California Air Resources Board

Appendix H

Health Analyses for the Proposed In-Use Locomotive Regulation

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I. Introduction

In support of the Proposed In-Use Locomotive Regulation (Proposed Regulation), California Air Resources Board (CARB) staff have conducted health analyses to evaluate the health impacts of emissions from diesel-powered locomotives operating throughout California. These health analyses examine the current and future impacts of the existing locomotive fleets in the state and compares them to the health benefits from implementing the Proposed Regulation.

This appendix describes two separate and important analyses, a Health Risk Characterization (HRC), and an Estimation of Health Benefits. The HRC focuses on cancer risk from exposure to "primary" (directly emitted) diesel particulate matter (DPM) emissions experienced by people who live near railyards. The Estimation of Health Benefits uses a Mortality and Illness analysis, which focuses on "primary" particulate matter (PM) emissions and "secondary" PM formed in the atmosphere from nitrogen oxides (NOx). Reducing exposure to these pollutants can result in health outcomes that lower rates of premature death from cardiopulmonary disease, hospital admissions, and emergency room (ER) visits.

This appendix highlights the anticipated effects of the Regulation in three specific years, 2020 (the baseline year), 2025 (the first year of emission benefits from the Proposed Regulation), and 2050 (the final year of changes analyzed for the Regulation). The approaches used in each of these health analyses are outlined below.

II. Health Risk Characterization for Locomotive Emissions at Railyards

A. Overview

Between 2005 and 2008, staff, in partnership with Union Pacific Railroad (UP) and BNSF Railway (BNSF), conducted Health Risk Analyses (HRA) at 18 major railyards throughout the state to assess risk from exposure to emissions from locomotives.[1] These HRAs illustrated that emissions from railyards increase cancer risk for people who live in surrounding communities (for more information on cancer impacts related to diesel engine emissions, see section III of this Appendix). To assess risk for the Proposed Regulation, staff built on the previous HRAs to perform a Health Risk Characterization (HRC).

The HRC is a process that involves the scaling of prior studies to reflect current conditions. The work is meant to assess if there was a need to do new facility-specific assessments. The HRC analyzed the results under the conservative assumption of an all Tier 4 locomotive fleet by the year 2045. The HRC focuses on DPM emitted from diesel-powered locomotives. This characterization is based on:

1. The 2005-2008 HRAs.

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[1] CARB, Railyard Health Risk Assessments, files accessed July 12, 2022. (weblink: https://ww2.arb.ca.gov/resources/documents/railyard-health-risk-assessments-and-mitigation-measures)

2. Locomotive fleet breakdown data, as described in the updated statewide freight line haul and switch locomotive DPM emissions inventory,[2] to adjust locomotive emissions to 2020 levels.
3. Cancer risk levels based on the 2015 update to the *Air Toxics Hot Spots Program Guidance Manual for the Preparation of Health Risk Assessments*[3] (2015 OEHHA Cancer Risk Guidance Manual).

All other modelling inputs (i.e., emission rates and source locations) were unchanged from the original 2005-2008 Health Risk Assessments. In order to compare the reductions in health risk using consistent methods of examination; the only variable was the lower DPM emissions that resulted from the introduction of cleaner diesel-powered locomotives over time.

Because the 2005-2008 Health Risk Assessments included all railyard sources, the HRC began by segregating locomotive emissions sources from all of other sources. Once the locomotives emissions were isolated from other sources, staff updated the 2005 cancer risk by applying the risk calculation methodology defined in the 2015 California Office of Environmental health Hazard Assessment (OEHHA) Cancer Risk Guidance Manual.

To calculate risk for the year 2020, staff updated the statewide freight line haul and switch locomotive DPM emissions inventory based on distribution of megawatt-hours (MWh) per Tier in the state. The updated emissions inventory was then used to calculate statewide average DPM emissions from freight line haul and switch locomotives operating within California. The statewide average was then used to calculate factors which were used to project the 2005 emissions to 2020 levels. To calculate risk for the year 2045, the same method was used, with the exception that all line haul and switcher locomotives at yard were assumed to have Tier 4 average emission levels.

Since the HRC is intended to characterize the reductions in health risks for a representative railyard facility, and not a specific facility, cancer risk is presented as the average cancer risk for residential receptors over a geographic area out to one mile from the railyard boundaries, rather than identifying specific receptors such as a point of maximum impact or maximally exposed individual resident. All health impact results were calculated using the methodology of 30-year individual cancer risk defined in the 2015 OEHHA Cancer Risk Guidance Manual.

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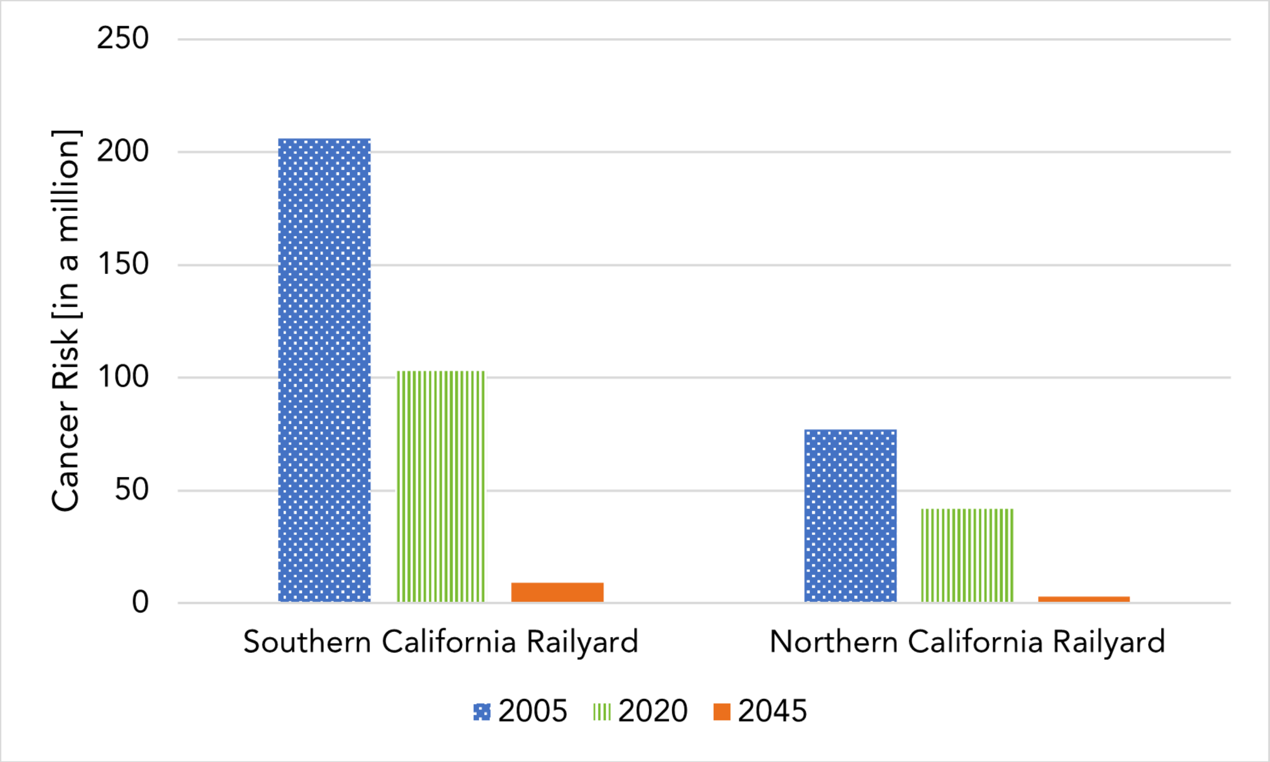
[2] CARB, Locomotive Inventory Values for the In-Use Locomotive Regulation Health Risk Characterization, 2020 MSEI - Documentation - Off-Road - Diesel Equipment _ California Air Resources Board, accessed on July 11, 2022. (weblink: *https://ww2.arb.ca.gov/our-work/programs/mobile-source-emissions-inventory/road-documentation/msei-documentation-road*)

[3] Office of Environmental Health Hazard Assessment: Air Toxics Hot Spots Program, Risk Assessment Guidelines, February 15, 2015. (weblink: *https://oehha.ca.gov/media/downloads/crnr/2015guidancemanual.pdf*)

Figure 1: Average Risk Within One Mile of a Railyard



B. Description of the Northern California and Southern California Railyards

Locomotives travel throughout the state and the country, transporting freight or passengers, often over long distances. When locomotive freight is transferred from train to train or to a new carrier (e.g., transferred to a truck or an ocean-going vessel) locomotives operate at railyards, seaports, intermodal facilities, and other locations that are often near sensitive receptors, such as schools, hospitals, elder care facilities, and residential neighborhoods. To characterize 2020 cancer risk from exposure to diesel-powered locomotive DPM emissions, staff selected two HRAs and updated them to characterize risk from DPM exposure under 2020 conditions. Staff selected one railyard, in Northern California, and one in Southern California.

The Southern California railyard is an intermodal railyard in which switch locomotives push or pull cars throughout a railyard that is flat (sometimes referred to as “flat switching”) within the facility boundary. Railyard facilities include classification tracks, which are typically parallel tracks used for sorting and separating railcars, a gate complex for inbound and outbound truck traffic, intermodal loading and unloading tracks where cargo is transferred to and from a locomotive to a truck, and various buildings and facilities supporting railroad and contractor operations. Figure 2 shows the geographical location of the Southern California railyard.

Figure 2: Geographical Location of Southern California Railyard

The Northern California railyard is a classification facility, and activities include receiving inbound trains, switching railcars, repairing railcars, servicing, and repairing locomotives. Figure 3 shows the geographic location of the Northern California railyard.

Figure 3: Geographical Location of Northern California Railyard

C. Freight Locomotive DPM Emission Inventory

Although locomotives operate across the state, their impact is often concentrated in communities near facilities where many locomotives may be operating simultaneously, moving around in railyards or on rail sidings, or dwelling near busy crossings as they approach a destination. Diesel-powered locomotives emit DPM.

CARB has recently updated the statewide emission inventory for locomotives. CARB's 2022 In-Use Locomotive Emission Inventory (Inventory), which can be found in Appendix G, reflects proposed improvements to a number of parameters from the 2017 Statewide Emissions Inventory for locomotives, including, but not limited to:

1. Population and age distribution;
2. Annual locomotive activity that occurs within the state; and
3. Remanufacture, turnover (replacement of old locomotives), and purchasing trends for locomotives.

The Inventory was used to scale the emission factors from 2005 to 2020 levels to yield the baseline inventory for the HRC; these scaled factors were subsequently used in the air dispersion model output files from 2005.

The emission inventories of freight locomotives in 2020 and 2045 are estimated based on statewide locomotive fleet average emissions, and projected patterns of locomotive remanufacture and locomotive replacement to Tier 4 line haul and switcher locomotives, as well as projected growth. For the purposes of the HRC, only the locomotive fleet is aged, everything else, including the type of locomotive activity and the locations of the emissions within railyards, are assumed to remain unchanged from the 2005 HRAs. Tables 1 and 2 summarize the freight locomotive emission inventories for 2005, 2020, and 2045 by activity categories and operation modes, where operation mode is defined as the engine setting (notch, dynamic brake, etc.) and activity category is the type of work being performed (stationary while refueling, performing switch work, etc.).

The DPM emissions from the Southern California railyard are estimated to be 5.32 tons per year (tpy) in 2020 and 0.44 tpy in 2045. This represents an approximate decrease in emissions of 49 percent in 2020 and about 96 percent in 2045 when compared to the 2005 emission levels. The decrease associated by 2045 assumes an average Tier 4 locomotive population, this represents a conservative approach, as the Proposed Regulation requires the introduction of Tier 4 or cleaner locomotive until 2030, zero emission (ZE) switch locomotives beginning in 2030, and ZE line haul locomotives beginning in 2035. For the Northern California railyard, the total estimated freight locomotive DPM emissions are estimated at 3.36 tpy in 2020 and 0.23 tpy in 2045. This represents an approximate decrease in emissions of 44 percent in 2020 and 96 percent in 2045 when compared to the 2005 emission levels.

Table 1: Estimated Freight Locomotive Diesel Particulate Matter Emission Inventory

Southern California Railyard	Activity	2005 DPM (tpy)	2020 DPM (tpy)	2045 DPM Average Tier 4 Fleet (tpy)
Line Haul	Idling while refueling	0.39	0.17	0.02
Line Haul	Crew change (arriving/departing)	0.19	0.08	0.01
Line Haul	Arriving/departing	3.47	1.48	0.16
Line Haul	Passing (excluding adjacent commuter rail operations)	2.31	0.99	0.11
Switcher	All Switching	4.06	2.61	0.14
Total	All	10.42	5.32	0.44

Table 2: Estimated Freight Locomotive Diesel Particulate Matter Emission Inventory

Northern California	Activity	2005 DPM (tpy)	2020 DPM (tpy)	2045 DPM Average Tier 4 Fleet (tpy)
Line haul and Switcher	Idling	2.90	1.49	0.12
Line haul and Switcher	Movement	3.12	1.85	0.16
Line haul and Switcher	Load Testing	0.03	0.01	0.001
Total	All	6.05	3.36	0.23

D. Emission Allocation and Scaling of Modeled Results

In common practice, there are two different, but equivalent, methods of entering emission rates in the American Meteorological Society/Environmental Protection Agency Regulatory Air Dispersion Modelling program known as AERMOD, to simulate the air dispersion process of a pollutant: (1) using the actual emission rates for each pollutant from each identified source, or (2) using a unit emission rate (1 g/sec or 1 g/sec-m^2), for each source. The final results are calculated by multiplying the actual emission rate of each source by the modeled concentration at each receptor, then summing the concentration of each source at that receptor. The unit emission rate is not chemical-specific, its use eliminates the need to run the model for each individual chemical emitted. To calculate the ambient air concentration of a particular chemical, the air modeling output is simply multiplied by the chemical emission rate. Both approaches will present equal modeling results. The second approach is often used in a dispersion model which involves multiple emission sources or multiple pollutants. In 2005, the Southern California railyard modeling work was based on a unit emission rate, while the Northern California railyard HRA modeling work was performed using actual emission rates from sources. In 2005, the Northern California railyard modeling also included commuter train activity (idle, movement, and mechanical service). This activity was aggregated with all other locomotive activity in the model, and so it remained within the HRC (Table 4). The same is true for switcher activity, which was differentiated in the emission inventory but was aggregated with all other locomotive activity in the model.

1. Southern California Railyard

The 2005 Southern California railyard HRA study used a series of air dispersion modeling simulations differentiated by operation modes from individual locomotive activities. These operation modes included locomotive idling, dynamic braking, and engine operation at various engine power notch settings. Because all non-freight locomotive emissions were treated as separate inputs in the previous modeled results, staff were able to segregate freight locomotive emissions from other DPM sources in the HRC. Table 3 summarizes the emission setup by activity categories and operation modes from the Southern California railyard based on the 2005 emission inventory.

Table 3: Activities and Operation Modes of Freight Locomotive DPM Emission (tpy) from Southern California Railyard HRA Study (2005)

Activity Category	Activity Description	Modeling Source Type	Operation Mode	Emission by Mode	Emission by Activity Category
A	Idling while Refueling	Point	idle	e_{A1}	$E_A = e_{A1}$
C	Crew Change	Point	idle	e_{C1}	$E_C = \Sigma e_{Ci}$
C	Crew Change	Volume	dynamic brake	e_{C2}	$E_C = \Sigma e_{Ci}$
C	Crew Change	Volume	notch 1	e_{C3}	$E_C = \Sigma e_{Ci}$
C	Crew Change	Volume	notch 2	e_{C4}	$E_C = \Sigma e_{Ci}$
C	Crew Change	Volume	notch 3	e_{C5}	$E_C = \Sigma e_{Ci}$
C	Crew Change	Volume	notch 4	e_{C6}	$E_C = \Sigma e_{Ci}$
C	Crew Change	Volume	notch 5	e_{C7}	$E_C = \Sigma e_{Ci}$
C	Crew Change	Volume	notch 6	e_{C8}	$E_C = \Sigma e_{Ci}$
C	Crew Change	Volume	notch 7	e_{C9}	$E_C = \Sigma e_{Ci}$
C	Crew Change	Volume	notch 8	e_{C10}	$E_C = \Sigma e_{Ci}$
D	Switching	Point	idle	e_{D1}	$E_D = \Sigma e_{Di}$
D	Switching	Volume	dynamic brake	e_{D2}	$E_D = \Sigma e_{Di}$
D	Switching	Volume	notch 1	e_{D3}	$E_D = \Sigma e_{Di}$
D	Switching	Volume	notch 2	e_{D4}	$E_D = \Sigma e_{Di}$
D	Switching	Volume	notch 3	e_{D5}	$E_D = \Sigma e_{Di}$
D	Switching	Volume	notch 4	e_{D6}	$E_D = \Sigma e_{Di}$
D	Switching	Volume	notch 5	e_{D7}	$E_D = \Sigma e_{Di}$
D	Switching	Volume	notch 6	e_{D8}	$E_D = \Sigma e_{Di}$
D	Switching	Volume	notch 7	e_{D9}	$E_D = \Sigma e_{Di}$

Activity Category	Activity Description	Modeling Source Type	Operation Mode	Emission by Mode	Emission by Activity Category
D	Switching	Volume	notch 8	$\mathbf{e}_{D10}$	$\mathbf{E}_D = \Sigma\, \mathbf{e}_{Di}$
E	Arriving & Departing Trains	Point	idle	$\mathbf{e}_{E1}$	$\mathbf{E}_E = \Sigma\, \mathbf{e}_{Ei}$
E	Arriving & Departing Trains	Volume	dynamic brake	$\mathbf{e}_{E2}$	$\mathbf{E}_E = \Sigma\, \mathbf{e}_{Ei}$
E	Arriving & Departing Trains	Volume	notch 1	$\mathbf{e}_{E3}$	$\mathbf{E}_E = \Sigma\, \mathbf{e}_{Ei}$
E	Arriving & Departing Trains	Volume	notch 2	$\mathbf{e}_{E4}$	$\mathbf{E}_E = \Sigma\, \mathbf{e}_{Ei}$
E	Arriving & Departing Trains	Volume	notch 3	$\mathbf{e}_{E5}$	$\mathbf{E}_E = \Sigma\, \mathbf{e}_{Ei}$
E	Arriving & Departing Trains	Volume	notch 4	$\mathbf{e}_{E6}$	$\mathbf{E}_E = \Sigma\, \mathbf{e}_{Ei}$
E	Arriving & Departing Trains	Volume	notch 5	$\mathbf{e}_{E7}$	$\mathbf{E}_E = \Sigma\, \mathbf{e}_{Ei}$
E	Arriving & Departing Trains	Volume	notch 6	$\mathbf{e}_{E8}$	$\mathbf{E}_E = \Sigma\, \mathbf{e}_{Ei}$
E	Arriving & Departing Trains	Volume	notch 7	$\mathbf{e}_{E9}$	$\mathbf{E}_E = \Sigma\, \mathbf{e}_{Ei}$
E	Arriving & Departing Trains	Volume	notch 8	$\mathbf{e}_{E10}$	$\mathbf{E}_E = \Sigma\, \mathbf{e}_{Ei}$
F1	Passing Line Haul	Point	idle	$\mathbf{e}_{F1,1}$	$\mathbf{E}_{F1} = \Sigma\, \mathbf{e}_{F1,i}$
F1	Passing Line Haul	Volume	dynamic brake	$\mathbf{e}_{F1,2}$	$\mathbf{E}_{F1} = \Sigma\, \mathbf{e}_{F1,i}$
F1	Passing Line Haul	Volume	notch 1	$\mathbf{e}_{F1,3}$	$\mathbf{E}_{F1} = \Sigma\, \mathbf{e}_{F1,i}$
F1	Passing Line Haul	Volume	notch 2	$\mathbf{e}_{F1,4}$	$\mathbf{E}_{F1} = \Sigma\, \mathbf{e}_{F1,i}$
F1	Passing Line Haul	Volume	notch 3	$\mathbf{e}_{F1,5}$	$\mathbf{E}_{F1} = \Sigma\, \mathbf{e}_{F1,i}$
F1	Passing Line Haul	Volume	notch 4	$\mathbf{e}_{F1,6}$	$\mathbf{E}_{F1} = \Sigma\, \mathbf{e}_{F1,i}$
F1	Passing Line Haul	Volume	notch 5	$\mathbf{e}_{F1,7}$	$\mathbf{E}_{F1} = \Sigma\, \mathbf{e}_{F1,i}$
F1	Passing Line Haul	Volume	notch 6	$\mathbf{e}_{F1,8}$	$\mathbf{E}_{F1} = \Sigma\, \mathbf{e}_{F1,i}$
F1	Passing Line Haul	Volume	notch 7	$\mathbf{e}_{F1,9}$	$\mathbf{E}_{F1} = \Sigma\, \mathbf{e}_{F1,i}$
F2	Non-Aff. Passing Line Haul	Volume	dynamic brake	$\mathbf{e}_{F2,1}$	$\mathbf{E}_{F2} = \Sigma\, \mathbf{e}_{F2,i}$

Activity Category	Activity Description	Modeling Source Type	Operation Mode	Emission by Mode	Emission by Activity Category
F2	Non-Aff. Passing Line Haul	Volume	notch 1	$\mathbf{e}_{F2,2}$	$\mathbf{E}_{F2} = \Sigma\ \mathbf{e}_{F2,i}$
F2	Non-Aff. Passing Line Haul	Volume	notch 2	$\mathbf{e}_{F2,3}$	$\mathbf{E}_{F2} = \Sigma\ \mathbf{e}_{F2,i}$
F2	Non-Aff. Passing Line Haul	Volume	notch 3	$\mathbf{e}_{F2,4}$	$\mathbf{E}_{F2} = \Sigma\ \mathbf{e}_{F2,i}$
F2	Non-Aff. Passing Line Haul	Volume	notch 4	$\mathbf{e}_{F2,5}$	$\mathbf{E}_{F2} = \Sigma\ \mathbf{e}_{F2,i}$
F2	Non-Aff. Passing Line Haul	Volume	notch 5	$\mathbf{e}_{F2,6}$	$\mathbf{E}_{F2} = \Sigma\ \mathbf{e}_{F2,i}$
F2	Non-Aff. Passing Line Haul	Volume	notch 6	$\mathbf{e}_{F2,7}$	$\mathbf{E}_{F2} = \Sigma\ \mathbf{e}_{F2,i}$
F2	Non-Aff. Passing Line Haul	Volume	notch 7	$\mathbf{e}_{F2,8}$	$\mathbf{E}_{F2} = \Sigma\ \mathbf{e}_{F2,i}$
F2	Non-Aff. Passing Line Haul	Volume	notch 8	$\mathbf{e}_{F2,9}$	$\mathbf{E}_{F2} = \Sigma\ \mathbf{e}_{F2,i}$
Total	**All activities**	**Sources for each activity**	**All modes for each source**	**Emissions for each mode**	**Etot = EA +EC + ED + ED +EF1+ EF2**

e_i: Means emission of operation mode, E_i: Means emission of activity category.
Non-Aff. Means from a railroad not affiliated with this yard.

When a unit emission rate is used as a model input, the DPM air concentrations are calculated at receptors and scaled by the actual emission rate of each operation mode. Then the air concentration at each receptor is calculated as a sum of contributions from all operation modes. Equation 1 presents the calculation details of air concentrations and cancer risk estimates.

Equation 1:

$$R(x,y) = \sum_i \left[\frac{e_i}{1} C_i(x,y)\right] r$$

Where for a given receptor at *(x,y)*,		Units
$R(x,y)$	= the sum of cancer risk estimates from all operation modes	chances in a million

e_i	= the emission rate of operation mode "i" in 2005, 2020, and 2045	g/sec or g/m^2/sec
1	= the unit emission rate for operation mode "i"	g/sec or g/m^2/sec
$C_i(x, y)$	= the DPM air concentration from 2005 modeled results for a unit emission rate	µg/m^3
r	= the DPM cancer risk conversion factor for 30-year cancer risk estimate for individual residents, equivalent to 744	chances in a million per (µg/m3) based on the 2015 OEHHA Guidelines

2. Northern California Railyard

Unlike the Southern California railyard, the 2005 Northern California railyard HRA modeling work was configured by activity categories, not operation mode. In addition, the modeling runs were performed using actual emission rates instead of unit emission rates for all activity categories.

Table 4 presents the emission input setup from the 2005 modeling work, including locomotive idling, movement, and load test for aggregated locomotive activities. For locomotive movement, the model assumed that daytime and nighttime locomotive movement was equal and applied half of the total emissions to each time period. The primary difference is that during the night, point sources have different source release heights and initial vertical dispersion parameters.

Table 4: Activities of Freight Locomotive DPM Emissions from Northern California Railyard HRA Study (2005)

Activity Category for Freight Locomotives and Commuter trains	**Activity Mode Description**	**Modeling Source Type**	**Emissions (tpy)[1]**
LI	Locomotive Idling	Point	E_{LI}
LM	Locomotive Movement (day time)	Volume	E_{LM}
LN	Locomotive Movement (night time)	Volume	E_{LN}
LT	Locomotive load testing	Point	E_{LT}
Total	All activities	**Sources for each activity**	$E_{tot} = E_{LI} + E_{LM} + E_{LN} + E_{LT}$

[1] E_i: is the emission of the activity category. Locomotive movement has an equal split for day time and night time emissions

Since the Northern California railyard modeling emission setting was based on the actual emission rate of each activity category, a scaling ratio to the previous 2005 emission rate was calculated to apply to the modeled concentrations at all receptors. The air concentration results at receptors were computed by summing the contributions from all activity category. Equation 2 shows the calculation details of air concentration and cancer risk estimates.

Equation 2:

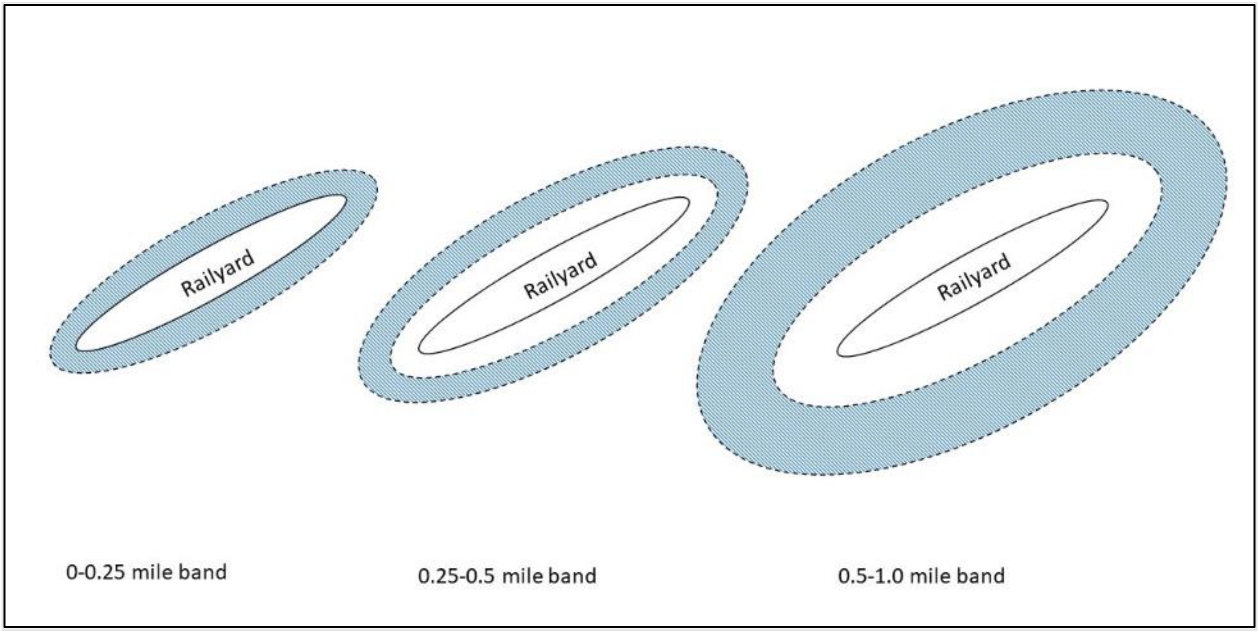
$$R(x,y) = \sum_i \left[\left(\frac{E_i}{E_i^o} \right) C_i(x,y) \right] r$$

Where for a given receptor at *(x,y)*,		Units
$R(x,y)$	= the sum of cancer risk estimates from all activity categories	chances in a million
E_i	= the emission rate of activity category "i" in 2005, 2020, and 2045	g/sec or g/m^2/sec
E_i^o	= the emission rate of each activity category "i" from 2005 modeling work	g/sec or g/m^2/sec
$C_i(x,y)$	= the DPM air concentration from 2005 modeled results based on the actual E_i^o emission rates	µg/m^3
r	= the DPM cancer risk conversion factor for 30-year cancer risk estimate for individual residents, equivalent to 744	chances in a million per (µg/m^3) of DPM inhalation exposure based on the 2015 OEHHA Guidelines

E. Freight Locomotive DPM Cancer Risk Estimate

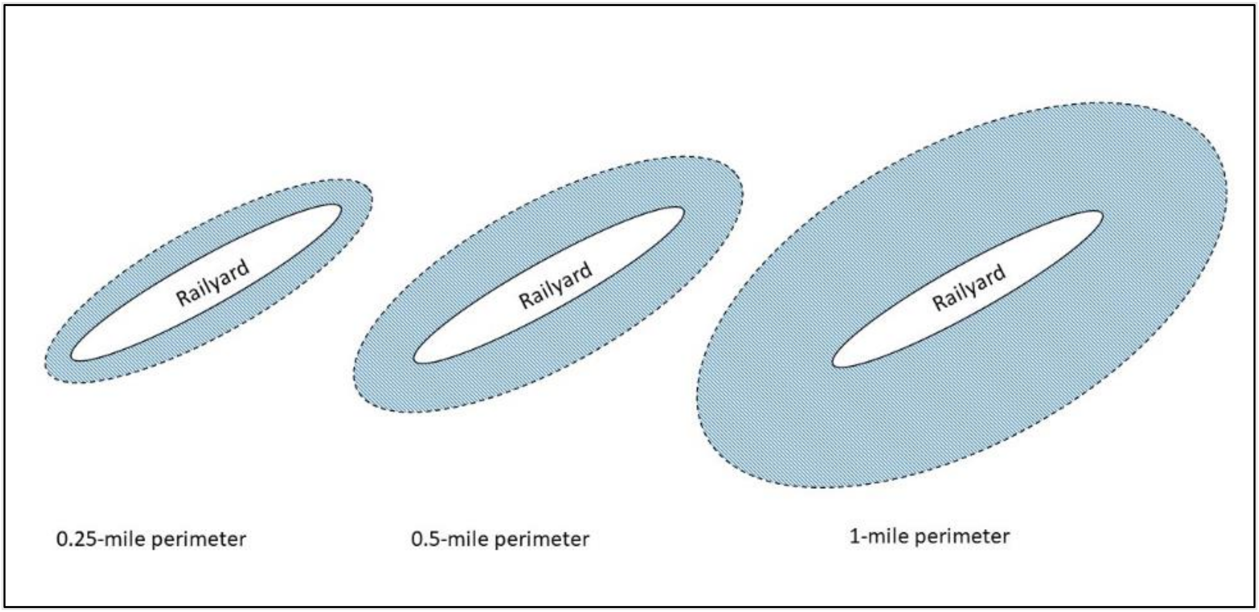
For the HRC, cancer risk is presented as averages within a one-mile distance from the facility boundary using two averaging methods. For Method I, the average cancer risk was calculated in three geographic areas (or banded areas) based on the distances from the railyard facility boundary. Figure 3 shows a generalized illustration of these areas. The first is from 0.25 miles, the second is from 0.25-0.5 miles, and the third is from 0.5-1.0 miles around the railyard facility boundary.

Figure 4: Illustration of Method I Banded Areas of 0.25, 0.5, and 1.0 Mile from Railyard Facility Boundary



For Method II, the average cancer risk was calculated by including increasingly larger areas around the railyards in three distances from the railyard facility boundary. Figure 4 shows a generalized illustration of these areas. The first out to 0.25 miles, the second out to 0.5 miles and the third out to 1.0 mile from the railyard facility boundary.

Figure 5: Illustration of Method II of Averaging Cancer Risk Estimate Based on the Perimetric Areas of 0.25, 0.5, and 1.0 Mile from Railyard Facility Boundary



In 2005, both the Southern California and Northern California railyard model settings used multiple grids with receptors spaced at different distances around the railyard facilities. In general, near the railyards, the receptor spacing was 50 meters, while receptors further away were spaced at greater distances. Figures 5 and 6 show the actual gridded receptors for the two railyards, where grids with 50, 250, and 500-meter receptor spacing was used for the

Southern California railyard and grids with 50, 100, 200, and 500-meter receptor spacing was used for the Northern California railyard respectively.

Figure 6: Receptor Spacing (50, 250, and 500 meters) from 2005 Southern California Railyard Modeling Configuration (Note: the actual modeling domain is larger than the indicated)

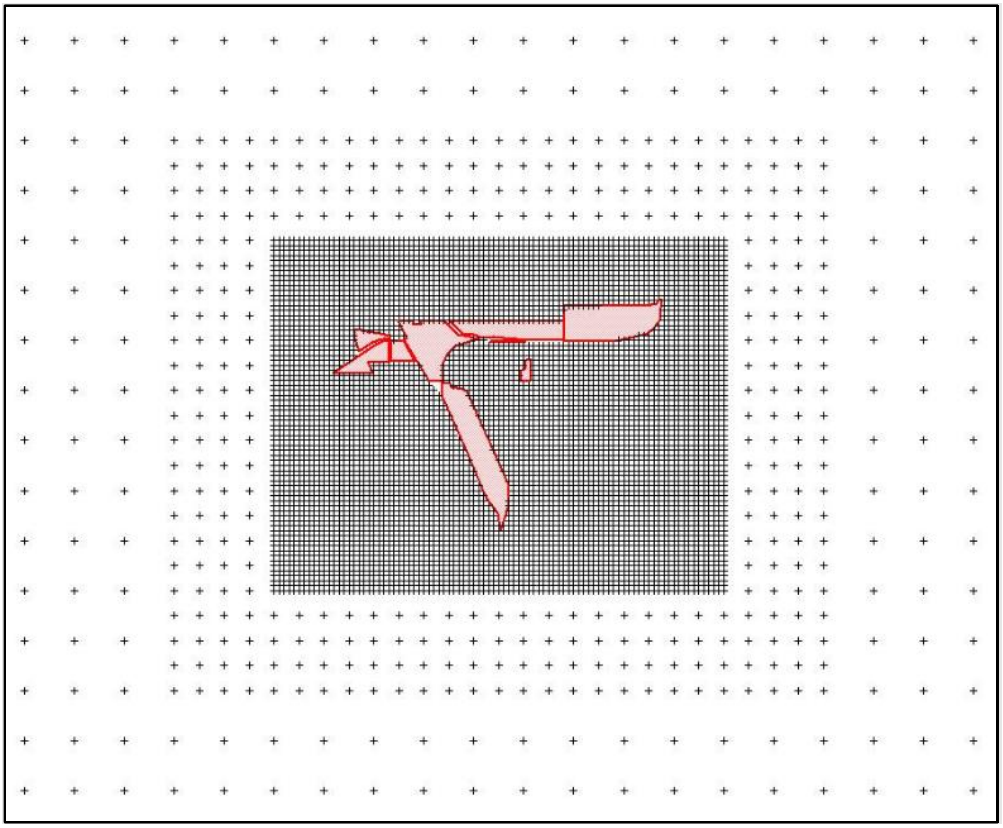
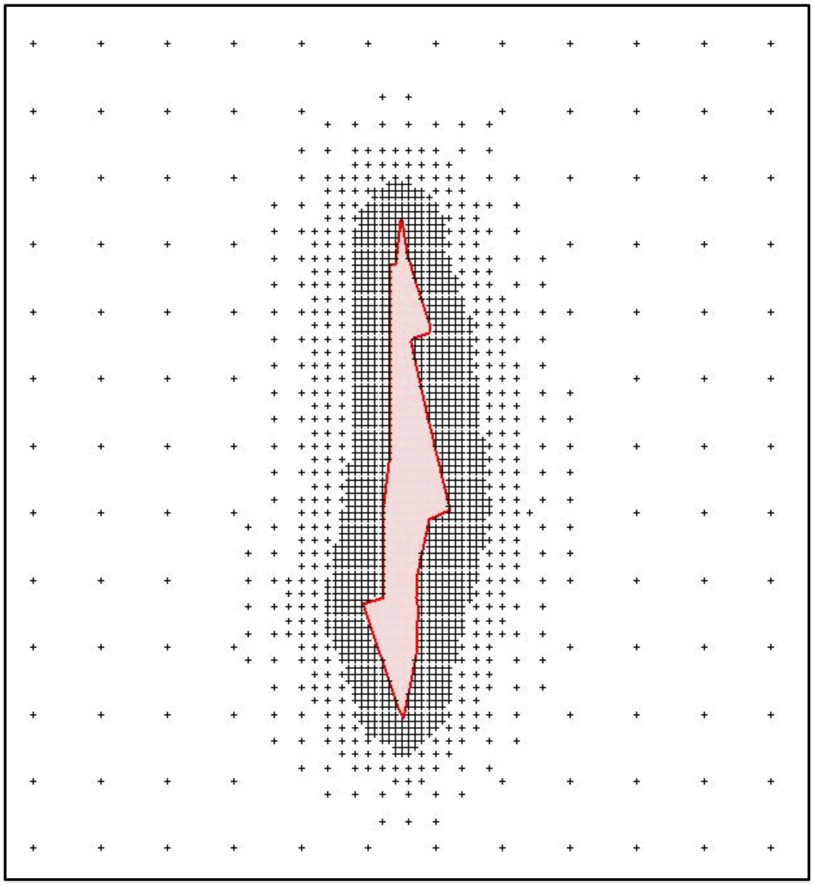


Figure 7: Receptor Spacing (50, 100, 200, and 500 meters) from 2005 Northern California Railyard Modeling Configuration (Note: the actual modeling domain is larger than the indicated)



To account for the different receptor spacing, the average cancer risk calculations for Method I and Method II were weighted to account for the differing receptor densities of each receptor grid. For both railyards, a weighting factor for each individual receptor was calculated as the gridded area the receptor presents in the model setting. For the Southern California railyard, the weighting factors were 50^2, 250^2, and 500^2 for the 50, 250, and 500-meter receptor spacing respectively. Similarly, the weighting factors of 50^2, 100^2, 200^2, and 500^2 were used for the 50, 100, 200, and 500-meter receptor spacing from the Northern California railyard. The averaging calculation was then further divided by the total of weighting factors (i.e., the sum of gridded areas) within each surrounding area defined in Method I and Method II to estimate the weighted average cancer risk.

As described previously, the approach of this HRC emphasizes the average cancer risk for residents at different proximity distances from the railyard facility boundaries. Table 5 shows the 30-year average individual cancer risk for the Southern California railyard in 2005, 2020, and 2045. The results generally indicate that cancer risk increases as proximity to the railyard increases.

Table 5: Average Cancer Risk from the Southern California Railyard (chances in a million) in 2005, 2020, and 2045

Study Method	Area Referenced	2005	2020	2045
Method I	0 - 0.25 mile band	436	215	19
Method I	0.25 – 0.5 mile band	199	99	9
Method I	0.5 – 1.0 mile band	110	56	5
Method II	0.25 mile perimeter	436	215	19
Method II	0.5 mile perimeter	319	158	14
Method II	1.0 mile perimeter	206	103	9

Similarly, Table 6 presents the averaged cancer risk estimates from Method I and Method II for the Northern California railyard. The results show cancer risk decrease in 2020 and 2045 when compared to the 2005 level.

Table 6: Average Cancer Risk from Northern California Railyard (chances in a million) in 2005, 2020, and 2045

Study Method	Area Referenced	2005	2020	2045
Method I	0 - 0.25 mile band	194	105	8
Method I	0.25 – 0.5 mile band	81	44	3
Method I	0.5 – 1.0 mile band	40	22	2
Method II	0.25 mile perimeter	194	105	8
Method II	0.5 mile perimeter	131	71	5
Method II	1.0 mile perimeter	77	42	3

Tables 7 and 8 present the percentage reduction of average cancer risks at both railyards in 2020 and 2045. The results show an evident agreement with the updated emission inventory, and an approximate decrease in the average cancer risk of 45 to 51 percent in 2020 and 95 to 98 percent in 2045 when compared to the 2005 level.

Table 7: Percentage Reduction of Average Cancer Risk from the Southern California Railyard in 2020 and 2045 as Compared to the 2005 Level

Study Method	Area Referenced	2005	2020	2045
Method I	0 - 0.25 mile band	-	50.7%	95.6%
Method I	0.25 – 0.5 mile band	-	50.3%	97.2%
Method I	0.5 – 1.0 mile band	-	49.1%	97.6%
Method II	0.25 mile perimeter	-	50.7%	95.6%
Method II	0.5 mile perimeter	-	50.5%	95.6%
Method II	1.0 mile perimeter	-	50.0%	95.6%

Table 8: Percentage Reduction of the Average Cancer Risk from the Northern California Railyard in 2020 and 2045 as Compared to the 2005 Level

Study Method	Area Referenced	2005	2020	2045
Method I	0 - 0.25 mile band	-	45.7%	95.9%
Method I	0.25 – 0.5 mile band	-	45.7%	96.3%
Method I	0.5 – 1.0 mile band	-	45.0%	95.0%
Method II	0.25 mile perimeter	-	45.8%	95.9%
Method II	0.5 mile perimeter	-	45.8%	96.2%
Method II	1.0 mile perimeter	-	45.5%	96.1%

Tables 9 and 10 show a reduction of 91 to 93 percent for the average cancer risk in 2045 from both railyards when compared to the 2020 level. The reduction is consistent with the projected emission inventory in 2045. The HRC indicates an overall cancer risk benefit from both railyards with the implementation of the Proposed Regulation.

Table 9: Percentage Reduction of Average Cancer Risk from the Southern California Railyard in 2045 as Compared to the 2020 Level

Study Method	Area Referenced	2020	2045
Method I	0 - 0.25 mile band	-	91.2%

Study Method	Area Referenced	2020	2045
Method I	0.25 – 0.5 mile band	-	90.9%
Method I	0.5 – 1.0 mile band	-	91.1%
Method II	0.25 mile perimeter	-	91.2%
Method II	0.5 mile perimeter	-	91.1%
Method II	1.0 mile perimeter	-	91.3%

Table 10: Percentage Reduction of the Average Cancer Risk from the Northern California Railyard in 2045 as Compared to the 2020 Level

Study Method	Area Referenced	2020	2045
Method I	0 - 0.25 mile band	-	92.4%
Method I	0.25 – 0.5 mile band	-	93.2%
Method I	0.5 – 1.0 mile band	-	90.9%
Method II	0.25 mile perimeter	-	92.4%
Method II	0.5 mile perimeter	-	93.0%
Method II	1.0 mile perimeter	-	92.9%

As can be seen through the Northern California and Southern California railyard studies, which compare cancer risk from locomotive emissions in 2005 and average modeled cancer risk with an all-Tier 4 fleet, it is clear that the introduction of freight locomotives with Tier 4 average emissions can result in a significant decrease in average cancer risks in the communities that surround railyards.

III. Health Benefits from the Proposed Regulation

This appendix describes the health impacts in two ways:

1. Impacts from reducing the emissions of diesel-powered locomotives through the implementation of the Proposed Regulation.
2. Impacts described in studies of rail operations or rail activity, in which locomotives are a significant contributor to emissions;

Emissions from diesel-powered locomotives in California contribute to high levels of criteria air pollutants and toxic air contaminants, which leads to adverse health effects including respiratory and cardiac illnesses, hospitalizations and deaths, and lung cancer. Thus, shifting towards cleaner and ZE locomotive technology will lead to substantial public health benefits.

For the current Proposed Regulation, staff have quantified a portion of the health benefits (i.e., cardiopulmonary mortality, hospitalizations, and emergency room visits) expected from the Proposed Regulation. In addition, this appendix also discusses the existing scientific literature looking at the health effects from air pollution, and from the diesel emissions associated with rail operations. Altogether, the Proposed Regulation will provide substantial improvements to public health, especially to the communities disproportionately impacted by rail operations.

IV. Estimation of Health Benefits

A. Methodology for the Mortality and Illness Analysis

Staff evaluated a limited number of statewide non-cancer health impacts associated with exposure to fine particles of 2.5 micrometer (μm) or smaller in diameter (PM2.5) and NOx emissions from locomotives. NOx includes nitrogen dioxide, a potent lung irritant, which can aggravate lung diseases such as asthma when inhaled.[4] The health impacts from NOx that are quantifiable by staff occur from the conversion of NOx into fine particles of ammonium nitrate (i.e., secondary PM2.5) through chemical processes in the atmosphere. PM2.5 formed in this manner is termed secondary PM2.5. Both directly emitted (primary) PM2.5 and secondary PM2.5 from mobile sources such as locomotives are associated with adverse health outcomes, such as cardiopulmonary mortality, hospitalizations for cardiovascular and respiratory illnesses, and ER visits for asthma. As a result, reductions in PM2.5 and NOx emissions are associated with improvements in these adverse health outcomes.

CARB uses the incidence-per-ton (IPT) methodology to quantify the health benefits of emission reductions in cases where air quality modeling results are not available. A description of this method is included on CARB's webpage.[5] CARB's IPT methodology is based on a methodology developed by the U.S. Environmental Protection Agency (U.S. EPA).[6,7,8]

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[4] U.S. EPA, Integrated Science Assessment for Oxides of Nitrogen – Health Criteria, EPA/600/R-15/068, January 2016. (weblink: *http://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=526855*).

[5] CARB, Methodology for Estimating the Health Effects of Air Pollution, accessed July 12, 2022. (weblink: *https://ww2.arb.ca.gov/resources/documents/carbs-methodology-estimating-health-effects-air-pollution).*

[6] Fann N, Fulcher CM, Hubbell BJ., The influence of location, source, and emission type in estimates of the human health benefits of reducing a ton of air pollution, Air Quality Atmosphere & Health, 2:169-176, 2009. (weblink: *https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2770129/*).

[7] Fann N, Baker KR, Fulcher CM., Characterizing the PM2.5-related health benefits of emission reductions for 17 industrial, area and mobile emission sectors across the U.S. Environmental International, 49:141-51, November 15, 2012. (weblink: *https://www.sciencedirect.com/science/article/pii/S0160412012001985*).

[8] Fann N, Baker K, Chan E, Eyth A, Macpherson A, Miller E, Snyder J., Assessing Human Health PM2.5 and Ozone Impacts from U.S. Oil and Natural Gas Sector Emissions in 2025, Environmental Science Technology, 52, pp 8095–8103, 2018. (weblink: *https://pubs.acs.org/doi/abs/10.1021/acs.est.8b02050*).

Under the IPT methodology, changes in emissions are approximately proportional to changes in health outcomes. IPT factors are derived by calculating the number of health outcomes associated with exposure to PM2.5 for a baseline scenario using measured ambient concentrations and dividing by the emissions of PM2.5 or a precursor. The calculation is performed separately for each air basin using the following equation:

$$IPT\ factor\ for\ air\ basin = \frac{number\ of\ health\ outcomes\ in\ air\ basin}{annual\ emissions\ in\ air\ basin}$$

After the IPT factor is calculated, it can be used to estimate health outcomes from emissions reduction data. For example, multiplying the emission reductions from the Proposed Regulation in an air basin by the IPT factor then yields an estimate of the reduction in health outcomes achieved by the Proposed Regulation. For future years the number of outcomes is adjusted to account for population growth. CARB's current IPT factors are based on a 2014-2016 baseline scenario, which represents the most recent data available at the time the current IPT factors were computed. IPT factors are computed for the two types of PM2.5: primary PM2.5 and secondary PM2.5 of ammonium nitrate aerosol formed from precursors. However, current methods do not capture benefits from all of the secondary pollutants involved in PM2.5 formation.

500 fewer hospitalizations due to cardiovascular illness, 597 fewer hospitalizations for respiratory illnesses, and 1,486 fewer asthma ER visits. The largest estimated health benefits correspond to regions in California with the most locomotive activity: South Coast, San Joaquin Valley, and Mojave Desert air basins.

B. Estimated Health Benefits from the Proposed Regulation

If the Proposed Regulation is adopted, CARB expects substantial health benefits through the reduction of diesel particulate matter (DPM) and NOx emissions.[9] Tables 11, 12, and 13 show the estimated avoided incidence of mortality and morbidity by California air basin, summed over the 2020 to 2050 time period. CARB estimates 3,233 fewer cardiopulmonary deaths.

Table 11: Proposed Regulation: Cumulative Reductions in Health Outcomes from $PM_{2.5}$ Emissions for 2020-2050*

Air Basin	Cardiopulmonary mortality	Hospitalizations for cardiovascular illness	Hospitalizations for respiratory illness	Emergency room visits for asthma
Mojave Desert	72 (56 - 88)	11 (0 - 21)	13 (3 - 23)	29 (18 - 39)

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[9] Aside from its role in the formation of secondary PM2.5, NOx is also a precursor to the formation of ozone. However, the health impacts associated with NOx-derived PM2.5 generally outweigh the impacts for NOx-derived ozone.

Air Basin	Cardiopulmonary mortality	Hospitalizations for cardiovascular illness	Hospitalizations for respiratory illness	Emergency room visits for asthma
Mountain Counties	18 (14 - 22)	2 (0 - 3)	2 (0 - 3)	6 (4 - 8)
North Central Coast	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
Northeast Plateau	4 (3 - 5)	0 (0 - 1)	1 (0 - 1)	2 (1 - 3)
Sacramento Valley	30 (24 - 37)	4 (0 - 7)	4 (1 - 8)	11 (7 - 15)
Salton Sea	27 (21 - 33)	4 (0 - 8)	5 (1 - 8)	13 (8 - 17)
San Diego County	3 (3 - 4)	0 (0 - 1)	1 (0 - 1)	1 (1 - 2)
San Francisco Bay	27 (21 - 33)	4 (0 - 8)	5 (1 - 9)	15 (9 - 20)
San Joaquin Valley	70 (55 - 86)	8 (0 - 16)	10 (2 - 18)	25 (16 - 34)
South Central Coast	1 (1 - 2)	0 (0 - 0)	0 (0 - 0)	1 (0 - 1)
South Coast	412 (321 - 505)	69 (0 - 136)	83 (19 - 146)	208 (131 - 285)
Statewide	665 (519 - 816)	103 (0 - 202)	123 (29 - 217)	309 (195 - 424)

*The values in parentheses represent the 95 percent confidence intervals of the central estimate. Totals may not add due to rounding. Air basins with zero impacts are not shown, and these are: Great Basins Valleys, Lake County, Lake Tahoe, and North Coast.

Table 12: Proposed Regulation: Cumulative Reductions in Health Outcomes from NOx Emissions for 2020-2050*

Air Basin	Cardiopulmonary mortality	Hospitalizations for cardiovascular illness	Hospitalizations for respiratory illness	Emergency room visits for asthma
Mojave Desert	147 (115 - 180)	21 (0 - 42)	26 (6 - 45)	56 (35 - 77)

Air Basin	Cardiopulmonary mortality	Hospitalizations for cardiovascular illness	Hospitalizations for respiratory illness	Emergency room visits for asthma
Mountain Counties	47 (37 - 58)	4 (0 - 9)	5 (1 - 9)	16 (10 - 21)
North Central Coast	1 (0 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
Northeast Plateau	3 (2 - 3)	0 (0 - 1)	0 (0 - 1)	1 (1 - 2)
Sacramento Valley	115 (90 - 141)	14 (0 - 28)	17 (4 - 30)	44 (28 - 60)
Salton Sea	66 (52 - 81)	10 (0 - 19)	12 (3 - 20)	31 (19 - 42)
San Diego County	13 (10 - 15)	2 (0 - 4)	2 (1 - 4)	5 (3 - 7)
San Francisco Bay	75 (58 - 91)	12 (0 - 23)	14 (3 - 25)	40 (26 - 55)
San Joaquin Valley	549 (430 - 670)	68 (0 - 133)	81 (19 - 142)	198 (125 - 270)
South Central Coast	11 (8 - 13)	2 (0 - 3)	2 (0 - 4)	5 (3 - 6)
South Coast	1542 (1207 - 1882)	264 (0 - 517)	315 (74 - 555)	781 (495 - 1067)
Statewide	2568 (2010 - 3135)	397 (0 - 778)	474 (111 - 836)	1176 (745 - 1608)

*The values in parentheses represent the 95 percent confidence intervals of the central estimate. Totals may not add due to rounding. Air basins with zero impacts are not shown, and these are: Great Basins Valleys, Lake County, Lake Tahoe, and North Coast.

Table 13: Proposed Regulation: Total Cumulative Reductions in Health Outcomes for 2020-2050*

Air Basin	Cardiopulmonary mortality	Hospitalizations for cardiovascular illness	Hospitalizations for respiratory illness	Emergency room visits for asthma
Mojave Desert	219 (171 - 268)	32 (0 - 63)	38 (9 - 68)	85 (53 - 116)

Mountain Counties	65 (51 - 79)	6 (0 - 12)	7 (2 - 13)	22 (14 - 30)
North Central Coast	1 (1 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 1)
Northeast Plateau	7 (5 - 9)	1 (0 - 2)	1 (0 - 2)	3 (2 - 4)
Sacramento Valley	145 (114 - 178)	18 (0 - 36)	22 (5 - 38)	55 (35 - 75)
Salton Sea	93 (72 - 114)	14 (0 - 27)	16 (4 - 29)	44 (27 - 60)
San Diego County	16 (12 - 19)	2 (0 - 4)	3 (1 - 5)	6 (4 - 9)
San Francisco Bay	102 (79 - 124)	16 (0 - 32)	19 (5 - 34)	55 (35 - 75)
San Joaquin Valley	620 (485 - 756)	76 (0 - 149)	91 (21 - 160)	222 (141 - 304)
South Central Coast	12 (9 - 15)	2 (0 - 4)	2 (1 - 4)	5 (3 - 7)
South Coast	1954 (1529 - 2387)	333 (0 - 653)	398 (93 - 701)	989 (626 - 1352)
Statewide	3233 (2529 - 3951)	500 (0 - 980)	597 (140 - 1053)	1486 (940 - 2032)

*The values in parentheses represent the 95 percent confidence intervals of the central estimate. Totals may not add due to rounding. Air basins with zero impacts are not shown, and these are: Great Basins Valleys, Lake County, Lake Tahoe, and North Coast.

Estimated health benefits are calculated with the assumption of full compliance with federal regulations on idling limits, therefore no emission reductions are assumed from the idling actions in the Proposed Regulation.

C. Uncertainties Associated with the Mortality and Illness Analysis

Although the estimated health outcome presented in this report are based on a well--established methodology, they are subject to uncertainty. Uncertainty is reflected in the 95 percent confidence intervals included with the central estimates in Tables 11, 12, and 13. These confidence intervals take into account uncertainties in translating air quality changes into health outcomes.

Other sources of uncertainty include the following:

- The relationship between changes in pollutant concentrations and changes in pollutant or precursor emissions is assumed to be proportional, although this is an approximation.
- Emissions are reported at an air basin resolution, and do not capture local variations.
- Future population estimates are subject to increasing uncertainty as they are projected further into the future.
- Baseline incidence rates can experience year-to-year variation.

D. Monetization of Health Impacts

In accordance with U.S. EPA practice, health outcomes were monetized by multiplying incidence by a standard value derived from economic studies.[10] This valuation per incident is provided in Table 14.

Table 14: Valuation per Incident Avoided Health Outcomes (2020$)

Outcome	Valuation per Incident[1]
Avoided Premature Deaths	$10,030,076
Avoided Acute Respiratory Hospitalizations	$51,678
Avoided Cardiovascular Hospitalizations	$59,247
Avoided Emergency Room Visits	$848

[1]Converted using California Department of industrial Relations Consumer Price Index

The valuation for avoided premature mortality is based on willingness to pay.[11] This value is a statistical construct based on the aggregated dollar amount that a large group of people would be willing to pay for a reduction in their individual risks of dying in a year, such that one death would be avoided in the year across the population. This is not an estimate of how much any single individual would be willing to pay to prevent a certain death of any particular person,[12] nor does it consider any specific costs associated with mortality such as hospital expenditures.

Unlike premature mortality valuation, the valuation for avoided hospitalizations and emergency room visits is based on a combination of typical costs associated with

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[10] National Center for Environmental Economics et al., Appendix B: Mortality Risk Valuation Estimates, Guidelines for Preparing Economic Analyses (EPA 240-R-10-001, Dec. 2010). (weblink: *https://www.epa.gov/sites/production/files/2017-09/documents/ee-0568-22.pdf*).

[11] U.S. EPA, Science Advisory Board (U.S. EPA-SAB), *An SAB Report on EPA's White Paper Valuing the Benefits of Fatal Cancer Risk Reduction*, EPA-SAB-EEAC-00-013, July 27, 2000. (weblink: *https://www.epa.gov/sites/default/files/2017-12/documents/ee-0483_all.pdf).*

[12] U.S. EPA, *Mortality Risk Valuation – What does it mean the place a value on a life?* Accessed July 22, 2022. (weblink: *https://www.epa.gov/environmental-economics/mortality-risk-valuation#means*).

hospitalization and the willingness of surveyed individuals to pay to avoid adverse outcomes that occur when hospitalized. These include hospital charges, posthospitalization medical care, out-of-pocket expenses, and lost earnings for both individuals and family members, lost recreation value, and lost household protection (e.g., valuation of time-losses from inability to maintain the household or provide childcare). These costs are most closely associated with specific cost savings to individuals and costs to the health care system.

Staff quantified the total statewide valuation due to avoided health outcomes from 2026 to 2050. These values are summarized in Table 15. The spatial distribution of these benefits follows the distribution of emission reductions and avoided adverse health outcomes; therefore, most benefits to individuals would occur in the South Coast, San Joaquin Valley, and Mojave Desert air basins.

Table 15: Statewide Valuation from Avoided Adverse Health Outcomes as a Result of the Proposed Regulation from 2025 to 2050 (2020$)

Outcome	Valuation
Avoided Premature Deaths	$31,895,938,673
Avoided Hospitalizations	$59,477,776
Avoided Emergency Room Visits	$1,239,324
Total Cost Savings	$31,956,655,772

In addition to the monetized health impacts, there are additional health benefits associated with the emissions reductions that would be achieved by the Proposed Regulation that are currently not monetized, including elevated vulnerability and impacts in disadvantaged communities, work loss days, brain and lung health, and cancer risk.

E. Potential Future Evaluation of Additional Health Benefits

While CARB's PM2.5 mortality and illness analysis has been, and continues to be, a useful method for valuing the health benefits of regulations, it only represents a portion of those benefits. The full health benefits of the Proposed Regulation are underestimated because not all the adverse health outcomes associated with PM2.5 and additional pollutants such as air toxics are evaluated and monetized. Also, CARB's current evaluation methodology does not take into account all PM2.5 precursor emissions. An expansion of the emissions inputs and an assessment for other health outcomes, including but not limited to, additional cardiovascular and respiratory illnesses, nonfatal/fatal cancers (beyond the non-monetized cancer risk presented in the HRC), nervous system diseases, and work loss days would provide a more complete picture of the benefits from reduced exposure to air pollution. In addition, in 2021, EPA issued a Technical Support Document (TSD) for their Cross-State Air Pollution Rule that provided both health functions and health evaluation for lung cancer incidence, Alzheimer's disease, and Parkinson's disease, among other health endpoints related to PM2.5 exposures.[13]

While CARB's mortality and illness valuation is just for PM2.5, there are other pollutants that can cause health issues. For instance, NOx reacts with other compounds to form ozone, which can then cause respiratory problems. Updated health impact functions and valuation for ozone are also provided in the aforementioned Cross-State Air Pollution Rule TSD provided by the U.S. EPA. Additionally, toxic air containments (TAC) emitted from diesel engines can lead to cancers. As described in Section II of this Appendix, staff have conducted an assessment of the average cancer risk from toxics within a mile of a railyard, although this is not quantified as monetized impacts.

Expanding CARB's health evaluation and valuation methodology to include any of the above additional strategies would allow the public to reach a better understanding of the benefits of reducing air pollution by moving toward cleaner combustion and zero emission technologies. Importantly, this understanding is valuable to the successful implementation of various emission reduction strategies, including moving towards Tier 4 and cleaner locomotives to protect public health.

The scientific literature has demonstrated the broad impacts of exposure to pollution, specifically living and working near locomotive activity, which go beyond what staff have quantified in Tables 11, 12, and 13 and are thus summarized in the next sections.

V. Diesel Pollution Impacts Human Health

Diesel-powered mobile sources, including locomotives, emit a complex mixture of air pollutants, including DPM and gases. The gaseous pollutants include volatile organic compounds (VOC) and NOx which can lead to the formation of ozone (O3) and the secondary formation of particulate matter (PM).[14]

A. Air Toxic Impacts

Examples of these carcinogenic chemicals include: polycyclic aromatic hydrocarbons (PAH), benzene, formaldehyde, acetaldehyde, acrolein, and 1,3-butadiene.[14] CARB listed DPM as a TAC in 1998, due largely to its association with lung cancer.[14] In 2012, additional studies on the cancer-causing potential of diesel exhaust published since CARB's listing led the International Agency for Research on Cancer (IARC) a division of the World Health

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[13] U.S. EPA. Technical Support Document (TSD) for the Final Revised Cross-State Air Pollution Rule Update for the 2008 Ozone Season NAAQS: Estimating PM2.5- and Ozone-Attributable Health Benefits. (EPA Docket EPA-HQ-OAR-2020-0272); March 2021. (weblink: *air_quality_modeling_tsd_final_revised_csapr_update.pdf (epa.gov)*).

[14] CARB, Overview: Diesel Exhaust & Health, accessed July 22, 2022. (weblink: *https://ww2.arb.ca.gov/resources/overview-diesel-exhaust-and-health*).

Organization, to classify diesel engine exhaust as "carcinogenic to humans".[14,15] In California, about 70 percent of known cancer risks from TACs are from diesel engine emissions.[14,16]

B. Particle Pollution Impacts

DPM is composed primarily of PM2.5.[17,18] Due to its small size, inhaled PM2.5 can reach the lower respiratory tract and potentially pass into the bloodstream to affect other organs.[17,19] In this way, PM2.5 air pollution contributes not only to increased cancer risk, but it also respiratory and cardiovascular diseases and even premature death; other adverse health outcomes from PM2.5 also include asthma, chronic heart disease, and heart attack.[17,19, 20, 21] Moreover, PM2.5 air pollution can result in respiratory, cardiac, and mortality effects over short time periods of exposure such as hours, days, or weeks.[21] Exposures to PM2.5 may also lead to myriad other health outcomes, including metabolic, nervous system, reproductive, and developmental effects.[21] For example, adverse health conditions with possible links to airborne PM2.5 include high blood pressure, insulin resistance, and other risk factors for Type II diabetes, as well as psychological/cognitive problems.[21] PM2.5 may especially impact women and children via health effects such as pre-term birth, reduced birth weight, and abnormal lung and cardiovascular development.[21]

In addition to its ability to increase risk for diseases, PM2.5 is also well known to exacerbate underlying illnesses such as asthma, bronchitis, and heart disease.[21] As a result, the health impacts of PM2.5 are typically studied not only using cancer diagnoses and the rates of onset for lung and cardiovascular diseases, but also via metrics on respiratory symptoms (e.g. cough, wheeze, and asthma medication usage), measures of abnormal lung and heart functioning (e.g. reduced lung volume, irregular heartbeat), rates of hospitalizations, ER visits, and restricted activity days associated with worsening of chronic lung and heart diseases.

C. Ozone Pollution Impacts

As a gaseous pollutant from diesel-powered locomotives, NOx can react with other compounds to form ozone, which is the main component of smog. Based on extensive evidence from scientific studies, the U.S. EPA has determined that short-term exposure from

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[15] IARC, Press Release N° 213, IARC: Diesel Engine Exhaust Carcinogenic, June 12, 2012. (weblink: *https://www.iarc.who.int/wp-content/uploads/2018/07/pr213_E.pdf*).

[16] Propper, R., P. Wong, S. Bui, J. Austin, W. Vance, Á. Alvarado, B. Croes and D. Luo. Ambient and Emission Trends of Toxic Air Contaminants in California, Environmental Science & Technology 49, 2015, pp.1329-11339.

[17] CARB, Inhalable Particulate Matter and Health (PM2.5 and PM10), accessed August 2, 2022. (weblink: *https://ww2.arb.ca.gov/resources/inhalable-particulate-matter-and-health*).

[18] U.S. EPA. Particulate Matter (PM) Pollution, Particulate Matter (PM) Basics, accessed August 2, 2022. (weblink: *https://www.epa.gov/pm-pollution/particulate-matter-pm-basics*).

[19] U.S. EPA, Health and Environmental Effects of Particulate Matter (PM), accessed August 2, 2022. (weblink: *https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm*).

[20] WHO, *Review of Evidence on Health Aspects of Air Pollution-REVIHAAP Project Technical Report*, 2013.

[21] U.S. EPA, Integrated Science Assessment for Particulate Matter, Issue EPA/600/R-19/188, December 2019. (weblink: *https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=347534*).

ozone is causally linked to adverse respiratory effects.[22] Ozone can cause irritation, damage lung tissue, and it can worsen asthma or chronic illnesses, including chronic obstructive pulmonary disease (COPD) and reduced lung function. For instance, a study conducted in the San Joaquin Valley showed that increased ozone pollution led to increased risk for asthma ER visits, especially for children and Black residents.[23] Metabolic functions are also likely to be affected by short-term ozone exposure, such as those leading to increased risk for complications and hospitalizations in diabetic individuals.[22] And, similar to PM2.5, other potential health effects from ozone exposure include impacts on the cardiovascular, nervous, reproductive systems, and even increased risk of mortality.[22]

VI. Rail Operations Impact Human Health

In addition to the multitude of studies showing the impacts of air pollution, there are also several studies that have specifically looked at the effects of rail operations. While these studies are limited, and more research would improve our understanding, the current available research provides insights into the potential cancer risks, respiratory conditions, and other health effects resulting from rail operations.

A. Rail Operations Impact Community Health

CARB has established or proposed numerous regulations that bring equipment operating at railyards, including on-road heavy-duty trucks, transport refrigeration units, drayage trucks, cargo handling equipment, and off-road equipment to zero emission. However, locomotives have remained a source of harmful emissions that CARB aims to address with the Proposed Regulation.

1. Cancer

One report shows that living near California's San Bernardino railyard elevates one's risk for all cancer types by 10 percent.[24] However, cancer risks for this railyard were even greater depending on race/ethnicity and gender. For example, the study showed risk for cancer near the San Bernardino railyard was elevated by 9 percent among Hispanic females and 18 percent among Hispanic males. For lung/bronchus cancer specifically, the risk was 34 percent higher than expected among non-Hispanic White females and 37 percent higher among non--Hispanic White males.[24] (For more discussion about cancer, Section II of this Appendix provides CARB's characterization of the average cancer risk from locomotive emission for those near railyards.)

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[22] U.S. EPA, Integrated Science Assessment for Ozone and Related Photochemical Oxidants, Issue EPA/600/R-20/012, April 2020. (weblink: *https://ordspub.epa.gov/ords/eims/eimscomm.getfile?p_download_id=540022*).

[23] Gharibi H, Entwistle MR, Ha S, Gonzalez M, Brown P, Schweizer D, Cisneros R. Ozone pollution and asthma emergency department visits in the Central Valley, California, USA, during June to September of 2015: a time-stratified case-crossover analysis. Journal of Asthma, VOL. 56, NO. 10, 1037–1048, 2019.

[24] Soret, S., & Montgomery, S., Project ENRRICH: A Public Health Assessment of Residential Proximity to a Goods Movement Railyard Project, Final Report, n.d.

2. Respiratory Adverse Health Outcomes

A variety of respiratory health problems have been observed more frequently in communities near railyards. For example, among those living near the San Bernardino railyard, 38 percent have reduced lung function and 19 percent exhibited airway inflammation. In addition, 28 percent self-reported wheezy breathing, 32 percent experienced morning or nighttime coughing, 40 percent experienced shortness of breath, and nearly 20 percent self-reported having a doctor-diagnosed respiratory condition.[24] The frequency of some respiratory health problems can be even greater for those living closest to the railyard, including doctor diagnosed conditions.[24]

3. Health Impacts on Children

Children are particularly vulnerable to pollution impacts from rail operations. For example, children attending school near the San Bernardino railyard are 59 percent more likely to experience reduced lung function, compared to children attending schools 7 miles from the railyard, regardless of age, gender, race, income, or residence near a major road.[24] In addition, those children were over 70 percent more likely to report cough and/or wheezing.[24,25] Moreover, female children in San Bernardino have higher odds than males for reduced lung function, and this gender difference increases with residence proximity to the railyard.[26]

These decrements in lung function among children exposed to pollution from locomotives translate to consequential health outcomes. Compared to children living elsewhere in California, children living within 5 miles of any one of California's 18 railyards have 15 percent higher odds for an asthma-related ER visit.[27] Furthermore, these elevated odds for an asthma--related emergency increase to 40 percent for children who live near 1 of the 5 railyards with highest diesel particulate matter emissions. (i.e., BNSF San Bernardino, BNSF Barstow, Union Pacific Railroad Stockton, Union Pacific Railroad Intermodal Container Transfer Facility/Dolores, and BNSF Watson).[27]

B. Locomotive Pollutants Impact Worker and Passenger Health

Studies have found that exposure to diesel exhaust is associated with respiratory diseases among railway workers.[28,29] Early cohort studies showed that exposure to diesel exhaust

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[25] Spencer-Hwang R, Soret S, Knutsen S, et al. Respiratory Health Risks for Children Living Near a Major Railyard. J Community Health, 40(5), pp.1015-1023, October 2015.

[26] Spencer-Hwang, R., et. al. Gender Differences in Respiratory Health of School Children Exposed to Rail Yard-Generated Air Pollution: The ENRRICH Study, Journal of Environmental Health, January 2016.

[27] Spencer-Hwang R, Pasco-Rubio M, Soret S, et al. Association of major California freight railyards with asthma-related pediatric emergency department hospital visits, Preventive Medicine Reports, 13, pp.73-79, May 2018.

[28] Hart JE, Laden F, Schenker MB, Garshick E., Chronic Obstructive Pulmonary Disease Mortality in Diesel-Exposed Railroad Workers, Environmental Health Perspectives, 114(7), pp. 1013-1017, July 2006.

[29] Lee MT, Whitmore GA, Laden F, Hart JE., Assessing lung cancer risk in railroad workers using a first hitting time regression model, Environmetrics, 15(5), pp.501-512, August 2004.

resulted in significantly elevated risk for lung cancer in railroad workers.[29,30,31] Based on the data in these cohort studies, researchers expanded the analysis from lung cancer to other diseases, including cardiovascular mortality[32] and ischemic heart diseases[28,33,34,35]. Later, it was suggested that diesel-exhaust exposure also contributed to COPD among railway workers.[28]

Pollutants emitted by locomotives can also result in elevated air pollution levels inside passenger trains. These air pollutants include particulates such as PM2.5. A study conducted in Sacramento, CA found that the concentrations of PM2.5 in train cabinets are the highest compared with other transportation modes (e.g., buses, light rail, bicycles).[36] Overall, both railroad workers and train passengers are impacted by pollutants emitted from locomotives.

C. Rail Operations Impact Health Disparities and Vulnerable Populations

Recent research demonstrates that mobile and stationary pollution exposures disproportionately impact people of color.[37] This inequity persists when looking specifically at rail activity. Communities with the highest pollution exposures from major railyards in California have larger proportions of people of color. In fact, Hispanic/Latino communities are disproportionately affected, experiencing pollution exposures from rail activity that are over 30 percent higher than average in the state.[38] This disproportionality was also identified in previous studies looking at specific California railyards. For example, in Los Angeles County in 1980, around the time when a major railyard was being approved for construction, more than half of a nearby community consisted of people of color.[38] In comparison, the demographics of the entire Los Angeles County at that time was more than half non-Hispanic white.[39] Similarly, in San Bernardino, Hispanics/Latinos comprised more than 71 percent of

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[30] Garshick, E., Schenker, M. B., Musnoz, A., Segal, M., Smith, T. J., Woskie, S. R., Hammond, S. K., & Speizer, F. E., A Retrospective Cohort Study of Lung Cancer and Diesel Exhaust Exposure in Railroad Workers, The American review of respiratory disease, pp. 820-825, April 1988.

[31] Garshick, E., Laden, F., Hart, J. E., Rosner, B., Smith, T. J., Dockery, D. W., & Speizer, F. E. (2004). Lung cancer in railroad workers exposed to diesel exhaust. Environ Health Perspect, 112(15), 1539–1543. (weblink: *https://doi.org/10.1289/ehp.7195*).

[32] Pope CA., Burnett RT, Thurston GD, et al. Cardiovascular Mortality and Long-Term Exposure to Particulate Air Pollution, Epidemiological Evidence of General Pathophysiological Pathways of Disease, 109(1), pp. 71-77, January 2004, accessed June 22, 2022.

[33] Finkelstein MM, Verma DK, Sahai D, Stefov E., Ischemic Heart Disease Mortality Among Heavy Equipment Operators. American Journal of Industrial Medicine, 46(1) pp.16-22, 2004.

[34] Hannerz H, Tüchsen F. Hospital admissions among male drivers in Denmark, Occup Environ Med, 58(4), pp.253-260, 2001.

[35] Tuchsen F, Endahl LA., Increasing inequality in ischaemic heart disease morbidity among employed men in Denmark 1981-1993: the need for a new preventive policy, International Journal of Epidemiology, 28(4), pp.640-644, 1999.

[36] Ham W, Vijayan A, Schulte N, Herner JD., Commuter exposure to PM2.5, BC, and UFP in six common transport microenvironments in Sacramento, California, Atmospheric Environment 167, pp.335-345, 2017.

[37] Apte JS, Chambliss SE, Tessum CW, Marshall JD., A Method to Prioritize Sources for Reducing High PM2.5 Exposures in Environmental Justice Communities in California, California Air Resources Board, November 21, 2019.

[38] Hricko A, Rowland G, Eckel S, Logan A, Taher M, Wilson J., Global Trade, Local Impacts: Lessons from California on Health Impacts and Environmental Justice Concerns for Residents Living near Freight Rail Yards. International Journal of Environmental Research and Public Health, 11(2), pp.1914-1941, February 10, 2014.

people sampled from a region that was on average 1.9 miles from a major freight railyard in that city.[41]

Railyards in the state are often located next to and near environmental justice (EJ) communities, which experience regionally specific and unjust inequities. In California, pursuant to State Bill (SB) 535, communities that rank within the top 25 percent in high amounts of pollution, health issues, and low socioeconomic factors are designated as disadvantaged communities (DAC).[39] The pollution indicators include air pollution and associated sources (PM2.5, ozone, DPM, traffic, toxic release facilities) as well as water pollution, pesticides, and hazardous chemical cleanup sites. Some of the DACs surrounding the San Bernardino railyard are ranked amongst the most disadvantaged when considering the combination of the above-mentioned pollution and population indicators. In fact, the census tract containing the majority of railyard property is in the 95th percentile for pollution burden. In 2011-2012, for people living within 2 miles of the San Bernardino railyard, 68.9 percent had at least a high school education level, over 46 percent were unemployed, and the median income was less than $44,000.[40] For comparison, overall for California, 81.5 percent of people had at least a high school education, 11.4 percent were unemployed, and the median household income was over $58,000 as estimated from the 2012 U.S. American Community Survey.[41]

Furthermore, CARB has established the Community Air Protection Program (CAPP) to focus on reducing air pollution exposures in such EJ communities, in response to Assembly Bill (AB) 617[42] and out of the ten AB 617 communities from the first year of this program, nine of them have rail activity as contributing factor.

VII. Conclusion

Locomotives generate criteria pollution and TACs that are known to cause serious health impacts. As shown in Tables 7 and 8, CARB estimates that the Proposed Regulation would result in a substantial reduction in cancer risk from exposure to DPM emitted by locomotives. As shown in Tables 11, 12, and 13, CARB estimates that shifting to a cleaner average Tier 4 scenario for locomotives would result in substantial non-cancer health and economic benefits, due to reduced cardiovascular/respiratory hospitalizations, asthma ER visits, and deaths. In addition, community exposures specific to railyards have been demonstrated to lead to cancer and are associated with respiratory and other adverse health outcomes. Similarly, worker and passenger exposures to rail activity are linked to health issues such as increased risk of lung cancer, as well as other health endpoints such as heart disease and COPD.

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[39] OEHHA, SB 535 Disadvantaged Communities, accessed August 2, 2022. (weblink: *https://oehha.ca.gov/calenviroscreen/sb535*).

[40] Arthur KN, Knutsen SF, Spencer-Hwang R, Shavlik D, Montgomery S., Health Predictive Social-Environmental Stressors and Social Buffers Are Place Based: A Multilevel Example From San Bernardino Communities, Journal of Primary Care & Community Health, 2019.

[41] U.S. Census Bureau., American Community Survey, 2012. (weblink: *https://data.census.gov*)

[42] CARB, Community Air Protection Program, accessed August 2, 2022. (weblink: *https://ww2.arb.ca.gov/capp/about*).

CARB's HRC and estimation of health benefits are limited and thus likely an underestimation, because it does not consider the various other health outcomes that could be avoided with cleaner locomotives. Furthermore, millions of residents in the state of California live in communities that are more heavily impacted by pollution exposures such as locomotives and railyards and also experience a combination of increased vulnerability to adverse health effects from pollution. For these residents, actions to reduce fossil fuel combustion through movement to cleaner power sources such as in the Proposed Regulation, as well as the elimination of unnecessary idling, are critical.