodology 6
Section C. Results 10
Section D. References 15
Appendix A. META Tool Inventory Values 16
Appendix B. Locomotive Inventory Values 19

Table 1. EMFAC2017 parameters 3
Table 2. META Tool parameters 4
Table 3. Line haul emission factors [grams/bhp-hr] 9
Table 4. Truck regulations, as reflected in the META Tool and the analysis 16
Table 5. META Tool inventory values 17
Table 6. Locomotive inventory values 20

Equation 1: Calendar years 2010 – 2016 truck emissions from EMFAC2017 5
Equation 2: Calendar years 2017 and newer truck emissions from META Tool 5
Equation 3: Number of trains 6
Equation 4: Total weight of freight on all trains 6
Equation 5: Total weight of empty railcars on all trains 7
Equation 6: Total weight of locomotives on all trains 7
Equation 7: GTM 7
Equation 8: GTM per gallon of diesel consumed by locomotives 8
Equation 9: Locomotive fuel consumption 8
Equation 10: Emissions from locomotives 9

Figure 1. Containers transported by trucks vs. trains 2
Figure 2. Communities within 20 miles of the Ports and communities 20-300 miles from the Ports 2
Figure 3. $PM_{2.5}$ emissions in communities within 20 miles of the Ports 2010 – 2050 11
Figure 4. $PM_{2.5}$ emissions in communities within 20 miles of the Ports 2020 – 2050 with alternate scenarios 11
Figure 5. NO_X emissions in communities within 20 miles of the Ports 2010 – 2050 12
Figure 6. NO_X emissions in communities within 20 miles of the Ports 2020 – 2050 with alternate scenarios 12

Figure 7. $PM_{2.5}$ emissions in communities 20-300 miles from the Ports 2010 – 2050 .. 13
Figure 8. $PM_{2.5}$ emissions in communities 20-300 miles from the Ports 2020 – 2050 with alternate scenarios 13
Figure 9. NO_X emissions in communities 20-300 miles from the Ports 2010 – 2050 ... 14
Figure 10. NO_X emissions in communities 20-300 miles from the Ports 2020 – 2050 with alternate scenarios 14

List of Acronyms and Abbreviations

Acronym	Term
ACF	Advanced Clean Truck Fleets Regulation
ACT	Advanced Clean Trucks Regulation
bhp-hr	Brake horsepower hour
CARB	California Air Resources Board or Board
GTM	Gross-ton-miles
HD I/M	Heavy-Duty Inspection and Maintenance
Low NO_X	Heavy-Duty Engine and Vehicle Omnibus Regulation
META Tool	August 24, 2020 version of draft On-Road Heavy-Duty Beta META Tool v2
NO_X	Oxides of nitrogen
PM_{10}	Particulate matter 10 micrometers or smaller in diameter
$PM_{2.5}$	Particulate matter 2.5 micrometers or smaller in diameter
POLA	Port of Los Angeles
Ports or San Pedro Bay Ports	Port of Los Angeles and Port of Long Beach
STB	Surface Transportation Board
U.S. EPA	United States Environmental Protection Agency
VMT	Vehicle miles traveled

List of Definitions

Term	Definition
Cargo Handling Equipment	Any off-road, self-propelled vehicle or equipment used at a port or intermodal railyard to lift or move container, bulk, or liquid cargo carried by ship, train, or another vehicle, or used to perform maintenance and repair activities that are routinely scheduled or that are due to predictable process upsets. Equipment includes, but is not limited to, rubber-tired gantry cranes, yard trucks, top handlers, side handlers, reach stackers, forklifts, loaders, aerial lifts, excavators, and dozers.
Class I Railroad	Railroads with 2018 revenue of at least $490 million.
Class 8 Truck	Any truck with a gross vehicle weight rating greater than 33,000 pounds.
Drayage Truck	A class 8 truck that is used for transporting containers, originating from a port or railyard to an intermediate destination, such as a warehouse.
EMFAC2017	The California Air Resources Board on-road mobile source emissions inventory. Contains emission factors from mobile sources, such as drayage and long haul trucks.
First-Mile/Last-Mile Emissions	Emissions associated with the first- and last-mile operations, such as from trucks and trains idling while waiting to be loaded and cargo handling equipment moving containers to be loaded.
Flat Car	Railcar with an open, flat deck designed to carry containers or trailers.
Gross Ton	Weight of all locomotive units, railcars, and contents.
Gross-Ton-Miles	Weight of all locomotive units, railcars, and contents moved one mile in transportation trains.
Gross Vehicle Weight Rating	The maximum amount of weight a vehicle is rated for, as specified by the manufacturer. Includes the weight of the vehicle, fuel, passengers, miscellaneous items, and trailer.
Idle Emissions	Truck emissions while the truck engine is idling.

Term	Definition
Line Haul Locomotive	United States Environmental Protection Agency defines line haul locomotives to be or greater than 2,300 horsepower. The California Air Resources Board categorizes line haul locomotives as greater than 4,000 horsepower.
Locomotive	A self-propelled piece of on-track equipment designed for moving or propelling cars that are designed to carry freight, passengers or other equipment, but which itself is not designed or intended to carry freight, passengers (other than those operating the locomotive) or other equipment.
Long Haul Truck	A class 8 truck that is used for transporting trailers containing cargo originally transported by a drayage truck to a destination, such as a distribution center.
Model Year	The annual production period of a truck manufacturer, which includes January 1st of a calendar year, or if the manufacturer has no annual production period, the calendar year.
On-Dock Rail	Rail tracks located inside ports where containers or other cargos are loaded onto railcars.
Railcar	A vehicle used for the carrying of cargo or passengers on rail tracks.
Running Exhaust Emissions	Truck emissions while the truck is in motion.
Start Emissions	Truck emissions during the brief period following engine start.
Tare Weight	Weight of an empty railcar.
Train	Connected locomotives and railcars moving as a unit.
Transloading	The act of repackaging cargo from one type of container in to another. For the purposes of this document, transloading refers to repackaging from a 40-foot container to a 53-foot trailer.
T7	An on-road heavy-duty inventory category. T7 refers to class 8 trucks with a gross vehicle weight rating greater than 33,000 pounds.

Section A. Introduction

Though moving cargo by trains may have produced fewer emissions than trucks in the past, trucks in California have become much cleaner over the last decade and are moving towards zero emission technology. The analysis used truck and train emissions inventories to compare particulate matter 2.5 micrometers in diameter or smaller ($PM_{2.5}$) and oxides of nitrogen (NO_X) exhaust emissions projections from trucks and trains transporting containers originating from the Port of Los Angeles and the Port of Long Beach (Ports) from 2010 through 2050. The analysis did not consider greenhouse gases. Based on these emissions projections and this analysis, trucks will be the cleaner mode to move cargo by 2023.

Section B. Detailed Methodology

1. Scenarios and Assumptions

The analysis modeled trucks and trains transporting containers originating from the Ports to a destination 300 miles away. For trucks, the analysis modeled a trip with drayage trucks transporting the containers the first 20 miles[1] and in-state long haul trucks transporting them the remaining 280 miles. For trains, the analysis modeled a trip with each train consisting of 4 line haul locomotives and 130 double-stacked railcars, based on samples of trains originating and terminating in the Ports, and the San Pedro Bay Ports Emissions Inventory.[3] The analysis estimated empty railcars at 26 tons,[2] and assumed the weight of a locomotive is 210 tons.[3]

The analysis assumed first- and last-mile emissions (such as from cargo handling equipment) are similar for trucks and trains, so those emissions are omitted from the analysis. The analysis assumed each of the 260 containers weighs 19 tons – a value consistent with the United States Environmental Protection Agency (U.S. EPA) Greenhouse Gas Emissions and Fuel Efficiency Standards.[4]

---

[1] UCLA Luskin Center for Innovation. 2019. Charging Infrastructure Strategies: maximizing the Deployment of Electric Drayage Trucks in Southern California.
[2] STB. 2018 Carload Waybill Sample (https://prod.stb.gov/reports-data/waybill/). Average tare weight of flat cars is 26 tons (trailer on flat car/container on flat car). Accessed August 11, 2020.
[3] Ports. April 2019. San Pedro Bay Ports Emissions Inventory Methodology Report Version 1.
[4] U.S. EPA/Department of Transportation's National Highway Traffic Safety Administration. August 2016. Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Vehicles, Regulatory Impact Assessment, EPA Report 420-R-16-900.

Figure 1. Containers transported by trucks vs. trains

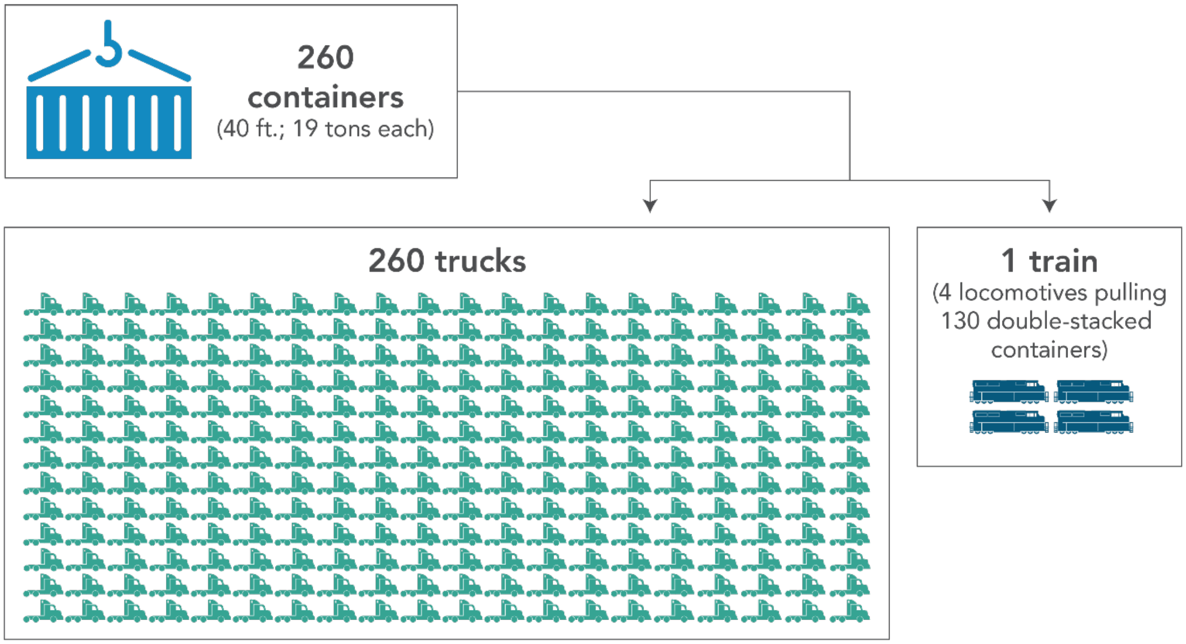
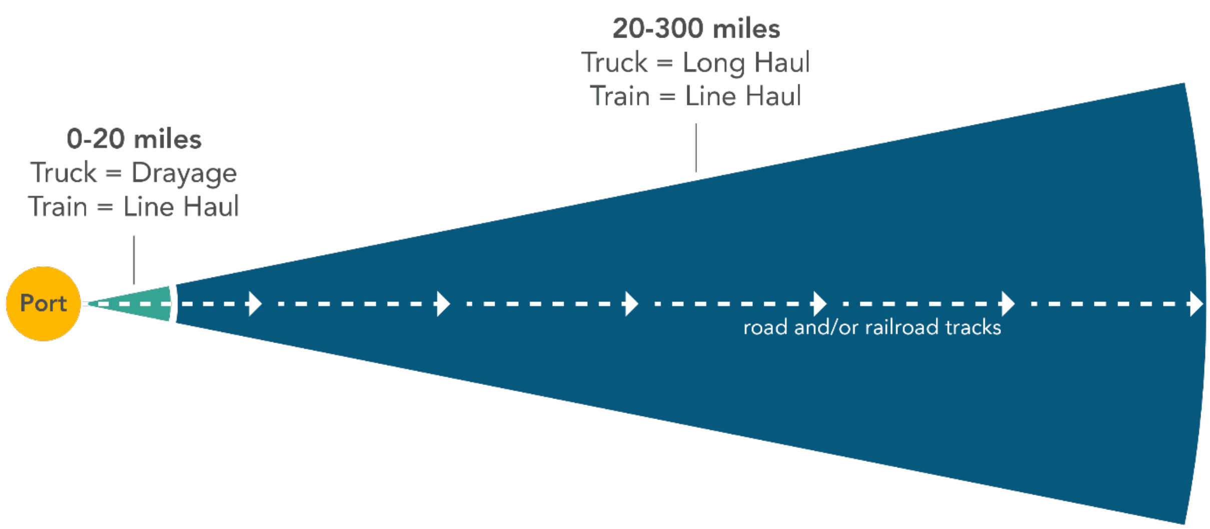


Figure 2. Communities within 20 miles of the Ports and communities 20-300 miles from the Ports



The analysis analyzed baseline scenarios and alternate scenarios. The truck baseline scenario includes Advanced Clean Trucks (adopted June 2020),[5] Heavy-Duty Engine

[5] CARB. June 25, 2020. Advanced Clean Trucks. https://ww2.arb.ca.gov/our-work/programs/advanced-clean-trucks.

and Vehicle Omnibus (adopted August 2020),[6] and Heavy-Duty Inspection and Maintenance (proposed Board date December 2021).[7] The train baseline scenario is based on projected natural turnover. The truck alternate scenario adds the Advanced Clean Fleets Regulation[8] to the baseline scenario, and the train alternate scenario assumes using 100 percent Tier 4 locomotives from 2020 to 2034 and 100 percent Tier 5 from 2035 to 2050.

2. Truck Methodology

The analysis used a combination of EMFAC2017[9] and an updated version of the draft On-Road Heavy-Duty Beta META Tool v2 (META Tool)[10] as the truck emissions inventory (see Appendix A for the relevant META Tool inventory data). The parameters used are shown in Table 1 and Table 2. The T7 POLA category represents drayage trucks operating near the Ports, and the T7 Tractor category represents in-state long haul trucks.

Table 1. EMFAC2017 parameters

Data Type	Emissions
Region	Statewide
Calendar Year	2010 – 2016
Season	Annual
Vehicle Category	EMFAC2011 Categories • T7 POLA • T7 Tractor
Model Year	Aggregated
Speed	Aggregated
Fuel	All

[6] CARB. August 27, 2020. Heavy-Duty Engine and Vehicle Omnibus Regulation. https://ww2.arb.ca.gov/our-work/programs/heavy-duty-low-nox.
[7] CARB. Heavy-Duty Inspection and Maintenance Program. https://ww2.arb.ca.gov/our-work/programs/heavy-duty-inspection-and-maintenance-program.
[8] CARB. February 12, 2020. Zero-Emission Fleet Rule Workshop Advanced Clean Truck Fleets.
[9] CARB. EMFAC2017 Web Database v1.0.2.
[10] CARB. August 24, 2020. Draft On-Road Heavy-Duty Beta META Tool v2 for 2020 Mobile Source Strategy.

Table 2. META Tool parameters

Data Type	Emissions
Region	Statewide
Calendar Year	2017 – 2050
Season	Annual
Vehicle Category	EMFAC2011 Categories • T7 POLA • T7 Tractor
Model Year	All
Speed	Aggregated
Fuel	All
Scenario	Midterm Goals
Fuel Consumption Options	Diesel
Federal or California Only Low NOX Regulation	California Only
Current Advanced Clean Trucks Regulation	TRUE

The analysis used EMFAC2017 to supplement the META Tool inventory, as the META Tool does not contain calendar years prior to 2017. The META Tool included the following regulations not present in EMFAC2017:

- Advanced Clean Trucks (adopted June 2020)[11]
- Heavy-Duty Engine and Vehicle Omnibus (adopted August 2020)[12]
- Heavy-Duty Inspection and Maintenance (proposed Board date December 2021)[13]

The analysis omitted emissions from transloading activities at intermediate facilities 20 miles from the Ports. These facilities repackage the cargo within the containers transported by the drayage trucks in to trailers pulled by long haul trucks, typically at a ratio of three containers to two trailers. In practice, there would be some cargo handling equipment emissions and truck idling emissions at these facilities.

Both the drayage truck and long haul truck categories in the analysis use the same baseline emission rates in EMFAC2017 and the META Tool. The baseline rates are based on class 8 trucks tested under the same conditions, with the same simulated trailer weights. Because of this, the analysis did not account for the reduction in the number of trucks from repackaging. The analysis assumed the same number of drayage trucks and long haul trucks, each carrying a container or trailer weighing 19 tons. If the emissions rates could account for the increase in trailer weight, truck emissions 20-300 miles from the Ports would likely be lower than the analysis shows.

[11] CARB. June 25, 2020. Advanced Clean Trucks. https://ww2.arb.ca.gov/our-work/programs/advanced-clean-trucks.
[12] CARB. August 27, 2020. Heavy-Duty Engine and Vehicle Omnibus Regulation. https://ww2.arb.ca.gov/our-work/programs/heavy-duty-low-nox.
[13] CARB. Heavy-Duty Inspection and Maintenance Program. https://ww2.arb.ca.gov/our-work/programs/heavy-duty-inspection-and-maintenance-program.

The analysis calculated emissions from EMFAC2017 for calendar years 2010 through 2016 using Equation 1.

Equation 1: Calendar years 2010 – 2016 truck emissions from EMFAC2017

$$emissions = distance \times trucks \times \left(\frac{total\ exhaust\ emissions}{VMT}\right)_{Category}$$

Where,

		<u>Units</u>
Emissions	= Total exhaust emissions from trucks	*tons*
Distance	= Total distance traveled	*miles*
Trucks	= Total number of trucks	-
Total exhaust emissions	= Exhaust emissions from EMFAC2017	*tons/day*
VMT	= Vehicle miles traveled from EMFAC2017	*miles/day*
Category	= T7 POLA or T7 Tractor	-

The analysis used 20 miles for drayage trucks and 280 miles for long haul trucks. The total exhaust emissions included running exhaust, idle, and start emissions. The analysis divided these emissions by VMT to produce an approximate emissions rate in tons per mile.

The analysis calculated emissions for 2017 and newer trucks similarly, but because the META Tool did not aggregate truck model years, the analysis first summed the total exhaust emissions and VMT before dividing using Equation 2.

Equation 2: Calendar years 2017 and newer truck emissions from META Tool

$$emissions = distance \times trucks \times \left(\frac{\sum total\ exhaust\ emissions}{\sum VMT}\right)_{Category}$$

Where,

		Units
Emissions	= Total exhaust emissions from trucks	*tons*
Distance	= Total distance traveled	*miles*
Trucks	= Total number of trucks	-
Total exhaust emissions	= Exhaust emissions from META Tool	*tons/day*
VMT	= Vehicle miles traveled from META Tool	*miles/day*
Category	= T7 POLA or T7 Tractor	-

For the total exhaust emissions, the analysis used the No Accelerated Turnover scenario in the META Tool, which only accounts for truck turnover from regulations and not additional turnover from incentives programs.

The analysis accounted for the Advanced Clean Fleets Regulation,[14] even though it is not present in the META Tool, by adding an alternate scenario in which drayage truck emissions are set to zero, starting in 2035 and all truck emissions are set to zero,

[14] CARB. February 12, 2020. Zero-Emission Fleet Rule Workshop Advanced Clean Truck Fleets.

starting in 2045. The Advanced Clean Fleets Regulation is expected to be presented to the Board in 2021/2022.

3. Train Methodology

The analysis calculated fuel consumption using gross-ton-miles (GTM), and then converted to brake horsepower-hour (bhp-hr)[15] to calculate the total $PM_{2.5}$ and NO_X emissions.

Gross-tons include the weight of the freight, the empty railcars, and the locomotives. The analysis calculated gross-tons by adding these weights together. The analysis then calculated GTM by multiplying the gross-tons by the distance. GTM is calculated using Equation 3 through Equation 7.

The analysis calculated the number of trains required to transport the number of containers using Equation 3.

Equation 3: Number of trains

$$(number\ of\ trains) = \frac{(total\ number\ of\ containers)}{(number\ of\ railcars\ per\ train) \times (number\ of\ containers\ per\ railcar)}$$

Where,

total number of containers	= 260
number of railcars per train	= 130
number of containers per railcar	= 2

The analysis calculated total weight of freight on all trains using Equation 4.

Equation 4: Total weight of freight on all trains

$$freight\ weight = (weight\ of\ a\ container) \times (number\ of\ railcars\ per\ train) \times (number\ of\ containers\ per\ railcar) \times (number\ of\ trains)$$

Where,

weight of a container	= 19 tons
number of railcars per train	= 130
number of containers per railcar	= 2
number of trains	= Number of trains, from Equation 3

The analysis calculated the total weight of the empty railcars on all trains using Equation 5.

[15] U.S. EPA Office of Transportation and Air Quality. April 2009. Emission Factors for Locomotives, EPA-420-F-09-025.

Equation 5: Total weight of empty railcars on all trains

$$empty\ railcar\ weight\ [tons] = (weight\ of\ an\ empty\ railcar\ [tons]) \times (number\ of\ railcars\ per\ train) \times (number\ of\ trains)$$

Where,

weight of an empty railcar	= 26 tons
number of railcars per train	= 130
number of trains	= Number of trains, from Equation 3

The analysis calculated total weight of locomotives on all trains using Equation 6.

Equation 6: Total weight of locomotives on all trains

$$locomotive\ weight = (weight\ of\ a\ single\ locomotive) \times (number\ of\ locomotives\ per\ train) \times (number\ of\ trains)$$

Where,

weight of a single locomotive	= 210 tons
number of locomotives per train	= 4
number of trains	= Number of trains, from Equation 3

The analysis calculated GTM by multiplying the total weight of the trains and the distance using Equation 7.

Equation 7: GTM

$$GTM = \{(freight\ weight) + (empty\ railcar\ weight) + (locomotive\ weight)\} \times (distance)$$

Where,

		Units
Freight weight	= Total weight of freight on all trains, from Equation 4	*tons*
Empty railcar weight	= Total weight of railcars on all trains, from Equation 5	*tons*
Locomotive weight	= Total weight of locomotives on all trains, from Equation 6	*tons*
Distance	= Total distance traveled	*miles*

To calculate fuel consumption from GTM, the analysis calculated fuel efficiency in GTM per gallon of diesel consumed.

Class I Railroads report their annual GTM in the Class I Railroad Annual Report ("R-1" report), published on the Surface Transportation Board (STB) website.[16] The analysis

[16] STB. Annual Report Financial Data. https://prod.stb.gov/reports-data/economic-data/annual-report-financial-data/. Accessed August 11, 2020.

used the total annual GTM from Union Pacific and BNSF R-1 reports for 2019 for both revenue and non-revenue services.[17]

The analysis used annual fuel consumption for the "Freight" category from the Union Pacific and BNSF R-1 reports for 2019 to estimate annual fuel consumption.

The analysis calculated GTM per gallon of diesel consumed using Equation 8.

Equation 8: GTM per gallon of diesel consumed by locomotives

$$GTM\ per\ gallon = \frac{annual\ GTM\ [gross\text{-}ton\text{-}miles]}{annual\ fuel\ consumption\ [gallons]}$$

Where,

		Units
GTM per gallon	= Gross-ton-miles from locomotives per gallon of diesel consumed	*GTM/gallon*
Annual GTM	= Annual gross-ton-miles reported in R-1 reports	*GTM*
Annual fuel consumption	= Annual diesel consumption reported in R-1 reports Freight category	*gallons*

The analysis used 1,004 GTM per gallon for the analysis calculated from the 2019 Union Pacific and BNSF R-1 report values.

The analysis calculated locomotive fuel consumption from GTM and GTM per gallon using Equation 9.

Equation 9: Locomotive fuel consumption

$$fuel\ usage = \frac{GTM}{GTM\ per\ gallon}$$

Where,

		Units
Fuel usage	= Diesel consumed by locomotives	*gallon*
GTM	= GTM from Equation 7	*GTM*
GTM per gallon	= GTM per gallon of diesel consumed, from Equation 8	*GTM/gallon*

Once the amount of fuel usage was determined, the analysis calculated the associated emissions by applying emission factors weighted by the locomotive tier distribution. The analysis calculated total emissions from locomotives using Equation 10.

[17] Non-revenue service accounts for about 1% of the total GTM.

Equation 10: Emissions from locomotives

$$\begin{aligned} total\ emissions \\ &= (fuel\ usage) \times CF \\ &\times \left\{ \begin{array}{c} (emission\ factor_{Pre\text{-}Tier\ 0}) \times (Distribution_{Pre\text{-}Tier\ 0}) \\ +(emission\ factor_{Tier\ 0}) \times (Distribution_{Tier\ 0}) \\ +(emission\ factor_{Tier\ 1}) \times (Distribution_{Tier\ 1}) \\ + \cdots \\ +(emission\ factor_{Tier\ 4}) \times (Distribution_{Tier\ 4}) \end{array} \right\} \end{aligned}$$

Where,

		Units
Total Emissions	= Total emissions from trains	*pounds*
Fuel usage	= Total diesel consumption	*gallons*
CF	= Conversion factor[15] $CF = \frac{20.8\ [bhp\text{-}hr/gallon]}{453.6\ [g/pounds]}$	
$emission\ factor_{Tier\ N}$	= Emission factor of Tier N locomotives	*g/bhp-hr*
$Distribution_{Tier\ N}$	= MWhr or bhp-hr Tier distribution of Tier N locomotives	-

The analysis used particulate matter 10 micrometers in diameter or smaller (PM_{10}) and NO_X emission factors from the U.S. EPA publication Emission Factors for Locomotives, EPA-420-F-09-025[15] for Tier 4 and older locomotives, and CARB Locomotive Technology Assessment[18] for proposed Tier 5 locomotives, as shown in Table 3. The analysis estimated $PM_{2.5}$ emission factors to be 0.96 times the PM_{10} emission factors consistent with the conversion factor from PM_{10} to $PM_{2.5}$ in the EMFAC2017 data.[19]

Table 3. Line haul emission factors [grams/bhp-hr]

	PM_{10}	NO_X
Uncontrolled	0.32	13.00
Tier 0	0.32	8.60
Tier 0+	0.20	7.20
Tier 1	0.32	6.70
Tier 1+	0.20	6.70
Tier2	0.18	4.95
Tier 2+ and Tier 3	0.08	4.95
Tier 4	0.015	1.00
Tier 5	0.006	0.15

For the baseline scenario, the analysis used tier distribution data from the unpublished draft locomotive line haul emissions inventory dated August 2020 (Appendix B). The baseline scenario only includes projected natural turnover. There is an alternative

[18] CARB. November 2016. Technology Assessment: Freight Locomotives.
[19] U.S. EPA publication Emission Factors for Locomotives, EPA-420-F-09-025 suggests using 0.97 to convert PM_{10} to $PM_{2.5}$.

scenario in which trains are 100 percent Tier 4 until 2034, and 100 percent Tier 5 from 2035 and beyond; the purpose of this scenario is to show that shifting freight from truck to train only reduces emissions when Tier 4 or cleaner locomotives are used.

Section C. Results

Drayage trucks have been able to move containers with lower $PM_{2.5}$ emissions than trains in communities within 20 miles of the Ports since 2012, due to the implementation of the 2007 Drayage Truck Regulation. As the 2010 Truck and Bus Regulation moves towards full implementation in 2023, trucks become cleaner than trains in all scenarios – long haul $PM_{2.5}$ emissions in communities 20-300 miles from the Ports become lower in 2020, long haul NO_X emissions become lower in 2022, and drayage NO_X emissions become lower in 2023.

Tier 4 and 5 locomotives can move containers with lower emissions than trucks in communities within 20 miles of the Ports through 2035, until the Advanced Clean Fleets Regulation[14] goal of 100 percent zero emission drayage trucks is achieved. The analysis also shows Tier 4 and 5 locomotives can move containers cleaner than long haul trucks until the Advanced Clean Truck Fleets Regulation (ACF)[9] brings all trucks to zero emissions in 2045. Figures 1 through 8 below show the results of the analysis.

The analysis focused on $PM_{2.5}$ and NO_X exhaust emissions; it did not consider greenhouse gases.

Figure 3. $PM_{2.5}$ emissions in communities within 20 miles of the Ports 2010 – 2050

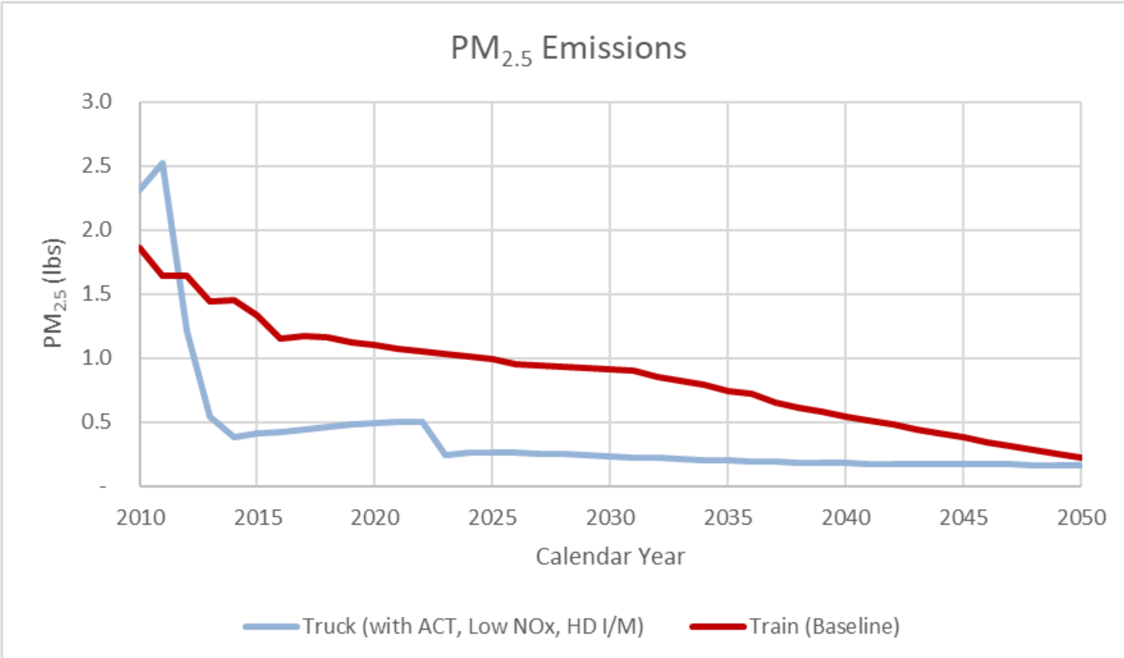


Figure 4. $PM_{2.5}$ emissions in communities within 20 miles of the Ports 2020 – 2050 with alternate scenarios

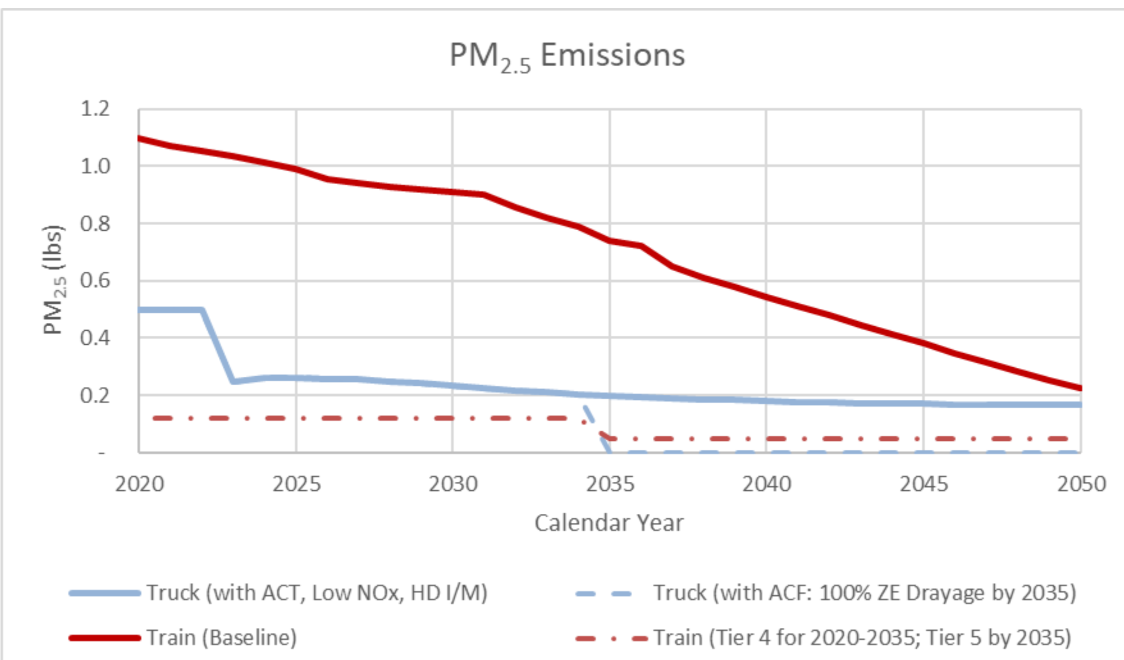


Figure 5. NO_X emissions in communities within 20 miles of the Ports 2010 – 2050

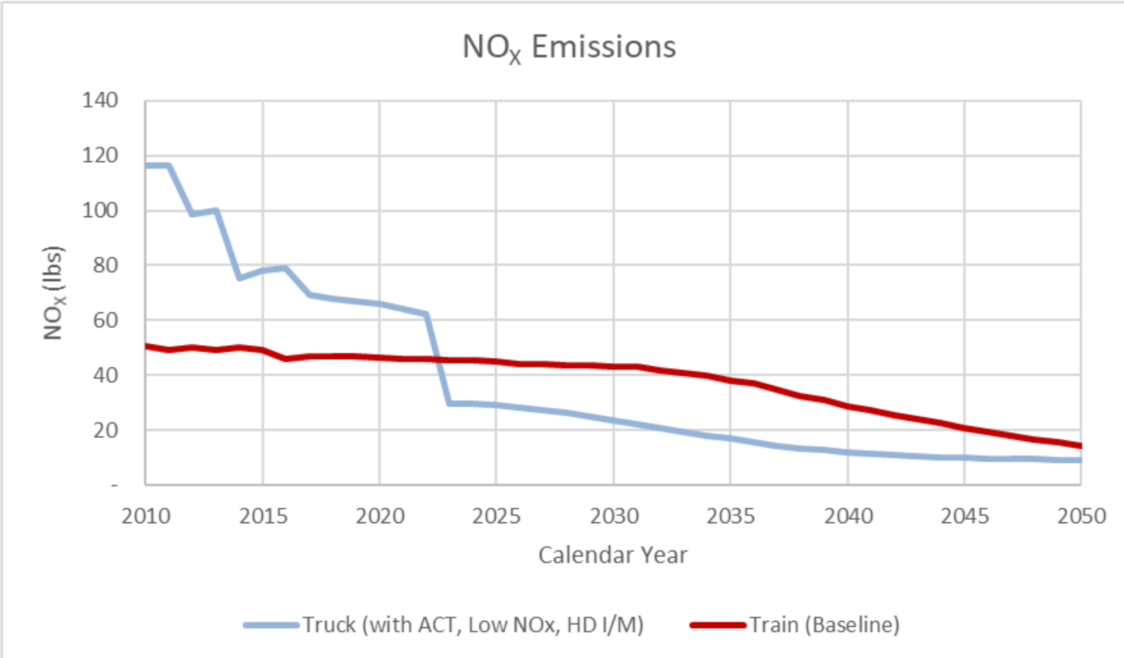


Figure 6. NO_X emissions in communities within 20 miles of the Ports 2020 – 2050 with alternate scenarios

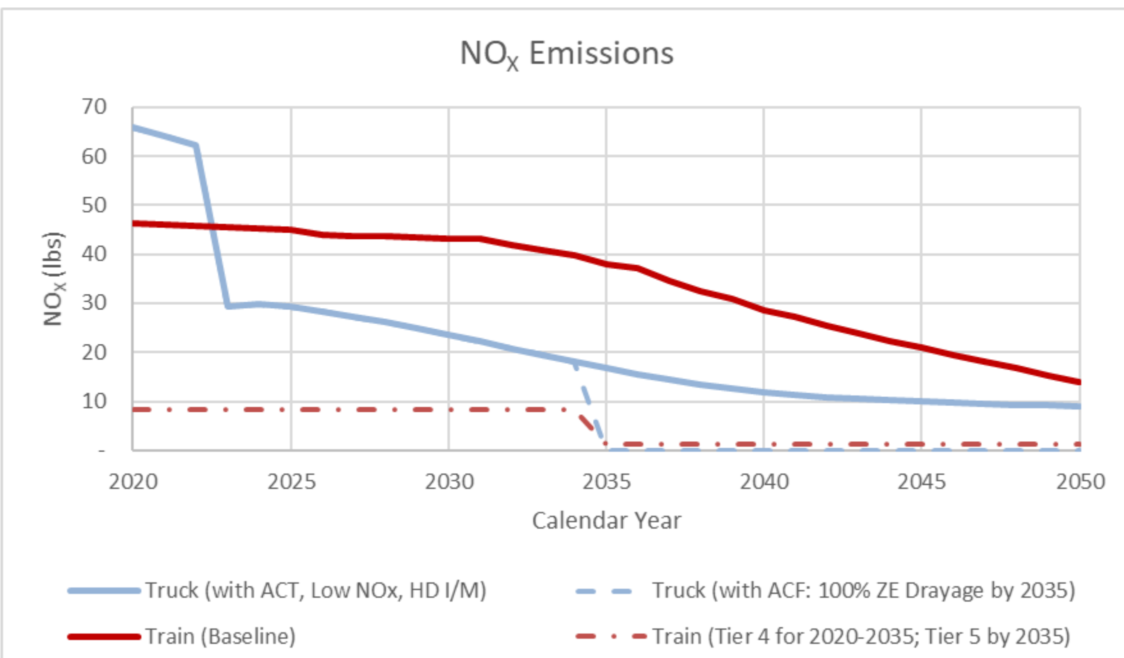


Figure 7. $PM_{2.5}$ emissions in communities 20-300 miles from the Ports 2010 – 2050

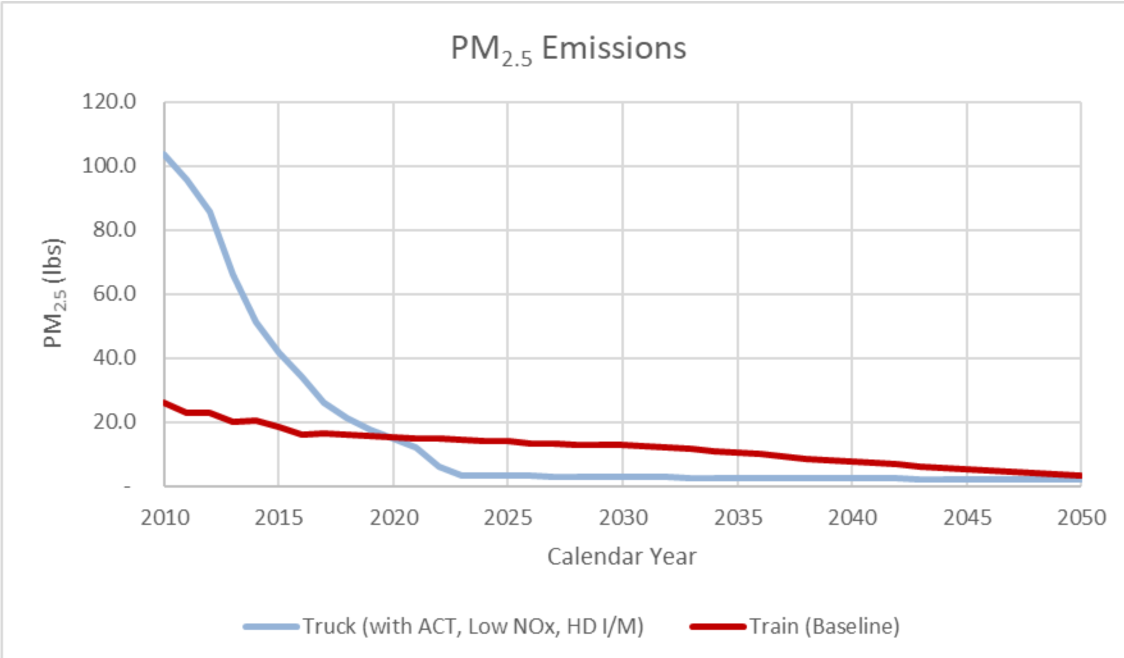


Figure 8. $PM_{2.5}$ emissions in communities 20-300 miles from the Ports 2020 – 2050 with alternate scenarios

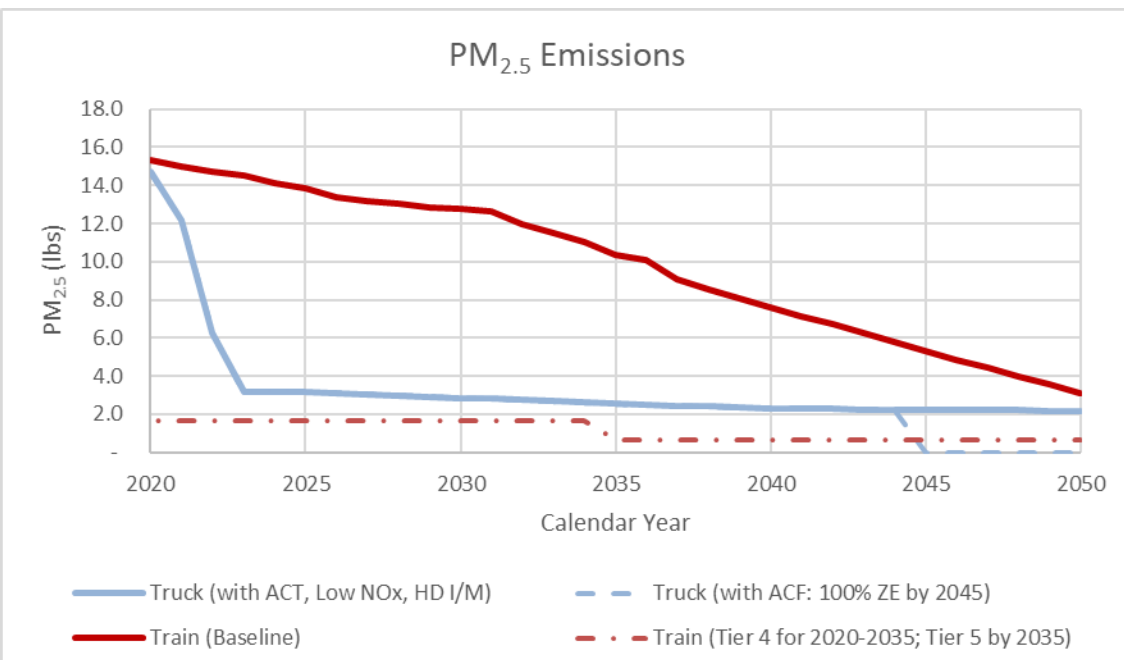


Figure 9. NO_X emissions in communities 20-300 miles from the Ports 2010 – 2050

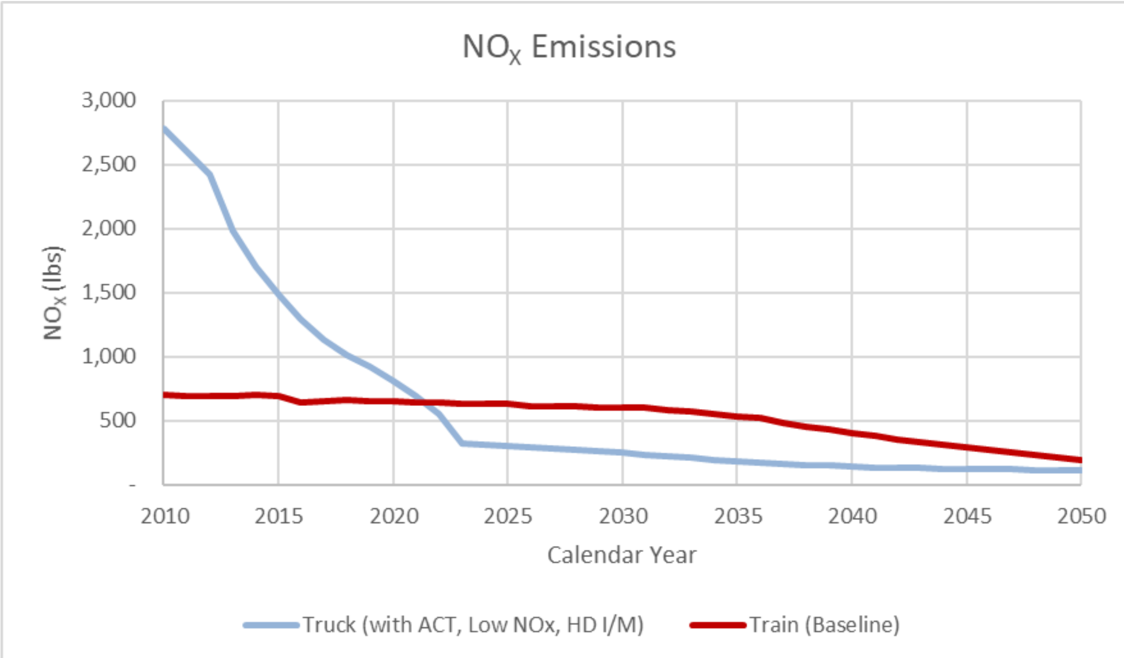
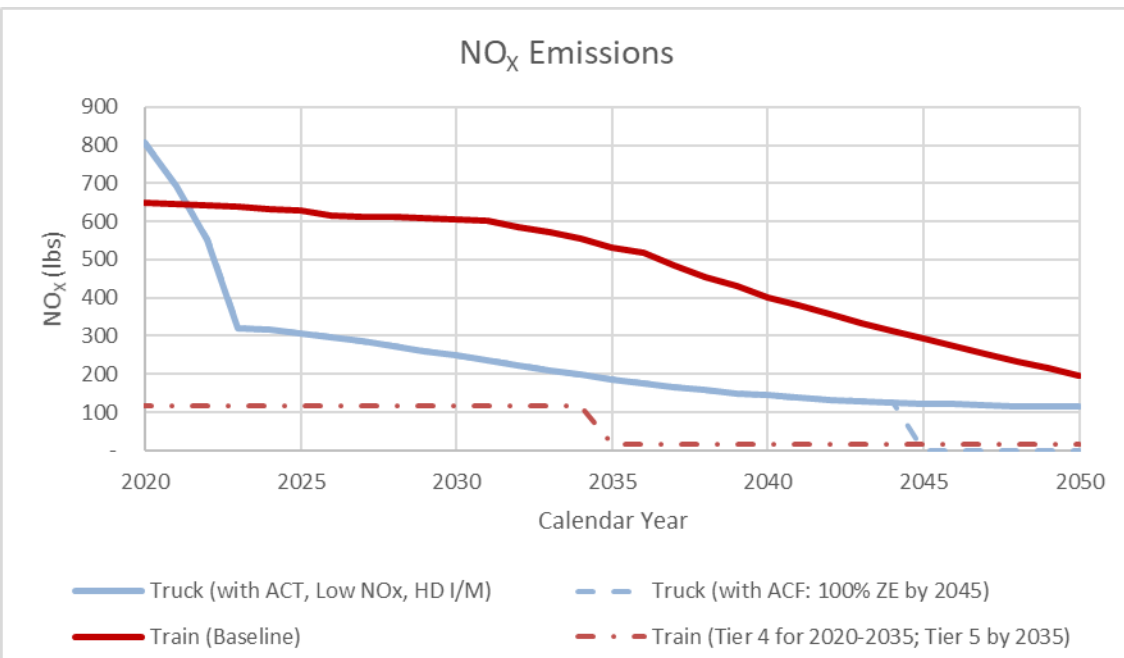


Figure 10. NO_X emissions in communities 20-300 miles from the Ports 2020 – 2050 with alternate scenarios



Section D. References

The analysis used the following references in the development of the Truck vs. Train Methodology.

UCLA Luskin Center for Innovation. 2019. Charging Infrastructure Strategies: Maximizing the Deployment of Electric Drayage Trucks in Southern California.

STB. 2018 Carload Waybill Sample. https://prod.stb.gov/reports-data/waybill/.

CARB. June 25, 2020. Advanced Clean Trucks. https://ww2.arb.ca.gov/our-work/programs/advanced-clean-trucks.

CARB. August 27, 2020. Heavy Duty Engine and Vehicle Omnibus Regulation. https://ww2.arb.ca.gov/our-work/programs/heavy-duty-low-nox.

CARB. Heavy Duty Inspection and Maintenance Program. https://ww2.arb.ca.gov/our-work/programs/heavy-duty-inspection-and-maintenance-program.

CARB. February 12, 2020. Zero Emission Fleet Rule Workshop Advanced Clean Truck Fleets.

CARB. EMFAC2017 Web Database v1.0.2. https://arb.ca.gov/emfac/2017/.

CARB. August 5, 2020. Draft On Road Heavy Duty Beta META Tool v2 for 2020 Mobile Source Strategy. See Appendix A for values.

CARB. November 2016, Technology Assessment: Freight Locomotives.

U.S. EPA/NHTSA. August 2016. Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Vehicles, Regulatory Impact Assessment, EPA Report 420-R-16-900.

CARB. February 12, 2020. Zero Emission Fleet Rule Workshop Advanced Clean Truck Fleets.

Ports. April 2019. San Pedro Bay Ports Emissions Inventory Methodology Report Version 1.

U.S. EPA Office of Transportation and Air Quality. April 2009. Emission Factors for Locomotives, EPA-420-F-09-025.

STB. 2019 Annual Report Financial Data. https://prod.stb.gov/reports-data/economic-data/annual-report-financial-data/.

Appendix A. META Tool Inventory Values

VMT and total emissions from the August 24, 2020 version of the META Tool[20] used in the analysis are shown in Table 4. Values shown are through 2050, as used in the baseline scenario in the analysis. The alternative ACF scenario sets T7 POLA to zero in 2035 and T7 Tractor to zero in 2045.

Table 4. Truck regulations, as reflected in the META Tool and the analysis

Scenario	Regulation	Implementation
Baseline (with ACT, Low NO_X, HD I/M)	Advanced Clean Trucks	Zero emission sales requirement: 5% in 2024 to 40% in 2032
	Heavy-Duty Engine and Vehicle Omnibus	From engine Model Year 2024
	Heavy-Duty Inspection and Maintenance	Deterioration rate reduction begins 2023
Alternative (with ACF)	Baseline + Advanced Clean Truck Fleets	• Drayage: 100% zero emission by 2035 • Long Haul: 100% zero emission by 2045

[20] CARB. August 24, 2020. Draft On-Road Heavy-Duty Beta META Tool v2 for 2020 Mobile Source Strategy.

Table 5. META Tool inventory values

Calendar Year	Category	VMT (miles)	Total NO_X Emissions (tons)	Total $PM_{2.5}$ Emissions (tons)
2017	T7 POLA	1592831.216	10.59693257	0.068048273
2018	T7 POLA	1679602.078	10.92926447	0.074935616
2019	T7 POLA	1779610.699	11.47131351	0.08262385
2020	T7 POLA	1891449.8	11.97432249	0.090208505
2021	T7 POLA	2040241.355	12.59298469	0.097982654
2022	T7 POLA	2189193.855	13.09437425	0.104653466
2023	T7 POLA	2342551.427	6.612959028	0.055517764
2024	T7 POLA	2488314.886	7.115235616	0.062660926
2025	T7 POLA	2645129.127	7.433741999	0.066538855
2026	T7 POLA	2823534.238	7.688878068	0.069993772
2027	T7 POLA	2993626.312	7.835552221	0.073203531
2028	T7 POLA	3179019.204	7.997394055	0.075944788
2029	T7 POLA	3367404.903	8.062647273	0.077933547
2030	T7 POLA	3560431.979	8.06978601	0.079402156
2031	T7 POLA	3731154.024	7.979470457	0.080587623
2032	T7 POLA	3903081.837	7.814954936	0.081575995
2033	T7 POLA	4079527.374	7.633533502	0.082490239
2034	T7 POLA	4261068.339	7.402784953	0.083343528
2035	T7 POLA	4447629.578	7.154297631	0.084348066
2036	T7 POLA	4640895.256	6.886783167	0.086930535
2037	T7 POLA	4838250.907	6.663010244	0.088388029
2038	T7 POLA	5039763.238	6.471319091	0.09005272
2039	T7 POLA	5245573.943	6.321239111	0.091941323
2040	T7 POLA	5455721.153	6.216606799	0.094050621
2041	T7 POLA	5632089.285	6.120916478	0.095772244
2042	T7 POLA	5842006.715	6.093124078	0.09814074
2043	T7 POLA	6056473.573	6.098200176	0.100665992
2044	T7 POLA	6275737.486	6.129201615	0.103324541
2045	T7 POLA	6500092.947	6.180084345	0.106098003
2046	T7 POLA	6723305.042	6.240922448	0.10887476
2047	T7 POLA	6951569.596	6.315353939	0.111764302
2048	T7 POLA	7185069.544	6.404322374	0.114794265
2049	T7 POLA	7423794.792	6.528251513	0.118132138
2050	T7 POLA	7734944.258	6.742549952	0.123261869

Table 5. META Tool inventory values (continued)

Calendar Year	Category	VMT (miles)	Total NO_X Emissions (tons)	Total $PM_{2.5}$ Emissions (tons)
2017	T7 Tractor	7953086.819	61.65820887	1.426022684
2018	T7 Tractor	8196374.401	57.15658338	1.201217189
2019	T7 Tractor	8450308.148	53.46060724	1.036406242
2020	T7 Tractor	8748669.114	48.58368424	0.883736154
2021	T7 Tractor	8903695.709	42.43465241	0.742134895
2022	T7 Tractor	9121551.988	34.60134253	0.391632648
2023	T7 Tractor	9421657.923	20.78390037	0.20341462
2024	T7 Tractor	9632068.269	20.89988261	0.209219516
2025	T7 Tractor	9749293.241	20.62617882	0.210252717
2026	T7 Tractor	9964248.222	20.40652907	0.212525335
2027	T7 Tractor	10181001.19	20.0217249	0.213695172
2028	T7 Tractor	10378538.47	19.53435172	0.213639686
2029	T7 Tractor	10552375.99	18.91797815	0.21235256
2030	T7 Tractor	10730271.93	18.32631449	0.211220652
2031	T7 Tractor	10919717.91	17.7206398	0.210408135
2032	T7 Tractor	11108280.19	17.04182054	0.208963542
2033	T7 Tractor	11301945	16.35852314	0.207365755
2034	T7 Tractor	11500592.16	15.64893717	0.205541846
2035	T7 Tractor	11704793.97	14.99362024	0.204017568
2036	T7 Tractor	11875117.16	14.33510703	0.203425298
2037	T7 Tractor	12049658.87	13.75494583	0.202197403
2038	T7 Tractor	12228035.03	13.23710176	0.201429714
2039	T7 Tractor	12410542.63	12.79321302	0.201175409
2040	T7 Tractor	12597563.76	12.43895504	0.201447022
2041	T7 Tractor	12795944.33	12.1526941	0.202214723
2042	T7 Tractor	12992423.69	11.91776107	0.203248206
2043	T7 Tractor	13193760.62	11.73363817	0.204628916
2044	T7 Tractor	13399489.77	11.60205464	0.206368158
2045	T7 Tractor	13610304.54	11.51073356	0.208377603
2046	T7 Tractor	13821212.05	11.4511201	0.210547527
2047	T7 Tractor	14036858.69	11.42411205	0.212899789
2048	T7 Tractor	14257193.19	11.4255371	0.215417415
2049	T7 Tractor	14482536.12	11.45651889	0.218130998
2050	T7 Tractor	14794207.4	11.57566228	0.222618462

Appendix B. Locomotive Inventory Values

The tier distribution in percentage of megawatt hours used for the baseline train scenario in the analysis is shown in Table 6. This data is from the unpublished draft locomotive line haul emissions inventory dated August 2020. Once the locomotive line haul emissions inventory is published, a link will be posted on the CARB Truck vs. Train website.

Table 6. Locomotive inventory values

	Pre-Tier 0	Tier 0	Tier 0+	Tier 1	Tier 1+	Tier 2	Tier 2+	Tier 3	Tier 4
2010	0.71%	16.20%	0.00%	22.13%	3.00%	55.43%	0.00%	2.53%	0.00%
2011	0.24%	11.49%	6.36%	15.93%	3.77%	46.45%	0.00%	15.76%	0.00%
2012	0.10%	14.20%	6.25%	8.91%	10.74%	48.80%	0.71%	10.29%	0.00%
2013	0.11%	12.68%	5.08%	6.45%	14.13%	30.92%	0.91%	29.72%	0.00%
2014	0.05%	14.02%	5.88%	3.88%	18.29%	29.50%	6.37%	21.97%	0.03%
2015	0.02%	10.05%	4.97%	3.24%	23.39%	20.73%	8.95%	28.13%	0.51%
2016	0.06%	4.80%	3.88%	3.31%	22.78%	14.88%	14.94%	31.07%	4.29%
2017	0.10%	5.69%	4.22%	1.30%	30.18%	11.06%	18.33%	23.82%	5.29%
2018	0.12%	6.06%	5.09%	1.04%	29.85%	9.16%	22.45%	20.76%	5.47%
2019	0.10%	5.52%	4.99%	0.73%	29.59%	7.53%	25.27%	20.58%	5.69%
2020	0.08%	5.05%	4.89%	0.52%	29.34%	6.22%	27.52%	20.46%	5.91%
2021	0.07%	4.64%	4.81%	0.36%	29.11%	5.15%	29.33%	20.39%	6.14%
2022	0.06%	4.26%	4.73%	0.26%	28.89%	4.28%	30.79%	20.37%	6.36%
2023	0.05%	3.93%	4.66%	0.18%	28.68%	3.56%	31.97%	20.38%	6.59%
2024	0.04%	2.80%	4.90%	0.13%	28.93%	2.97%	32.97%	20.43%	6.83%
2025	0.03%	2.00%	5.03%	0.09%	29.03%	2.48%	33.77%	20.50%	7.07%
2026	0.03%	1.41%	2.29%	0.07%	29.81%	2.05%	35.63%	20.88%	7.85%
2027	0.02%	1.01%	2.06%	0.05%	29.81%	1.71%	36.23%	20.99%	8.11%
2028	0.02%	0.72%	2.11%	0.03%	29.70%	1.43%	36.59%	21.08%	8.31%
2029	0.02%	0.52%	1.66%	0.02%	29.69%	1.20%	37.07%	21.23%	8.60%
2030	0.01%	0.37%	1.67%	0.02%	29.53%	1.01%	37.28%	21.33%	8.79%
2031	0.01%	0.26%	1.67%	0.01%	29.13%	0.84%	37.57%	21.47%	9.03%
2032	0.01%	0.19%	1.15%	0.01%	26.41%	0.70%	38.50%	21.87%	11.16%
2033	0.01%	0.13%	0.33%	0.01%	24.99%	0.58%	38.45%	22.12%	13.38%
2034	0.01%	0.10%	0.27%	0.00%	22.90%	0.49%	38.21%	22.29%	15.74%
2035	0.01%	0.07%	0.20%	0.00%	20.30%	0.41%	36.76%	22.83%	19.42%
2036	0.00%	0.05%	0.15%	0.00%	19.82%	0.34%	34.68%	22.94%	22.01%
2037	0.00%	0.03%	0.09%	0.00%	15.40%	0.28%	32.97%	23.62%	27.60%
2038	0.00%	0.02%	0.04%	0.00%	14.63%	0.23%	31.08%	20.20%	33.79%
2039	0.00%	0.02%	0.00%	0.00%	13.97%	0.20%	27.25%	20.50%	38.07%
2040	0.00%	0.01%	0.00%	0.00%	14.01%	0.16%	25.86%	14.68%	45.27%
2041	0.00%	0.01%	0.00%	0.00%	12.92%	0.14%	23.12%	14.85%	48.95%
2042	0.00%	0.01%	0.00%	0.00%	12.32%	0.11%	21.26%	12.35%	53.94%
2043	0.00%	0.00%	0.00%	0.00%	11.29%	0.10%	18.96%	11.30%	58.34%
2044	0.00%	0.00%	0.00%	0.00%	9.84%	0.08%	16.50%	11.48%	62.10%
2045	0.00%	0.00%	0.00%	0.00%	8.43%	0.07%	14.08%	11.59%	65.82%
2046	0.00%	0.00%	0.00%	0.00%	7.08%	0.06%	11.77%	11.51%	69.58%
2047	0.00%	0.00%	0.00%	0.00%	5.76%	0.05%	9.54%	11.41%	73.25%
2048	0.00%	0.00%	0.00%	0.00%	4.47%	0.04%	7.37%	11.29%	76.83%
2049	0.00%	0.00%	0.00%	0.00%	3.20%	0.03%	5.27%	11.17%	80.33%
2050	0.00%	0.00%	0.00%	0.00%	1.95%	0.03%	3.23%	11.04%	83.76%