California Air Resources Board

Appendix E

Development Process for the Spending Account Equation and Inputs

Prepared for the Proposed In-Use Locomotive Regulation

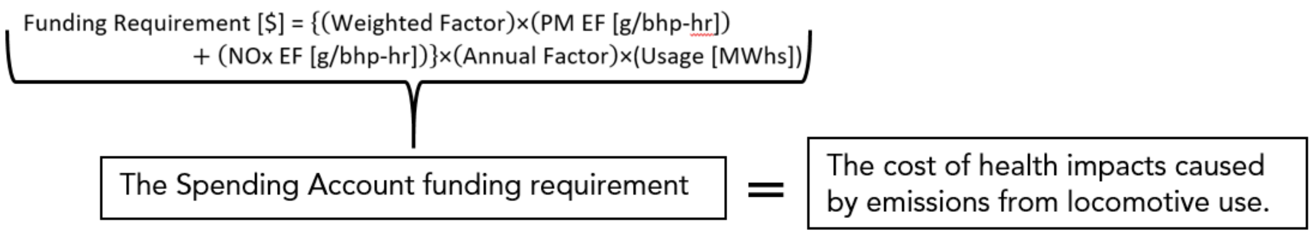
Contents

This appendix explains the development process California Air Resources Board (CARB) staff used to create the Spending Account equation and Weighted Factor and Annual Factor inputs used for calculating the Spending Account funding requirement included in the draft In-Use Locomotive Regulation, hereafter referred to as the "Proposed Regulation."

I. Background

The Proposed Regulation requires all California locomotive operators to set aside funds in a Spending Account (SA) to be used for the purchase, lease, or rental of Tier 4, zero emission (ZE) or ZE capable locomotives, ZE rail equipment, ZE infrastructure, or ZE demonstration or pilots. As shown in Figure I-1, the funding requirement, the amount to be set aside in the SA, is based on the estimated cost to Californians due to adverse health effects from the amount of pollution emitted by the operator's locomotives in California, determined by locomotive emission factors and usage.

Figure I-1: Spending Account Calculation



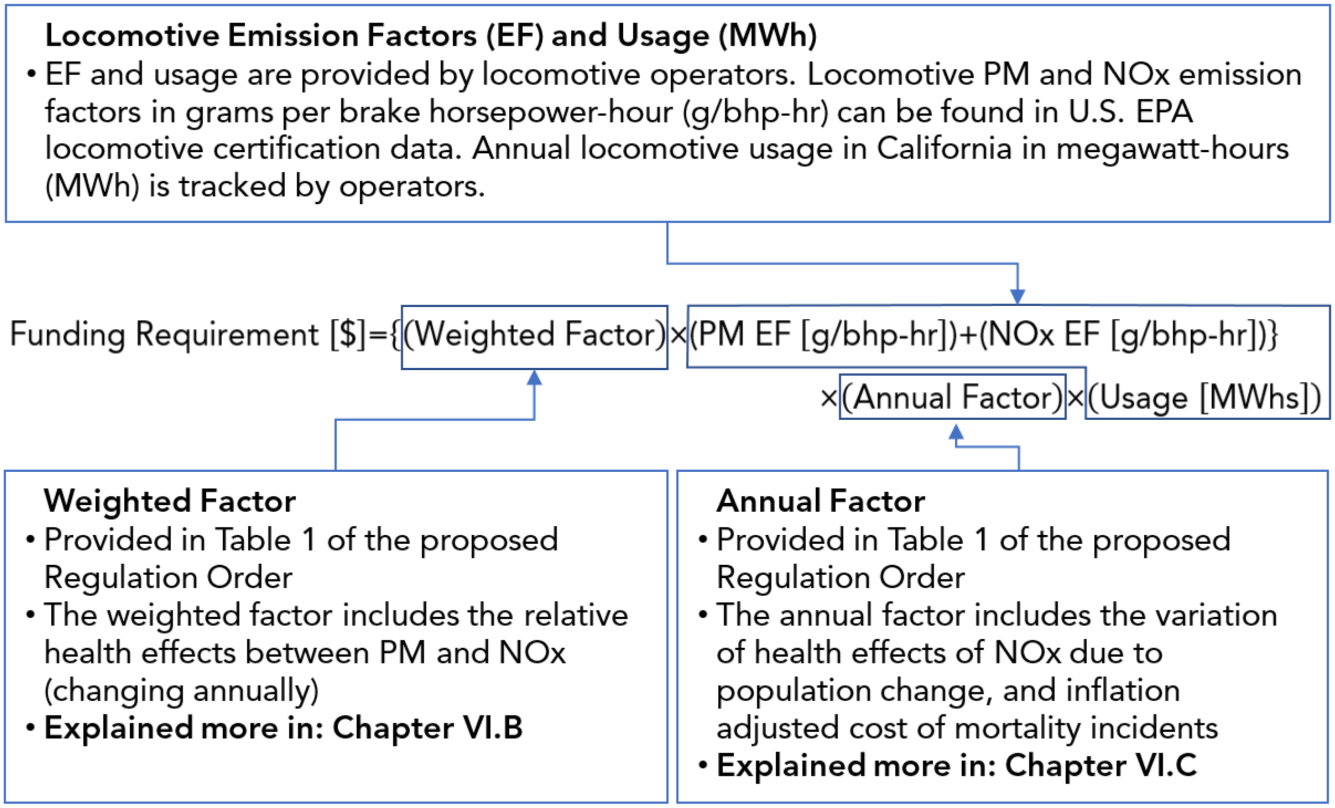
The incidence-per-ton (IPT) methodology developed by CARB[1,2] is used to calculate the adverse health effects, such as cardiopulmonary mortality, from diesel emissions in California. This document describes how staff used the IPT methodology to calculate the number of cardiopulmonary mortality incidents from locomotive emissions based on emission factors and locomotive usage. While the IPT methodology can also calculate numbers of hospitalization and emergency room visits, staff used only numbers of cardiopulmonary mortality incidents from locomotive emissions for the development of the inputs for the spending account equation because the cardiopulmonary mortality incidents account for 99.8 percent of the cost of the adverse health effects. This document further describes how staff developed the spending account equation and inputs using costs due to cardiopulmonary mortality incidents.

Figure I-2 shows an overview of the development of the spending account equation and inputs. The diagram explains what each input is and in what chapters of this document more details can be found.

[1] CARB, Methodology for Estimating Ambient Concentrations of Particulate Matter from Diesel-Fueled Engine Emissions, 2010. (weblink: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2010/truckbus10/correctedappj.pdf).

[2] CARB, Estimating the Health Benefits of Reductions in Emissions of PM2.5 or its Precursors: Short Description, accessed June 15, 2022. (weblink: https://ww2.arb.ca.gov/resources/documents/estimating-health-benefits-reductions-emissions-pm25-or-its-precursors-short).

Figure I-2: Overview of Development of Spending Account Equations and Inputs



II. Incidence-Per-Ton Methodology

Reductions in fine particulate matter (PM2.5) emissions are associated with reductions in the risk of premature deaths, hospitalizations, and emergency room visits.[3] To estimate the health benefits resulting from the reduction of PM2.5 emitted directly from sources and from PM2.5 formed from precursor oxides of nitrogen (NOx) by chemical processes in the atmosphere, CARB uses the Incident Per Ton (IPT) methodology.[4] CARB's IPT methodology is based on the methodology developed by U.S. EPA.[5]

The basis of the IPT methodology is that changes in emissions are approximately proportional to changes in health outcomes. The IPT factors used in the IPT Methodology equal the number of PM-related health effects divided by emissions of PM2.5 or the precursor NOx. The health outcome is calculated separately for each air basin.

Because of the approximate linear relationship assumed between premature deaths (or other health outcomes) and emission concentrations, the number of premature deaths can be estimated by multiplying emissions by the IPT factor. The IPT factors are used to estimate the

[3] U.S. EPA, Quantitative Health Risk Assessment for Particulate Matter, June 2010. (weblink: https://www3.epa.gov/ttn/naaqs/standards/pm/data/PM_RA_FINAL_June_2010.pdf).

[4] CARB, Methodology for Estimating Ambient Concentrations of Particulate Matter from Diesel-Fueled Engine Emissions, 2010. (weblink: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2010/truckbus10/correctedappj.pdf).

[5] CARB, Estimating the Health Benefits of Reductions in Emissions of PM2.5 or its Precursors: Short Description, accessed June 15, 2022. (weblink: https://ww2.arb.ca.gov/resources/documents/estimating-health-benefits-reductions-emissions-pm25-or-its-precursors-short).

reduction in health outcomes achieved by CARB regulations. For future years, the IPT factors are adjusted to account for population growth. CARB's current IPT factors are based on a 2014-2016 baseline scenario used to develop the IPT methodology.

CARB's Estimating Health Benefits Associated with Reductions in Diesel Particulate Matter and NOx Emissions provides a detailed explanation of how health impacts are estimated.[6]

III. Spending Account Equation and Inputs

The SA equation found in the Proposed Regulation is used to calculate the annual funding requirement for each locomotive based on how much the locomotive is operated each annually (usage). Locomotive operators track individual locomotive usage on a megawatt-hour (MWh) basis.

The SA funding requirement is based on the cost of the negative health outcomes of using the locomotive. One MWh of locomotive use and the associated emissions have different health outcomes depending on the air basin[7] where the emissions occur. To simplify the spending account equation, staff averaged the health outcomes per MWh of locomotive usage in different air basins into a single California average value. Because the health outcomes from different air basins are averaged, the spending account equation needs only the total California usage.

The health outcome per MWh of locomotive usage also depends on how much PM2.5 and NOx the locomotive emits per MWh of usage. The same amount of PM2.5 and NOx have different health outcomes. One gram of PM2.5 can cause several times more negative health incidents than one gram of NOx. PM2.5 and NOx have different health effects depending on the population distribution of a region and a regions topography. Different air basins have different population density, and NOx and PM2.5 affect them differently. The Spending Account's Weighted Factor and Annual Factor inputs account for the health impact differences of one gram of PM2.5 compared to one gram of NOx and average the health outcomes of varying air basins.

Prior to developing the Annual Factor, staff needed to determine air basin health outcomes from locomotive emissions. Staff used a draft Class I line haul and switch locomotive inventory to develop the Weighted Factor and Annual Factor inputs for the SA equation. Updated Class III, passenger, and industrial locomotive inventories were not yet available when developing the SA equation or equation inputs. However, accounting for Class III, passenger, and industrial locomotives does not greatly change the results of the SA equation inputs used for the Proposed Regulation (less than a one to five percent difference overall). This is because Class I and other categories of locomotives share the same tracks or are operationally dependent on one another, thus their activities occur in the same or adjacent air basins. Additionally, Class I locomotive activities are several times larger than the other categories and the air basin distribution is weighted heavily towards the distribution of Class I

[6] CARB, Estimating Health Benefits Associated with Reductions in PM and NOx Emissions: Detailed Description, 2019. (weblink: https://ww2.arb.ca.gov/sites/default/files/2019-08/Estimating%20the%20Health%20Benefits%20Associated%20with%20Reductions%20in%20PM%20and%20NOX%20Emissions%20-%20Detailed%20Description.pdf).

[7] California is divided geographically into air basins for the purpose of managing the air resources of the state on a regional basis. An air basin generally has similar meteorological and geographic conditions throughout. California is currently divided into 15 air basins.

locomotive emissions. Staff used the Class I line haul and switch locomotive inventory as the representative locomotive activity distribution in California because they account for the majority of the California locomotive activity, and locomotive activities of other operators depend on their operations.

(a) To verify the validity of the initial input calculations for the Proposed Regulation, once CARB's 2022 In-Use Locomotive Emission Inventory: Regulatory Scenarios were completed, staff analyzed how the SA equation inputs would change if the final locomotive emissions inventories were used. Staff determined updating the SA inputs by using the final emission inventory would have increased the SA fund requirement on average by one to five percent and chose to continue with proposing the SA fund amount more favorable to operators. Staff did not update the SA equation inputs to reflect the final emission inventory.

IV. Less Commonly Used Mathematical Symbols

This document explains how the SA equation used to calculate the SA funding requirement in the Proposed Regulation was developed. The development of the SA equation involves various algebraic operations some of which use less commonly seen mathematical symbols. The SA equation mathematical symbols and their meaning are explained in this section.

A. ≡ (defined as)

This symbol means and is read as "defined as." Staff used the symbol ≡ to simplify equations. For example:

Equation 1:

$$\text{(Annual Factor)}$$

$$\equiv \text{IPT}_{\text{weighted,NOx}} \times 4.05\times10^{-6} \frac{\text{[tons/day]}}{\text{[MWh-g/bhp-hr]}} \times (\text{Cost per Mortality Incident})_{\text{Reference Year}}$$

$$\times (\text{Inflation Adjustment})$$

In equation one, staff uses the ≡ symbol to show that the Annual Factor is simply "defined as" (≡) the total of the calculations following the symbol. This simplifies the subsequent equations and the results.

B. ∑ (Sigma)

The symbol ∑, pronounced "sigma," means the sum of all terms following the symbol. For example, in Equation 2, the $\text{TPD}_{\text{CA,NOx}}$ is defined as all the sum of all air basins' TPD_{NOx}.

Equation 2:

$$\text{TPD}_{\text{CA,NOx}} \equiv \sum_{\text{All Air Basins}} \text{TPD}_{\text{NOx}}$$

Equation 2 can also be written without using the ∑ symbol as:

$$TPD_{CA,NOx} = TPD_{Great\ Basin\ Valleys,NOx}+TPD_{Lake\ County,NOx}+TPD_{Lake\ Tahoe,NOx}+\cdots$$
$$+TPD_{San\ Joquin\ Valley,NOx}+TPD_{South\ Central\ Coast,NOx}+TPD_{South\ Coast,NOx}$$

To simplify, staff used the symbol ∑ with subscript "All Air Basins" throughout this document.

V. Weighted IPT Methodology

A. Calculation of Weighted IPT Factors

The Spending Account funding requirement is based on the number of mortality incidents in California. The IPT Methodology calculates the number of mortality incidents for each air basin separately and then sums them up for a statewide total. However, for the purposes of simplifying the SA calculation, staff chose to calculate the number of mortality incidents in California using the statewide MWh usage, rather than per air basin usage. To achieve this, staff needed to determine the California average IPT Factors for locomotives since IPT factors vary by air basin. The California average IPT Factors are called "Weighted IPT Factors." Statewide weighted IPT factors enabled staff to determine the SA funding requirements using total statewide usage in MWh, regardless of the air basin in which the locomotive operates.

In addition to simplifying the SA calculation, developing statewide weighted IPT factors avoids higher SA fund requirements for locomotive operators in more population dense air basins, which could incentivize the relocation of railyards or locomotive activity to air basins with lower SA fund requirements.

Equation 3, shows the process that staff used to establish the weighted IPT factor. The statewide weighted IPT factor for NOx (or PM2.5) is the sum of the air basin NOx (or PM2.5) IPT factors weighted by the proportion of NOx (or PM2.5) emissions in each air basin, as shown in Equation 3.

Equation 3:

$$IPT_{weighted,NOx} \equiv \sum_{All\ Air\ Basins} \left(IPT_{NOx} \cdot \frac{TPD_{NOx}}{TPD_{CA,NOx}} \right)$$

$$IPT_{weighted,PM25} \equiv \sum_{All\ Air\ Basins} \left(IPT_{PM25} \cdot \frac{TPD_{PM25}}{TPD_{CA,PM25}} \right)$$

Where;

IPT_{NOx}: IPT factor for NOx for specific air basin

TPD_{NOx}: NOx emissions in tons per day (tpd) for the locomotive in a specific air basin

$TPD_{CA,NOx}$: NOx emissions in tons per day (tpd) for the locomotive in California

IPT_{PM25}: IPT factor for PM2.5 for specific air basin

TPD_{PM25}: PM2.5 emissions in tons per day (tpd) for the locomotive in a specific air basin

$TPD_{CA,PM25}$: PM2.5 emissions in tons per day (tpd) for the locomotive in California

Once the weighted IPT factors were known, mortality incidents for both PM2.5 and NOx were determined by multiplying the statewide emissions by the weighted IPT factor. Total mortality incidents from locomotive emissions is the sum of NOx and PM2.5 related incidents, as shown in Equation 4.

Equation 4:

$$(\text{Total Mortality Incidents}) = (IPT_{weighted,NOx} \times TPD_{CA,NOx}) + (IPT_{weighted,PM25} \times TPD_{CA,PM25})$$

The following discussion explains how Equation 4 is equivalent to the IPT methodology in which total statewide mortality is calculated by adding mortality incidents evaluated at an air basin-level (Equation 5).

Equation 5 uses the IPT methodology to calculate the number of total statewide mortality incidents caused by a given locomotive operating in California. The PM2.5 and NOx IPT factors ($IPT_{PM25,}$ IPT_{NOx}) are multiplied by the locomotive's PM2.5 and NOx emissions ($TPD_{PM25,}$ TPD_{NOx}) that occurred within each air basin, respectively. The number of total statewide mortality incidents from the locomotive is calculated by adding all mortality incidents in all air basins, as shown in Equation 5.

Equation 5: Number of mortality incidents calculated using air basin level IPT factors and emissions.

$$(\text{Total Mortality Incidents}) = \sum_{\text{All Air Basins}} [(IPT_{NOx} \times TPD_{NOx}) + (IPT_{PM25} \times TPD_{PM25})]$$

Where;

(Total Mortality Incidents): Total mortality incidents from the locomotive's emissions in California for a given year

IPT_{NOx}: IPT factor for NOx for specific air basin

TPD_{NOx}: NOx emissions in tons per day (tpd) for the locomotive in a specific air basin

IPT_{PM25}: IPT factor for PM2.5 for specific air basin

TPD_{PM25}: PM2.5 emissions in tons per day (tpd) for the locomotive in a specific air basin

Equation 6 is algebraic manipulation beginning from Equation 5. Algebraic manipulation involves rearranging and substituting for variables to obtain an algebraic expression in a desired form, without changing the value of the expression. Manipulation from Equation 5 to Equation 6 shows how air basin level IPT factors (IPT_{NOx}, IPT_{PM25}) and emissions (TPD_{NOx}, TPD_{PM25}) can be aggregated to statewide $IPT_{weighted,NOx}$ and $IPT_{weighted,PM25}$. The resulting equation makes it possible to calculate the number of total mortality incidents from statewide IPT factors and emissions instead of using air basin level values.

Equation 6: Number of mortality incidents calculated using statewide weighted IPT factors and statewide emissions

$$(\text{Total Mortality Incidents}) = \sum_{\text{All Air Basins}} [(IPT_{NOx} \times TPD_{NOx}) + (IPT_{PM25} \times TPD_{PM25})]$$

$$= \sum_{\text{All Air Basins}} \left(IPT_{NOx} \cdot \frac{TPD_{NOx}}{\sum_{\text{All Air Basins}} TPD_{NOx}} \right) \times \sum_{\text{All Air Basins}} TPD_{NOx}$$

$$+ \sum_{\text{All Air Basins}} \left(IPT_{PM25} \cdot \frac{TPD_{PM25}}{\sum_{\text{All Air Basins}} TPD_{PM25}} \right) \times \sum_{\text{All Air Basins}} TPD_{PM25}$$

$$= (IPT_{weighted,NOx} \times TPD_{CA,NOx}) + (IPT_{weighted,\ PM25} \times TPD_{CA,PM25})$$

Where;

$$IPT_{weighted,NOx} \equiv \sum_{\text{All Air Basins}} \left(IPT_{NOx} \cdot \frac{TPD_{NOx}}{\sum_{\text{All Air Basins}} TPD_{NOx}} \right)$$

$$TPD_{CA,NOx} \equiv \sum_{\text{All Air Basins}} TPD_{NOx}$$

$$IPT_{weighted,PM25} \equiv \sum_{\text{All Air Basins}} \left(IPT_{PM25} \cdot \frac{TPD_{PM25}}{\sum_{\text{All Air Basins}} TPD_{PM25}} \right)$$

$$TPD_{CA,PM25} \equiv \sum_{\text{All Air Basins}} TPD_{PM25}$$

Equation 6 shows that the number of statewide mortality incidents can be calculated by multiplying the total statewide emissions ($TPD_{CA,NOx}$, $TPD_{CA,PM25}$) and IPT factors weighted by emissions in each air basin ($IPT_{weighted,NOx}$, $IPT_{weighted,PM25}$). Table 1 shows the steps of Equation 6 to calculate the weighted NOx IPT factor in a graphical format. The weighted PM2.5 IPT factor was calculated by staff in the same manner.

Table 1: Graphical interpretation of Equation 6. Lower right cell ($IPT_{weighted,NOx}$) is the statewide IPT factor*

Air Basin	(A) NOx emissions in each air basin (TPD_{NOx})	(B) NOx Emissions Distribution ((A)/(Total of Column A))	(C) IPT Factor of each air basin (IPT_{NOx})	(D) Weighted IPT Factor ((B)×(C))
Great Basin Valleys	Total NOx emissions in tpd in Great Basin Valleys	Total NOx emissions in Great Basin Valleys divided by Total NOx emissions in California	IPT Factor of Great Basin Valleys	IPT Factor of Great Basin Valleys (Column C) multiplied by NOx emissions distribution (Column B)
Lake County	Total NOx emissions in tpd in Lake County	Total NOx emissions in Lake County divided by Total NOx emissions in California	IPT Factor of Lake County	IPT Factor of Lake County (Column C) multiplied by NOx emissions distribution (Column B)

Air Basin	(A) NOx emissions in each air basin (TPD_{NOx})	(B) NOx Emissions Distribution ((A)/(Total of Column A))	(C) IPT Factor of each air basin (IPT_{NOx})	(D) Weighted IPT Factor ((B)×(C))
Lake Tahoe	Total NOx emissions in tpd in Lake Tahoe	Total NOx emissions in Lake Tahoe divided by Total NOx emissions in California	IPT Factor of Lake Tahoe	IPT Factor of Lake County (Column C) multiplied by NOx emissions distribution (Column B)
San Joaquin Valley	Total NOx emissions in tpd in San Joaquin Valley	Total NOx emissions in San Joaquin Valley divided by Total NOx emissions in California	IPT Factor of San Joaquin Valley	IPT Factor of Lake County (Column C) multiplied by NOx emissions distribution (Column B)
South Central Coast	Total NOx emissions in tpd in South Central Coast	Total NOx emissions in South Central Coast divided by Total NOx emissions in California	IPT Factor of South Central Coast	IPT Factor of Lake County (Column C) multiplied by NOx emissions distribution (Column B)
South Coast	Total NOx emissions in tpd in South Coast	Total NOx emissions in South Coast divided by Total NOx emissions in California	IPT Factor of South Coast	IPT Factor of Lake County (Column C) multiplied by NOx emissions distribution (Column B)
Total	**Total NOx emissions in tpd in California ($TPD_{CA,NOx}$)**	**1.000**	**N/A**	**$IPT_{weighted,NOx}$**

* Not all Air Basins are shown. The process for all Air Basins is the same.

Table 2 shows the emissions distribution (weight used for $IPT_{weighted,NOx}$ and $IPT_{weighted,PM25}$) from Class I locomotive operators for selected years calculated from the baseline scenario. Weighted IPT Factors were calculated by weighting NOx and PM2.5 IPT factors in each air basin using the process shown in Table 1.

Table 2: Class I locomotives NOx emissions distribution among air basins in the baseline scenario

Air Basin	2020	2030	2040	2050
Great Basin Valleys	0.000	0.000	0.000	0.000
Lake County	0.000	0.000	0.000	0.000
Lake Tahoe	0.000	0.000	0.000	0.000
Mojave Desert	0.408	0.408	0.398	0.373
Mountain Counties	0.054	0.054	0.053	0.048
North Central Coast	0.001	0.001	0.001	0.001
North Coast	0.000	0.000	0.000	0.000
Northeast Plateau	0.033	0.033	0.032	0.030
Sacramento Valley	0.057	0.057	0.057	0.059

Air Basin	2020	2030	2040	2050
Salton Sea	0.080	0.079	0.077	0.071
San Diego County	0.012	0.012	0.012	0.012
San Francisco Bay	0.029	0.029	0.031	0.036
San Joaquin Valley	0.122	0.122	0.123	0.125
South Central Coast	0.003	0.003	0.003	0.003
South Coast	0.202	0.202	0.213	0.243
Total	**1.000**	**1.000**	**1.000**	**1.000**

Table 3: Class I locomotives PM2.5 emissions distribution among air basins in the baseline scenario

Air Basin	2020	2030	2040	2050
Great Basin Valleys	0.000	0.000	0.000	0.000
Lake County	0.000	0.000	0.000	0.000
Lake Tahoe	0.000	0.000	0.000	0.000
Mojave Desert	0.411	0.409	0.396	0.360
Mountain Counties	0.055	0.054	0.052	0.046
North Central Coast	0.001	0.001	0.001	0.001
North Coast	0.000	0.000	0.000	0.000
Northeast Plateau	0.033	0.033	0.032	0.028
Sacramento Valley	0.056	0.056	0.057	0.060
Salton Sea	0.080	0.080	0.077	0.068
San Diego County	0.012	0.012	0.012	0.012
San Francisco Bay	0.028	0.029	0.031	0.038
San Joaquin Valley	0.122	0.122	0.123	0.126
South Central Coast	0.003	0.003	0.003	0.003

Air Basin	2020	2030	2040	2050
South Coast	0.199	0.201	0.215	0.257
Total	**1.000**	**1.000**	**1.000**	**1.000**

B. Calculation of Emissions Using Emission Factors and Usage

To determine mortality incidents, staff needed to convert emission factors (g/bhp-hr) and usage (MWh) to tpd. The SA equation requires locomotive emission factors in g/bhp-hr and usage in MWh because these inputs are more easily accessible and readily available for the regulated community than the total locomotive emissions in tpd.

Equation 7 shows how total emissions in tpd were calculated using emission factors in g/bhp-hr and usage in MWh. Equation 7 shows the unit conversion used to calculate emissions in tpd where emission factor and usage are in g/bhp-hr and MWh per year.

Equation 7: Total emissions shown using emission factors (g/bhp-hr) and Usage (MWh)

$$TPD_{CA,NOx}\ [\text{tons/day}]$$

$$= NOx\ EF\ [\text{g/bhp-hr}] \times \left(\frac{\text{Usage [MWh]}}{\text{1 year}}\right) \times \left(1341\,\frac{\text{bhp-hr}}{\text{MWh}}\right) \times \left(\frac{\text{1 ton}}{\text{907,185 gram}}\right) \times \left(\frac{\text{1 year}}{\text{365 day}}\right)$$

$$= NOx\ EF\ [\text{g/bhp-hr}] \times \text{Usage [MWh]} \times 4.05\times10^{-6}\,\frac{[\text{tons/day}]}{[\text{MWh-g/bhp-hr}]}$$

$$TPD_{CA,PM25}\ [\text{tons/day}]$$

$$= PM2.5\ EF\ [\text{g/bhp-hr}] \times \left(\frac{\text{Usage [MWh]}}{\text{1 year}}\right) \times \left(1341\,\frac{\text{bhp-hr}}{\text{MWh}}\right) \times \left(\frac{\text{1 ton}}{\text{907,185 gram}}\right) \times \left(\frac{\text{1 year}}{\text{365 day}}\right)$$

$$= PM\ EF\ [\text{g/bhp-hr}] \times \frac{PM2.5\ EF\ [\text{g/bhp-hr}]}{PM\ EF\ [\text{g/bhp-hr}]} \times \text{Usage [MWh]} \times 4.05\times10^{-6}\,\frac{[\text{tons/day}]}{[\text{MWh-g/bhp-hr}]}$$

In Equation 7, (PM2.5 EF)/(PM EF) accounts for the ratio of the PM2.5 emission factor to the PM10 emission factor. The conversion between PM2.5 and PM10 is necessary because PM emission factors (PM EF) in U.S. EPA Locomotive Engine Certifications are for PM10 whereas the IPT methodology uses PM2.5. A conversion factor of (PM2.5 EF)/(PM EF) = 0.92 was used to be consistent with the CARB locomotive emissions inventory.

Equation 8 continues from Equation 6. Equation 6 shows how staff calculated the number of total mortality incidents caused by locomotive emissions using statewide weighted IPT factors ($IPT_{weighted,NOx}$ and $IPT_{weighted,PM25}$) and statewide emissions ($TPD_{CA,NOx}$ and $TPD_{CA,PM25}$). Equation 8 uses the results from Equation 7 to replace the statewide emissions with locomotive emission factors (NOx EF and PM EF) and statewide usage (Usage).

Equation 8: Number of mortality incidents calculated using statewide weighted IPT factors, locomotive emission factors, and statewide usage.

(Total Mortality Incidents)

$$=\left(IPT_{weighted,NOx} \times TPD_{CA,NOx}\right)+\left(IPT_{weighted,PM25} \times TPD_{CA,PM25}\right)$$

$$=\left\{(NOx\ EF\ [g/bhp\text{-}hr])+\left(\frac{IPT_{weighted,PM25}}{IPT_{weighted,NOx}} \cdot \frac{PM2.5\ EF\ [g/bhp\text{-}hr]}{PM\ EF\ [g/bhp\text{-}hr]} \times PM\ EF\ [g/bhp\text{-}hr]\right)\right\}$$

$$\times IPT_{weighted,NOx} \times 4.05 \times 10^{-6} \frac{[tons/day]}{[MWh\text{-}g/bhp\text{-}hr]} \times Usage\ [MWh]$$

$$=\{NOx\ EF\ [g/bhp\text{-}hr] + (Weighted\ Factor) \cdot PM\ EF\ [g/bhp\text{-}hr]\}$$

$$\times IPT_{weighted,NOx} \times 4.05 \times 10^{-6} \frac{[tons/day]}{[MWh\text{-}g/bhp\text{-}hr]} \times Usage\ [MWh]$$

Where;

$$(Weighted\ Factor) \equiv \frac{IPT_{weighted,PM25}}{IPT_{weighted,NOx}} \cdot \frac{PM2.5\ EF\ [g/bhp\text{-}hr]}{PM\ EF\ [g/bhp\text{-}hr]}$$

Equation 8 uses algebraic manipulation to rearrange and collect various terms, which results in a more concise equation that is simpler to use. The newly defined term, the Weighted Factor, includes statewide weighted IPT factors ($IPT_{weighted,NOx}$ and $IPT_{weighted,PM25}$). As described in the Chapter VI.A, the statewide weighted IPT factors are air basin level IPT factors weighted by air basin emissions distribution. The weighted IPT factors for NOx and PM2.5 are different because the same weight of NOx and PM2.5 have different health outcomes. Additionally, due to population changes in air basins, the ratio between the two weighted IPT factors change annually. The Weighted Factor simplifies the equation by combining the IPT factor differences between NOx and PM2.5, their annual changes, and the ratio of PM2.5 and PM10 into a single term that changes annually.

C. Calculation of Cost of Cardiopulmonary Mortality Incidents from Locomotive Emissions: Calculation of Annual Factor

Based on the U.S. EPA default value of statistical life estimate, staff used 9.87 million dollars as cost per mortality incident to calculate the cost of locomotive emissions.[8] To adjust for inflation annually from 2023-2050, an Inflation Adjustment factor of 2.7 percent year-over-year is added. Staff determined the Inflation Adjustment based on the fact that the

[8] U.S. EPA, Guidelines for Preparing Economic Analyses: Mortality Risk Valuation Estimates (Appendix B), December 2010. (weblink: https://www.epa.gov/sites/default/files/2017-09/documents/ee-0568-22.pdf).

national consumer price index increased 2.4 percent on average between 1990 and 2019, and the California consumer price index increased 2.7 percent for that time period.[9]

Equation 9 shows that the cost of mortality incidents is a product of three terms; total number of mortality incidents, cost per mortality incident, and inflation adjustment. Equation 9 replaces the total number of mortality incidents with Equation 8. The result shows how staff calculated the cost of mortality incidents from locomotive emission factors and annual locomotive usage.

Equation 9: Cost of mortality incidents from annual locomotive usage

$$
\begin{aligned}
&(\text{Cost of Mortality Incidents}) \\
&= (\text{Total Mortality Incidents}) \times (\text{Cost per Mortality Incident})_{\text{Reference Year}} \times (\text{Inflation Adjustment}) \\
&= \{(\text{NOx EF [g/bhp-hr]}) + (\text{Weighted Factor}) \cdot (\text{PM EF [g/bhp-hr]})\} \\
&\quad \times IPT_{\text{weighted,NOx}} \times 4.05\times10^{-6} \frac{\text{[tons/day]}}{\text{[MWh-g/bhp-hr]}} \times \text{Usage [MWh]} \\
&\quad \times (\text{Cost per Mortality Incident})_{\text{Reference Year}} \times (\text{Inflation Adjustment}) \\
&= \{(\text{NOx EF [g/bhp-hr]}) + (\text{Weighted Factor}) \cdot (\text{PM EF [g/bhp-hr]})\} \\
&\quad \times (\text{Annual Factor}) \times \text{Usage [MWh]}
\end{aligned}
$$

Where;

$$
\begin{aligned}
&(\text{Annual Factor}) \\
&\equiv IPT_{\text{weighted,NOx}} \times 4.05\times10^{-6} \frac{\text{[tons/day]}}{\text{[MWh-g/bhp-hr]}} \times (\text{Cost per Mortality Incident})_{\text{Reference Year}} \\
&\quad \times (\text{Inflation Adjustment})
\end{aligned}
$$

The Annual Factor includes

- $IPT_{\text{weighted,NOx}}$: Yearly variations in weighted IPT due to population growth differences among air basins.
- (Cost per Mortality Incident) $_{\text{Reference Year}}$ × (Inflation Adjustment): Changes to the cost per mortality incident due to inflation.
- $4.05\text{x}10^{-6}$ [tons/day]/[MWh-g/bhp-hr]: Unit conversions between grams and tons, MWh and bhp-hr, and year and day.

[9] Cost-Savings per Incident (2020$) converted using California Department of Industrial Relations Consumer Price Index, available at Office of the Director - Research Unit: California Consumer Price Index. (weblink: https://www.dir.ca.gov/oprl/CPI/EntireCCPI.PDF).

The reference year for the Cost per Mortality Incident and inflation is 2019, and (Cost per Mortality Incident)$_{\text{Reference Year}}$ and (Inflation Adjustment) are calculated as:

$$(\text{Cost per Mortality Incident})_{\text{Reference Year}}=\$9{,}865{,}658$$

$$(\text{Inflation Adjustment})=(1.027)^{(\text{Year})-(\text{Reference Year})}$$

$$(\text{Reference Year})=2019$$

Where Year is calendar year for which the SA funding requirement is being calculated.

Equation 9 outlines the cost of mortality incidents from the annual locomotive usage. It is equal to the SA funding requirement as shown in the Proposed Regulation (Equation 10).

Equation 10: Cost of mortality incidents used in the Funding Requirement for the SA.

$$\text{Funding Requirement [\$]}=\{(\text{Weighted Factor})\times(\text{PM EF [g/bhp-hr]})+(\text{NOx EF [g/bhp-hr]})\}\times(\text{Annual Factor})\times(\text{Usage [MWhs]})$$

D. Year-Over-Year Change

Inputs for the SA equation (Weighted Factor and Annual Factor) change year over year because:

- IPT factors for each air basin for every year is adjusted for the projected change in population.
- As shown in Table 2, the distribution of NOx and PM2.5 emissions among air basins changes each year, so the ratio $IPT_{\text{weighted, PM2.5}}/IPT_{\text{weighted, NOx}}$ varies year over year.
- The Annual Factor changes with inflation adjustments and changes in $IPT_{\text{weighted,NOx}}$.

Table 4 shows Weighted Factor and Annual Factor calculated for 2022-2050 using the development process outlined in this document.

Table 4: Weighted Factor and Annual Factor

Year	Weighted Factor	Annual Factor
2022	13.1	79.1
2023	13.1	82.3
2024	13.1	85.6
2025	13.1	89.0
2026	13.1	92.6
2027	13.1	96.2
2028	13.1	99.9

Year	Weighted Factor	Annual Factor
2029	13.1	103.8
2030	13.1	107.3
2031	13.1	111.4
2032	13.1	115.8
2033	13.1	120.4
2034	13.2	125.1
2035	13.2	130.1
2036	13.2	135.1
2037	13.2	140.6
2038	13.2	146.4
2039	13.2	152.1
2040	13.2	158.5
2041	13.2	164.8
2042	13.2	171.5
2043	13.2	178.5
2044	13.2	185.7
2045	13.2	193.3
2046	13.3	201.2
2047	13.3	209.6
2048	13.4	218.5
2049	13.4	228.0
2050	13.5	238.1