Appendix G

CARB's 2022 In-Use Locomotive Emission Inventory: Regulation Proposal and Scenarios

Air Quality Planning and Science Division
Mobile Source Analysis Branch
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CALIFORNIA AIR RESOURCES BOARD

Table of Contents

Tables

Figures

I. Introduction

Locomotives in California are a key part of the State's freight and passenger transportation system. However, locomotives almost exclusively operate on diesel fuel, producing harmful particulate matter (PM) and oxides of nitrogen (NOx). PM and NOx emissions are harmful at both regional and local levels and impact communities along California's extensive rail network, as shown in Figure 1. This report describes the California Air Resources Board's (CARB's) Proposed In-Use Locomotive Regulation (Proposed Regulation) and staff's projected emission benefits of the Proposed Regulation. CARB's detailed official emissions inventories for California's locomotive sectors, including data sources, methodology, and resulting emissions are located online in the locomotives section[1].

Figure 1: California Rail Network

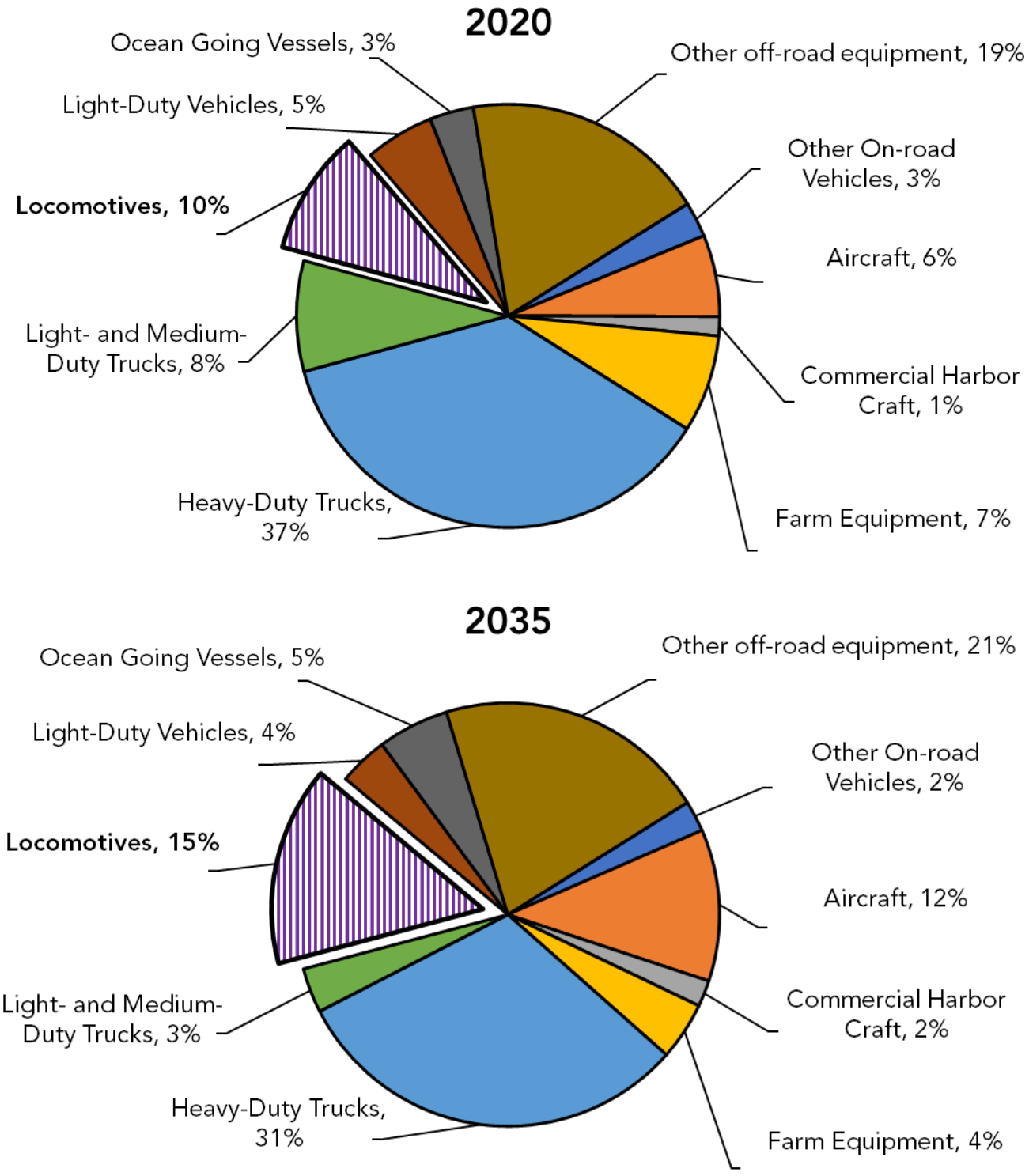
This Proposed Regulation covers all locomotives moving within California and are divided into five categories: Class I Line haul, Class I Switchers, Short line, Passenger, and Industrial. Line haul locomotives typically move freight across the State, as well as across state or country borders, comprised of two to four line haul locomotives either pushing or pulling a single line of freight railcars that can be miles long. Switchers operate in rail yards to move individual railcars or segments of trains, typically to build a line of railcars that will be pulled by line haul locomotives. Short line rail is limited to smaller regional operations that usually own a few locomotives. Passenger rail includes inter-city, intrastate (within the State), and interstate (exiting the State) passenger operations such as Amtrak, Metrolink, and others. For purposes of this Proposed Regulation, any Passenger rail exiting the State are excluded from

[1] CARB, Mobile Source Emissions Inventory. (weblink: *https://ww2.arb.ca.gov/our-work/programs/mobile-source-emissions-inventory/road-documentation/msei-documentation-road*)

the analysis. The industrial locomotive category includes approximately 39 California industrial operators that typically conduct short-range goods movement within and around their facilities.

In 2020, California's locomotive sector was responsible for 10 percent of NOx emissions from all mobile sources in California. The contribution of the locomotive sector as it relates to total statewide NOx emissions is projected to grow to 15 percent in 2035, as shown in Figure 2. While most other mobile sectors in California are expected to significantly reduce emissions over the next 15 years as they adopt cleaner engines, the locomotive sector's relative contribution will increase, absent implementation of the Proposed Regulation. NOx emissions from other sectors in California are expected to decrease primarily due to the penetration of 2010 or later model year on-road engines in the heavy-duty on-road sector and Tier 4 Final engines in the off-road sectors, driven by regulation programs (such as the Truck and Bus Regulation or In-Use Off-Road Diesel-Fueled Fleets Regulation), incentive programs (such as the Funding Agricultural Replacement Measures for Emissions Reductions Program that incentivizes tractor replacements), as well as natural turnover of equipment. Sectors where NOx emissions are expected to continue increasing generally do not have emissions standards that control emissions with the same stringency as CARB-regulated sources (such as ocean-going vessels or aircraft) or do not have requirements or programs for accelerated turnover to accelerate adoption of cleaner engines (such as locomotives).

Figure 2: Mobile Source NOx Emissions Contributions in 2020 and 2035[2]



[2] Pie charts do not account for recently adopted regulations such as HD Omnibus and Advanced Clean Trucks. CARB, EMFAC (weblink: *https://arb.ca.gov/emfac/*)

A. Additional Background

Currently, two Class I locomotive operators operate in California: Union Pacific (UP) and BNSF Railway (BNSF). Over the last decade, old line haul locomotives have been remanufactured and there have been few new locomotive purchases. Table 1 outlines, from 2010 onward, the combined number of new line haul locomotives UP and BNSF have purchased between 2010 and 2020, as recorded in their annual R-1 reports[3]. The table includes cost expenditures for these purchases and the percentage of newly purchased line haul locomotives compared to the fleet population. The table confirms that in recent years (from 2017 onward), rail company purchases represent less than one percent of the total in-service fleet population. From 2010 to 2016, new purchases averaged 2.8 percent of the total in-service fleet population.

Table 1: Quantity of New Line Haul Locomotives Acquired from 2010 to 2020

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number of New Units	196	327	509	385	742	590	336	139	48	4	64
Total Cost [$ Millions]	377	677	1,146	859	1,733	1,469	859	311	156	4	101
Total Diesel Locomotives in Service	14,643	14,865	15,234	15,394	16,123	16,434	16,692	16,795	16,540	15,566	15,202
Percent of New Units vs Total Diesel Locomotives in Service	1.30%	2.20%	3.30%	2.50%	4.60%	3.60%	2.00%	0.80%	0.30%	0.00%	0.40%

B. Proposed Regulation Overview

Significant emission reductions are possible if the Proposed Regulation is adopted. The Proposed Regulation and the alternative scenarios evaluated would achieve emission reductions by accelerating turnover to newer, cleaner locomotives, including requiring zero emission (ZE) locomotives. Figure 3 shows Class I line haul NOx emissions measured in tons per day (tpd) for the baseline inventory (referred to as Business as Usual or BAU), with lines indicating emissions from the Proposed Regulation, Alternative 1, Alternative 2, and Sensitivity Analysis Scenarios.

[3] *Surface Transportation Board (stb.gov)* R-1 annual reports covering 11 years (UP and BNSF report separately), (weblink: *https://www.stb.gov/reports-data/economic-data/annual-report-financial-data/*)

Figure 3: Annual Class I Line Haul Statewide NOx Emissions and Reduction Scenarios

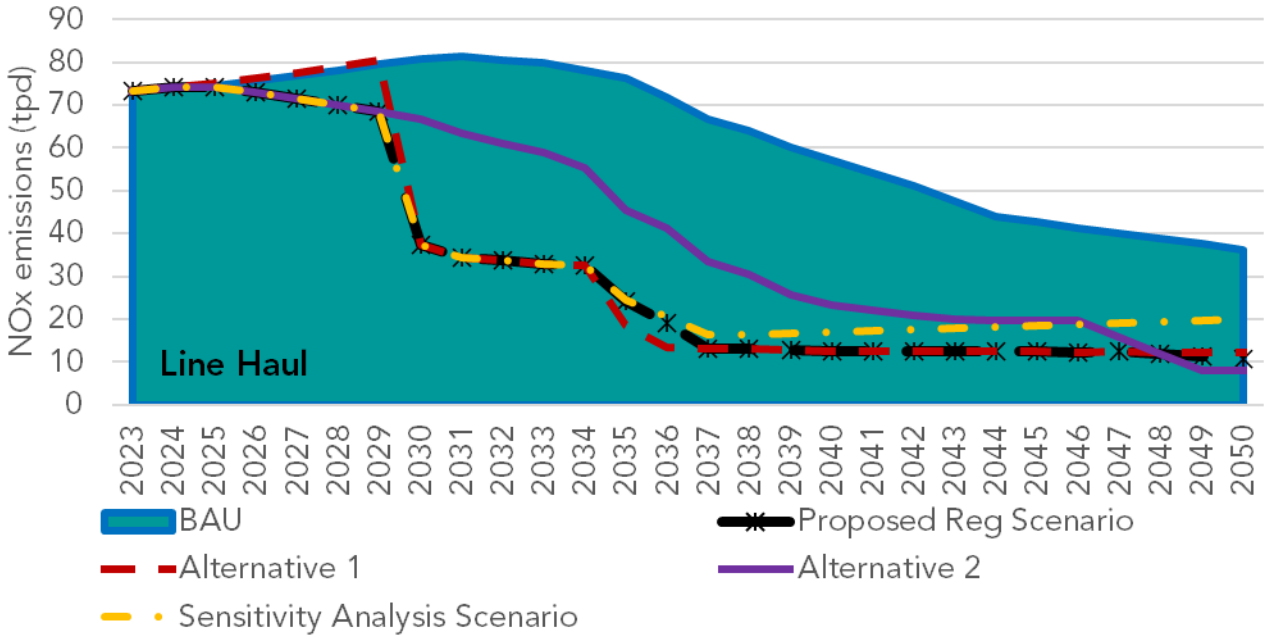
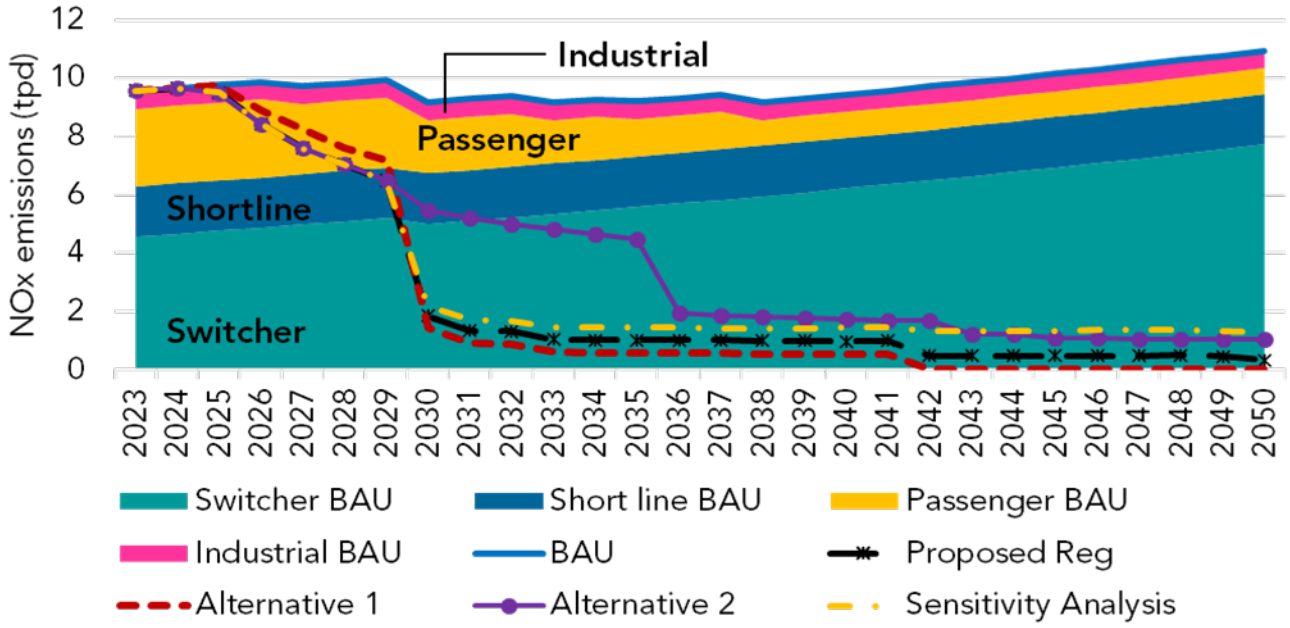


Figure 4 combines NOx emissions for the other locomotive categories: Class I Switchers, Short line, Passenger, and Industrial. The stacked area represents the combined baseline NOx emissions, and adds lines to indicate the Proposed Regulation scenario and the three additional scenarios. These locomotive categories are modeled independently, as described later in this report, but are shown cumulatively here to demonstrate the scope of anticipated reductions from the strategies.

Figure 4: Combined Switcher, Short line, Passenger and Industrial Statewide NOx Emissions and Reduction Scenarios



II. Emission Inventory Development Summary

Each category's locomotive emissions inventory is developed independently, as the data sources and methodology are unique. Each inventory's technical report is posted online[4].

Several general principles are the same in each inventory. One key component is understanding the locomotive's emission tier. An emission tier represents the emission standard the manufacturer was required to meet when making or remanufacturing (rebuilding) a locomotive. The emission standard is the maximum allowable limit on emissions for a newly manufactured engine. Older tier standards have higher emissions, while newer tier standards (particularly Tier 4) must meet more stringent standards and therefore have lower emissions.

Emission factors are the emissions levels that engines produce, usually measured in grams per unit of work (in this case, grams per brake horsepower-hour). The emission factors are usually similar to emission standards, but that can vary. Sometimes the emission factors will be lower than the emission standard, such as when the engines produced are cleaner than required. However, emission factors can also be higher than emission standards when manufacturers use credits or averaging to produce engines emitting above the emission standard. Table 2 shows the U.S. EPA locomotive tiers and NOx and PM emission factors for line haul and switcher locomotives measured in grams per brake horsepower-hour (g/bhp-hr), which are constant values over the life of the equipment. PM emissions are reduced by over 95 percent, and NOx emissions are reduced by over 92 percent when older uncontrolled Pre-Tier 0 locomotives are replaced with new Tier 4 locomotives.

Table 2: Line Haul and Switcher Locomotive Emission Factors (g/bhp-hr) [5]

Tier	Class I Line Haul NOx Emission Factor	Class I Line Haul PM Emission Factor	Class I Switcher NOx Emission Factor	Class I Switcher PM Emission Factor
Pre-Tier 0	13	0.32	17.4	0.44
Tier 0	8.6	0.32	12.6	0.44
Tier 0+	7.2	0.20	10.6	0.23
Tier 1	6.7	0.32	9.9	0.43
Tier 1+	6.7	0.20	9.9	0.23
Tier 2	4.95	0.18	7.3	0.19
Tier 2+	4.95	0.08	7.3	0.11
Tier 3	4.95	0.08	4.5	0.08
Tier 4	1.0	0.015	1.0	0.015

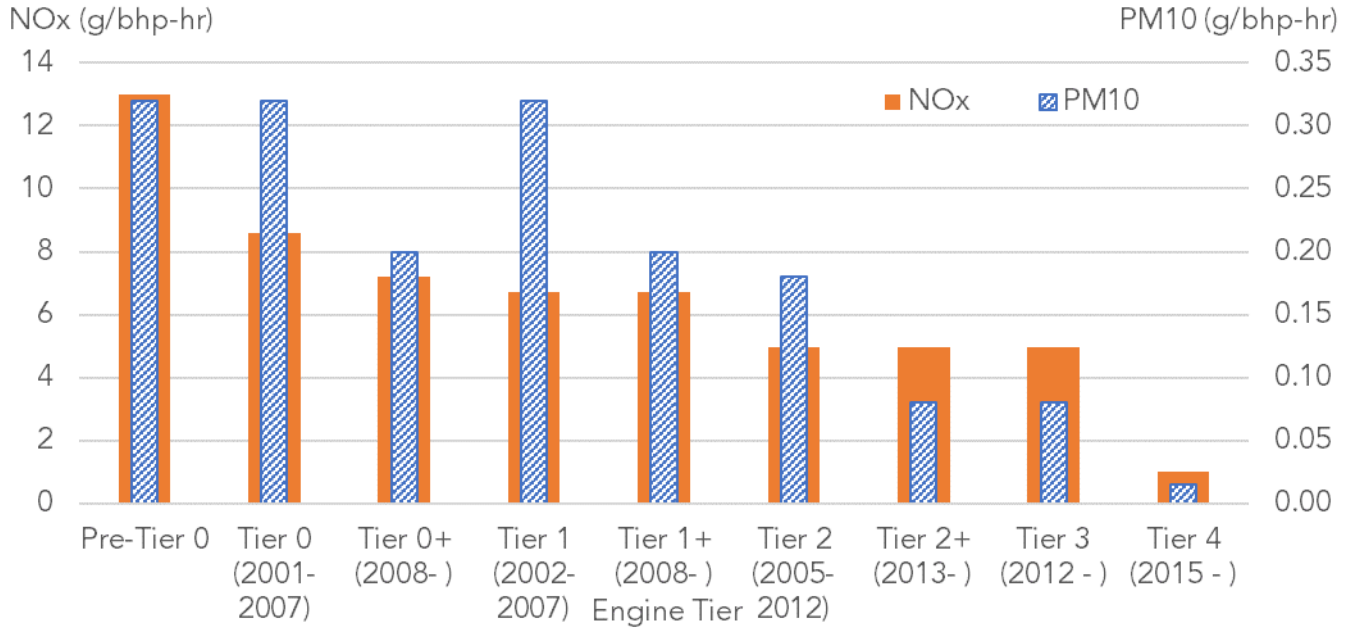
Figure 5 illustrates this decline in emission factors by tier, with NOx emissions represented using orange bars on the left axis and PM emissions in blue bars on the right axis. Engine

[4] CARB, Mobile Source Emissions Inventory. (weblink: *https://ww2.arb.ca.gov/our-work/programs/mobile-source-emissions-inventory/road-documentation/msei-documentation-road*)

[5] U.S. EPA, Emission Factors for Locomotives (EPA-420-F-09-025), Office of Transportation and Air Quality, April 2009. (weblink: *https://nepis.epa.gov/Exe/ZyPDF.cgi/P100500B.PDF?Dockey=P100500B.PDF*)

tiers are shown on the x-axis with the years introduced notated in parentheses. Emission factors are measured in grams per brake horsepower-hour (g/bhp-hr). Remanufactured tiers, notated with the '+' symbol, are also shown. For example, a remanufactured Tier 2 locomotive would be notated as a Tier 2+. Remanufacturing occurs as the locomotive either reaches a certain age or acquires a certain number of hours of use. Remanufactured units can have their own emission standards and factors.

Figure 5: Class I Line Haul Locomotive Emission Factors



The broad principles applicable to each inventory include:

- Developing a base year inventory of locomotives, including age, emission tier, and activity (generally working with locomotive operators to collect data),
- Forecasting future year populations by modeling the rate at which older equipment retire and are replaced, along with the overall growth in population or activity needed to meet demand (from increasing freight movement), and
- Calculating emissions by tier using emission factors multiplied by population and activity (which may be expressed in megawatts, gallons of fuel used, or annual hours of use).

III. Emission Reduction Strategies

The Proposed Regulation combines two strategies developed by CARB staff to reduce the locomotive sector's emissions: (1) Spending Account and (2) In-Use Operational Requirements (IUOR). Five locomotive categories (Class I Line haul, Class I Switcher, Class III Short line, Passenger, and Industrial) address each scenario separately due to their unique properties and because the Spending Account will be applied separately for each locomotive owner. Military locomotive operators are exempt from the suggested regulation actions.

A. Spending Account

This regulation action requires locomotive operators to deposit funds into a Spending Account that can be used to purchase cleaner locomotives, starting with Tier 4 and then ZE or ZE capable Locomotives, depending on the calendar year. A ZE capable locomotive is one that can be operated in a ZE configuration when in California. Funds can also be used for certain ZE demonstration and infrastructure projects. The funds deposited into the Spending Account are calculated using a combination of the locomotives' emission factors and their annual activity, measured in MWh. Emission factors and annual activity reflect estimates of the health cost burden on Californians due to these locomotive emissions. If operating older and dirtier tier units, railroads will be required to deposit more funds into the account, while fewer funds will be required if operating newer, cleaner locomotives.

Each railroad has an individual Spending Account, and the account funds may only be withdrawn by the contributing railroad to purchase Tier 4 or ZE locomotives.

1. Spending Account Methodology

The following assumptions and methodology were used in modeling the emission impacts of the Spending Account.

1. The Spending Account will collect funds beginning in 2024 from all locomotive categories based on activity in 2023. The fund collection is an annual process and considers the locomotives' annual activity operating in California. Because this process commences on the effective date of the Proposed Regulation, assumed to be October 2023, locomotive operators deposit funds for the last three months of 2023 (from October to December 2023) due to the effective date of the suggested regulations.
2. Starting in 2025, the Spending Account would first bring additional Tier 4 locomotives into the locomotive fleet and then ZE capable locomotives (or ZE locomotives when they are commercially available). Additional Tier 4 locomotives will arrive in 2025, accounting for the year needed for manufacture and delivery. The additional Tier 4 locomotives will displace a weighted average of all the remaining Tiers of older locomotives (Pre-Tier 0 to Tier 3).[6] Because the regulation does not require the purchase of any new Tier 4 or ZE locomotive, other options remain available to an operator. For example, an operator may retrofit older locomotives to a Tier 4 or better emissions system, add a battery or hydrogen fuel cell railcar to create a ZE capable locomotive, purchase a used higher-tier locomotive to replace a dirtier, older-tier locomotive, or bring a cleaner locomotive out of storage. Not all of these options could take advantage of Spending Account funds, although all those options would result in lower emissions and thus a smaller Spending Account obligation over time.

[6] Under current U.S. EPA regulations, manufacturers must build new locomotives to a Tier 4 standard or better. Therefore, a limited stock of pre-Tier 4 locomotives remain in existence. It is thus reasonable to assume that introduction of new Tier 4 (or better) locomotives will dilute the pool of older-tiered locomotives. The older-tiered locomotives, due to age, are also better candidates for retirement and replacement. Therefore, over time, funds used to purchase additional locomotives necessarily have a positive effect on the weighted average emissions of the locomotive fleet.

Spending Account funds can also be used for related ZE infrastructure. Given limited resources, the modeling cannot account for all these permutations separately and instead focuses on the primary change: the transition to a fleet with a higher percentage of Tier 4 and, over time, ZE or ZE capable locomotives. Thus, for simplicity, we assume that operators will use Spending Account funds to purchase a new Tier 4 or new ZE locomotive to replace an average locomotive in their fleet.[7]

3. For Class I railroads, 72 percent of the nationwide line haul locomotives visit California in any given year. Therefore, it is assumed that the same portion of the locomotives added due to the Spending Account visit California.
4. Railroads will use Spending Account funds as much as possible every year. For example, if the Spending Account has enough money to fund 50 Tier 4 purchases, but only 20 older locomotives were retired in that year due to old age, the rail company will purchase 50 locomotives and make the next oldest locomotives retire earlier.
5. When a fleet reaches 100 percent Tier 4 locomotives or cleaner, railroads will only purchase locomotives to meet the natural growth demand. In the case when railroads invest non-Spending Account money to purchase these locomotives (those outside the Proposed Regulation specification), the scenario assumes the railroads would purchase the scenario's least expensive option (meaning if they need to purchase additional locomotives to meet demand, and are not required to buy ZE locomotives, they would purchase Tier 4 locomotives assuming they cost less).
6. Switcher, Short line (Class III), Passenger, and Industrial locomotives are captive to California, meaning they do not leave the State. Line haul locomotives that enter California have varying megawatt-hours (MWh), depending on tier. As shown above in Figure 3 and Figure 4, Class I line haul locomotives are the rail category with the greatest emissions in California. Table 3 shows the statewide average MWhs per unit in the emission inventory and reflected in this analysis.

Table 3. Baseline Statewide MWhs per Locomotive Category

Tier	MWhs per Class I Line haul unit	MWhs per Class I Switcher unit	MWhs per Class III (Short line) unit	MWhs per Passenger unit
Pre-Tier 0	15.0	456.9	251.4	1846.5
Tier 0	127.3	456.9	64.3	1242.1
Tier 0+	160.6	456.9	239.4	1617.7
Tier 1	148.2	456.9	239.4	1617.7
Tier 1+	245.6	456.9	239.4	1617.7
Tier 2	194.7	456.9	239.4	1985.3
Tier 2+	399.4	456.9	239.4	1617.7
Tier 3	333.9	456.9	229.3	465.3
Tier 4	351.3	456.9	240.8	1827.7
ZE	351.3	456.9	240.8	1827.7

[7] Note that for purposes of this modeling, a ZE capable locomotive has the same effect as a ZE locomotive—both create ZE when operating in California.

Note: Based on CARB staff's assessment of data collected under the 1998 Locomotive NOx Fleet Average Emissions Agreement in the South Coast Air Basin (1998 MOU[8]) and CARB's Locomotive Emission Inventory. For more information, see the emission inventory documentation posted online.[9]

2. Spending Account Costs

Table 4 lists the locomotive costs, by engine category, used to determine when a locomotive operator will purchase a locomotive.

Table 4: Locomotive Assumed Costs

Category	Tier 4	Zero Emission[10]	ZE infrastructure cost[11]
Class 1 Line haul	$3.1 million	$5.25 million	$0.1 million per Hydrogen Fuel Cell line haul
Class 1 Switcher	$2.7 million	$3.4 million	$0.3 million per BE switcher
Short line	$2.7 million	$3.4 million	$0.3 million per BE switcher
Passenger	$7.5 million	$13 million	$1.5M per Passenger Locomotive
Industrial	$2.16 million	$3.1 million	$0.3 million per BE switcher

B. In-Use Operational Requirements

Beginning in 2030, the In-Use Operational Requirements (IUOR) regulate the operating age of California's locomotives. Under the IUOR, all units with original engine build dates over 23 years old shall be prohibited from operating in California. As locomotives turn 23 years of age, it is assumed, for purposes of this modeling, that railroads will replace them with Tier 4 or ZE locomotives. Other options remain available to the railroads because the regulation does not require the purchase of new locomotives. Railroads could modify the older locomotive to operate in a ZE configuration, or retrofit the older locomotive emissions technology to a Tier 4 or better standard. Railroads could also devote a portion of their Tier 4 fleet to California activities. Given limited modeling resources, staff have modeled a likely approach for operators whereby the operator replaces a locomotive that is older than 23 years with a new locomotive that is Tier 4 or ZE.

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[8] CARB, 1998 MOU Summary Data Archive. (weblink: *https://ww2.arb.ca.gov/1998-mou-summary-data-archive*)
[9] CARB, Mobile Source Emissions Inventory. (weblink: *https://ww2.arb.ca.gov/our-work/programs/mobile-source-emissions-inventory/road-documentation/msei-documentation-road*).
[10] Assumes a locomotive newly built to be ZE only. A ZE capable, or hybridized locomotive, could be less expensive from the operator's perspective if an operator retrofits an existing locomotive. Currently, staff believe that original equipment manufacturers will focus on transitioning to ZE only locomotives, leaving hybridization options to retrofitting by operators or third parties.
[11] ZE infrastructure costs would be approximately the same for a ZE capable locomotive, assuming a full ZE runtime when operating in California.

Additionally, under the IUOR, all switchers and industrial locomotives with an original engine build date of 2030 or newer, and all line haul locomotives with an original engine build date of 2035 or newer, must operate in a ZE configuration when in California from 2030 and 2035, respectively.

1. In-Use Operating Requirements Methodology

The following assumptions and methodology were used in modeling the emission impacts of the IUOR.

1. IUOR removes all non-ZE locomotives older than 23 years from operating in California, beginning on January 1, 2030, and every year thereafter. The emission benefits are claimed each year beginning on January 1.
    a. The line haul locomotive's age is determined by the locomotive's manufacture year.
    b. In CARB's Class I Switcher inventory, where only tier information was available, the locomotive tier introduction date was used. The average age by tier was used when aggregating data in the Short line and Passenger scenarios, because the average age was available for these categories.
2. When a locomotive is removed from California operation due to the IUOR, California locomotive operators will replace that locomotive with a ZE locomotive[12] for Class I Switcher, Short line, Industrial, and Passenger for ZE operation to achieve emission benefits starting on January 1, 2030. Similarly, a Class I Line haul locomotive older than 23 years will be replaced with a Tier 4 locomotive from January 1, 2030 to December 31, 2034 and a ZE locomotive from January 1, 2035 onward.

IV. Locomotive Summary and Emissions by Category

A. Class I Line Haul Locomotives

California's two Class I railroads, UP and BNSF, operate approximately 12,000 freight interstate line haul locomotives annually within the State, representing about 85 percent of the statewide locomotive activity and emissions. UP and BNSF also operate about 600 switcher locomotives, or those traveling around rail yards, representing about five percent of the statewide locomotive activity and emissions.

The recently published 2021 Line haul locomotive emission inventory was developed by considering the two railroads' retirement, remanufacture and replacement patterns observed from 2010 to 2018 in California. More detailed information on the 2021 Line haul locomotive emission inventory is available at the Mobile Source Emission Inventory (MSEI) website[13]. Figure 6 presents statewide NOx projections for CARB's 2021 Line haul Emission Inventory.

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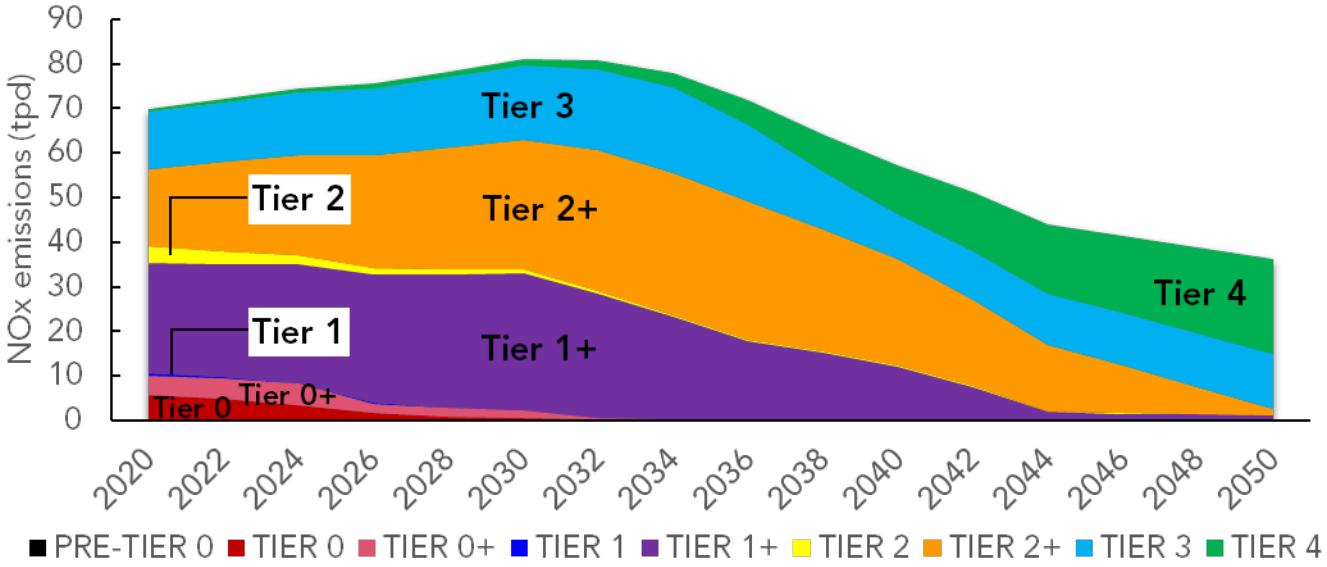
[12] Or ZE capable locomotive. For purposes of the emission inventory, modeled use of a ZE or a ZE capable locomotive would have the same result for modeled emissions.

[13] CARB, 2021 Class I Line Haul Locomotive Emission Inventory, February, 2021 (weblink: *https://ww2.arb.ca.gov/sites/default/files/2022-07/2021%20Line-Haul%20Locomotive%20Emission%20Inventory%20%28Final%29%202022%20July%20Update.pdf*).

Figure 6: Statewide Line Haul NOx Projections by Tier



1. Line Haul Emission Reduction Scenarios

For the Proposed Regulation, CARB staff analyzed four scenarios: (1) Proposed Regulation, (2) Alternative 1, (3) Alternative 2, and (4) Sensitivity Analysis. The Proposed Regulation includes two emission-reducing regulation concepts: The Spending Account and the In-Use Operating Requirements (IUOR). Alternative 1 assumes the requirement that locomotives operate in ZE configuration when in California would start sooner than the Proposed Regulation scenario, and, consequently, there would be no Spending Account-funded Tier 4 locomotive purchases from 2025 to 2029. Alternative 2 assumes the IOUR prohibits operation of locomotives with original engine build dates older than 35 years— rather than the Proposed Regulation's 23 years—when operating in California.

Funds for locomotive purchases may come from two sources, either the Spending Account or non-Spending Account funds. Generally, it is assumed that locomotive operators purchase new locomotives with Spending Account funds every year, for the reasons discussed previously. When additional locomotive units are still needed to meet the required total activity demand (which is defined as MWhs deficit in the 2021 Line haul emission inventory document), even after purchasing locomotives using Spending Account funds, the operators will use non-Spending Account funds for additional locomotives purchases.

The Proposed Regulation scenario for Class I Line haul locomotives assumes that Spending Account funds would be used to purchase Tier 4 locomotives in 2024. These Spending Account-funded Tier 4 locomotives would start operating in California in 2025. Given that approach, and estimated locomotive activity, the Spending Account funds would be sufficient to support consecutive Tier 4 purchases until 2029.

From 2029 to 2033, Class I Line Haul Spending Account funds would be used for ZE line haul locomotive infrastructure installation. This is a likely scenario because a shift to ZE or ZE capable locomotive operation requires an investment in infrastructure, prior to or in parallel with, the shift to ZE operation. This assumption also conservatively gives Class I railroads until

2033 before they begin purchasing ZE locomotives that will begin operation in 2035. The infrastructure cost per ZE line haul unit is estimated to be $100,000, and staff assume that railroads would pay the infrastructure cost in 2029 and 2030, based on the calculated total number of ZE locomotives by 2050. Because the same Class I companies also own and operate the switcher locomotives, Class I Line Haul Spending Account funds would also be used to purchase Class I ZE switchers until all non-Tier 4 switchers are replaced with Tier 4s or ZE switchers. Once all Class I Switchers are either Tier 4 or ZE, the Spending Account funds would remain in the Class I Spending Account until line haul ZE locomotives become commercially available for purchase in 2034. As such, Class I railroads would adopt a significant number of Tier 4s with non-Spending Account funds from 2029 to 2033, in anticipation of the requirements that older switcher and line-haul locomotives (by original engine build date) could no longer operate in California beginning in 2030 and 2035, respectively. Some increased demand is also assumed, caused by natural business growth.

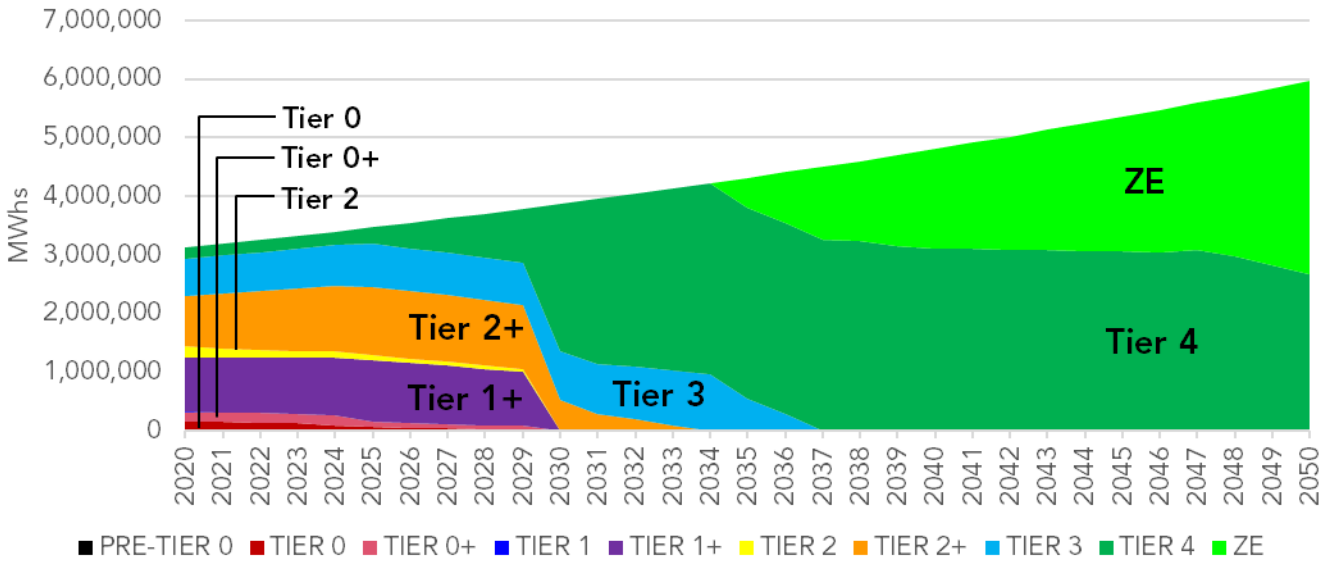
Non-Spending Account funds would purchase new Tier 4 locomotives until 2033.

It is assumed that by 2034, ZE locomotives would be available in the market, and at that point Spending Account funds would be spent to purchase ZE locomotives. (ZE capable locomotives are, for purposes of this modeling, assumed to be equivalent in emissions and could be substituted for ZE locomotives here.) Non-Spending Account funds would purchase new Tier 4 locomotives until 2033. The shift from Tier 4 to ZE purchases is assumed to happen around this timeframe for several reasons: (1) maturity and commercial availability of the ZE technology; (2) the prohibition on older locomotives (those with 23+ year original engine build dates) from operating in California unless using a ZE configuration; and (3) the requirement that locomotives with engine build dates of 2030 or 2035, for switchers and line-hauls, respectively, operate in a ZE configuration when in California. Staff anticipate that a reasonable, cost-effective response to these changes would be a shift in purchasing from Tier 4 to ZE locomotives around this time, and thus this model assumes that ZE locomotives will start replacing older locomotives in the fleet beginning in 2035.

The Sensitivity Analysis, in contrast, requires railroads procure only Tier 4 locomotives with non-Spending Account funds.

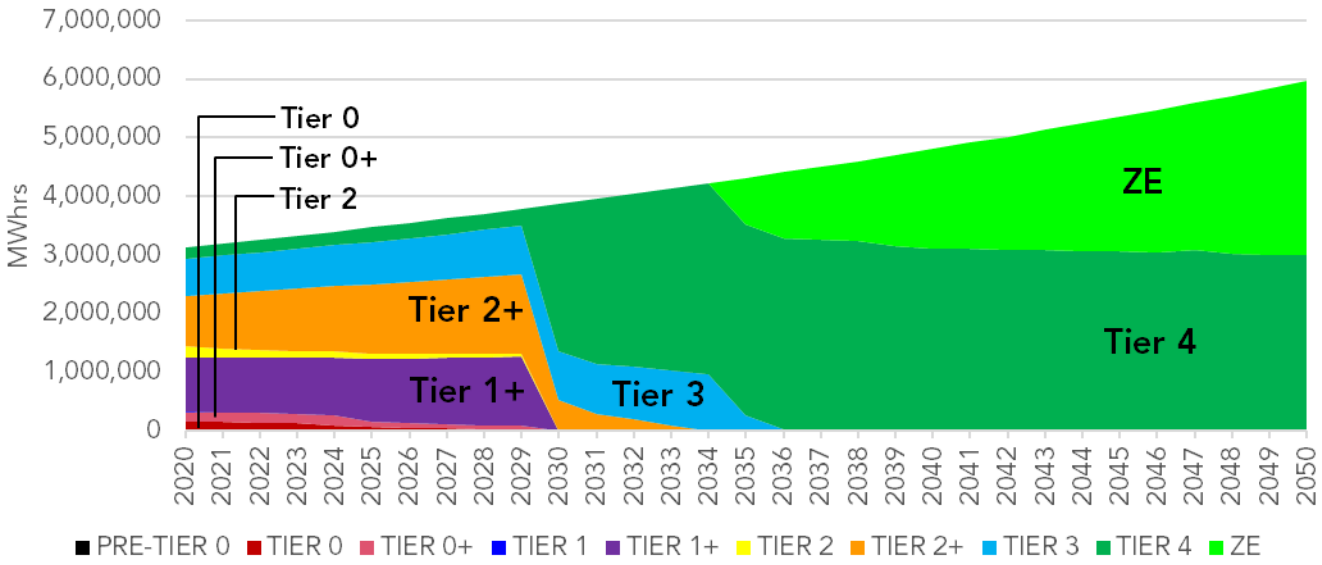
Figure 7 shows the accelerated Tier 4 and ZE line haul locomotive adoption due to the suggested regulation concepts.

Figure 7: Proposed Regulation Scenario Line Haul Locomotive Activity in MWh



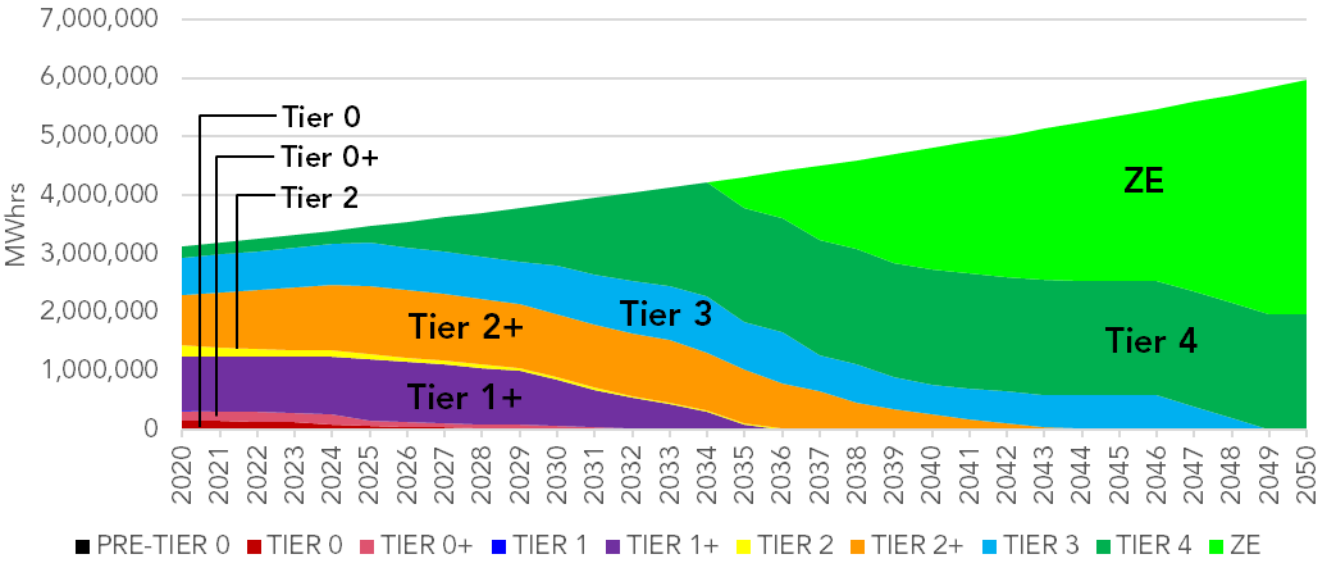
Alternative 1 assumes ZE line haul infrastructure investment and Class I ZE switcher purchases begin in 2025. In Alternative 1, there would be no Spending Account-funded Tier 4 locomotive purchases. Class I railroads may purchase up to 25 ZE switchers each year starting in 2025, as there is an assumed manufacturer production limit. Alternative 1 limits ZE switchers purchased by Class I railroads to 25 per year until 2029 to model OEMs ramping up production capacity as Alternative 1 assumes earlier ZE adoption than the Proposed Regulation scenario. Under this scenario, it is assumed Class I railroads will save the Spending Account funds from 2024 to 2033 and then purchase ZE line hauls starting in 2034 as they become commercially available. Alternative 1 assumes Class I railroads will need to purchase Tier 4s with non-Spending Account funds from 2029 to 2033 to meet increased locomotive activity to replace locomotives removed from California operations by the IUOR and from natural business growth. Figure 8 shows the fleet mix resulting from modeling Alternative 1.

Figure 8: Alternative 1 Line Haul Locomotive Activity in MWh



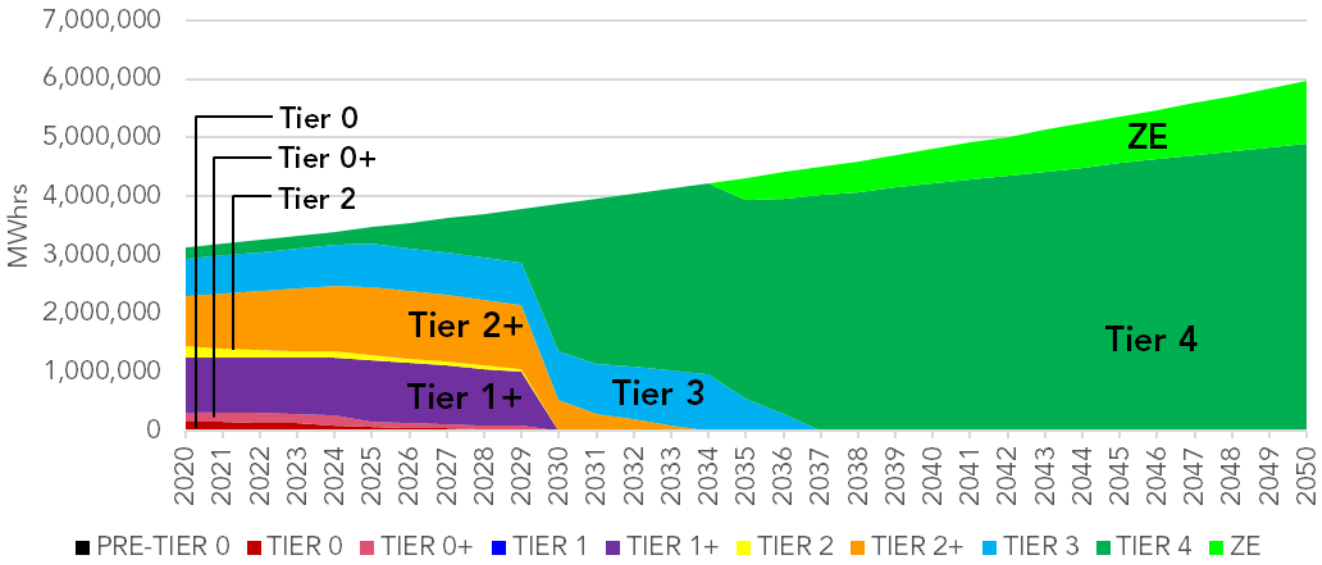
Alternative 2 assumes that starting in 2030, only locomotives less than 35 years old can operate in California instead of 23 years old as proposed under the IUOR in the Proposed Regulation. Because of the additional time locomotives can operate under Alternative 2, the locomotive replacement rate is much slower than the Proposed Regulation scenario. Figure 9 presents the Class I Line haul's activity (MWhs) for Alternative 2.

Figure 9: Alternative 2 Line Haul Locomotive Activity in MWh



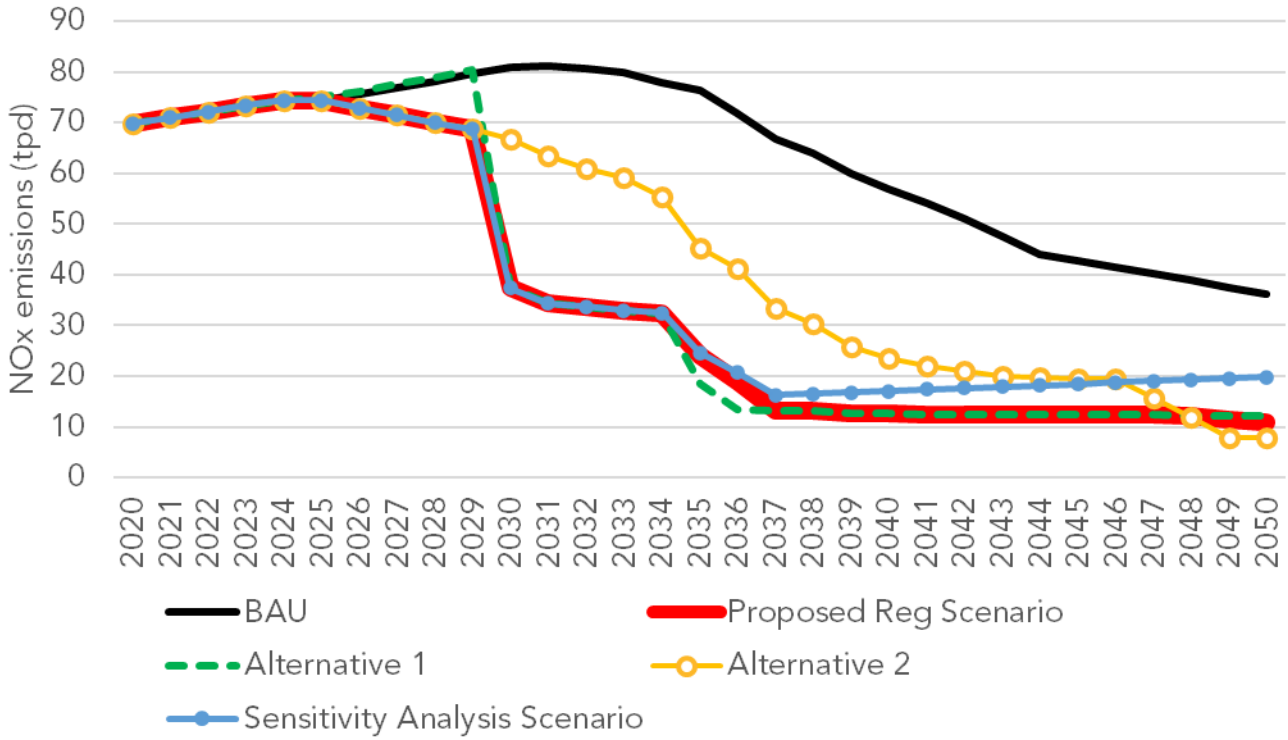
The Sensitivity Analysis assumes railroads will only purchase ZE Locomotives with Spending Account funds and will only purchase Tier 4s with non-Spending Account funds for the duration of the Proposed Regulation. Figure 10 shows the forecasted Tier-specific activity in MWhs for the Sensitivity Analysis.

Figure 10: Sensitivity Analysis Line Haul Locomotive Activity in MWh



Each regulation scenario evaluated (Proposed Regulation, Alternative 1, Alternative 2, and Sensitivity Analysis) will reduce NOx emissions compared to the baseline BAU. Figure 11 shows the NOx emissions for each scenario.

Figure 11: Class I Line Haul NOx Emissions with Reduction Strategies



B. Class I Switchers

Switchers are used in and around California's Class I rail yards to move individual railcars or segments of trains. Switchers in this inventory represent locomotives operated by UP and BNSF based at the 28 Class I rail yards in California. Smaller railroads that have switching activity are included in the short line inventory (described immediately after this section).

Switchers generally have lower horsepower than line haul locomotives. In CARB's 2022 Switcher Rail Yard Emission Inventory[14], BNSF and UP reported activity at each rail yard in terms of Full-Time Equivalent (FTE). A single FTE is equivalent to one locomotive working 24 hours a day, 365 days a year. Fuel consumption for these locomotives is then estimated based on the U.S. EPA analysis that one FTE switcher consumes 82,490 gallons of fuel per year.[15]

For the Proposed Regulation analyses, CARB converted switcher FTE units to an estimated locomotive population to determine when Railroads would purchase new locomotives. To estimate population, CARB used data from the 2005 to 2007 Health Risk Analysis at Rail yards, that showed the average rail yard had 6.03 switchers for every FTE. Therefore, for every 1 FTE in the switcher inventory, CARB estimates there are 6 switchers in use, rounded to the nearest whole number.

CARB's 2022 switcher inventory does not predict significant turnover, barring State actions. But switcher fuel consumption projections follow the growth rate adopted by 2021 Class I Line haul inventory of 2.19 percent growth annually. Because the inventory is based on FTE, not locomotive population, the number of switchers in the Proposed Regulation scenarios remains constant. Figure 12 depicts the switcher statewide FTE by tier and assumes used Tier 2 line haul locomotives will replace any remaining Pre-Tier 0 locomotives by 2030. The inventory does not assume any adoption of Tier 4 switchers, as the Railroads did not indicate plans for turnover or new purchases.

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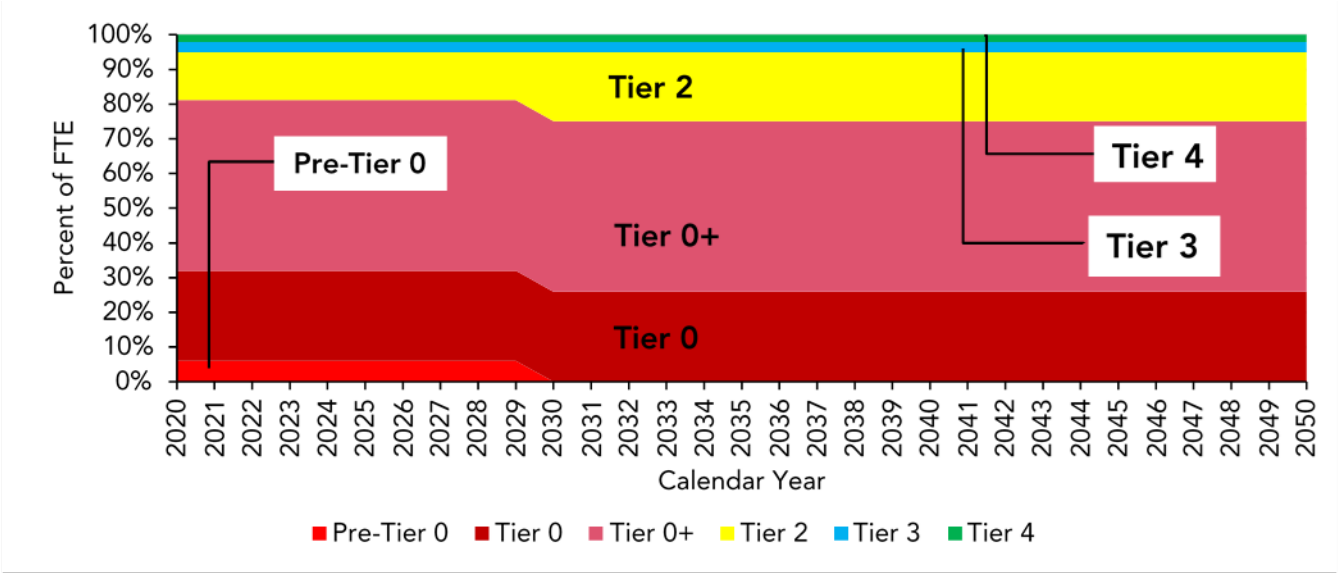
[14] CARB's 2022 Switcher Rail Yard Emission Inventory, July 2022. (weblink: *https://ww2.arb.ca.gov/sites/default/files/2022-07/2022 Class I Switcher Emission Inventory technical document 07112022.pdf).*

[15] US EPA, Procedures for Emission Inventory Preparation - Vol IV: Mobile Sources; Publication EPA420-R-92-009, December 1992, p. 207 (weblink: *https://nepis.epa.gov/Exe/ZyPDF.cgi/P1009ZEK.PDF?Dockey=P1009ZEK.PDF*).

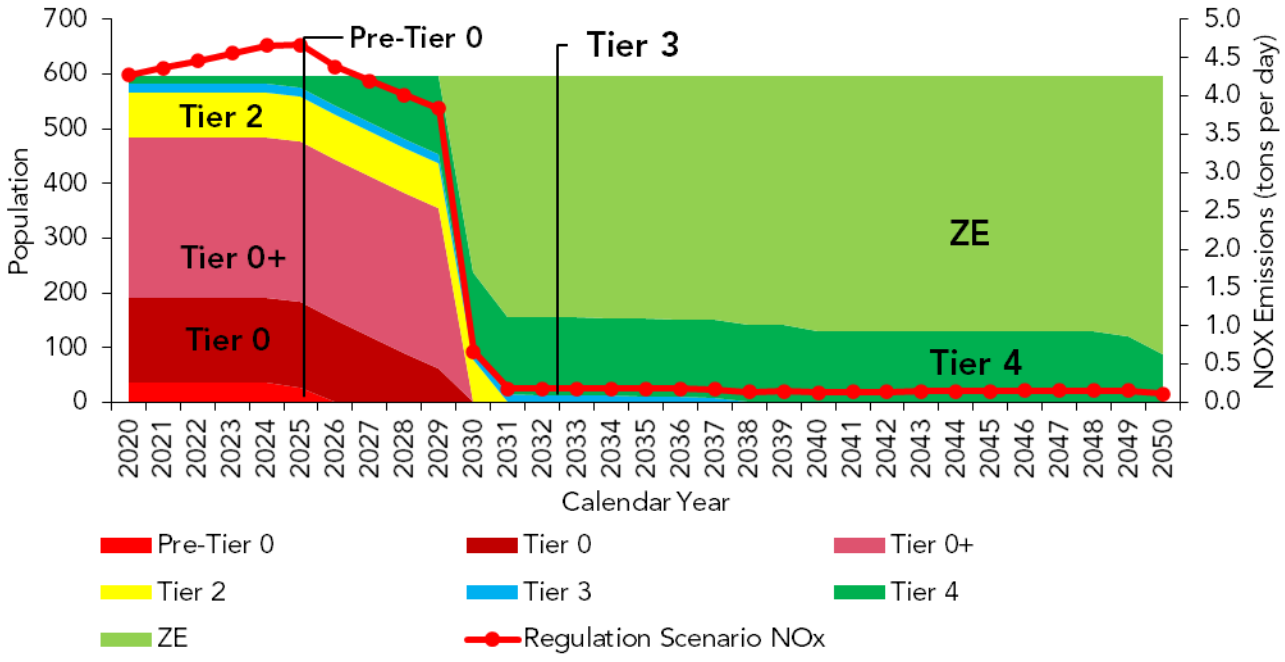
Figure 12: Percent of Statewide Switcher FTE by Tier



1. Switcher Emission Reduction Scenarios

Figure 13 illustrates the estimated statewide switcher population and associated NOx emissions with impacts from the Proposed Regulation scenario, utilizing the Spending Account and IUOR. Note that switchers are modeled independently of line haul locomotives, even though the same two companies own them. The stacked graph shows estimated locomotive population by tier using the left axis with the red line indicating NOx emissions using the right axis.

Figure 13: Proposed Regulation Scenario for Statewide Switcher Population and NOx Emissions



The three additional scenarios (Alternative 1, Alternative 2, and Sensitivity Analysis) combine different Tier introduction timelines and locomotive retirement ages as part of this analysis. Figure 14 depicts the emissions impacts of all four different scenario reduction strategies analyzed for the Proposed Regulation with the inventory baseline emissions (noted as BAU).

Figure 14: Switcher Baseline NOx with Reduction Scenarios

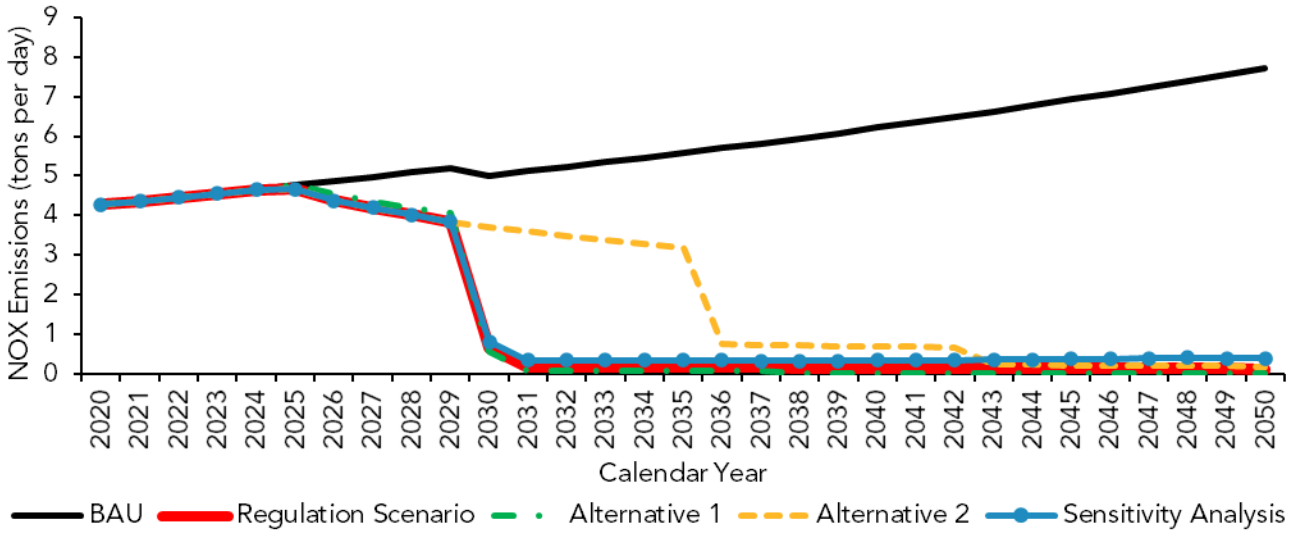


Figure 15: Proposed Regulation Scenario Switcher Activity in MWh

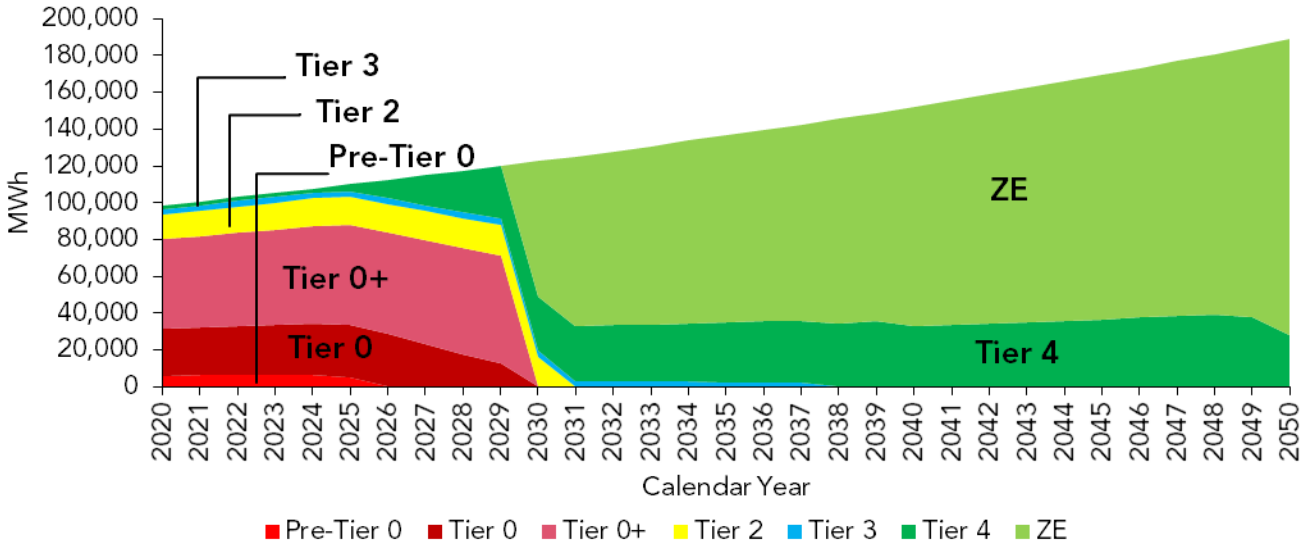


Figure 16: Alternative 1 Switcher Activity in MWh

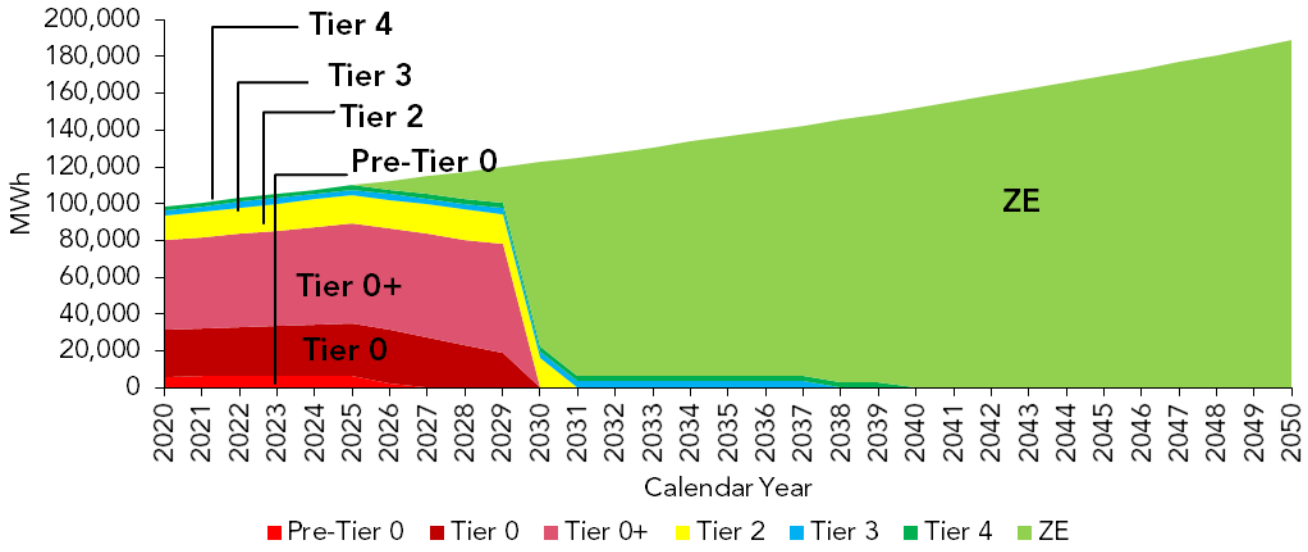


Figure 17: Alternative 2 Switcher Activity in MWh

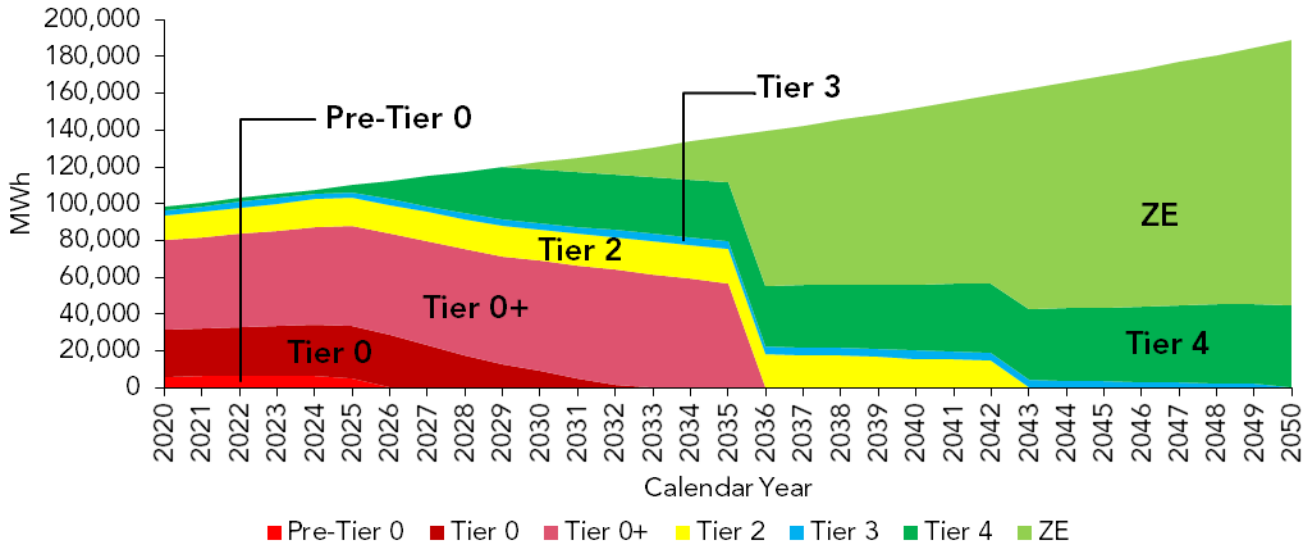
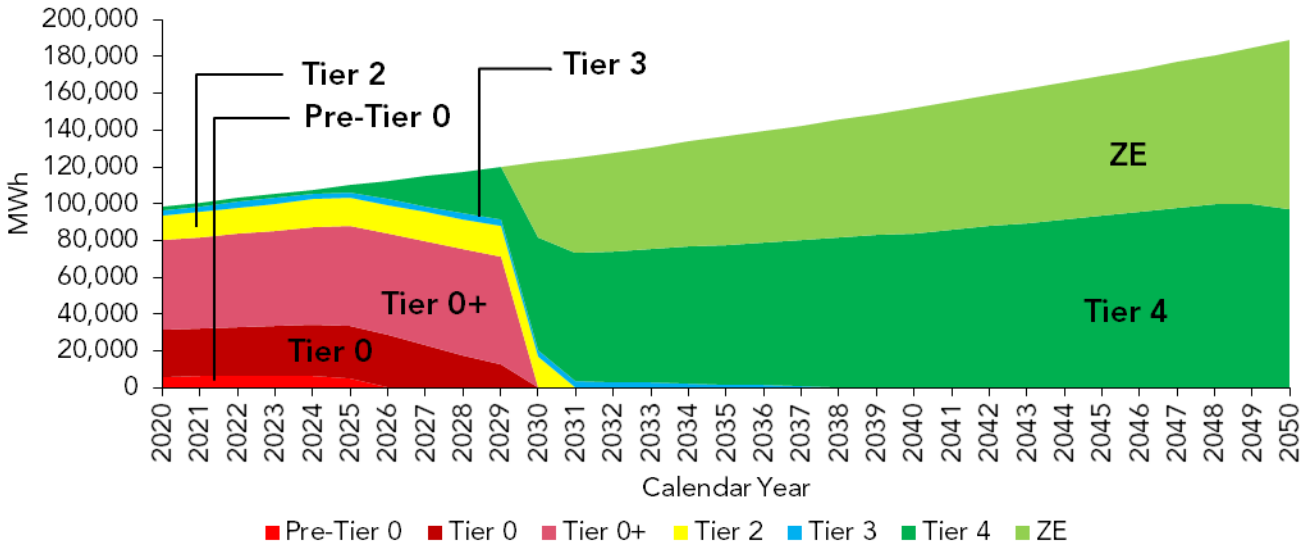


Figure 18: Sensitivity Analysis Switcher Activity in MWh



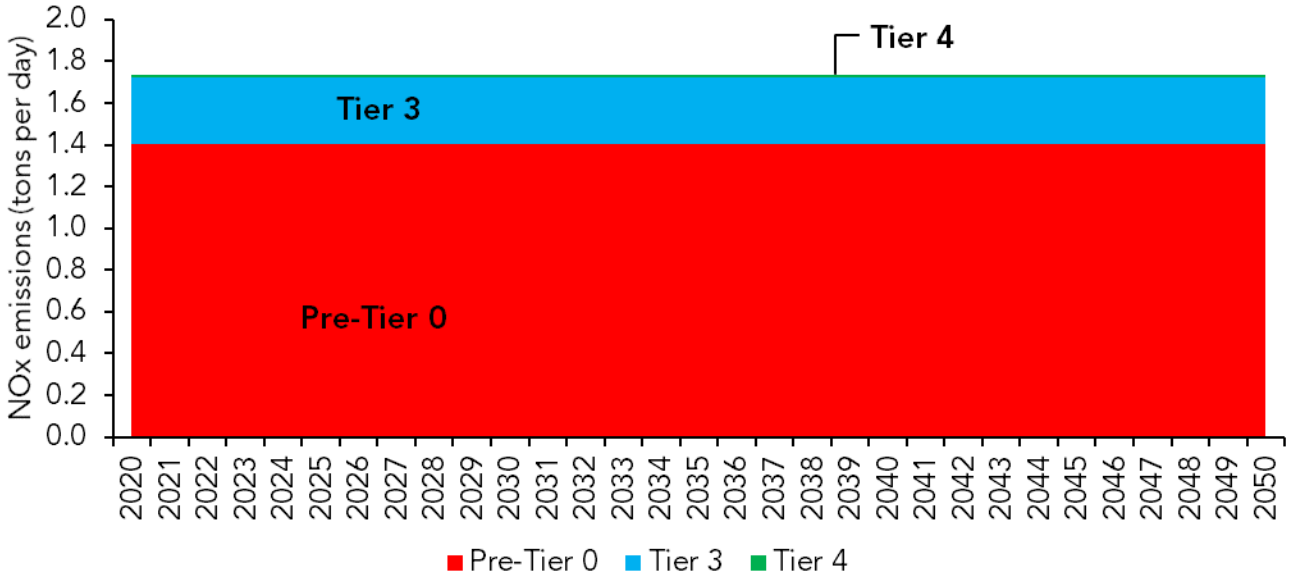
C. Short Line Freight Railroads

California has 25 short line (or Class III) railroads operating within the State. These smaller freight rail operations typically feed a small number of railcars to UP and BNSF, which the Class I railroads in turn transport across the North American freight rail network. Combined, California's short line railroads operate approximately 160 locomotives statewide.

CARB's 2017 Short line Rail Emission Inventory[16] consists of 25 companies operating within California that each has an annual operating revenue less than $36.6 million.[17] Short line rail operators tend to be small businesses, as compared to Class I operators, and have no reporting obligations to any organization. They sometimes are subsidiaries of a large holding company, such as Genesee & Wyoming, that owns and leases over a hundred freight railroads worldwide. Data supplied voluntarily by the short line rail operators were used to forecast emissions, including locomotive information (model year, horsepower, and emission standards tier) and 2015 reported fuel. Activity is projected to remain constant because no growth was reported nor expected by the short line operators. Figure 19 shows Statewide Short line NOx emissions at roughly 1.7 tpd, with Pre-Tier 0 locomotives contributing over 80 percent of the short line statewide NOx emissions.

[16] CARB, 2017 Short line Rail Emissions Model, June 2017. (weblink: *https://ww3.arb.ca.gov/msei/ordiesel/locoshortline2017ei.docx*).
[17] U.S. Surface Transportation Board, Revisions to Railroad Annual Report Form R-1 and Quarterly Operating Reports, April 24, 2017. (weblink: *https://www.govinfo.gov/content/pkg/FR-2017-04-24/pdf/2017-08236.pdf*).

Figure 19: Statewide Short line NOx Emission Projections by Tier



1. Short line Regulation Emission Reduction Scenarios

Figure 20 shows the short line rail population and NOx emission projections resulting from the Proposed Regulation scenario, which incorporates Spending Account and IOUR. The stacked area represents locomotive population by tier using the left axis. The right axis depicts NOx emissions using the black line.

Figure 20: Proposed Regulation Scenario for Statewide Short line Population and NOx Emissions

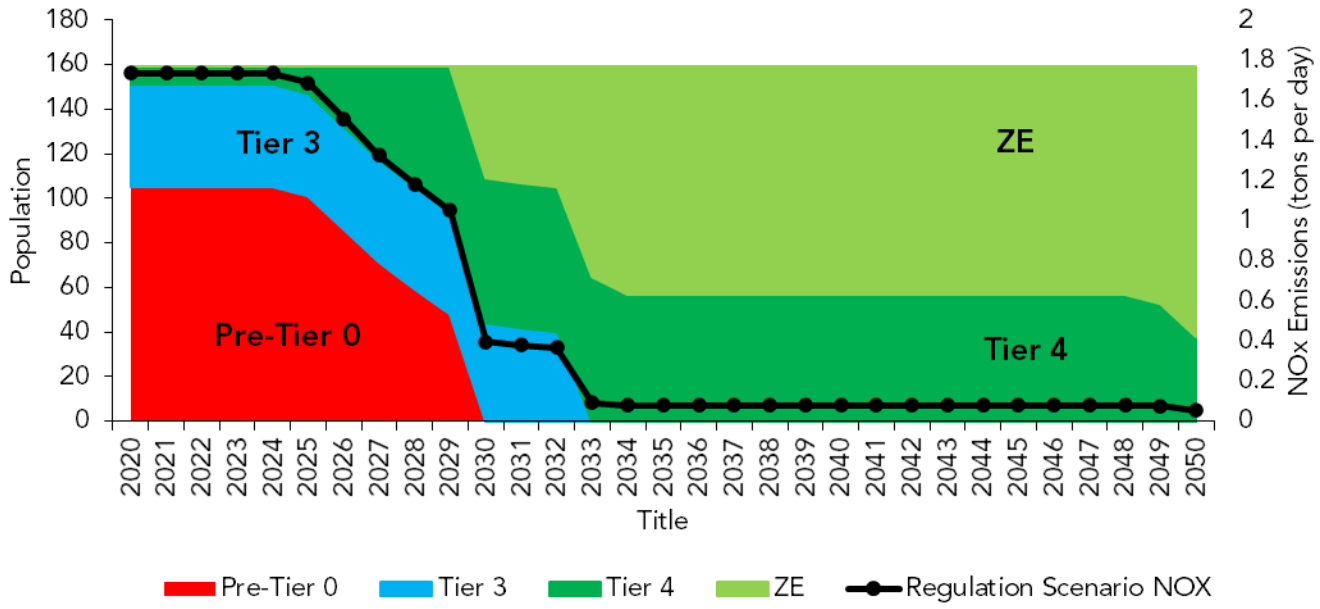


Figure 21, Figure 22, Figure 23, and Figure 24 illustrate the activity for short line locomotives in each of the four scenarios.

Figure 21: Proposed Regulation Scenario Short line Activity in MWh

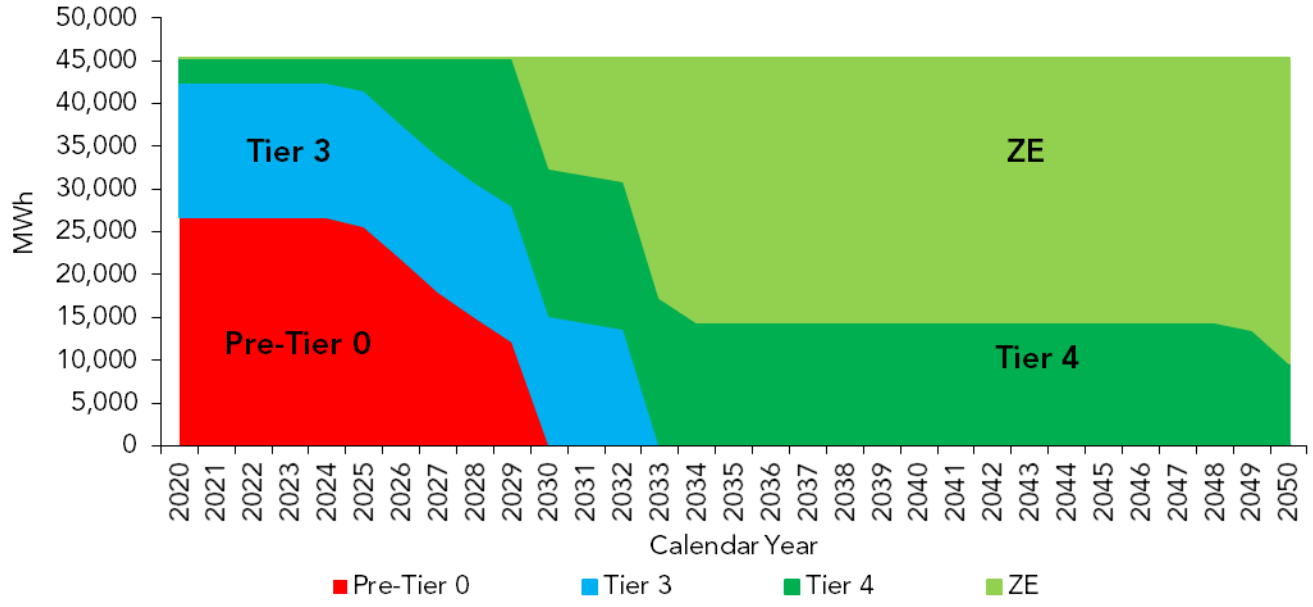


Figure 22: Alternative 1 Short line Activity in MWh

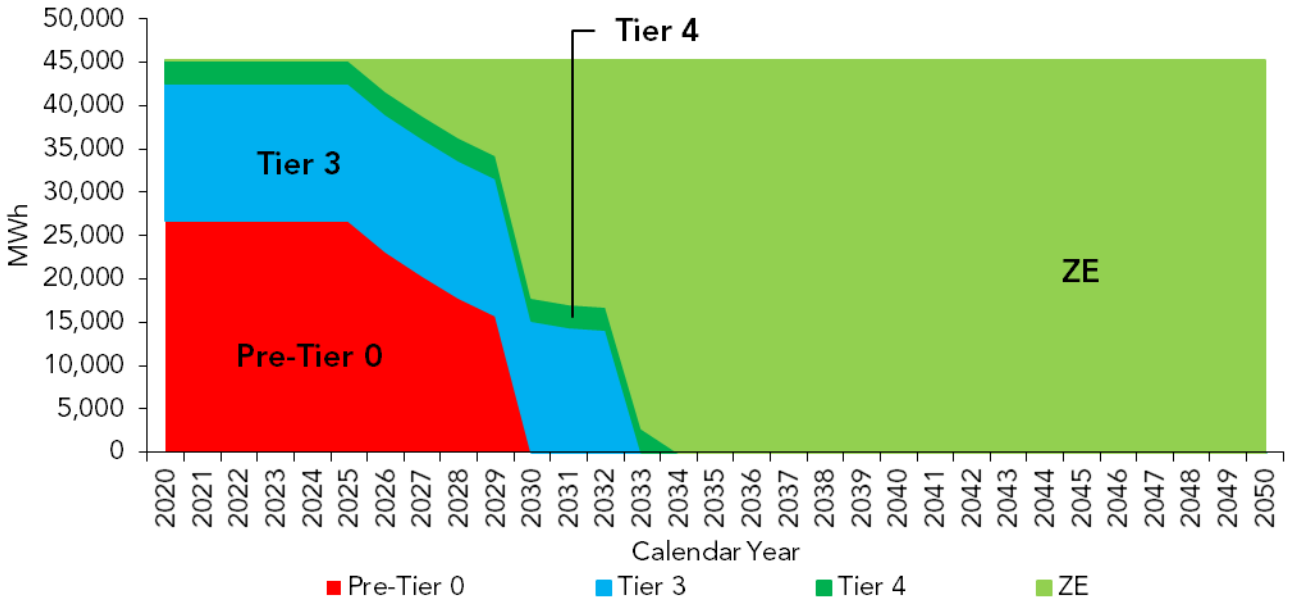


Figure 23: Alternative 2 Short line Activity in MWh

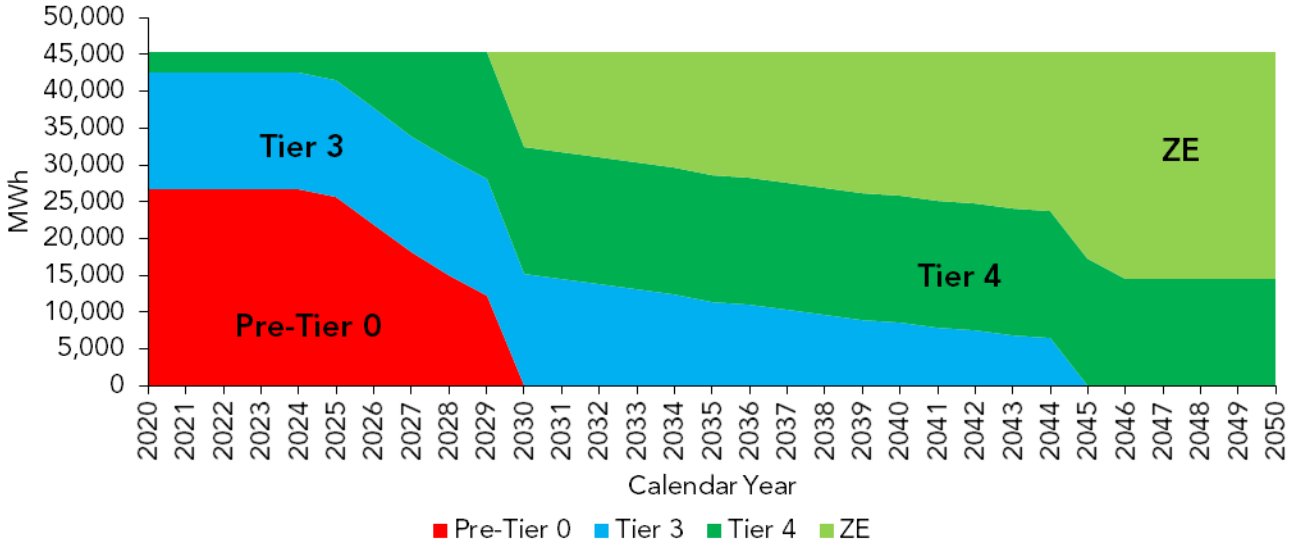


Figure 24: Sensitivity Analysis Short line Activity in MWh

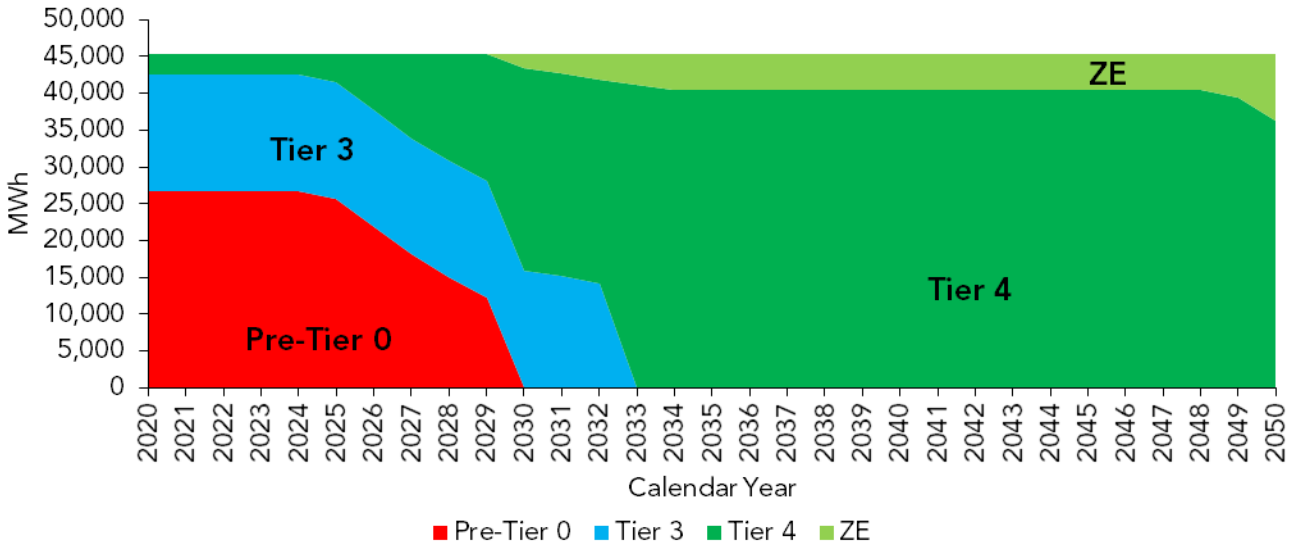
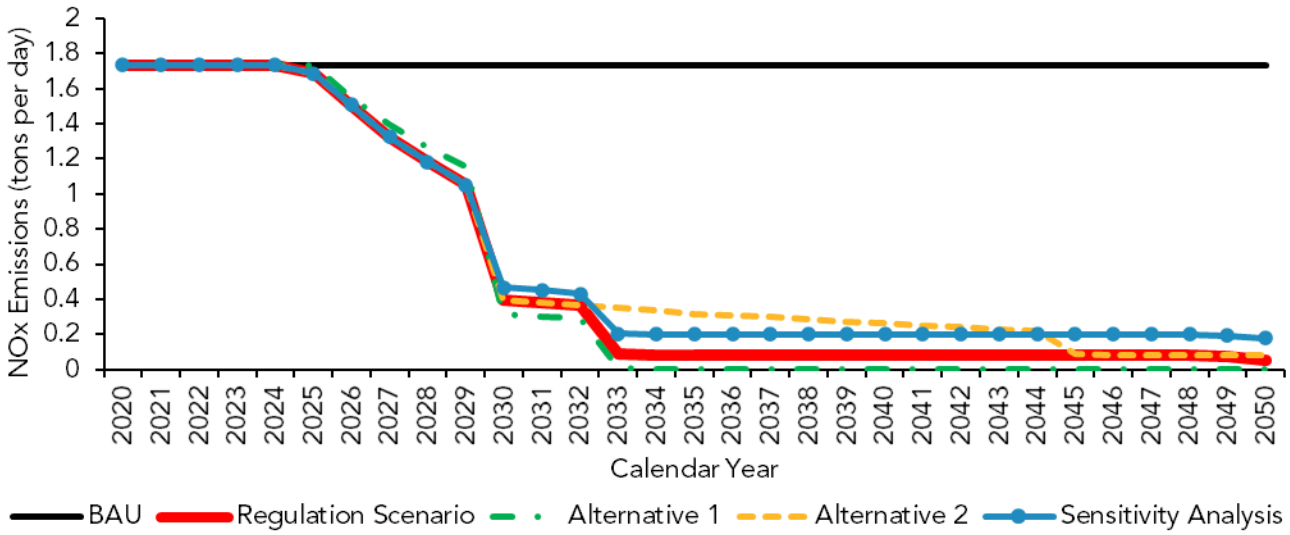


Figure 25 illustrates statewide NOx emissions for the regulation scenario, the three additional scenarios (Alternative 1, Alternative 2, and Sensitivity Analysis), and the inventory baseline emissions (notated as BAU).

Figure 25: Short line NOx Emissions with Reduction Scenarios



D. Passenger Railroads

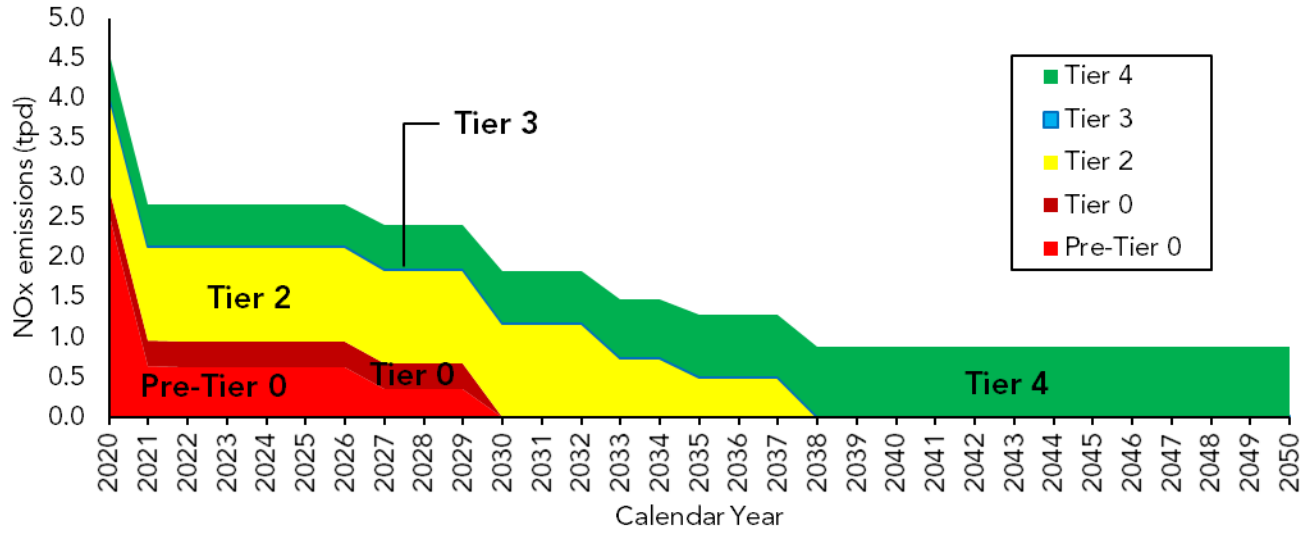
CARB's 2017 Passenger Rail Emission Inventory[18] includes Altamont Corridor Express, Pacific Surfliner, Caltrain, Capitol Corridor, San Joaquin Corridor, Metrolink, and the North County Transit District. These rail lines travel intra-state only, meaning they transport passengers locally or regionally inside California. Of these passenger railroads, Capitol Corridor, San Joaquin, and Pacific Surfliner are State-supported intercity routes. Amtrak has four inter-state passenger routes: California Zephyr, Coast Starlight, Sunset Limited, and Southwest Chief. Because these routes leave California, their locomotive population, fuel, and emissions are excluded from the regulation baseline inventory used for all analyses associated with the Proposed Regulation and scenarios. However, they are included in CARB's official passenger rail inventory[19]. California's passenger railroads operate about 130 locomotives, with more than half of the State's fleet operating Tier 4 or electric locomotives.

CARB's 2017 Passenger Rail Emissions Inventory is based on voluntarily provided data, varying by company, which may include locomotive ID, model year, tier, horsepower, route mileage, and fuel consumption. The inventory uses 2015 as the base year. Growth is assumed to be constant based on input from several rail companies explaining they do not expect fuel use to change in the future. Figure 26 shows intra-state passenger rail's NOx emission projections for purposes of this regulation analysis (inter-state passenger rail emissions are excluded). NOx emissions are stacked by tier and decline as the rail companies transition to cleaner Tier 4 or ZE locomotives, which is separate from the Proposed Regulation.

[18] CARB, 2017 Passenger Rail Emissions Model, June 2017. (weblink: *https://ww3.arb.ca.gov/msei/ordiesel/locopassenger2017ei.docx*)

[19] Sonoma-Marin Area Rail Transit (SMART) is excluded from the official inventory because it is newer than the current inventory. It will be included in future inventory development, when data becomes available.

Figure 26: Statewide Baseline Intra-State Passenger NOx Emission Projections by Tier



1. Passenger Locomotive Emission Reductions

Figure 27 shows the passenger rail population and NOx emissions resulting from the Proposed Regulation, which incorporates the benefits of both the Spending Account and IUOR. The stacked area chart shows locomotive population by tier using the left axis, while the right axis depicts NOx emissions with a red line. The figure's legend lists' electric' separately from 'ZE' locomotives to denote those locomotives with scheduled replacement by the rail company that are independent from the Proposed Regulation (denoted by 'electric') and those locomotives that are replaced due to the scenarios (denoted 'ZE').

Figure 27: Proposed Regulation Scenario for Passenger Population and NOx Emissions

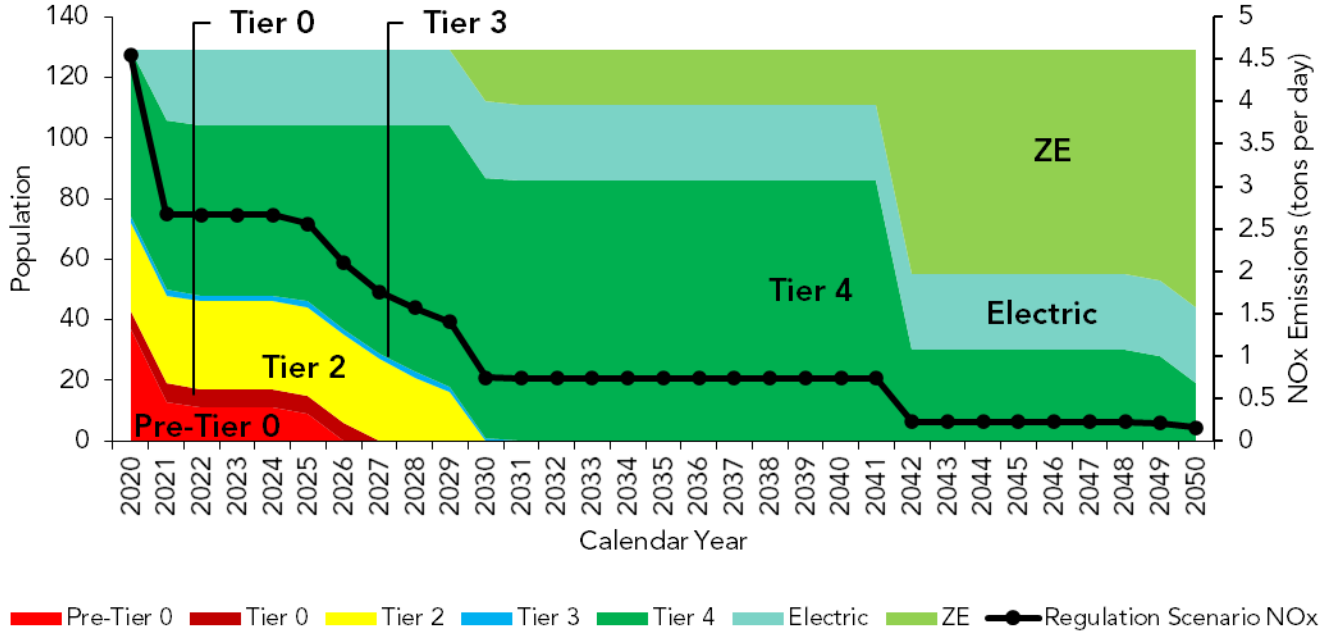


Figure 28, Figure 29, Figure 30, and Figure 31 each display Passenger rail activity in each of the four scenarios.

Figure 28: Proposed Regulation Passenger Activity in MWh

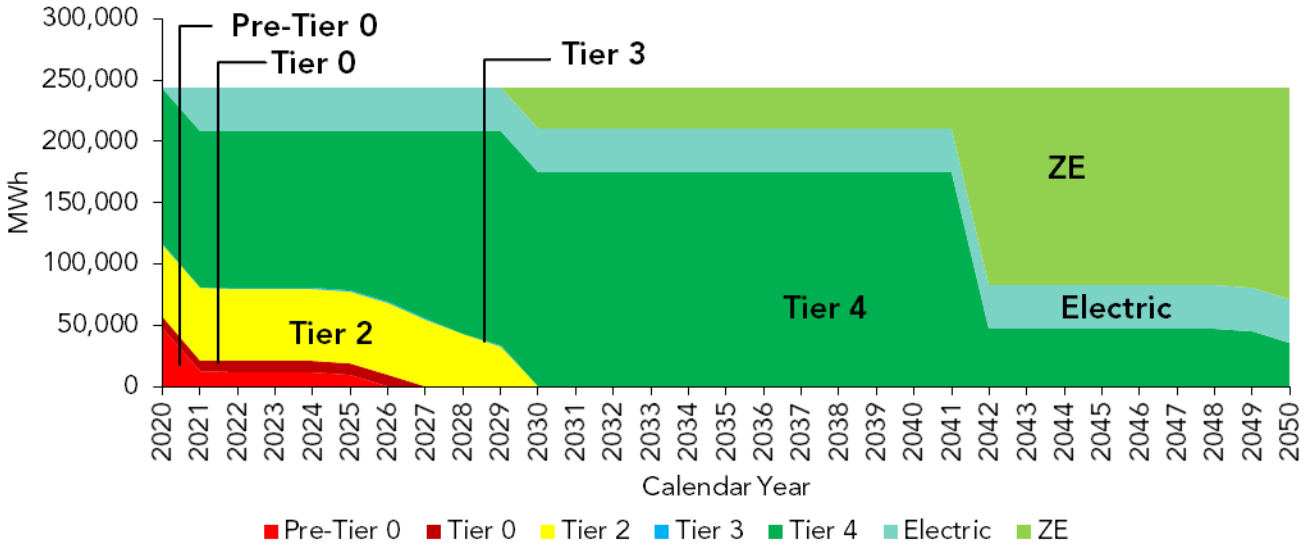


Figure 29: Alternative 1 Passenger Activity in MWh

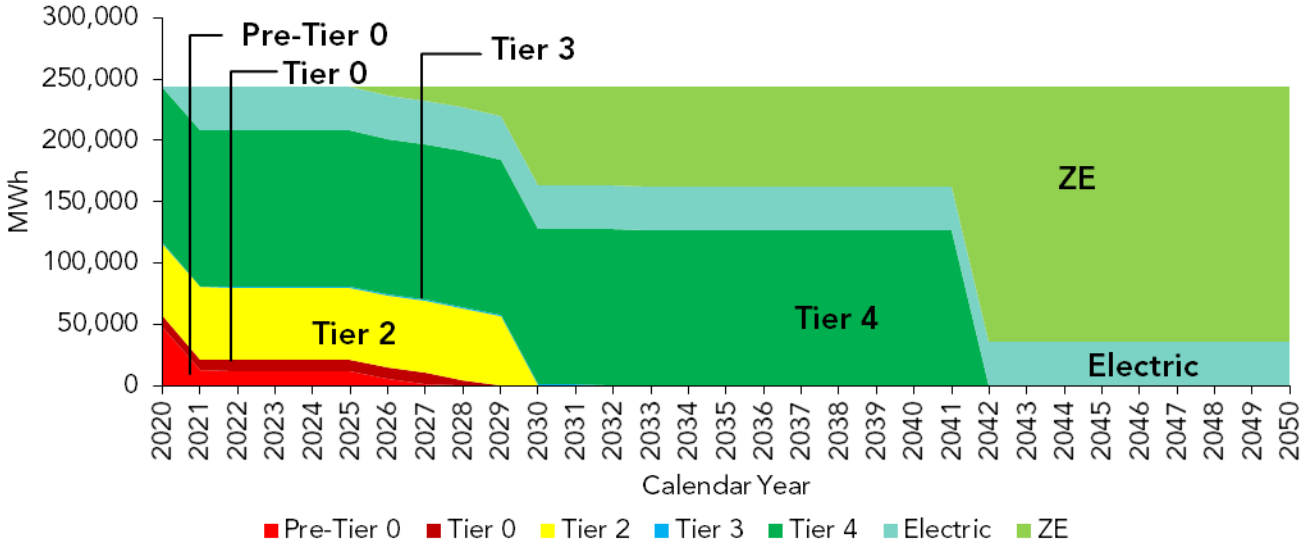


Figure 30: Alternative 2 Passenger Activity in MWh

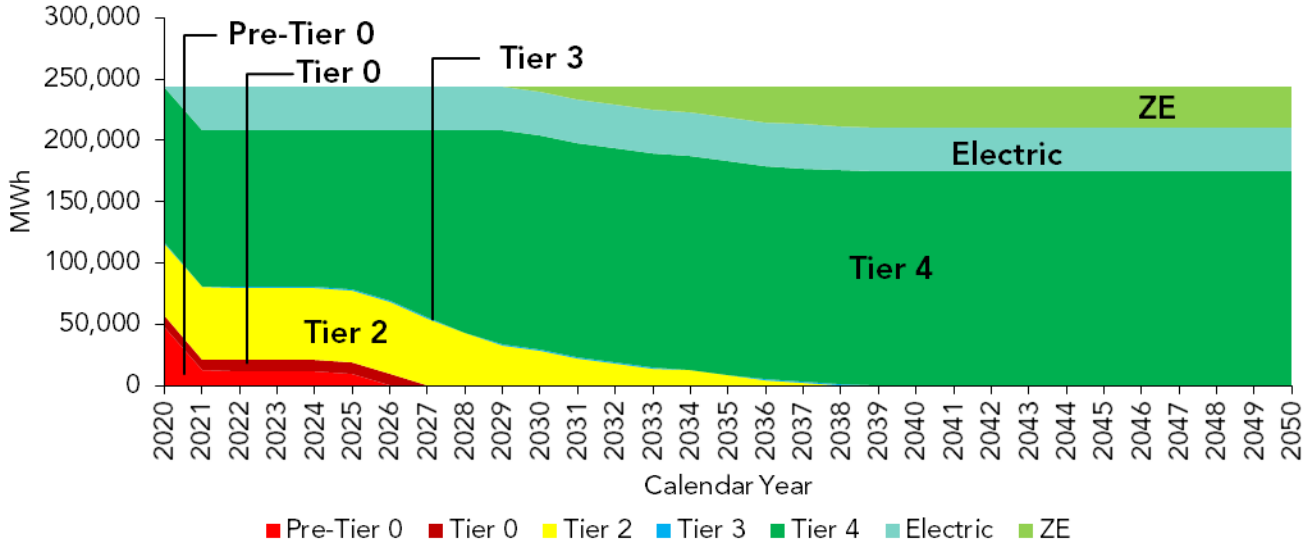


Figure 31: Sensitivity Analysis Passenger Activity in MWh

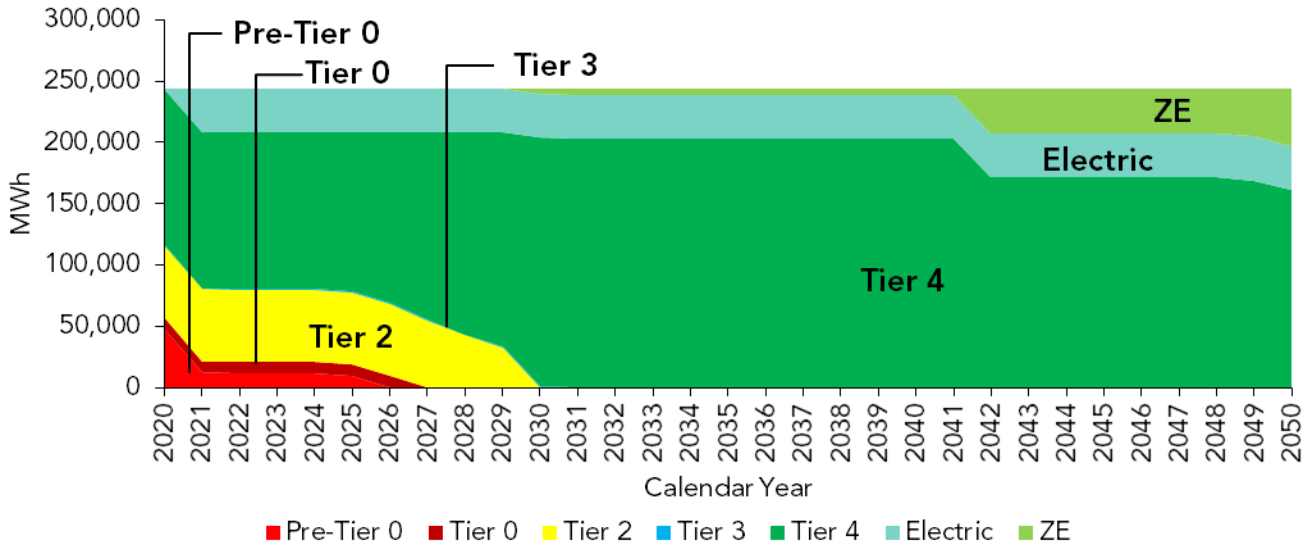
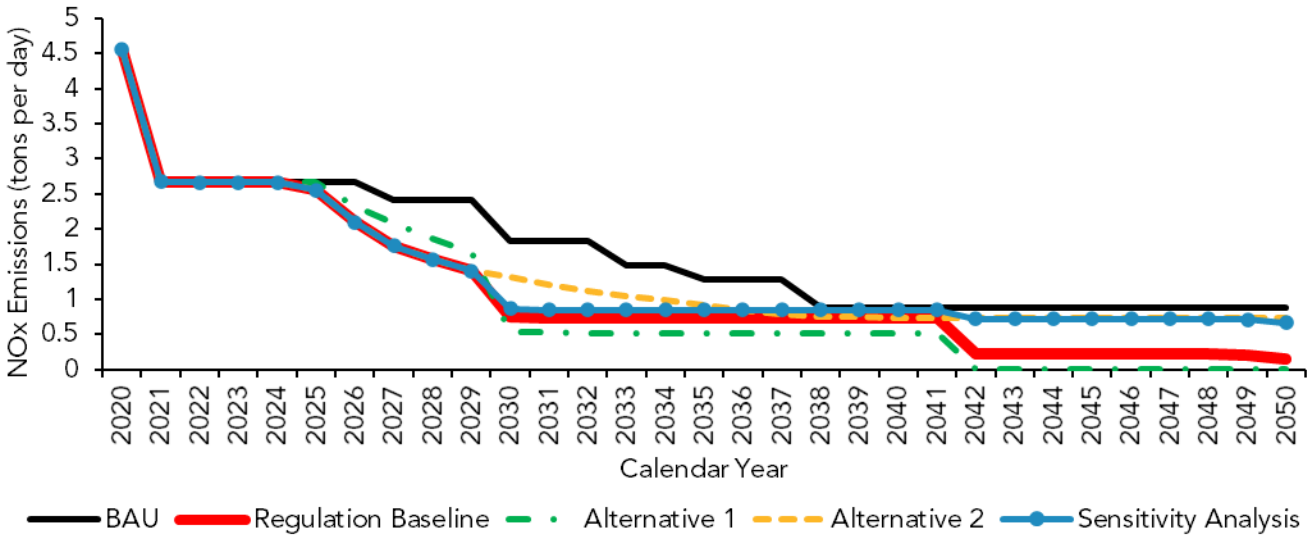


Figure 32 displays Passenger rail statewide NOx emissions for the Proposed Regulation scenario, the three additional scenarios (Alternative 1, Alternative 2, and Sensitivity Analysis), and the inventory baseline emissions (noted as BAU).

Figure 32: Passenger NOx Emissions with Reduction Scenarios



E. Industrial Locomotives

The Industrial Locomotive Inventory[20] represents industrial operators using locomotives typically to move their products within and around their facility (not captured by the Class III Short line rail inventory). It is responsible for 0.76 percent of the total NOx emissions from the locomotive sector in California. Industrial locomotives are a subset of the Military and Industrial Locomotives inventory and account for 98 percent of NOx emissions from this inventory. The industrial locomotive category includes 39 California industrial operators with 72 locomotives. The average age of Industrial locomotives operating in California is approximately 50. As forementioned, the Proposed Regulation excludes military locomotives.

Industrial locomotive operators provided data, including Locomotive ID, model year, emissions tier, locomotive build year, frame ID, annual fuel consumption, etc. According to the historical trend of annual fuel consumption, no significant growth is expected in the future; therefore, activity is assumed to remain constant.

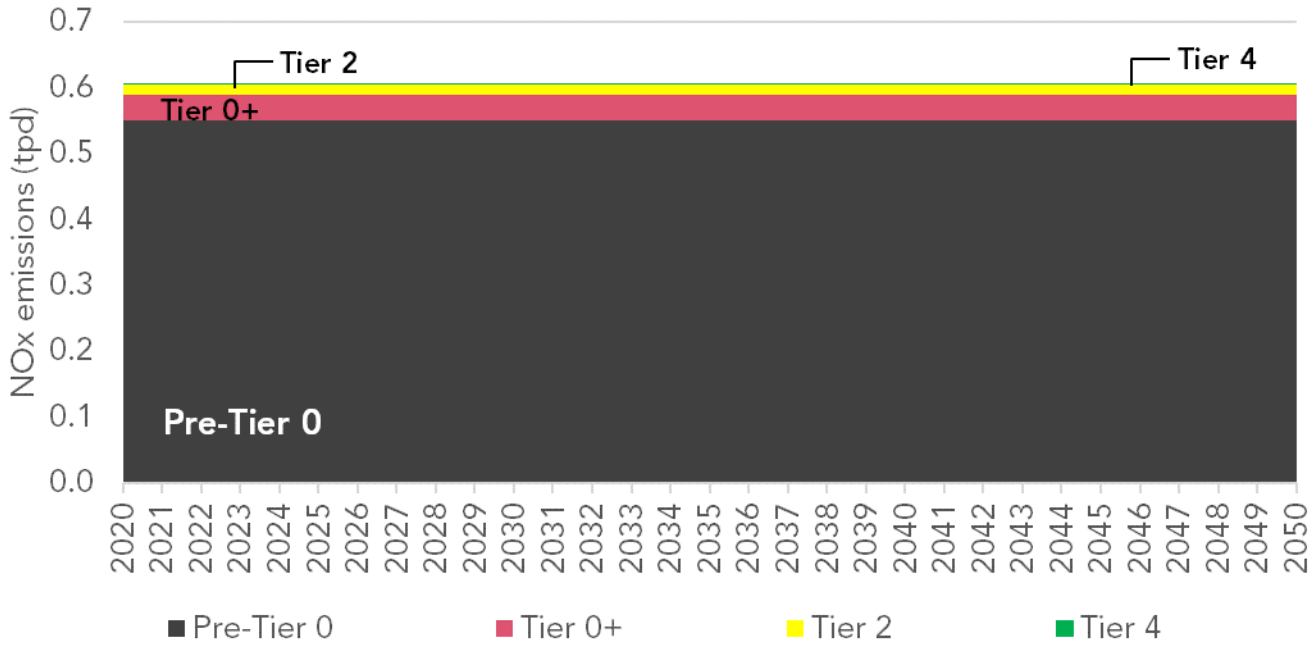
The applied regulation concepts are consistent with all previous rail strategies. CARB staff calculated the Spending Account funds collected from 2024 for each railroad and determined the schedule and the number of locomotives replaced. The IUOR aims to replace the most in-use industrial locomotives in 2030, and the Spending Account balance contributes to purchasing ZE Locomotives in 2029.

The regulation inventory assumes that locomotive replacement does not change the utilization rate of the locomotive. Once an old (23-year-old and older) diesel industrial locomotive is retired, it is assumed a new ZE locomotive takes over the same duties and

[20] CARB, 2022 Military and Industrial Locomotive Emission Inventory, July 2022. (weblink: *https://ww2.arb.ca.gov/sites/default/files/2022-07/2022%20MI%20Locomotive%20Emission%20Inventory%20Document%2007112022%20ADA%20Checked.pdf).*

workload (activity in MWhs) as the retired unit. Figure 33 shows statewide industrial NOx emissions at about 0.6 tpd, with Pre-Tier 0 locomotives responsible for 91 percent of the total NOx emissions.

Figure 33: Statewide Industrial Locomotive NOx Emission Projections by Tier



1. Industrial Locomotive Emission Reductions

Figure 34 shows the industrial locomotive activity of the Proposed Regulation scenario, which incorporates the Spending Account and IUOR. Implementation of the Spending Account results in immediate emission reductions beginning in 2025 by eliminating a significant impact of Pre-Tier 0 locomotives.

Figure 34: Industrial Locomotive Activity and NOx Emissions with Proposed Regulation Scenario

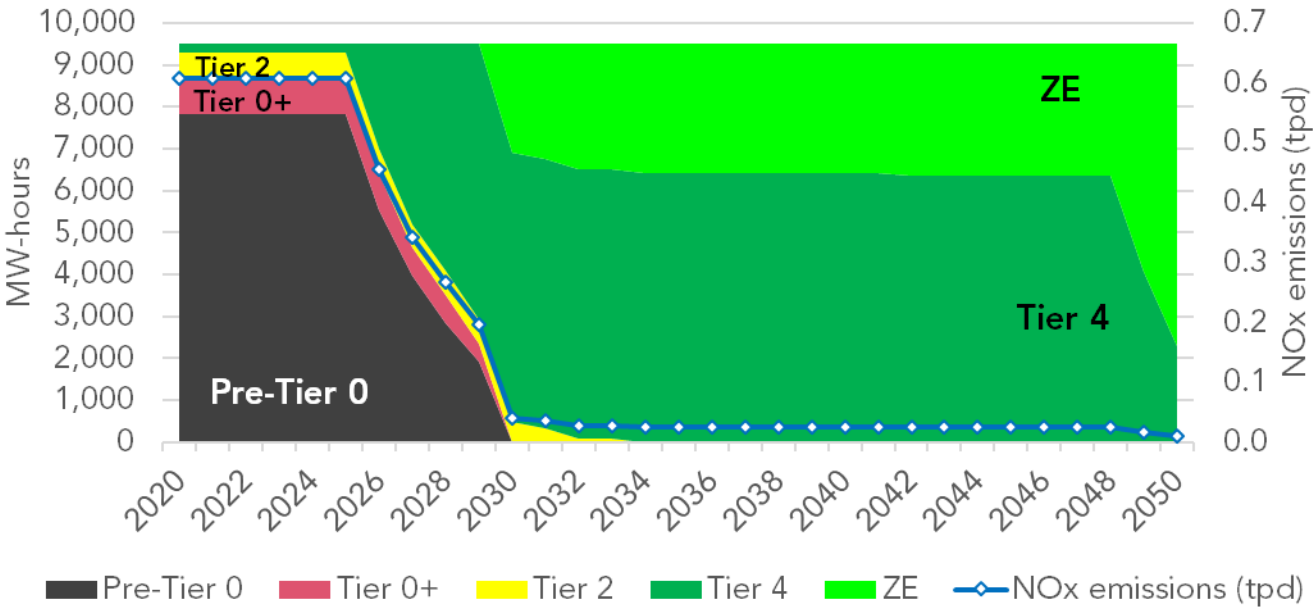
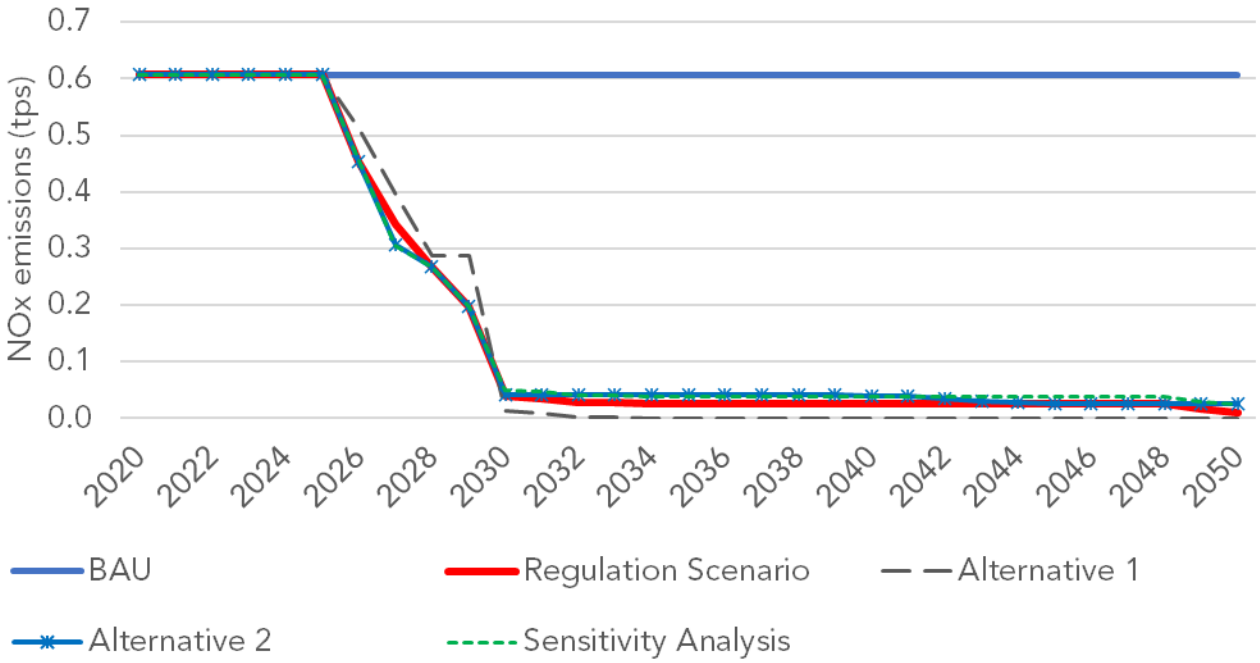


Figure 35 shows Industrial Locomotive statewide NOx emissions for the Proposed Regulation and three additional scenarios (Alternative 1, Alternative 2, and Sensitivity Analysis).

Figure 35: Statewide Industrial Locomotive NOx Emissions with Reduction Scenarios



V. Statewide Locomotive Emissions

This section first looks at NOx emissions and then PM emissions for all locomotive categories according to the four emission reduction scenarios, and then explains the emission reductions achieved.

A. NOx Emissions by Scenario

Table 5 lists the estimated NOx emissions for the Proposed Regulation scenario, including use of the Spending Account and IUOR for each locomotive category, followed by analysis of the additional three scenarios.

Table 5: Statewide Locomotive NOx Emissions (tpd) for Proposed Regulation Scenario

Year	Line Haul	Switcher	Short line	Passenger	Industrial	Total
2020	69.91	4.27	1.73	4.55	0.61	81.08
2021	71.01	4.37	1.73	2.67	0.61	80.39
2022	72.16	4.46	1.73	2.66	0.61	81.62
2023	73.36	4.56	1.73	2.66	0.61	82.92
2024	74.37	4.66	1.73	2.66	0.61	84.04
2025	74.36	4.66	1.69	2.56	0.61	83.88
2026	72.90	4.38	1.51	2.10	0.45	81.34
2027	71.53	4.20	1.33	1.76	0.34	79.16
2028	70.01	4.01	1.18	1.57	0.27	77.04
2029	68.68	3.84	1.05	1.41	0.20	75.17
2030	37.43	0.66	0.39	0.75	0.04	39.28
2031	34.33	0.18	0.38	0.74	0.04	35.67
2032	33.72	0.18	0.37	0.74	0.03	35.03
2033	32.99	0.18	0.09	0.74	0.03	34.03
2034	32.49	0.18	0.08	0.74	0.03	33.51
2035	24.09	0.18	0.08	0.74	0.03	25.11
2036	18.99	0.18	0.08	0.74	0.03	20.01
2037	13.19	0.17	0.08	0.74	0.03	14.21
2038	13.14	0.14	0.08	0.74	0.03	14.13
2039	12.76	0.14	0.08	0.74	0.03	13.75
2040	12.60	0.13	0.08	0.74	0.03	13.58
2041	12.53	0.14	0.08	0.74	0.03	13.51
2042	12.49	0.14	0.08	0.22	0.03	12.96
2043	12.45	0.14	0.08	0.22	0.03	12.92
2044	12.40	0.15	0.08	0.22	0.03	12.88
2045	12.35	0.15	0.08	0.22	0.03	12.83
2046	12.31	0.15	0.08	0.22	0.03	12.79
2047	12.50	0.15	0.08	0.22	0.03	12.98
2048	12.05	0.16	0.08	0.22	0.03	12.54
2049	11.42	0.15	0.07	0.21	0.02	11.88
2050	10.79	0.11	0.05	0.16	0.01	11.12

Tables 6, 7, and 8 list the estimated NOx emissions for Alternative 1, Alternative 2, and Sensitivity Analysis scenarios from each locomotive sector, respectively.

Table 6: Statewide Locomotive NOx Emissions (tpd) for Alternative 1

Year	Line Haul	Switcher	Short line	Passenger	Industrial	Total
2020	69.91	4.27	1.73	4.55	0.61	81.08
2021	71.01	4.37	1.73	2.67	0.61	80.39
2022	72.16	4.46	1.73	2.66	0.61	81.62
2023	73.36	4.56	1.73	2.66	0.61	82.92
2024	74.37	4.66	1.73	2.66	0.61	84.04
2025	75.00	4.76	1.73	2.66	0.61	84.77
2026	76.23	4.54	1.55	2.32	0.51	85.14
2027	77.65	4.35	1.40	2.09	0.40	85.88
2028	78.96	4.19	1.27	1.87	0.29	86.58
2029	80.51	4.06	1.16	1.67	0.29	87.68
2030	37.43	0.56	0.31	0.53	0.01	38.85
2031	34.33	0.08	0.30	0.53	0.01	35.25
2032	33.72	0.07	0.29	0.52	0.00	34.61
2033	32.99	0.08	0.01	0.51	0.00	33.59
2034	32.49	0.07	0.00	0.51	0.00	33.07
2035	18.55	0.07	0.00	0.51	0.00	19.13
2036	13.45	0.07	0.00	0.51	0.00	14.03
2037	13.19	0.07	0.00	0.51	0.00	13.78
2038	13.14	0.01	0.00	0.51	0.00	13.67
2039	12.76	0.01	0.00	0.51	0.00	13.29
2040	12.60	0.00	0.00	0.51	0.00	13.12
2041	12.53	0.00	0.00	0.51	0.00	13.05
2042	12.49	0.00	0.00	0.00	0.00	12.49
2043	12.45	0.00	0.00	0.00	0.00	12.45
2044	12.40	0.00	0.00	0.00	0.00	12.40
2045	12.35	0.00	0.00	0.00	0.00	12.35
2046	12.31	0.00	0.00	0.00	0.00	12.31
2047	12.50	0.00	0.00	0.00	0.00	12.50
2048	12.18	0.00	0.00	0.00	0.00	12.18
2049	12.14	0.00	0.00	0.00	0.00	12.14
2050	12.10	0.00	0.00	0.00	0.00	12.10

Table 7: Statewide Locomotive NOx Emissions (tpd) for Alternative 2

Year	Line Haul	Switcher	Short line	Passenger	Industrial	Total
2020	69.91	4.27	1.73	4.55	0.61	81.08
2021	71.01	4.37	1.73	2.67	0.61	80.39
2022	72.16	4.46	1.73	2.66	0.61	81.62
2023	73.36	4.56	1.73	2.66	0.61	82.92
2024	74.37	4.66	1.73	2.66	0.61	84.04

Year	Line Haul	Switcher	Short line	Passenger	Industrial	Total
2025	74.36	4.66	1.69	2.56	0.61	83.88
2026	72.90	4.38	1.51	2.10	0.45	81.34
2027	71.53	4.20	1.33	1.76	0.31	79.12
2028	70.01	4.01	1.18	1.57	0.27	77.04
2029	68.68	3.84	1.05	1.41	0.22	75.19
2030	66.72	3.72	0.39	1.32	0.04	72.21
2031	63.40	3.60	0.38	1.20	0.04	68.62
2032	60.93	3.48	0.37	1.12	0.04	65.94
2033	59.06	3.38	0.35	1.04	0.04	63.88
2034	55.49	3.29	0.34	1.00	0.04	60.15
2035	45.39	3.19	0.32	0.92	0.04	49.87
2036	41.17	0.75	0.31	0.84	0.04	43.11
2037	33.41	0.74	0.30	0.80	0.04	35.29
2038	30.39	0.73	0.28	0.76	0.04	32.20
2039	25.83	0.71	0.27	0.75	0.04	27.60
2040	23.42	0.69	0.26	0.74	0.04	25.15
2041	21.99	0.68	0.25	0.74	0.04	23.70
2042	20.89	0.66	0.24	0.74	0.04	22.57
2043	19.89	0.23	0.23	0.74	0.03	21.12
2044	19.67	0.23	0.22	0.74	0.03	20.89
2045	19.60	0.23	0.09	0.74	0.03	20.68
2046	19.57	0.22	0.08	0.74	0.03	20.64
2047	15.81	0.22	0.08	0.74	0.03	16.87
2048	11.92	0.22	0.08	0.74	0.03	12.99
2049	7.93	0.21	0.08	0.74	0.03	8.98
2050	7.93	0.18	0.08	0.74	0.03	8.95

Table 8: Statewide Locomotive NOx Emissions (tpd) for Sensitivity Analysis

Year	Line Haul	Switcher	Short line	Passenger	Industrial	Total
2020	69.91	4.27	1.73	4.55	0.61	81.08
2021	71.01	4.37	1.73	2.67	0.61	80.39
2022	72.16	4.46	1.73	2.66	0.61	81.62
2023	73.36	4.56	1.73	2.66	0.61	82.92
2024	74.37	4.66	1.73	2.66	0.61	84.04
2025	74.36	4.66	1.69	2.56	0.61	83.88
2026	72.90	4.38	1.51	2.10	0.45	81.34
2027	71.53	4.20	1.33	1.76	0.31	79.12
2028	70.01	4.01	1.18	1.57	0.27	77.04
2029	68.68	3.84	1.05	1.41	0.20	75.17
2030	37.43	0.81	0.47	0.87	0.05	39.64
2031	34.33	0.35	0.45	0.85	0.05	36.04
2032	33.72	0.34	0.43	0.85	0.04	35.39
2033	32.99	0.34	0.20	0.85	0.04	34.43

Year	Line Haul	Switcher	Short line	Passenger	Industrial	Total
2034	32.49	0.34	0.20	0.85	0.04	33.92
2035	24.61	0.34	0.20	0.85	0.04	26.05
2036	20.69	0.34	0.20	0.85	0.04	22.12
2037	16.27	0.33	0.20	0.85	0.04	17.70
2038	16.51	0.33	0.20	0.85	0.04	17.93
2039	16.79	0.34	0.20	0.85	0.04	18.22
2040	17.06	0.34	0.20	0.85	0.04	18.50
2041	17.34	0.35	0.20	0.85	0.04	18.78
2042	17.62	0.36	0.20	0.72	0.04	18.94
2043	17.90	0.36	0.20	0.72	0.04	19.23
2044	18.19	0.37	0.20	0.72	0.04	19.52
2045	18.47	0.38	0.20	0.72	0.04	19.81
2046	18.75	0.39	0.20	0.72	0.04	20.10
2047	19.03	0.40	0.20	0.72	0.04	20.39
2048	19.31	0.40	0.20	0.72	0.04	20.68
2049	19.58	0.40	0.20	0.71	0.03	20.92
2050	19.86	0.39	0.18	0.67	0.02	21.12

Figure 36, Figure 37, Figure 38, and Figure 39 display NOx emissions for each proposed scenario by locomotive sector (stacked area) compared to the combined BAU NOx emissions (line).

Figure 36: Combined Statewide NOx Emissions for Proposed Regulation

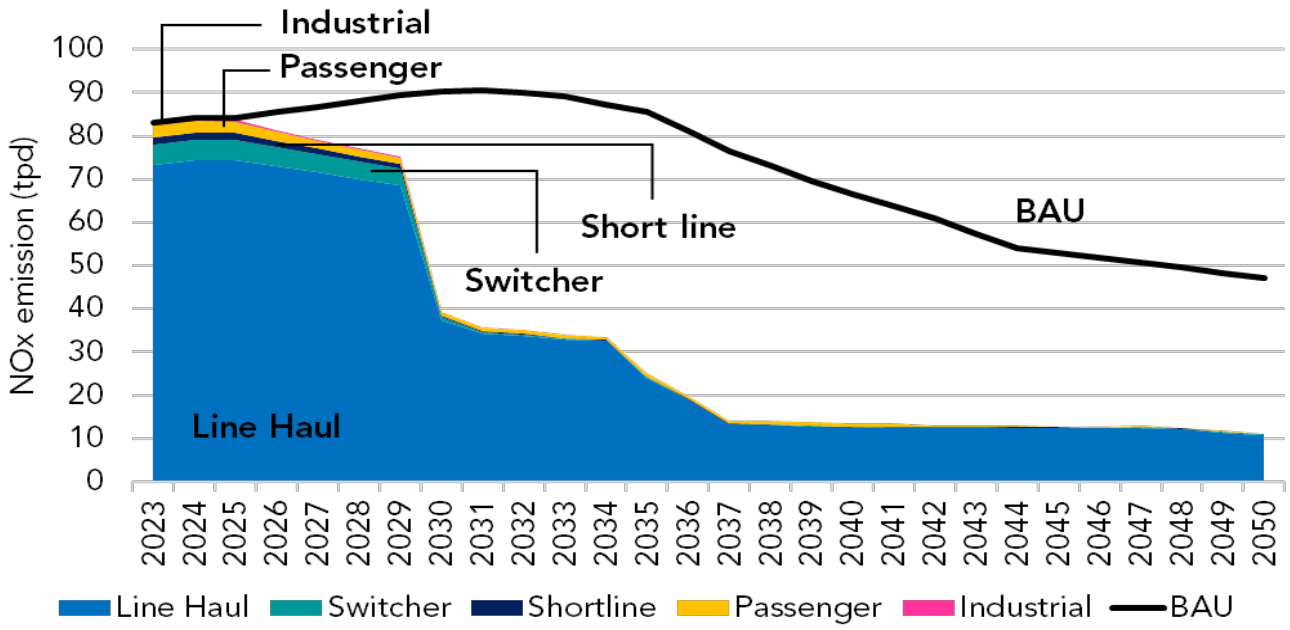


Figure 37: Combined Statewide NOx Emissions for Alternative 1

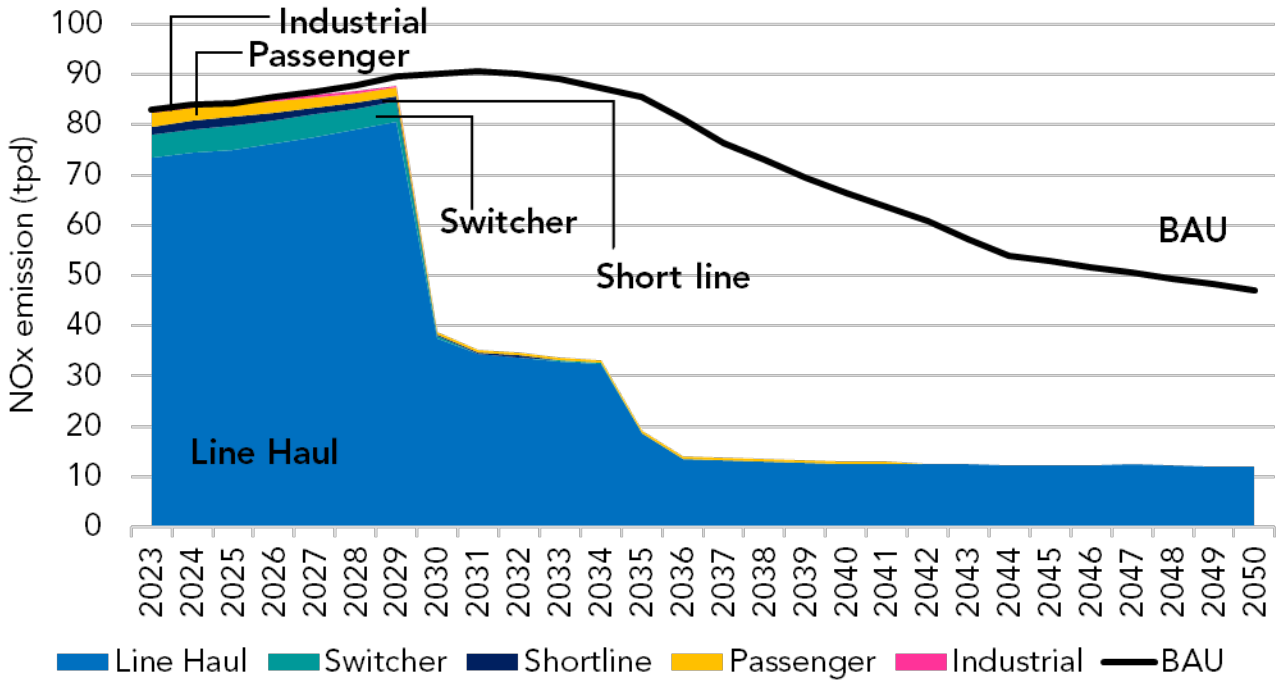


Figure 38. Combined Statewide NOx Emissions for Alternative 2

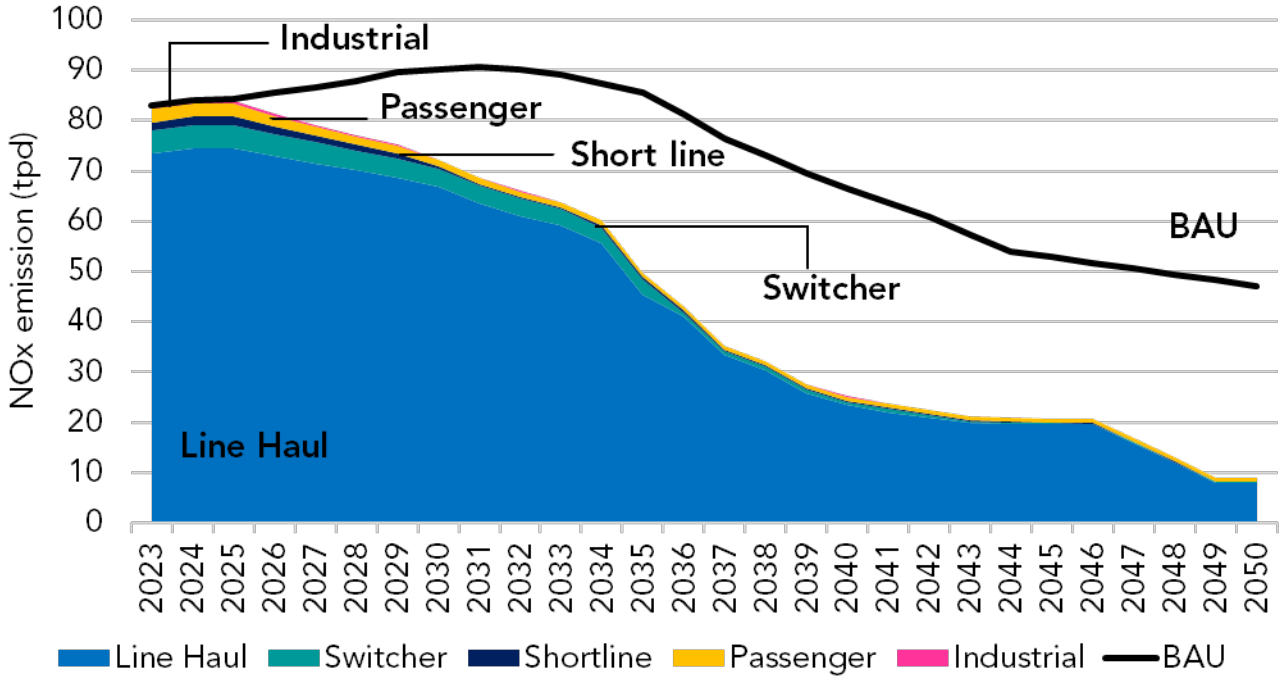
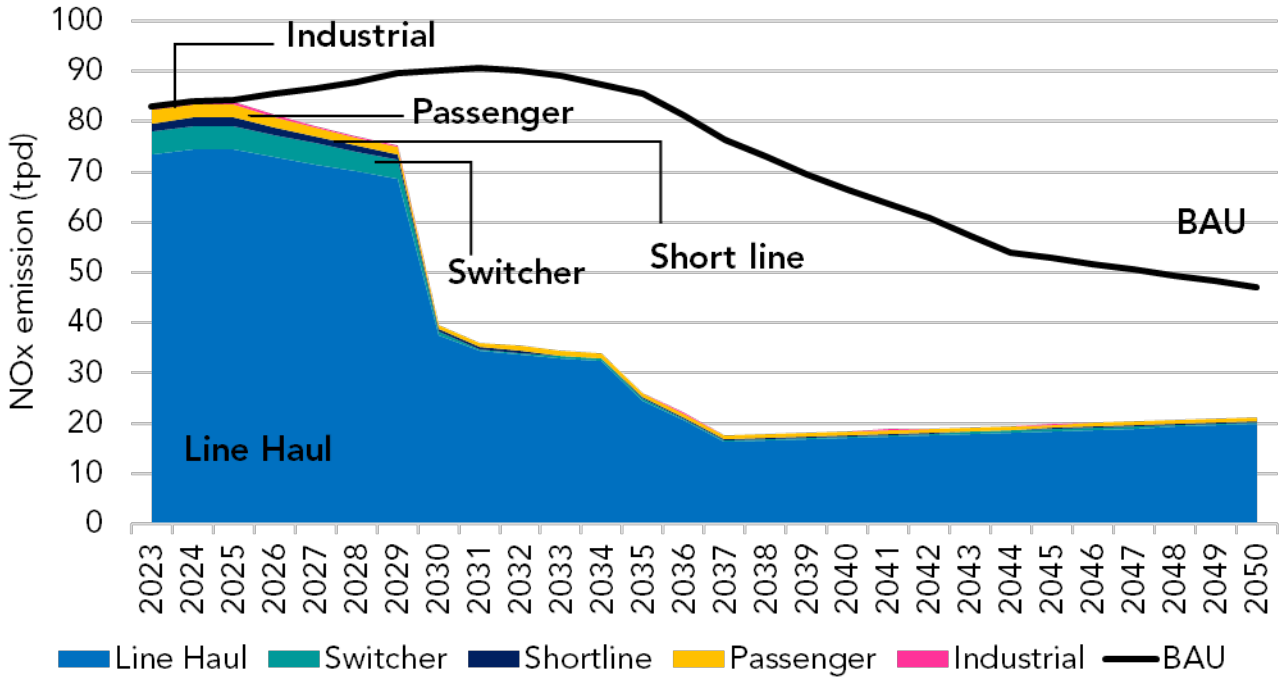


Figure 39. Combined Statewide NOx Emissions for Sensitivity Analysis Scenario



B. PM Emissions by Scenario

The estimated PM emissions of the scenarios considered are presented in Tables 9, 10, 11, and 12, respectively.

Table 9: Statewide Locomotive PM Emissions (tpd) for Proposed Regulation Scenario

Year	Line Haul	Switcher	Short line	Passenger	Industrial	Total
2020	1.729	0.092	0.029	0.085	0.015	1.950
2021	1.728	0.094	0.029	0.053	0.015	1.919
2022	1.733	0.096	0.029	0.052	0.015	1.925
2023	1.741	0.098	0.029	0.052	0.015	1.936
2024	1.737	0.100	0.029	0.052	0.015	1.934
2025	1.708	0.100	0.029	0.051	0.015	1.899
2026	1.652	0.094	0.029	0.043	0.011	1.908
2027	1.603	0.089	0.029	0.034	0.008	1.922
2028	1.550	0.083	0.029	0.029	0.006	1.936
2029	1.506	0.077	0.029	0.025	0.005	1.961
2030	0.597	0.009	0.029	0.011	0.001	1.963
2031	0.543	0.003	0.029	0.011	0.001	1.933
2032	0.532	0.003	0.029	0.011	0.000	1.894
2033	0.519	0.003	0.029	0.011	0.000	1.844
2034	0.510	0.003	0.029	0.011	0.000	1.771
2035	0.374	0.003	0.029	0.011	0.000	1.745
2036	0.292	0.003	0.029	0.011	0.000	1.593

2037	0.198	0.003	0.029	0.011	0.000	1.497
2038	0.197	0.002	0.029	0.011	0.000	1.421
2039	0.191	0.002	0.029	0.011	0.000	1.340
2040	0.189	0.002	0.029	0.011	0.000	1.267
2041	0.188	0.002	0.029	0.011	0.000	1.192
2042	0.187	0.002	0.029	0.003	0.000	1.111
2043	0.187	0.002	0.029	0.003	0.000	1.017
2044	0.186	0.002	0.029	0.003	0.000	0.922
2045	0.185	0.002	0.029	0.003	0.000	0.900
2046	0.185	0.002	0.029	0.003	0.000	0.879
2047	0.187	0.002	0.029	0.003	0.000	0.859
2048	0.181	0.002	0.029	0.003	0.000	0.839
2049	0.171	0.002	0.029	0.003	0.000	0.819
2050	0.162	0.002	0.029	0.002	0.000	0.799

Table 10: Statewide Locomotive PM Emissions (tpd) for Alternative 1

Year	Line Haul	Switcher	Short line	Passenger	Industrial	Total
2020	1.729	0.092	0.029	0.085	0.015	1.950
2021	1.728	0.094	0.029	0.053	0.015	1.919
2022	1.733	0.096	0.029	0.052	0.015	1.925
2023	1.741	0.098	0.029	0.052	0.015	1.936
2024	1.737	0.100	0.029	0.052	0.015	1.934
2025	1.724	0.102	0.029	0.052	0.015	1.923
2026	1.734	0.098	0.026	0.047	0.013	1.917
2027	1.753	0.093	0.023	0.043	0.010	1.923
2028	1.769	0.089	0.021	0.038	0.007	1.924
2029	1.795	0.084	0.019	0.033	0.007	1.939
2030	0.597	0.007	0.005	0.008	0.000	0.618
2031	0.543	0.001	0.005	0.008	0.000	0.557
2032	0.532	0.001	0.005	0.008	0.000	0.546
2033	0.519	0.001	0.000	0.008	0.000	0.528
2034	0.510	0.001	0.000	0.008	0.000	0.519
2035	0.284	0.001	0.000	0.008	0.000	0.293
2036	0.202	0.001	0.000	0.008	0.000	0.211
2037	0.198	0.001	0.000	0.008	0.000	0.207
2038	0.197	0.000	0.000	0.008	0.000	0.205
2039	0.191	0.000	0.000	0.008	0.000	0.199
2040	0.189	0.000	0.000	0.008	0.000	0.197
2041	0.188	0.000	0.000	0.008	0.000	0.196
2042	0.187	0.000	0.000	0.000	0.000	0.187
2043	0.187	0.000	0.000	0.000	0.000	0.187
2044	0.186	0.000	0.000	0.000	0.000	0.186
2045	0.185	0.000	0.000	0.000	0.000	0.185
2046	0.185	0.000	0.000	0.000	0.000	0.185

Year	Line Haul	Switcher	Short line	Passenger	Industrial	Total
2047	0.187	0.000	0.000	0.000	0.000	0.187
2048	0.183	0.000	0.000	0.000	0.000	0.183
2049	0.182	0.000	0.000	0.000	0.000	0.182
2050	0.181	0.000	0.000	0.000	0.000	0.181

Table 11: Statewide Locomotive PM Emissions (tpd) for Alternative 2

Year	Line Haul	Switcher	Short line	Passenger	Industrial	Total
2020	1.729	0.092	0.029	0.085	0.015	1.950
2021	1.728	0.094	0.029	0.053	0.015	1.919
2022	1.733	0.096	0.029	0.052	0.015	1.925
2023	1.741	0.098	0.029	0.052	0.015	1.936
2024	1.737	0.100	0.029	0.052	0.015	1.934
2025	1.708	0.100	0.028	0.051	0.015	1.903
2026	1.652	0.094	0.025	0.043	0.011	1.826
2027	1.603	0.089	0.022	0.034	0.007	1.755
2028	1.550	0.083	0.020	0.029	0.006	1.688
2029	1.506	0.077	0.017	0.025	0.005	1.631
2030	1.408	0.073	0.006	0.024	0.001	1.513
2031	1.284	0.070	0.006	0.021	0.001	1.382
2032	1.193	0.066	0.006	0.019	0.001	1.285
2033	1.120	0.063	0.006	0.018	0.001	1.207
2034	1.010	0.061	0.005	0.017	0.001	1.094
2035	0.766	0.059	0.005	0.015	0.001	0.846
2036	0.662	0.010	0.005	0.013	0.001	0.691
2037	0.536	0.010	0.005	0.012	0.001	0.563
2038	0.485	0.010	0.004	0.011	0.001	0.512
2039	0.411	0.010	0.004	0.011	0.001	0.437
2040	0.371	0.009	0.004	0.011	0.001	0.396
2041	0.347	0.009	0.004	0.011	0.001	0.372
2042	0.329	0.009	0.004	0.011	0.001	0.354
2043	0.312	0.004	0.004	0.011	0.001	0.331
2044	0.309	0.004	0.003	0.011	0.000	0.327
2045	0.308	0.004	0.001	0.011	0.000	0.324
2046	0.307	0.004	0.001	0.011	0.000	0.323
2047	0.246	0.003	0.001	0.011	0.000	0.262
2048	0.183	0.003	0.001	0.011	0.000	0.200
2049	0.119	0.003	0.001	0.011	0.000	0.135
2050	0.119	0.003	0.001	0.011	0.000	0.134

Table 12: Statewide Locomotive PM Emissions (tpd) for Sensitivity Analysis

Year	Line Haul	Switcher	Short line	Passenger	Industrial	Total
2020	1.729	0.092	0.029	0.085	0.015	1.950
2021	1.728	0.094	0.029	0.053	0.015	1.919

Year	Line Haul	Switcher	Short line	Passenger	Industrial	Total
2022	1.733	0.096	0.029	0.052	0.015	1.925
2023	1.741	0.098	0.029	0.052	0.015	1.936
2024	1.737	0.100	0.029	0.052	0.015	1.934
2025	1.708	0.100	0.028	0.051	0.015	1.903
2026	1.652	0.094	0.025	0.043	0.011	1.826
2027	1.603	0.089	0.022	0.034	0.007	1.755
2028	1.550	0.083	0.020	0.029	0.006	1.688
2029	1.506	0.077	0.017	0.025	0.005	1.630
2030	0.597	0.011	0.007	0.013	0.001	0.629
2031	0.543	0.005	0.007	0.013	0.001	0.569
2032	0.532	0.005	0.007	0.013	0.001	0.557
2033	0.519	0.005	0.003	0.013	0.001	0.541
2034	0.510	0.005	0.003	0.013	0.001	0.531
2035	0.382	0.005	0.003	0.013	0.001	0.403
2036	0.317	0.005	0.003	0.013	0.001	0.339
2037	0.244	0.005	0.003	0.013	0.001	0.265
2038	0.248	0.005	0.003	0.013	0.001	0.269
2039	0.252	0.005	0.003	0.013	0.001	0.273
2040	0.256	0.005	0.003	0.013	0.001	0.277
2041	0.260	0.005	0.003	0.013	0.001	0.282
2042	0.264	0.005	0.003	0.011	0.001	0.284
2043	0.269	0.005	0.003	0.011	0.001	0.288
2044	0.273	0.006	0.003	0.011	0.001	0.293
2045	0.277	0.006	0.003	0.011	0.001	0.297
2046	0.281	0.006	0.003	0.011	0.001	0.301
2047	0.285	0.006	0.003	0.011	0.001	0.306
2048	0.290	0.006	0.003	0.011	0.001	0.310
2049	0.294	0.006	0.003	0.011	0.000	0.314
2050	0.298	0.006	0.003	0.010	0.000	0.317