Ed Avol Testimony on Locomotives

For Letter Regarding Proposed Locomotive Action at the United States Environmental Protection Agency.

1. **Please introduce yourself.**

My name is Edward (Ed) Avol. I am currently employed as a Professor of Clinical Population and Public Health Sciences and the Division Chief of Environmental Health in the Department of Population and Public Health Sciences (formerly the Department of Preventive Medicine) at the Keck School of Medicine at the University of Southern California (USC).

I have been a Faculty member at USC for almost 30 years. My areas of expertise are exposure assessment and health impacts in humans, especially among children. I have been involved in National Institutes of Health (NIH) and competitively-funded research since the mid-1970s, and I have authored or co-authored roughly 150 peer-reviewed publications on airborne contaminants, their chemical and physical characterization, and on the short- and long-term health effects of those ambient chemical pollutants. I have served on several US EPA expert panels to assist the Clean Air Science Advisory Committee (CASAC) in their mandated reviews for oxides of nitrogen, oxides of sulfur, particulate matter, and ozone.

During my time at USC, I have developed and currently lead the undergraduate Environmental Health Teaching Track in the Health Promotion and Disease Prevention program. I have taught hundreds of students per year about environmental health, equity, exposure, and risk, as well as about environmental health policy and climate change. I am a Co-Principal Investigator on an NIH training grant (EH MATTERS) to teach undergraduate students of diverse backgrounds and social disparities about the environment so that they can help to change those disproportionate exposure disparities. I also serve as co-Director of a Exposure Factors Core within a NIH-funded P30 Center to provide access and support for investigators to tools needed to improve their respective research efforts.

In recognition of my career efforts, I was awarded the 2017 Constance Mehlman Award from the International Society of Exposure Science (ISES) for helping to shape National or State policy with exposure analysis leading to a reduction or prevention of human exposure.

My comments will focus on the issues of the health impacts of exposure to airborne contaminants (often described as “air pollution”), the chemical/physical/toxicological attributes of those pollutants and pollution by-products, and the intersection of these environmental health issues with locomotive operations in or near communities, especially communities of color. Understanding these issues is important because outdoor air pollution continues to affect the health of millions of people in ways that impact their daily and long-term health, their quality of life, and how long they live. Air pollution is a societal health and quality-of-life issue that we can do something about, and there are reasonable and feasible alternatives available to reduce pollution emissions. This is especially important in communities already stressed by socio-economic and environmental issues that lead to disproportionately-impacted communities. As I will discuss in my declaration, reducing pollution emissions can have real and substantial effects on human health.

2. **Have you submitted testimony to the U.S. EPA before?**

I have not previously formally submitted written testimony to EPA, but I have participated as an expert in several previous panels and thereby provided input, advice, and recommendations. I have previously served on a number of CASAC (Clean Air Science Advisory Committee) review panels for assorted NAAQS (National Ambient Air Quality Standards), including the cycles for NO_x (nitrogen oxides) and SO_x (sulfur oxides) in 2009 and 2014, for PM (Particle Matter) in 2014, and for O_3 (ozone) in 2014.

Air Pollution Summary.

3. **Who is most at risk from exposure to air pollution?**

Exposure to air pollution is one of the leading risk factors for worldwide deaths, according to recent Global Burden of Disease estimates (REF1). The determination of precisely who is "most" at risk from exposure to air pollution may be debatable, but it is undeniable that those "most" at risk share at least two commonalities – excessive exposure and increased susceptibility. Historically, those most susceptible have included the young, the old, the ill, and pregnant mothers (to protect fetal development). As our understanding of exposure and risk has improved, other population segments have also been identified as being at increased risk by virtue of their residential, activity, or work locations. Those who live, work, or play near busy roadways have been shown to be at increased risk, due to heightened exposures associated with close proximity to direct pollution emissions. Those who regularly exercise near elevated exposure sources (for example, in recreational green spaces near busy roads, on playing fields alongside freeways, or along roadways during times of traffic congestion) have been shown to be at increased risk for a wide range of negative health effects. Workers who spend extended periods of time outdoors, at high breathing rates (due to heavy physical labor), are also considered to be at increased risk from air pollution. Additionally, there is a substantial segment of the population who may be genetically pre-disposed to air pollution sensitivity by virtue of the presence or absence of certain inheritable traits (REF2). Because their options for reducing personal exposure are few, those who live in under-served or low-socio-economic-status (SES) or disadvantaged communities (DACs) tend to be at increased risk. Often, these communities are close to or interspersed with industrial, manufacturing, or mixed-use zoning activities that may lower property values compared to other neighborhoods. Since financial resources in DACs are more limited, DACs residents lack the potential for relocating or seeking substantive remediation if something in the neighborhood is concerning to their health or welfare. They may lack political power to contest questionable living or working conditions, and typically cannot afford legal counsel or representation to challenge authority. For all these reasons DACs, which are often communities of color, are included among those "most at risk" for exposure to air pollution.

4. What is ground-level ozone?

Ground-level ozone is a clear and colorless gas present in the troposphere. The troposphere is the lowest level of Earth's atmosphere and is closest to where we live and breathe - hence the term "ground level". At the highest reaches of our atmosphere, ozone is very important as a protective filter to shield the Earth from incoming ultra-violet radiation from the sun. At ground level however, ozone is considered an air contaminant with substantial negative health, vegetation, material, and aesthetic effects (REF3). The chemical formula for ozone is O_3, which connotes the fact that an ozone molecule is made up of three oxygen atoms chemically bound together. Ozone is one of six specifically identified air pollutants named under the United States (U.S.) Clean Air Act, in which there are specified Federal Standards (National Ambient Air Quality Standards, or "NAAQS") established to protect the public health.

5. How is ozone formed?

Ozone is formed through a complex series of chemical reactions in the atmosphere, driven by the photochemical energy provided in sunlight through ultraviolet radiation. Ozone is a "secondary" pollutant, meaning it is not directly emitted from any tailpipe, smokestack, or direct emissions. It is the result of chemical reactions that take place in the outdoor air during long days of intense sunlight (primarily during daylight hours) between directly-emitted gases (known as "primary" pollutants) from both anthropogenic ("man-made") and naturally-occurring processes. Man-made emissions of primary pollutants include direct emissions of nitrogen oxides from incomplete combustion processes (such as vehicle exhaust), volatile organic compounds (also known as VOCs, from carbon-containing gases and vapors such as fossil fuels and solvents), and carbon monoxide (REF3). Naturally-occurring emissions sources include vegetation, burning biomass (such as from controlled burns or wildfires), and lightning (REF3).

Incomplete combustion of fossil fuels (be it gasoline, diesel, natural gas, coal, or biomass) results in airborne emissions. These include nitrogen oxides, VOCs, carbon monoxide, and particles that are important in chemical reactions that lead to the formation of ozone. In most urban areas, emissions associated with assorted combustion processes, especially vehicle emissions, are of paramount importance in ambient photochemical ozone production. Ozone levels tend to be higher away from busy roads and immediate sources of nitrogen oxides. This is due to shifts in chemical reactions due to competition for certain chemical species present in limited amounts in the atmosphere.

It is often the case that the highest observed ozone levels will be downwind of rather than in large metropolitan areas (in other words, some distance away from primary nitrogen oxides emissions). Meteorological and topological conditions (wind and temperature effects, as well as impacts by the presence of mountains or valleys) help to shape the flow and movement of gases and particles across regional areas. Because of this, areas downwind of large cities or emissions can often be impacted by plumes of pollution from communities many miles away.

6. What are the current state and federal ozone standards?

Under the Federal Clean Air Act (Section 177), California has historically been granted waivers to set more restrictive air quality standards to address persistent and severe air pollution problems. Currently in California, there is both a one-hour and an eight-hour ozone standard. The one-hour California Ambient Air Quality Standard for ozone is 0.09 parts per million (90 parts per billion), measured by ultra-violet photometry (REF4). The eight-hour California Ambient Air Quality Standard for ozone is 0.070 parts per million (70 parts per billion), measured by ultra-violet photometry (REF3). At the national (NAAQS) level, the one-hour ozone level was revoked in 1997 in favor of a more protective eight-hour standard (although regions are still required to attain the standard). The eight-hour NAAQS for ozone is 0.070 parts per million (70 parts per billion), measured by ultra-violet photometry.

Under the U.S. Clean Air Act, *Primary Standards* are those set with an adequate margin of safety to protect the public health. *Secondary Standards* are those set to protect the public welfare from adverse effects. Welfare effects under the Clean Air Act include effects on soils, water, wildlife, vegetation, visibility, weather, climate, materials, economic values, and personal comfort and well-being (REF4). At the current time, there is only a primary California Ozone Standard in effect. At the Federal level, the National Primary and Secondary Ozone standards are the same.

7. What are the health consequences of ozone pollution?

As of July 11, 2021, there were over 5,248 peer-reviewed publications identified on a PubMed web search of the health effects of ozone. (PubMed is a computer search resource developed and maintained by the National Center for Biotechnology Information at the National Institutes of Health).

Under the Federal Clean Air Act, the USEPA is required to review the latest science and information available regarding the NAAQS pollutants every five years and make a determination as to whether the respective NAAQS for each pollutant is protective of the public health with "an adequate margin of safety" in the judgement of the EPA Administrator (REF3). The data that serve as the basis for those judgements are summarized in pollutant-specific "Integrated Scientific Assessment" (ISA) documents posted by the EPA on a NAAQS-focused website accessible to the public. Due to the volume of data available regarding the health impacts (both short and long-term) of ozone, several dozen summary tables regarding the health impacts of ozone exposure are presented in the current ozone document (REF3). For summary purposes, I provide one table from the most recent ozone review document (REF3) (see Table 1), which identifies the various organ systems of targeted health concern (demonstrating the breadth of ozone's effect on human health), as well as the level of confidence in assigning those effects to ozone exposure in the two most recent NAAQS reviews.

Summary determinations are provided for both short-term exposures (on the order of minutes, hours, or days) and long-term (over the course of months or years). Short-term health effects have been documented for respiratory, cardiovascular (heart-and-circulatory related), metabolic (glucose and insulin regulation, changes in inflammatory or liver bio-markers indicating some disruption of typical cell function), total mortality (death), and central nervous system (brain and motor function) endpoints. Long-term health effects have been documented for respiratory, cardiovascular (heart-and-circulatory related), metabolic (glucose and insulin regulation, changes in inflammatory or liver bio-markers indicating some disruption of typical cell function, total mortality (death), reproductive (including fertility, reproduction, and birth outcomes), central nervous system (brain and motor function), and cancer outcomes.

For each of these health endpoints, the USEPA documentation provides some judgment regarding the strength of evidence for a specific health outcome (REF3). Respiratory effects cover a wide range of outcomes, including increased airway inflammation, airway hyper-responsiveness, lowered lung function, increased symptoms, increased asthma medication usage, increased hospital admissions for asthma and chronic obstructive pulmonary disease (COPD), the development of new disease (asthma), and death (REF3). Cardiovascular outcomes include hypertension (high blood pressure), arrhythmias, myocardial infarctions (heart attacks), and increased emergency room visits or hospital admissions, and death (REF3). Metabolic effects include changes in assorted biomarkers reflecting a shift from routine biologic function that could lead to inflammatory responses, dysregulation, and metabolic-related macro-diseases such as diabetes, fatty liver disease, or obesity. Central nervous system effects include effects on short-term and long-term memory, sleep patterns, and behavior (REF3).

Table 1: Summary of Causality determinations by exposure duration and health outcome for ozone exposures (Table ES-1 from EPA ISA for Ozone, listed as REF3)

Health Outcome[a]	Conclusions from 2013 Ozone ISA	Conclusions in the 2020 ISA
Short-term exposure to ozone		
Respiratory effects	Causal relationship	Causal relationship
Cardiovascular effects	Likely to be causal relationship	Suggestive of, but not sufficient to infer, a causal relationship[c]
Metabolic effects	No determination made	Likely to be causal relationship[b]
Total mortality	Likely to be causal relationship	Suggestive of, but not sufficient to infer, a causal relationship[c]
Central nervous system effects	Suggestive of a causal relationship[d]	Suggestive of, but not sufficient to infer, a causal relationship
Long-term exposure to ozone		
Respiratory effects	Likely to be causal relationship	Likely to be causal relationship
Cardiovascular effects	Suggestive of a causal relationship[d]	Suggestive of, but not sufficient to infer, a causal relationship
Metabolic effects	No determination made	Suggestive of, but not sufficient to infer, a causal relationship[b]
Total mortality	Suggestive of a causal relationship[d]	Suggestive of, but not sufficient to infer, a causal relationship
Reproductive effects	Suggestive of a causal relationship[d]	Effects on fertility and reproduction: suggestive of, but not sufficient to infer, a causal relationship[b]
		Effects on pregnancy and birth outcomes: suggestive of, but not sufficient to infer, a causal relationship[b]
Central nervous system effects	Suggestive of a causal relationship[d]	Suggestive of, but not sufficient to infer, a causal relationship
Cancer	Inadequate to infer a causal relationship	Inadequate to infer the presence or absence of a causal relationship[e]

[a]Health effects (e.g., respiratory effects, cardiovascular effects) include the spectrum of outcomes, from measurable subclinical effects (e.g., decrements in lung function, blood pressure) to observable effects (e.g., medication use, hospital admissions) and cause-specific mortality. Total mortality includes all-cause (nonaccidental) mortality, as well as cause-specific mortality.

[b]Denotes new causality determination.

[c]Denotes change in causality determination from 2013 Ozone ISA.

[d]Since the 2013 Ozone ISA, the causality determination language has been updated and this category is now stated as suggestive of, but not sufficient to infer, a causal relationship.

[e]Since the 2013 Ozone ISA, the causality determination language has been updated and this category is now stated as inadequate to infer the presence or absence of a causal relationship.

8. What is fine particulate matter (PM2.5)?

Particulate matter can be thought of as being very small pieces of dirt or droplets floating around in the air. Particles exist in a very wide range of sizes, from those barely visible (such as grains of sand or wind-blown dust) to those on the sub-microscopic or molecular level. *Fine Particle Matter* is the designation for particles with a nominal particle diameter of 2.5 microns (two-and-a-half millionths of a meter) or less, herein referred to as $PM_{2.5}$. This working definition of an air pollutant by physical size is an acknowledgement that particles can come from many different sources, be made of many different chemicals, and have different weight, shape, surface roughness and area, as well as different toxicological properties.

9. How is PM2.5 formed?

In the atmosphere, $PM_{2.5}$ is the result of so-called “primary” or “secondary” emissions. Emissions occur as the result of incomplete combustion [burning or heating of some fuel or substance], by-product release [venting or removal of some chemical or chemicals), re-intrainment (“kicking up” of some deposited material back into the air), or through chemical reactions in the atmosphere. These releases can lead to new particle formation or particle growth from very small particles – called ultra-fines – up into larger size ranges, such as $PM_{2.5}$ or larger. A summary of the formation, composition, and sources of ambient PM is summarized in Table 2 below.

Direct emissions arise from either natural or man-made (anthropogenic) sources. Natural sources include wind-blown dust, atmospheric photochemistry (chemical reactions that take place in the open air), sea-spray aerosol, volcanic emissions, and vegetative burning. Man-made sources include vehicle emissions, boiler operations, power-plant or industrial emissions, and any abrasion, grinding, or frictional-force (like braking) operations (REF5). In the atmosphere, gases can also chemically react with each other to create new small particles or condense or react on pre-existing smaller particles that can then “grow” into larger particles by accumulation of material (REF5). The sources present in a given region (such as vehicle traffic, vegetation, and industrial operations), the gases present in the air (such as nitrogen or sulfur oxides, oxygen, volatile organics, and solvents), the meteorology of the area (including wind, heat, and the amount of atmospheric mixing) and the topology of the region (the presence of bodies of water or open land, tall mountains, deep canyons, or broad valleys) all affect the extent to which particles can and will form, collect, or be trapped in a given geographic location.

Table 2: Particle Formation, composition, and sources (Table 2-2 in EPA ISA for PM, listed as REF 5)

	UFP	$PM_{2.5}$	$PM_{10-2.5}$
Formation processes	Combustion Pyrogenesis Homogeneous and/or heterogeneous nucleation Condensation and adsorption (gas-particle partitioning)	Gas-particle partitioning Particle agglomeration Reactions of gases in or on particles Cloud droplet evaporation	Mechanical degradation of solid materials (crushing, grinding, abrasion of surfaces) Evaporation of sea spray Suspension of dust
Typical chemical/material components	Sulfate Elemental carbon Metal compounds Low volatility organic compounds	Sulfate, nitrate, ammonium, and hydrogen ions Elemental carbon Low and moderate volatility organic compounds Metals: compounds of Pb, Cd, V, Ni, Cu, Zn, Mn, Fe, etc. Water	Suspended soil or street dust Fly ash from coal, oil, and wood combustion Nitrates/chlorides/sulfates from HNO_3/HCl/SO_2 reactions with coarse particles Oxides of crustal elements (Si, Al, Ti, Fe) Sea salt (Na, K, Ca, carbonate, sulfate, and chloride) Pollen, mold, fungal spores Plant and animal detritus Tire, brake pad, and road wear debris
Dominant[a] primary particle sources	Combustion of fossil fuels and biomass High temperature processes (i.e., smelters, steel mills, etc.)	Combustion of fossil fuels and biomass High temperature processes	Resuspension of industrial dust and soil tracked onto roads and streets. Suspension from disturbed soil (e.g., farming, mining, unpaved roads) Construction and demolition Coal and oil combustion Sea spray Biological sources

10. What are the current state and federal PM2.5 standards?

The California ambient air quality standard and NAAQS for $PM_{2.5}$ are based on an annual arithmetic mean (or what we commonly describe as the "average" or mean value) of micrograms of $PM_{2.5}$ per cubic meter of air volume (ug/m^3). The annual arithmetic mean California ambient air quality standard for $PM_{2.5}$ is 12 ug/m^3, measured by gravimetric or beta-attenuation methods (REF4). There currently is no 24-hour average California ambient air quality standard for $PM_{2.5}$.

As previously stated, under the U.S. Clean Air Act, *Primary Standards* are those set with an adequate margin of safety to protect the public health. *Secondary Standards* are those set to protect the public welfare from adverse effects. Welfare effects under the Clean Air Act include effects on soils, water, wildlife, vegetation, visibility, weather, climate, materials, economic values, and personal comfort and well-being (REF4). The current 24-hour average NAAQS for $PM_{2.5}$ is 35 ug/m^3 (with both primary and secondary standards being the same) (REF4). The current annual arithmetic mean NAAQS for $PM_{2.5}$ is 12 ug/m^3 for the primary NAAQS, and 15 ug/m^3 for the secondary NAAQS (REF4).

11. What are the health consequences of exposure to PM2.5?

As of 14 July 2021, there were 3,165 peer-reviewed publications identified during a PubMed web search on the topic of health effects of $PM_{2.5}$.

A summary of the known science regarding the health effects of $PM_{2.5}$ was provided in the USEPA Integrated Science Assessment for Particulate Matter, which was issued as a final report dated December 2019 (REF5). A broad array of health consequences associated with ambient $PM_{2.5}$ exposures were reported, including cardiovascular (heart and circulatory-system related), respiratory, and death (REF5). Long-term exposures have been associated with cardiovascular, respiratory, mortality, reproductive/developmental, and cancer/mutagenicity/genotoxicity endpoints (REF5). More recent data has provided evidence of the association between long-term $PM_{2.5}$ exposures and a variety of nervous system effects, including neurodegeneration, cognitive decrements, Alzheimer's, autism spectrum disorder, and dementia (REF 6-8). In 2013, the International Agency for Research on Cancer listed outdoor air pollution, especially PM, as a human carcinogen, based on the review of over 1,000 research articles.

12. What is diesel exhaust?

Diesel exhaust is a combination of gases and particles that are produced during incomplete combustion of diesel fuel. (It should be noted that all engine combustion processes are less than 100% efficient, so any combustion process leads to incomplete combustion and potential release of particles). Most of the particles associated with diesel exhaust are characteristically very small in diameter. More than 90% of diesel exhaust particles are less than 1 micron in diameter, or one-millionth of a meter [REF9,10), with most of these less than 0.1 micron, or one-tenth of one-millionth of a meter, in a size range known as ultra-fine particles. The particles themselves are composed of a solid elemental carbon core, with the surface of the particle coated with organic carbon compounds and other chemicals. The gases emitted in diesel exhaust include thousands of different chemicals, and several air pollutants of health and regulatory concern. Some of these include acetaldehyde, acrolein, benzene, 1,3-butadiene, formaldehyde, and an assortment of gases collectively known as polycyclic aromatic hydrocarbons (PAHs) (REF10).

Diesel engines, by nature of their operation, also emit a substantial amount of carbon monoxide and nitrogen oxides along with the other gases and particles (REF10). The reduction of nitrogen oxides and particles emissions are especially challenging, as manufacturers seek to optimize engine operating and vehicle performance conditions to minimize particle soot formation (which occurs at lower engine combustion temperatures) and nitrogen oxides production (which occurs at higher engine combustion chamber temperatures) (REF10).

13. How is diesel exhaust formed?

Diesel exhaust is formed during and after the combustion process that takes place within a functioning diesel engine. Diesels operate by mixing fuel and air in the combustion compartment, and then compressing the mixture under high pressure. The high pressure leads to high temperature, which causes the fuel mixture to spontaneously ignite. The chemical energy of this explosion is then converted into mechanical energy, turning the engine and moving the vehicle. However, there are many variables that affect this activity, including air-fuel ratio, combustion chamber turbulence, air-fuel concentration, and combustion temperature, so incomplete combustion occurs, and variations in diesel exhaust occur (REF11). The gases and particles are exhausted from the engine and react with each other as well as with other gases and particles in the air.

14. What are the health consequences of exposure to diesel exhaust?

Diesel exhaust has been identified as a Toxic Air Contaminant by the State of California (in 1998) and as a known human carcinogen by the International Agency for Research on Cancer (IARC) in 2012 (REF9,12). These determinations have been made based upon numerous published health studies, especially those involving long-term occupational exposure in the railroad, mining, and trucking industries.

Diesel particles are just one of the many kinds of particles present in $PM_{2.5}$, so many of the negative health outcomes associated with generic $PM_{2.5}$ have also been ascribed to diesel exhaust. Diesel exhaust in and of itself has also been identified with many health effects. These include cardiovascular effects (arrhythmia, heart rate variability, blood pressure changes, systemic inflammation, thrombosis, myocardial infarction, and death), respiratory effects (pulmonary function, allergic responses), central nervous system effects, reproductive/developmental/prenatal/neonatal outcomes, immune system, mutagenic, and genotoxic effects (REF13,14).

In addition to the particle component, several of the gases associated with diesel exhaust (nitrogen oxides, PAHs, benzene, and 1,3 butadiene) have also been associated with negative health outcomes. Nevertheless, the focus of health concern has generally been on the particle phase, since diesel particles contain both a solid carbon core and adsorbed gases on its surface. At the current time, there are no state or national air quality standards for diesel particulate matter or diesel exhaust.

15. How is diesel particulate matter (diesel PM) different from PM2.5?

Diesel PM is a subset of $PM_{2.5}$. $PM_{2.5}$ is a class of pollutants defined by their physical size, and diesel PM is one of many types of PM pollution that falls within that physical size category. However, diesel PM contains many known carcinogens and has been specifically identified as a known human carcinogen. There are many other contributors to the $PM_{2.5}$ category, including fossil fuel combustion, fugitive dust from paved and unpaved roads and fields, prescribed or inadvertent burning, mobile source exhaust from fuels other than diesel, bioaerosols (portions of pollen, plant and insect fragments), and secondary formation of particles in the atmosphere through photochemistry (REF5).

16. What are ultrafine particles, and how are they formed?

Ultrafine particles are a special segment of the overall particle size spectrum and comprise very small particles whose mean diameters are less than 0.1 micron (or one-tenth of one-millionth of a meter). These particles are so small that they behave like gases, moving along with the airstream. They are so small that they can stay suspended in air for long periods of time because they have very little mass and are not substantively affected by gravity. They are not easily captured by general filter technologies in widespread use, and they have very large surface areas for their relative size. Their large surface area makes them important in ambient air photochemistry because they provide lots of common space for chemicals to interact. Ultra-fine particles are considered to be quite chemically reactive and can readily be found downwind of urban sources such as vehicle traffic on or near busy roadways (REF15), or near the exhaust coming from refineries or smokestacks. Ultra-fine particles can react with gasses in the air or with other particles, to "grow" into a larger size range, becoming particles in the $PM_{2.5}$ mode. They can vary quite dramatically from location to location, and are often quite high in concentration close to their source, decreasing dramatically in concentration within a few hundred meters. Ultra-fine particles are generally formed from combustion processes (i.e., the burning of wood, biomass, or fossil fuels such as coal, gasoline, or diesel oil), from condensation of gases, and as a result of ambient photochemistry (REF5,15).

17. What are the health consequences of exposure to ultrafine particles?

The health consequences of exposure to ultrafine particles are an increasingly active area of research. Their extremely small size and dynamic behavior make ultra-fine particles both interesting to study and potentially concerning. Because of their small size, they can cross the air-blood barrier in the lung and enter the bloodstream. Once in the circulatory system, they can travel to virtually any organ system in the body, and even find their way into cell mitochondria. There, disruption of normal cell function can occur, leading to inflammation, up or down-regulation of enzymes and endocrine function, and the triggering of a pathway of stress and functional changes in cellular systems. Ultra-fine particles have also been documented to enter the body through the nasal olfactory bulb, and travel directly to the brain, raising concerns regarding central nervous system and executive motor function processes (REF5,16,17). Ultrafine particles have also been linked to negative cardiovascular health outcomes (REF5) and in fetal development (REF18). At the current time, there are no state standards or NAAQS for ultrafine particles.

18. What is nitrogen dioxide (NO_2)?

Nitrogen dioxide (NO_2) is a common air pollutant most frequently associated with the incomplete combustion of fossil fuels (such as coal, oil, natural gas, gasoline, diesel, or biomass) and subsequent chemical oxidation in the atmosphere.

19. How is NO_2 formed?

Whenever combustion takes place (for example, burning of wood for heating; use of gasoline or diesel fuels in motor vehicles, locomotives, or ships for transportation or goods movement; fossil fuels in power plants or industrial boilers for energy production), oxygen and nitrogen combine at high temperature in a chemical reaction to form nitric oxide (NO), which quickly reacts with additional oxygen in the atmosphere to form nitrogen dioxide (NO_2). With continued chemical reactions and energy from sunlight (ultra-violet radiation), the nitrogen species can go on to form other gases and particles (the particles constituting a group known as particulate nitrates, which are a subset of $PM_{2.5}$). Nitrogen oxides are important in terms of their own health impacts, but they also are involved in a series of chemical reactions that can lead to formation of ozone in the atmosphere or to a re-adjustment in the equilibrium concentration of ozone in the atmosphere. Accordingly, having accurate information about the airborne concentrations of NO_2 and implementing effective strategies to reduce ambient NO_2 are needed to not only effectively address ambient NO_2 but also to reduce some of the important precursors that affect ozone and particulate matter formation in the atmosphere (REF2).

20. What are the current state and federal NO_2 standards?

The current California Ambient Air Quality Standard for NO_2 is in the form of a one-hour and an annual arithmetic mean. The one-hour California standard is 0.18 parts per million (equivalent to 180 parts per billion), measured by gas-phase chemiluminescence (REF4). The annual arithmetic mean is 0.030 parts per million (equivalent to 30 parts per billion), measured by gas-phase chemiluminescence. The federal primary standard is also in two forms, a one-hour value of 100 parts per billion (which is equivalent to 0.100 parts per million), and an arithmetic annual mean value of 0.053 parts per million, or 53 parts per billion. For the NAAQS, the Federal Reference measurement method is also gas-phase chemiluminescence.

21. What are the health consequences of NO_2 pollution?

Exposure to NO_2 has been shown to affect several organ systems and lead to a variety of negative health outcomes. The evidence for respiratory effects is quite strong, and the relationship between NO_2 and respiratory effects was determined to be “likely causal” in the 2016 review of the health literature under the Clean Air Act NAAQS process (REF2). Exposure to NO_2 has been linked to increases in risk of respiratory infections, symptoms, exacerbation of asthma, and development of asthma (REF2). Lowered lung function performance among children and increased risk for asthma exacerbation have also been repeatedly observed (REF2).

Although the mechanisms are not well-understood, there is evidence to suggest associations between NO_2 exposure and cardiovascular effects, including myocardial infarctions (heart attacks) (REF2). Recent research also provides increasing evidence that NO2 exposures are associated with diabetes (REF2, 20). There is also data linking long-term air pollution NO_2 exposure with lung and breast cancer (REF20, 21). These conclusions are complicated by co-exposures to other traffic-related pollutants, proximity to roadway, and racial sub-group differences, but do suggest that certain sub-groups in the general population are at increased risk.

Health Impacts of Air Pollution from Locomotives and Railyards.

22. **There are three main types of diesel locomotives: switcher locomotives, line-haul locomotives, and passenger locomotives. Please describe how switcher locomotives operate, where they typically operate, and what communities they typically operate in.**

Switcher locomotives are a type of typically smaller locomotive engines primarily used to assemble and dis-assemble trains in a railyard (i.e., moving cars around – hence the term "switching"). (REF22) These operations are used to form longer trains for transport from one location to another. To perform the task at hand, switchers usually are low-powered but high-torque configurations, to provide needed traction to move stationary heavy cars in the yard (REF23). Most of the time, switcher locomotives operate in idle (waiting to move cars, providing power for crew air conditioning or heating, maintaining air-brake pressure) (REF24) or in a low-power setting (moving heavy rail cars from a stationary position to connect with other cars) (REF25), which has implications for local emissions. Occasionally, older line-haul locomotives may also be assigned switcher duties (REF26). Switcher locomotive use, by definition, is focused in railyard or intermodal transfer yard locations, but can also be used for local short-haul or transfer activities (REF23,26). As such, they typically operate in communities near railyards or regional intermodal transfer facilities.

23. **Please describe how line-haul locomotives operate, where they typically operate, and what communities they typically operate in.**

Line-haul locomotives refer to locomotives involved in the movement of freight over long distances on a portion of the company's operating line, excluding any switching activities, pick-up, or delivery (REF27). Much or the operational time for line-haul locomotives is therefore characterized by engine operation in high-power settings (REF25), which has implications for local emissions. Line-haul operations can occur over wide regional areas covering hundreds or thousands of miles, as the trains move from one area to another to transport goods. Air pollution, noise, vibration, local area blight, and public safety concerns have combined to make it less desirable to live immediately adjacent to operating rail lines in many regions of the country. Lower socioeconomic-status (SES) and/or more community populations of color are often found inhabiting neighborhoods transected by operating rail lines. Based on a recent viewing of CalEnviroscreen 4.0, a large portion of the Southern California neighborhoods transected by rail lines are disproportionately-exposed communities at higher cumulative health risk (REF28).

24. Please describe how passenger locomotives operate, where they typically operate, and what communities they typically operate in.

Passenger locomotives refer to passenger-carrying trains. These are operated typically on many of the same company lines as freight (line-haul) locomotives, and they have higher-priority for line usage (REF29) and a set time schedule for travel. They operate in many configurations, from commuting for daily work to long-distance travel with sleeping and dining cars. They can be operated to maximize convenience or timeliness. To maximize convenience, they may schedule frequent stops at multiple stations along a prescribed route to accommodate passenger boarding and de-boarding, or they may arrange to operate in an "express" fashion and only stop at a few selected intermediate stations to minimize travel time length between two more distant locations.

Passenger locomotives can operate inter-city or across regions, as a commuter train, light-rail system or more extended regional travel option. Because of this wide range of possible operational formats, passenger locomotives can be found in an equally wide range of communities.

25. What are the air pollution issues with switcher locomotives?

Because the use of switcher locomotives is generally confined to a specific yard or location for the purpose or assembling or disassembling trains for regional or national hauls, the emissions associated with switcher locomotives are primarily localized to the adjacent community. Because a large portion of a switcher locomotive's operational time is spent idling in the yard, air pollution associated with excessive fuel consumption while idling (as well as noise-related issues) are key attributes of switcher locomotive usage and health concerns (REF30).

Air contaminants of relevant regulatory health and pollution concerns include NO_x and $PM_{2.5}$, in addition to carbon monoxide (CO) and hydrocarbons (HC) (REF31). As previously described (see responses to Questions 11 through 21 above), there are both broader and more specific health concerns regarding exposures to NO_2, $PM_{2.5}$, and ultra-fine PM (PM smaller than 0.1 microns diameter), with ultra-fines currently an unregulated class of pollutants but increasingly being associated with negative health outcomes.

An important element of the "air pollution issues" discussion with locomotive engines in general and switcher locomotives in particular is the level of pollution control technology being applied to any given locomotive engine. This is typically identified by "Tier" category, which directly refers to emissions amounts but indirectly refers to different demonstrated air pollution control technologies (such as exhaust gas after-treatment, particulate filters, high-efficiency after-treatment technologies, and so on). In practical terms, increasingly stringent Tier-level controls (From Tier 0 to Tier 4) reflect increased controls and decreased emissions.

Examples of the extent to which switcher locomotive emissions play a role in air pollution issues is viewable in State of California data. California conducts regular emission inventories and estimates current and future emissions as a component of regulatory compliance with U.S. Clean

Air Act guidelines. Estimates of the statewide NO_x and $PM_{2.5}$ contributions from switcher locomotives are illustrated in the Figures 1 and 2 below, which illustrate successive year emissions for NO_x and PM, respectively.

Given the historic challenges of air quality in specific locations across California, switcher emissions by major air basin within California are also provided for comparison (see Figure 3 below).

As can be seen in Figure 3, switcher locomotive emissions in the South Coast Air Basin account for the major portion of statewide switcher emissions. To put this into geographical and population context, the South Coast Air Basin includes portions of Riverside, San Bernardino, Los Angeles, and Orange Counties, and is home to roughly half of California's 39 million-plus population (REF33).

Figure 1: Statewide Switcher NOx, tons per day by year and Tier level control (REF32)

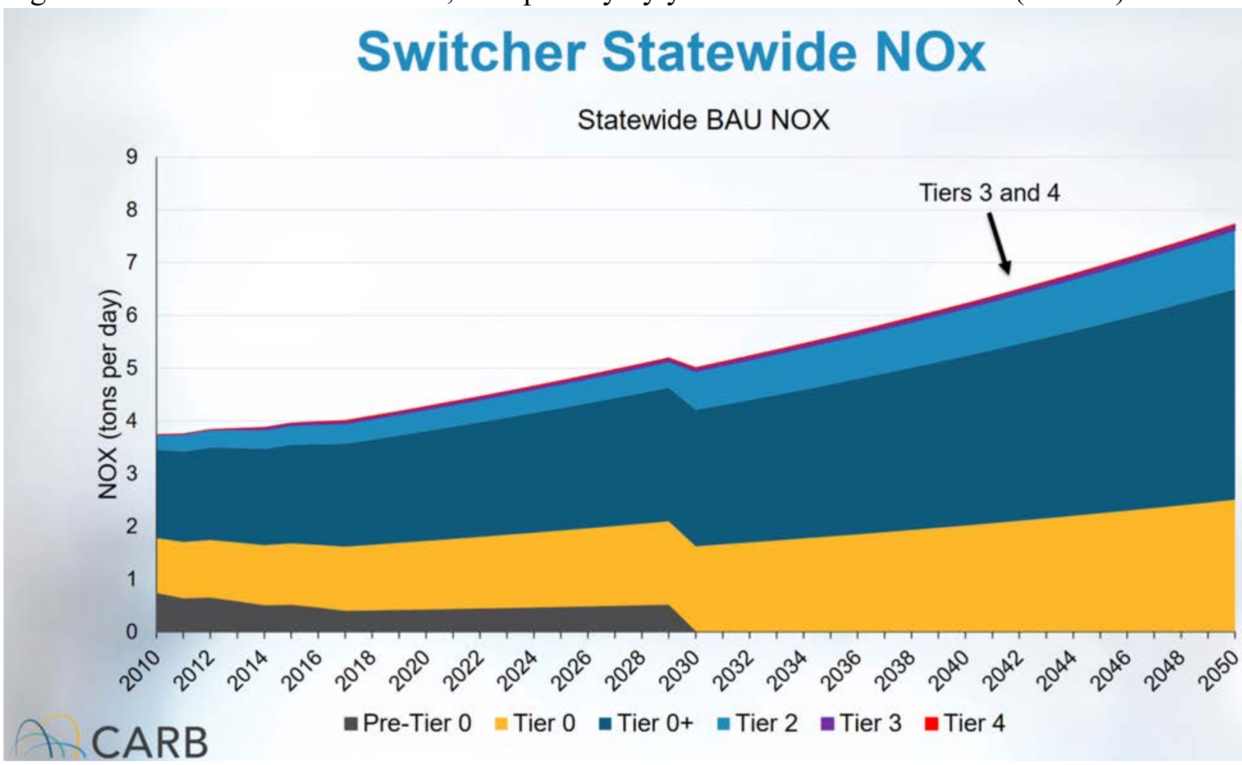


Figure 2: Statewide Switcher PM, tons per day by year and Tier level control (REF32)

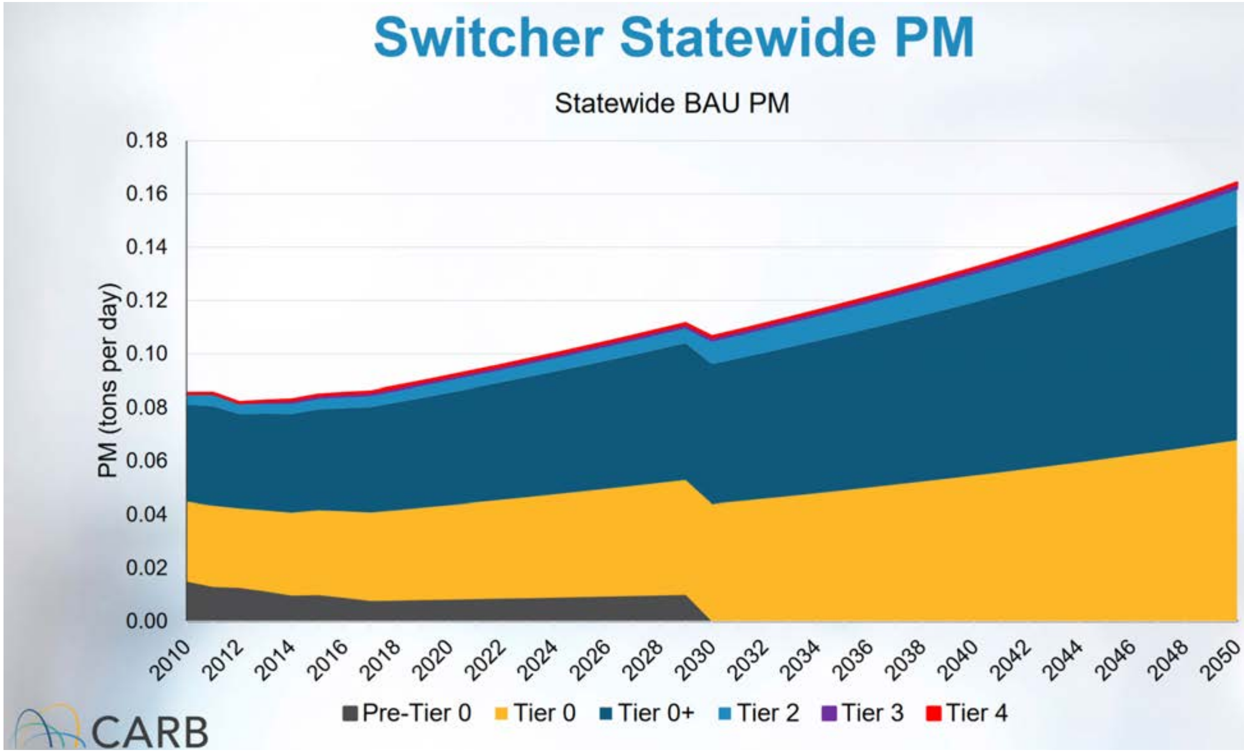
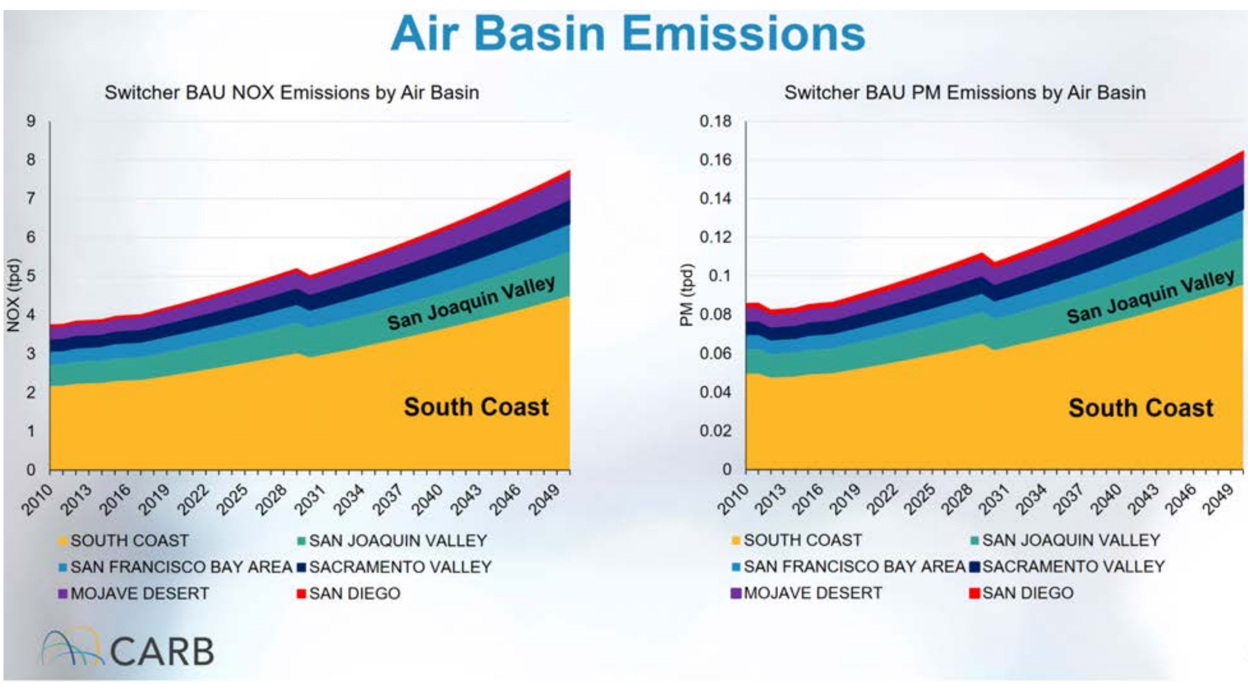


Figure 3: Air Basin Emissions Inventory Estimates for NOx and PM (tons per day by year and Tier level) by selected California air quality regions



26. What are the air pollution issues with railyard equipment?

Air pollution sources associated with railyard equipment include a variety of railyard equipment. Operations within the railyard are focused on the assembly of trains, the movement of railcars, maintenance and repair, and the facilitation of loading, unloading, and transport of goods to assorted destinations. Potential sources of pollution within the railyard include locomotives (both switcher and long-haul), drayage trucks, cargo-handling equipment (such as cranes, yard hostlers, forklifts, yard trucks, and yard tractors), Transportation Refrigeration Units (both for trucks and railcars), and assorted miscellaneous equipment (such as refueling trucks) (REF34,35). Air pollution issues associated with these sources include airborne releases of nitrogen oxides, particulate matter of various sizes including diesel exhaust, various hydrocarbon and solvent emissions (sometimes denoted as **T**otal **O**rganic **G**ases or TOGs), and carbon monoxide. These pollutants are the result of incomplete combustion (fuel consumption), frictional forces (braking and frictional movement), and evaporative emissions. Although the primary focus is on diesel exhaust in most discussions of locomotive emissions, it should also be noted that some of the railyard equipment are gasoline-operated and therefore do provide some gasoline-related emissions as well (REF35).

27. Describe the air quality near railyards.

Air quality near railyards is a function of both regional and local emissions. The regional air quality provides a foundational base into which additional emissions are locally contributed. Both play a role in overall air quality and on health impacts to local and regional residents (REF36,37). For example, the Los Angeles-San Bernardino metropolitan region is one of several areas in the US in non-compliance with National Ambient Air Quality Standards (NAAQS) for ozone and $PM_{2.5}$ (REF38). In addition to millions of on-road vehicles, two large seaports, and numerous local manufacturing operations, there are nine major railyards in Southern California (see Figure 4 below). Three of these railyards (one southeast of downtown Los Angeles, one within a few miles of the Ports of Los Angeles and Long Beach, and one near San Bernardino) operate at significant volume and emit a substantial amount of diesel exhaust into the surrounding community; see Table 3 below for railyard emissions comparison (REF39). The Hobart railyard near downtown Los Angeles is among the largest in the country (REF39). Accordingly, emissions from these operating facilities contribute to the unacceptable atmospheric conditions that residents are routinely exposed to, so efforts to reduce local emissions are of important to consider.

Figure 4: Major Class I Railyards in Southern California (from REF39)

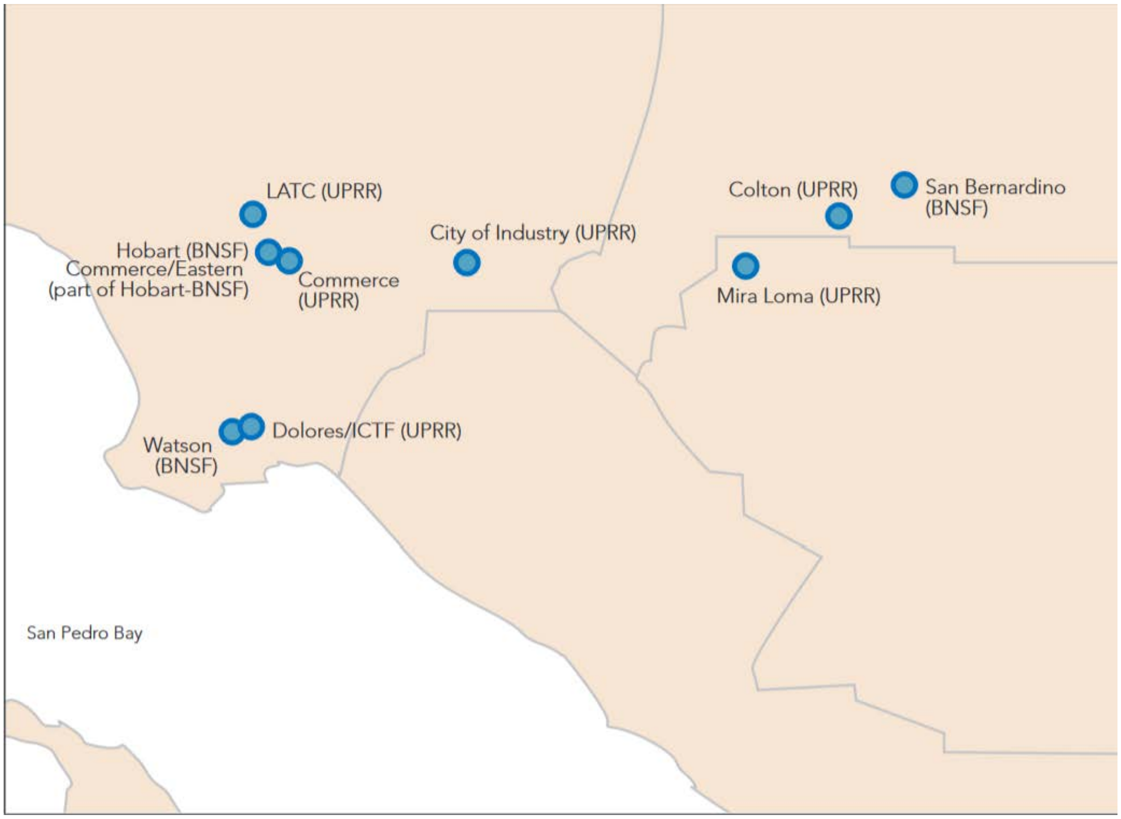


Table 3: Southern California railyard diesel exhaust emissions by source type (tons per year) and percent contribution, 2005 data (see REF39)

Railyard	Locomotives		Cargo-Handling Equipment		On-Road Trucks		Off-Road Trucks and Stationary Sources		Total
BNSF San Bernardino[38]	10.6	48%	3.7	17%	4.4	20%	0.75	3%	22.0
UP Colton[39]	16.3	99%	NA	NA	0.2	1%	0.05	0.3%	16.5
UP City of Industry[40]	5.9	54%	2.8	26%	2.0	18%	0.3	3%	10.9
UP ICTF/ Dolores[41]	9.8	41%	4.4	19%	7.5	32%	2.0	8%	23.7
UP Commerce[42]	4.9	40%	4.8	40%	2.0	17%	0.4	3%	12.1
UP LATC[43]	3.2	44%	2.7	37%	1.0	14%	0.50	7%	7.3
UP Mira Loma[44]	4.4	90%	NA	NA	0.2	4%	0.2	4%	4.9
BNSF Hobart[45]	5.9	25%	4.2	18%	10.1	42%	3.7	15.5%	23.9
BNSF Watson[46]	1.9	100%	NA	NA	<0.01	<1%	0.04	<1%	1.9

28. What are the health risks of exposure to air pollution from switcher locomotives?

As previously explained, emissions from switcher locomotives, by virtue of their generally geographically-limited operation within railyards, will likely have an outsized impact on local air quality. Direct emissions of potential health concern from switch locomotive operations include NO_2, $PM_{2.5}$, diesel exhaust, ultrafine PM, and TOGs. Downwind health impacts from switcher locomotives are related to regional transport of TOGs and NO_2 that can result in ozone and PM formation miles away from the location of initial emissions (REF2,3,5,36). The health impacts associated with exposure to these

Are summarized above, in the responses to Questions 7 (ozone health effects), 11 (PM health effects), 14 (diesel exhaust health effects), 17 (ultra-fine PM health effects), and 21 (NO_2 health effects).

29. What are the health risks of exposure to air pollution from railyards?

Health exposure risks from railyard air pollution are associated with exposure to the airborne contaminants caused by railyard operations and from auditory exposure to the noise from railyard operations. Air pollution-related concerns have been previously discussed and result from exposure to NO_2, $PM_{2.5}$, diesel exhaust, ultrafine PM, and TOGs. These contaminants affect the health of many organ systems in the body, including the respiratory (lungs), cardiovascular (heart), metabolic (liver, kidneys, digestive system), and neurologic (brain and central nervous) systems. Health impacts associated with persistent or periodic noise, such as that associated with railyard operations, have been the subject of increasing scrutiny (REF40-44), particularly for the observed effects among young children and pregnant mothers. Health consequences from noise and vibration include low birth weight, elevated blood pressure, cognitive interference, increased stress, and cardiovascular changes (REF44).

30. Please describe the health risks of residing or working near a railyard, and who bears those risks.

As described previously, living or working near a railyard places one in close proximity to local and direct exposures of NO_2, $PM_{2.5}$, diesel exhaust, ultrafine PM, TOGs, vibration and noise pollution. The health impacts of these may occur either in the short-term (hours to days) or long-term (months to years) and can affect the respiratory, cardiovascular, metabolic, and neurologic systems of the body. Given the noise, commotion, space requirements, and around-the-clock operation of railyards, living near a railyard is frequently viewed as a less-than-desirable choice of residential location. On the basis of what is known about exposures and potential negative health outcomes, the California Air Resources Board has provided advisory recommendation in their Land Use Guidebook to "...avoid siting new sensitive and uses within 1,000 feet of a major service and maintenance rail yard..." (REF45). For those in lower socioeconomic strata with limited incomes, there is often limited flexibility in choice of residential location, regardless of health status or sensitivity. For these and other reasons, neighborhoods and communities adjacent to railyards tend to be inhabited by disproportionately by those with limited financial resources and often by people of color. These population groups are often already dealing with several concurrent health, social, financial, and exposure issues, and they are the quintessential definition of a “sensitive” sub-group within the general population.

31. What are the air pollution issues with line-haul locomotives?

Line-haul locomotives are those that “...provide interstate freight transportation for containers, liquid material, or bulk material...” (REF46). In terms of airborne contaminants emitted and of potential exposure and health concern, the list is identical to that previously presented. These include both gases and particles - NO_2, $PM_{2.5}$, diesel exhaust, ultrafine PM, and TOGs.

In the case of line-haul locomotives however, although improved pollution control systems have become available since 2015 (so-called TIER 4 locomotive engines), the predicted penetration of TIER 4 locomotives into the functional fleet has turned out to be far more optimistic than the actual rate. In California, for example, actual TIER 4 locomotive engine penetration rates have been less than 1% per year (compared to the 7% per year prediction) (REF46). Figure 5 shows the distribution of Tier locomotive engines in California and in the Los Angeles-San Bernardino regional pollution area (identified in the figure as “South Coast”, which refers to the regional air quality district in which Los Angeles and San Bernardino are located). As can be seen in the figures, roughly 6% or fewer of the line-haul locomotives in use are of TIER 4 level operation. Table 4 summarizes locomotive engine emission guidelines as a function of TIER level for NOx and PM. As can be readily interpreted from these table and figures, pollution emissions are considerably higher in the lower TIER locomotive engine categories, and these are the ones primarily in use in California.

Figure 5: Percentage distribution of TIER locomotive engines in California and in the South Coast Air Basin (the Los Angeles-San Bernardino regional area) (See REF46).

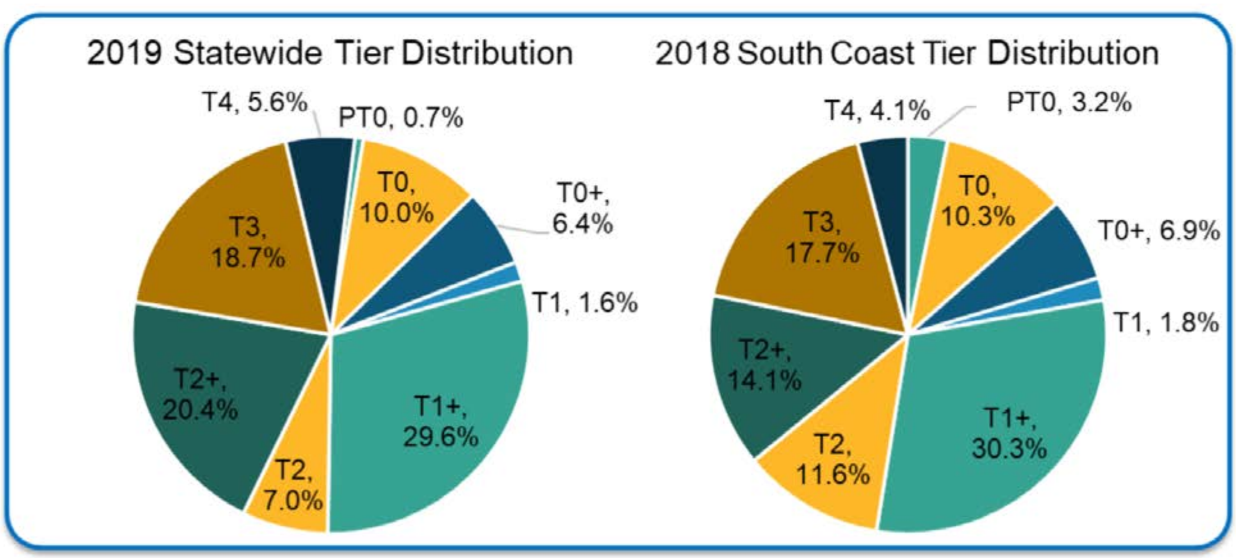


Table 4: Line-Haul Emission Factors for NOx and PM10 in grams per brake horsepower-hour (g/bhp-hr), a unit of energy or work commonly used to describe heavy-duty engine emissions (SEE REF46)

Tier	PM10	NOx
Pre-Tier 0	0.320	13
Tier 0	0.320	8.6
Tier 0+	0.200	7.2
Tier 1	0.320	6.7
Tier 1+	0.200	6.7
Tier 2	0.180	4.95
Tier 2+	0.080	4.95
Tier 3	0.080	4.95
Tier 4	0.015	1.0

32. What are the health risks of exposure to air pollution from line-haul locomotives?

Health risks from airborne exposures from line-haul locomotives differ somewhat in terms of proximity to the source but less so in terms of specific contaminants and their myriad organ impacts. Because line-haul locomotives are involved in the movement of cargo or goods over tens to hundreds of miles, the duration of proximal exposure (such as might be the case living or working near a railyard where switcher locomotives are largely confined to in-yard operations) is very different. Exposure to air pollution from line-haul locomotives has more of a regional component to it rather than local, but the cumulative effects can still be potentially significant. Long-haul locomotive operations emit both gases and particles - NO_2, $PM_{2.5}$, diesel exhaust, ultrafine PM, and TOGs – and the association of both acute and chronic exposures to these contaminants is diverse and increasingly well-documented (REF 1-3, 5-9, 12-21).

33. What are the air pollution issues with passenger locomotives?

Passenger locomotives provide a somewhat different set of environmental exposure conditions, due to proximity of operation and type of power system utilized. Passenger locomotives include community, inter-city, and interstate passenger line operations (REF32). In California, for example, this might vary from local use of electric catenary operations (such as LA METRO) to regional or state use of various TIER locomotives, such as those used by Metrolink, Pacific Surfliner, or Caltrain to provide inter-city connections across California (REF32).

Diesel-powered passenger locomotives have been shown to expose passengers to higher levels of virtually every pollutant monitored – ultra-fine particles, NO_2, $PM_{2.5}$, black carbon, and benzo(a)pyrene (one of many organic gases and a known carcinogen) - compared to electric trains (REF47). It should be noted that there are air pollution issues associated with electric passenger locomotives (in other words, electric train operations do incur some exposure), especially in the case of underground lines, which can lead to exposure of some transition metals of health concern (such as hexavalent chromium) (REF48). As a general overview, however, exposures (and health risks) associated with electric passenger locomotives are several times lower than those associated with diesel-powered locomotives.

34. What are the health risks of exposure to air pollution from passenger locomotives?

Since the specific pollutants emitted (NO_2, $PM_{2.5}$, diesel exhaust, ultrafine PM, and TOGs) from passenger locomotive operations (if they are diesel-powered) are essentially identical to those of line-haul locomotives, the regional health risks for those exposed are similar. For those on-board passengers or workers, there could be additional localized exposures of interest to polycyclic aromatic hydrocarbons (PAHs) and some transition metals, to elevated ultra-fine PM as well as to $PM_{2.5}$ and NO_2, if the train is powered by a diesel locomotive (REF 46,47).

Health Impacts of Air Pollution from Locomotives and Railyards in San Bernardino County, California

35. You have described health-based state and federal standards for air quality. Does the air quality in San Bernardino County, California meet these standards?

San Bernardino County is located east of Los Angeles and includes virtually all the area from roughly 60 miles east of Los Angeles to the California-Nevada state line. It is the largest county in the United States (excluding Alaska) and is roughly the size of West Virginia (REF48). It includes a wide range of communities and geographies, from deserts to mountains to cities to rural areas. The county is physically located in two California air quality management districts – Mojave Valley (which covers much of the desert regions northeast of the Los Angeles metropolitan region) and South Coast (which includes parts of Los Angeles, Orange, Riverside, and San Bernardino counties). Most (but not all) of the San Bernardino County urban centers are located in the South Coast Air Quality Management District. Although there is a large concentration of manufacturing, industry, and warehousing activities in the San Bernardino region, it is also downwind of Los Angeles and connected to Los Angeles industrial and manufacturing by several freeways and railroad lines. Historically, air quality in the South Coast-defined region of San Bernardino County has been moderate to poor, due to both local pollution generation and downwind impacts of regional photochemical pollution much of which is initiated in the Los Angeles region (REF50). Year after year, the South Coast region is identified as being among the poorest air quality regions in the country, in the annual "State of the Air" report by the American Lung Association (REF51). Currently, this region – including the western portions of San Bernardino County – are in violation of the National Ambient Air (NAAQS) and State of California Air Quality Standards for Ozone and $PM_{2.5}$.

36. How does the air quality in San Bernardino County compare to the ozone standard?

As described above, San Bernardino County covers a large geographical area and is overseen administratively by two different air quality management districts, Mojave Valley and South Coast. The current USEPA listing (as of June 30, 2021) of non-attainment areas for ozone lists San Bernardino County as being in "Severe-15 non-compliance" for the eight-hour ozone NAAQS (REF38). This means that area eight-hour ozone levels are in the range between 0.105 and 0.111 parts per million (with the standard being a level not to exceed 0.070 parts per million).

37. How does the air quality in San Bernardino County compare to the PM2.5 standard?

The current USEPA listing (as of June 30, 2021) of non-attainment areas for PM2.5 lists San Bernardino County as being in "severe non-attainment" for the $PM_{2.5}$ (2012) NAAQS (REF38).

38. How does the air quality in San Bernardino County compare to the NO2 standard?

Air quality in San Bernardino County for the NAAQS for NO2 is currently considered to be a "maintenance area (redesignated from non-attainment" (REF38).

39. Describe the major air pollution issues in San Bernardino County.

Major pollutants of concern in San Bernardino County include $PM_{2.5}$, O_3, and NO_2, per their respective non-compliance or maintenance designations under the Clean Air Act. Ongoing concerns about warehouse expansions, cargo goods movement, and railyard activity has focused community interest on diesel exhaust and related health and environmental exposures.

40. Please describe the health consequences of exposure to air pollution in San Bernardino County.

The health consequences of exposure to air pollution in San Bernardino County Have been summarized above in discussions regarding specific pollutants – see responses to Questions 7 (ozone health effects), 11 (PM health effects), 14 (diesel exhaust health effects), 17 (ultra-fine PM health effects), and 21 (NO_2 health effects).

41. How are these health burdens distributed in San Bernardino County?

These health burdens are unequally distributed in San Bernardino County. They fall disproportionately on communities of color and lower socio-economic status, because these are the populations who reside near railyards and rail lines. The residential disproportionality exists because housing is less expensive (and more affordable by these less-desirable living locations.

42. Describe the socioeconomic status of the communities that are bearing the burden of air pollution in San Bernardino County.

The socioeconomic status of communities bearing the burden of air pollution in San Bernardino County covers a broader range than first imagined, since poor regional air quality affects everyone. As previously noted (see responses to Questions 36 to 39 above), the urbanized region of San Bernardino County is in violation of the Clean Air Act (i.e., exceeds the outdoor air quality concentrations deemed safe to breathe) for ozone and $PM_{2.5}$. For NO_2, the region is currently in a "maintenance" mode- in other words, the observed outdoor concentrations of NO_2 meet recommended EPA guidelines, but objective demonstration that the observed levels can be maintained for several consecutive years is currently being evaluated.

43. Please provide an assessment of the air pollution health impacts from operations at the Burlington Northern Santa Fe (BNSF) San Bernardino Railyard.

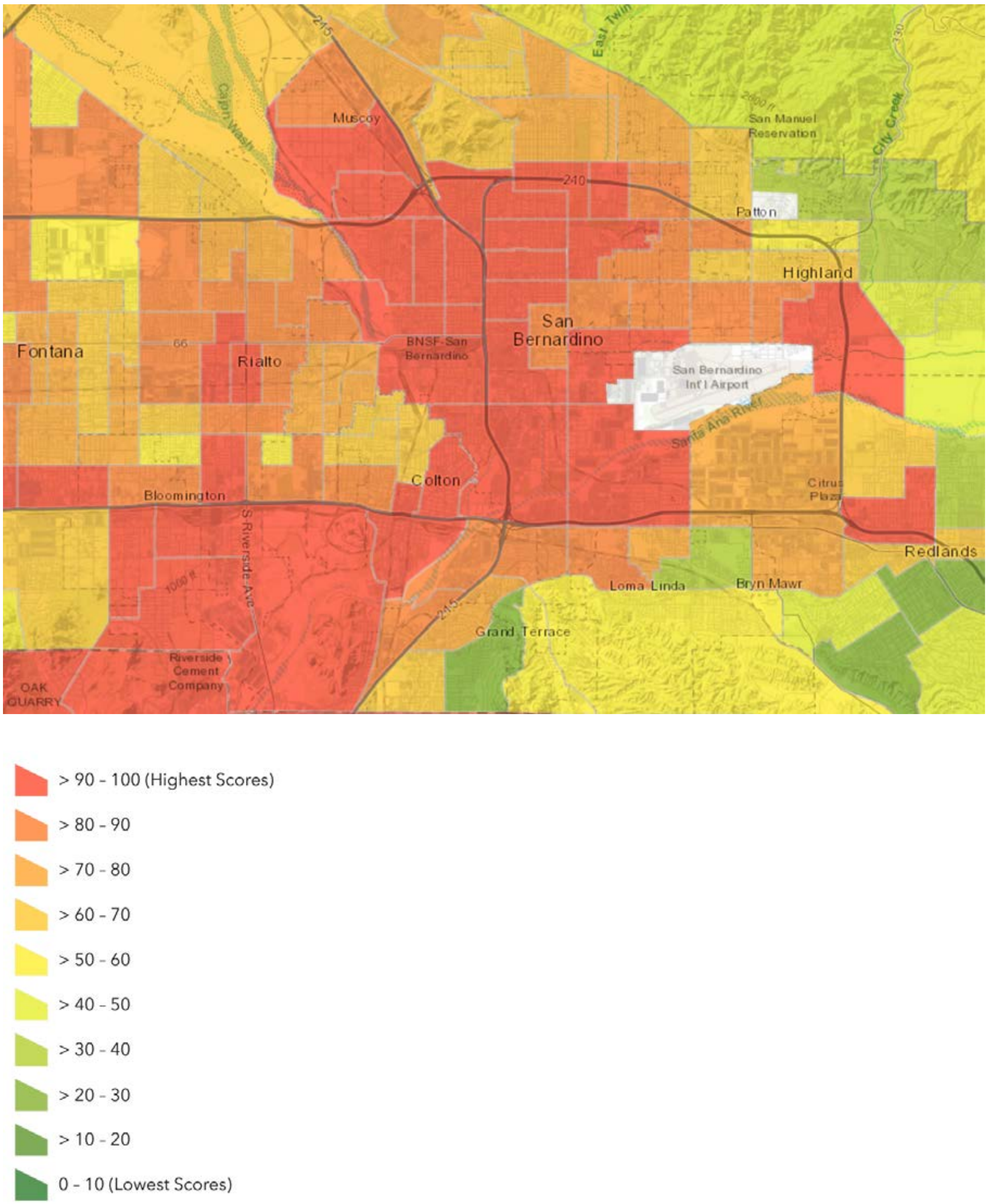
Assessment of the air pollution health impacts at the BNSF San Bernardino Railyard involves a multi-dimensional approach that considers the emissions associated with railyard operations, the proximity of those exposed in the surrounding communities, and the cumulative pre-existing and ongoing environmental and health burdens already weighing on those communities.

Under the 1998 Memo of Understanding (MOU) with the State of California, only limited emissions information is available to the public regarding specific current operating emissions and then only at the county level (REF52). Accordingly, emissions data provided by the railroads several years ago are used in a modeling projection facilitated through the California Emissions Projection Analysis Model known as "CEPAM" (REF 53,54). Recent residential, county, and census data can then be used to assess proximity of potentially exposed populations, and a broader understanding of the many environmental and health challenges already facing adjacent communities can be visualized using CalEnviroScreen, a geospatial visualization tool developed to identify California communities with disproportionate environmental health burdens (REF55).

When these data sources are applied to operations at the BNSF San Bernardino Railyard, a concerning picture emerges. As described above (see responses to Questions 35 to 42), the San Bernardino area is a region of recurring poor air quality, and the substantial locomotive and related railyard operations emissions at the San Bernardino yard only exacerbate the issue for the residents there. A recent CalEnviroScreen figure (see Figure 6 below) summarizes the health hazards for area residents.

Figure 6: CalEnviroScreen 4.0 Visualization of San Bernardino CA area.

As the Legend below the Figure shows, most of San Bernardino is in the highest (90 to 100th percentile, or most highly exposed) grouping of environmentally-impacted census tract areas in California; Note that the BNSF San Bernardino Railyard appears in the center of the figure, just to the left of the vertical black line that represents the 215 Freeway (FROM REF55).



It should be noted that the San Bernardino Railyard is among the top five railyards in California in terms of diesel particulate emissions in tons per year (REF 56).

44. Please describe the health risks that the California Air Resources Board (CARB) found related to the BNSF San Bernardino Railyard in its 2008 Health Risk Assessment.

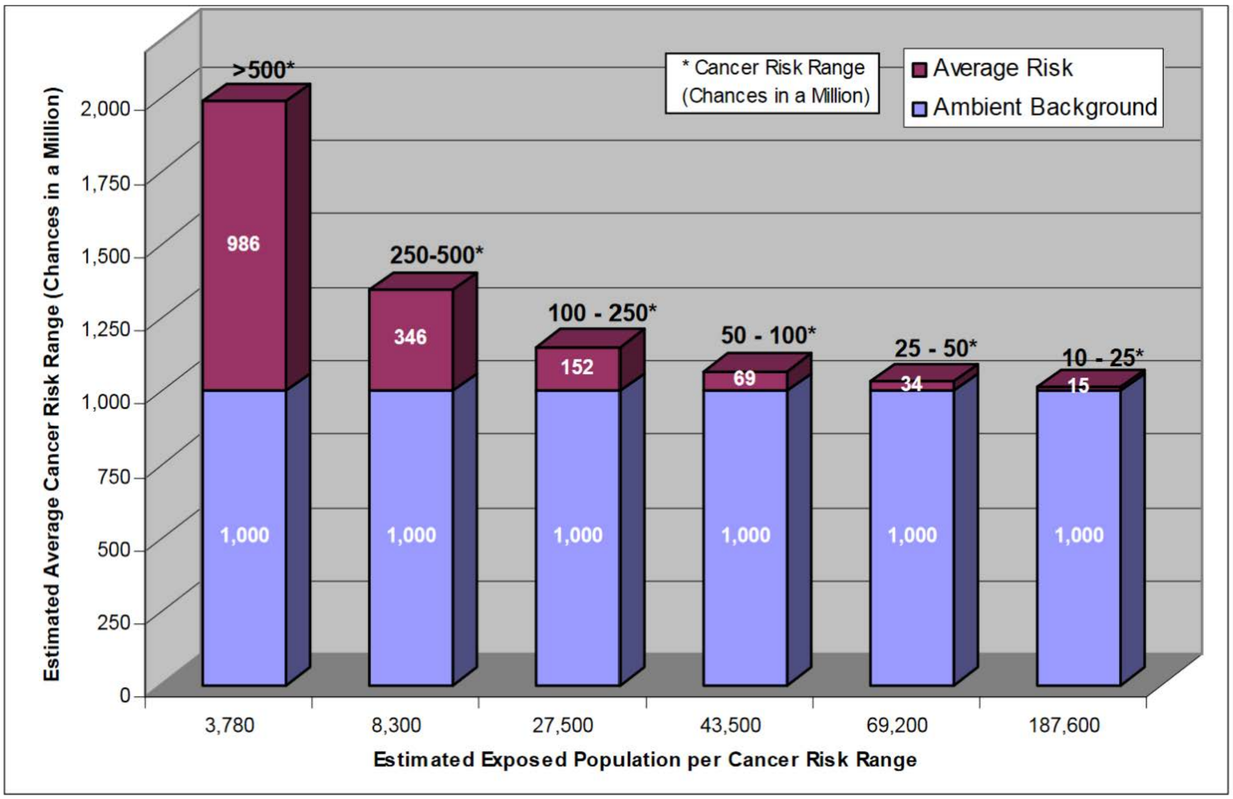
In its 2008 Health Risk Assessment of the BNSF San Bernardino Railyard (REF56), the California Air Resources Board (CARB) considered both cancer and non-cancer risks associated with railyard operations. Cancer risks were calculated based on emissions inventory data and previously provided potency factors for various railyard emissions of known carcinogenic concern (for diesel particulate matter, 1-3 butadiene, benzene, formaldehyde, and acetaldehyde; the last four chemicals named are often combined and included in a catch-all category of "total organic gases"). In terms of cancer risk, CARB estimated that the BNSF San Bernardino Railyard posed an estimated cancer risk for the surrounding population of over 500 in a million at the railyard boundaries, declining to about 25 in a million about two miles away from the facility (see Figure 7). At the Point of Maximum Impact (PMI), which is the location of the maximum cancer risk for a given receptor, the estimated cancer risk was about 3,300 chances in a million based on a 70-year lifetime exposure (REF56).

Figure 7: Cancer risk associated with BNSF San Bernardino Railyard Operations.

The black outline is the Railyard boundary, and the white curved lines around the railyard display the area of increased cancer risk at gradations as shown (100 chances in a million, 250, 500, ...) (From REF56).

This increase in cancer risk is from the railyard operations specifically and do not include regional potential cancer risks. To compare the BNSF San Bernardino Railyard cancer risk contribution to the surrounding population and the regional background risk, and additional figure was included in the 2008 CARB Health Risk Assessment document and appears below as Figure 8.

Figure 8: Comparison of Estimated Cancer Risks from the BNSF San Bernardino Railyard and regional background risk levels (from REF56).



The non-cancer health risk estimates reported in the 2008 Health Risk Assessment of the BNSF San Bernardino Railyard are presented in terms of a "Health Hazard Index" (REF57). The reported values were from 0.5 to 0.3, depending on location (See Figure 9). Since these values are less than one, they indicate "... that the potential non-cancer public health risks are less likely to happen." (REF56). However, the document also notes that there was a great deal of uncertainty associated with these non-cancer risk determinations, and the document suggests the focus be on diesel PM cancer risk as the predominant risk driver. As more recent assessments have shown, there are considerable health implications in the potential non-cancer public health risk category (REF58). These include increased risk for asthma-related emergency room visits for children and adults, increased cardiopulmonary mortality, and increased hospitalizations for cardiovascular and respiratory illness (REF58)

Figure 9: Estimated non-cancer health risks (Hazard Index) associated with operations at the BNSF San Bernardino Railyard.

45. Please describe the health impacts from operations at the BNSF San Bernardino Railyard.

Health impacts from operations at the BNSF San Bernardino railyard are summarized in the response to Question 44.

46. Please describe the communities that are bearing these health impacts from operations at the BNSF San Bernardino Railyard.

The demographics of San Bernardino CA reflect a susceptible community disproportionately exposed to multiple environmental burdens.

As shown in Figure 6 above, the communities surrounding the BNSF San Bernardino Railyard are in the highest category of most disproportionately-exposed census tract areas in California. In addition to the direct emissions from the railyard, they face a number of other environmental and health hazards that collectively place them in a very susceptible and at-risk category. Socio-economic concerns (including education, access to health care, access to fresh fruit and vegetables, access to greenspace, issues of community violence, unemployment, employment "at a living wage", limited political voice, and quality housing) all combine to put these communities at risk.

From a demographic perspective, the percentage of African-American residents living in close proximity to the BNSF San Bernardino railyard was slightly higher (roughly 12% vs. 10%, respectively) than the corresponding percentage of African-American residents in San Bernardino County (REF59). The percentage of Latinx residents living in close proximity to the San Bernardino railyard compared to County estimates was dramatically higher (roughly 72% vs. 36%, respectively) (REF59). For the proportion of low-income households, the percentage of low-income households was dramatically higher in close proximity to the BNSF San Bernardino railyard (roughly 58%) compared to the corresponding percentage for San Bernardino County (roughly 34%) (REF59). These stark differences raise the issue of systematic environmental injustice in the communities bearing the health impacts of railyard operations.

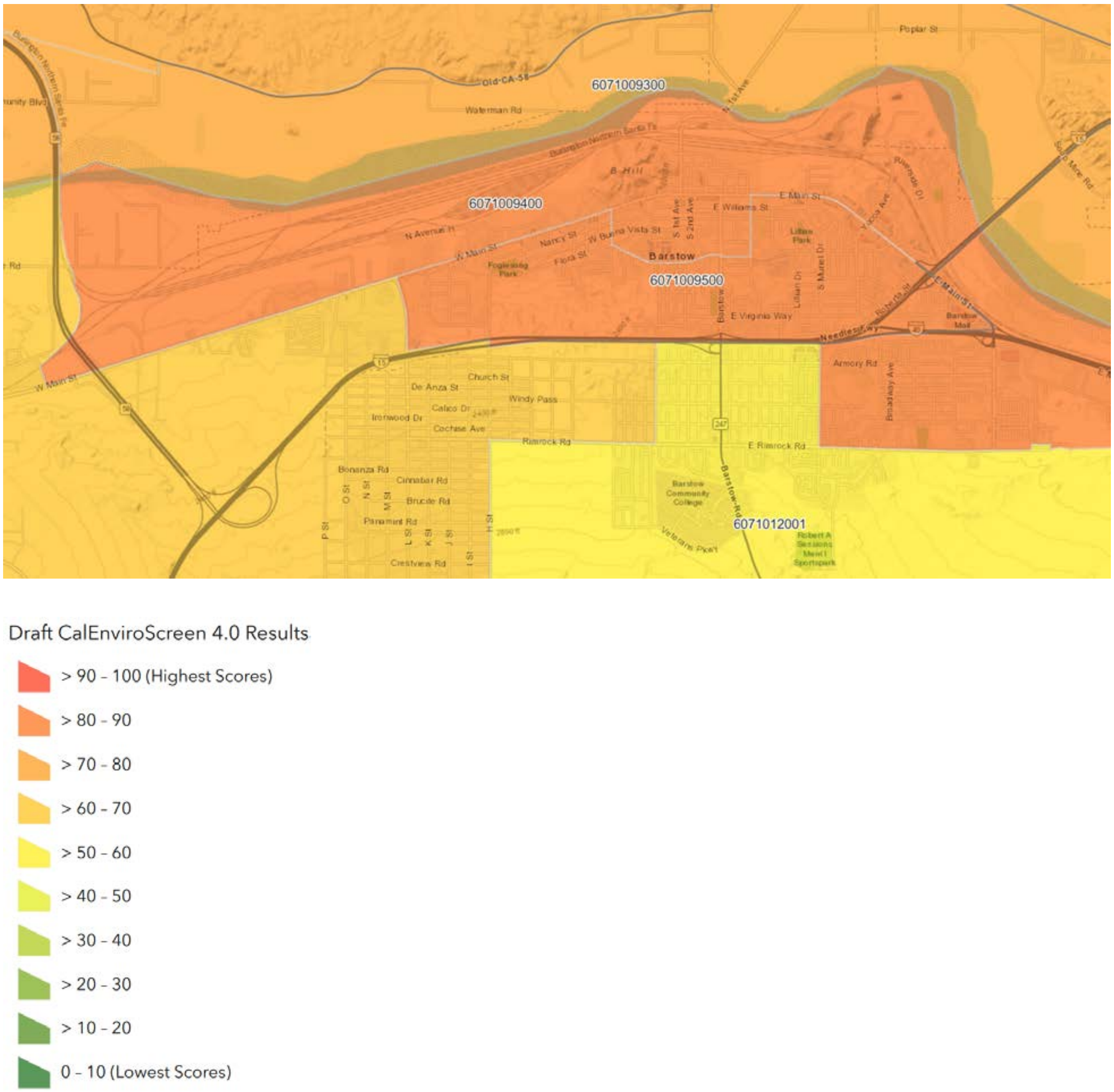
47. Please provide an assessment of the air pollution health impacts from operations at the BNSF Barstow Railyard.

As summarized in the response to Question 43, an assessment of the air pollution health impacts from operations at the BNSF Barstow Railyard involves a multi-dimensional approach that considers the emissions associated with railyard operations, the proximity of those exposed in the surrounding communities, and the cumulative pre-existing and ongoing environmental and health burdens already weighing on those communities.

The Barstow railyard is the major BNSF maintenance yard for California operations and the major California location for engine refueling and technical service of trains and locomotives (REF60). It is the highest emitter of diesel particulate emissions (in tons per year) of all 18 railyards in California (REF59). The population of Barstow is approximately 23,000 people (REF61), so local emission impacts a smaller population than the San Bernardino railyard, for example, which is surrounded by almost ten times that population (roughly 216,000 people) (REF62).

Figure 10: CalEnviroScreen 4.0 Visualization of Barstow CA area.

As the Legend below the Figure shows, Barstow is in the next -to-highest (80 to 90th percentile) grouping of environmentally-impacted census tract areas in California; Note that the BNSF Barstow Railyard appears in the center of the figure, as a centerline just below the green stripe (FROM REF55).



48. Please describe the health risks that CARB found related to the BNSF Barstow Railyard in its 2008 Health Risk Assessment.

The 2008 Health Risk Assessment performed by CARB for the BNSF Barstow Railyard reported both on cancer and non-cancer risks. At the Point of Maximum Impact (PMI), the potential cancer risk was about 1000 in a million (REF60), although there was a gradation of risk with varying distance and wind direction (see Figure 11).

The contribution of the BNSF Barstow railyard operations on cancer risk for the surrounding population is substantial, as portrayed in Figure 12 below, which shows the relative regional and Barstow railyard cancer risk contributions. As can be seen in the figure, the estimated cancer risk from BNSF Barstow railyard operations is larger than regional contributions for thousands of Barstow residents.

For the non-cancer risks associated with BNSF Barstow Railyard operations, CARB reported a Hazard Index ranging between 0.02 to 0.20 (see Figure 13). Because this index is below 1.0, this indicates that exposure is less likely to result in non-cancer effects. Due to uncertainties in methodology and calculations at the time, however, CARB recommended that cancer risk be focused upon as the primary risk driver. Since that 2008 assessment, additional research has led CARB to acknowledge that there are additional non-cancer health risks (including increased risk for asthma-related emergency room visits for children and adults, increased cardiopulmonary mortality, and increased hospitalizations for cardiovascular and respiratory illness (REF58).

Figure 11: Cancer risk associated with BNSF Barstow Railyard Operations.

The black outline is the Railyard boundary, and the white curved lines around the railyard display the area of increased cancer risk at gradations as shown (50, 100, and 250 chances in a million, respectively) (From REF60).

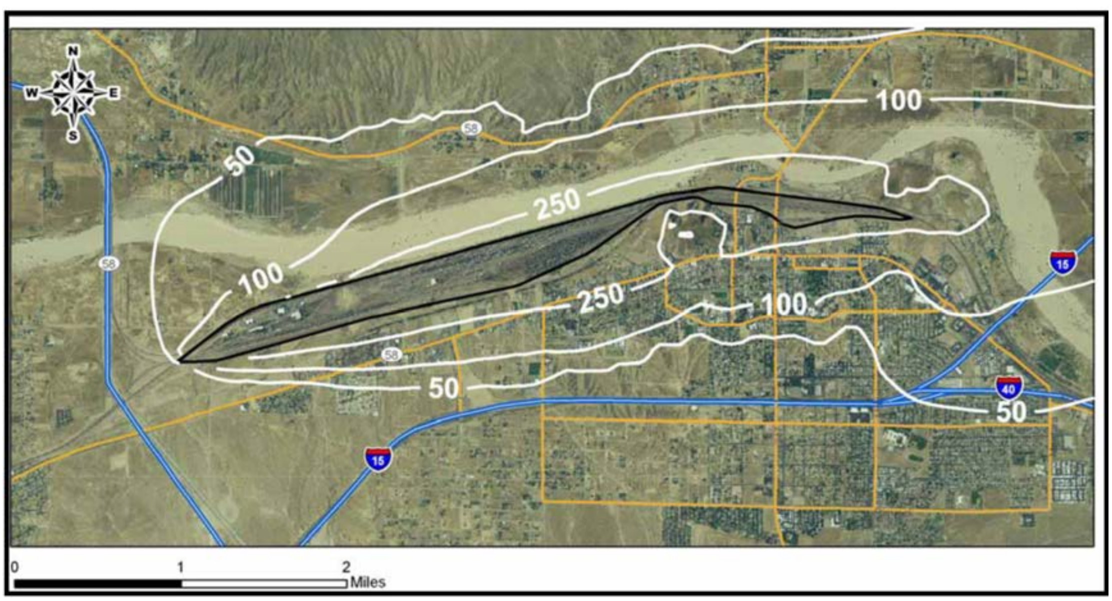
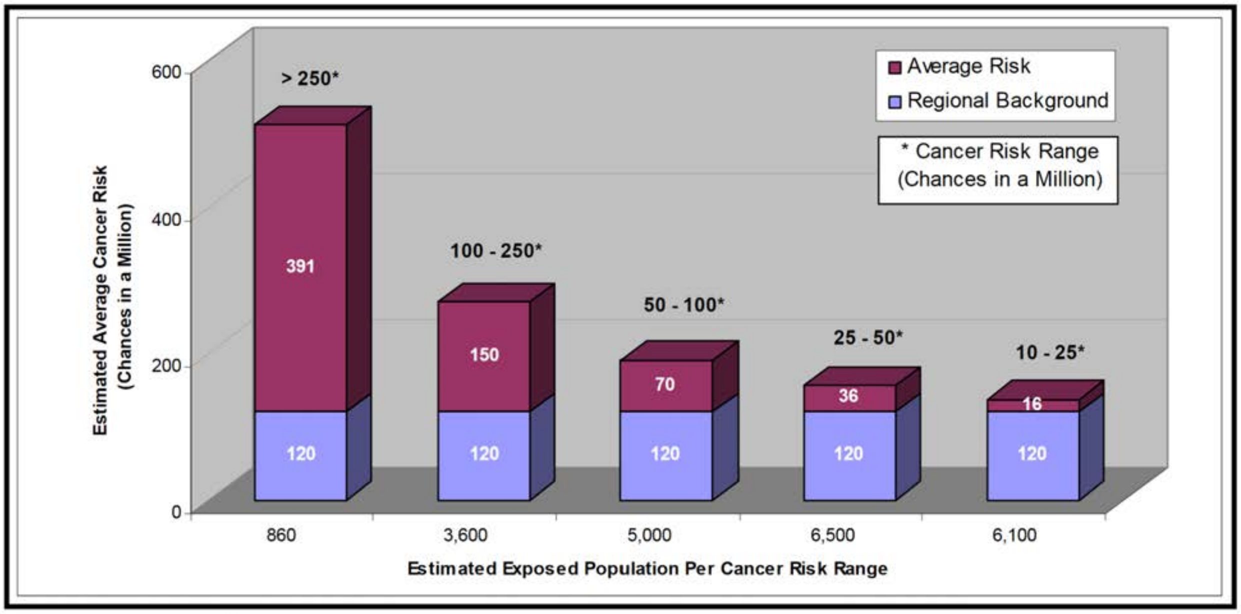
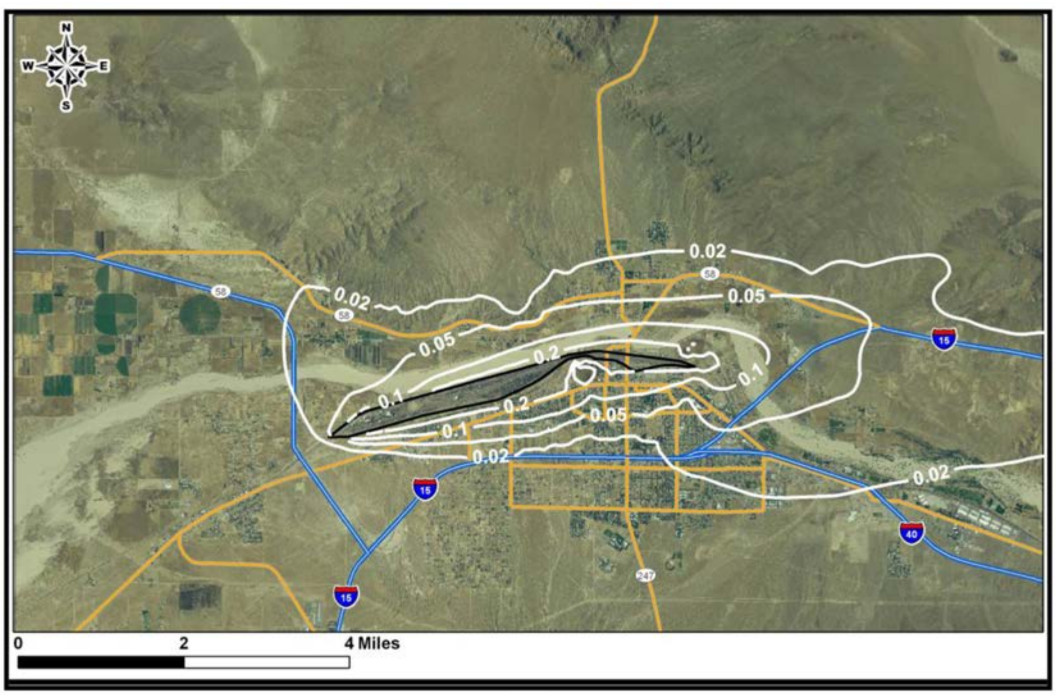


Figure 12: Comparison of regional and BNSF Barstow Railyard operations estimated cancer risk (REF60)



**No toxics monitoring in the Mojave Desert Air Basin,
**Regional background risk is only from diesel PM, because we don't have data available for other TACs for Mojave Desert Air basin.

Figure 13: Estimated non-cancer risks (Hazard Index) from operations at the BNSF Barstow Railyards (REF60).



49. Please describe the health impacts from operations at the BNSF Barstow Railyard.

The health impacts from operations at the BNSF Barstow Railyard are described in the response to Question 48.

50. Please describe the communities that are bearing these health impacts from operations at the BNSF Barstow Railyard.

From a demographic perspective, the percentage of African-American residents living in close proximity to the BNSF Barstow Railyard was equivalent (roughly 9%) to the percentage of African-American residents in San Bernardino County (REF59). The percentage of Latinx residents living in close proximity to the BNSF Barstow Railyard compared to County estimates was somewhat higher (roughly 49% vs. 40%, respectively) (REF59). For the proportion of low-income households, the percentage of low-income households was dramatically higher in close proximity to the BNSF Barstow Railyard (roughly 64%) compared to the corresponding percentage for San Bernardino County (roughly 35%) (REF59). These differences raise the issue of systematic environmental injustice in the communities bearing the health impacts of railyard operations.

51. Please provide an assessment of the air pollution health impacts from operations at the Union Pacific (UP) Colton Railyard.

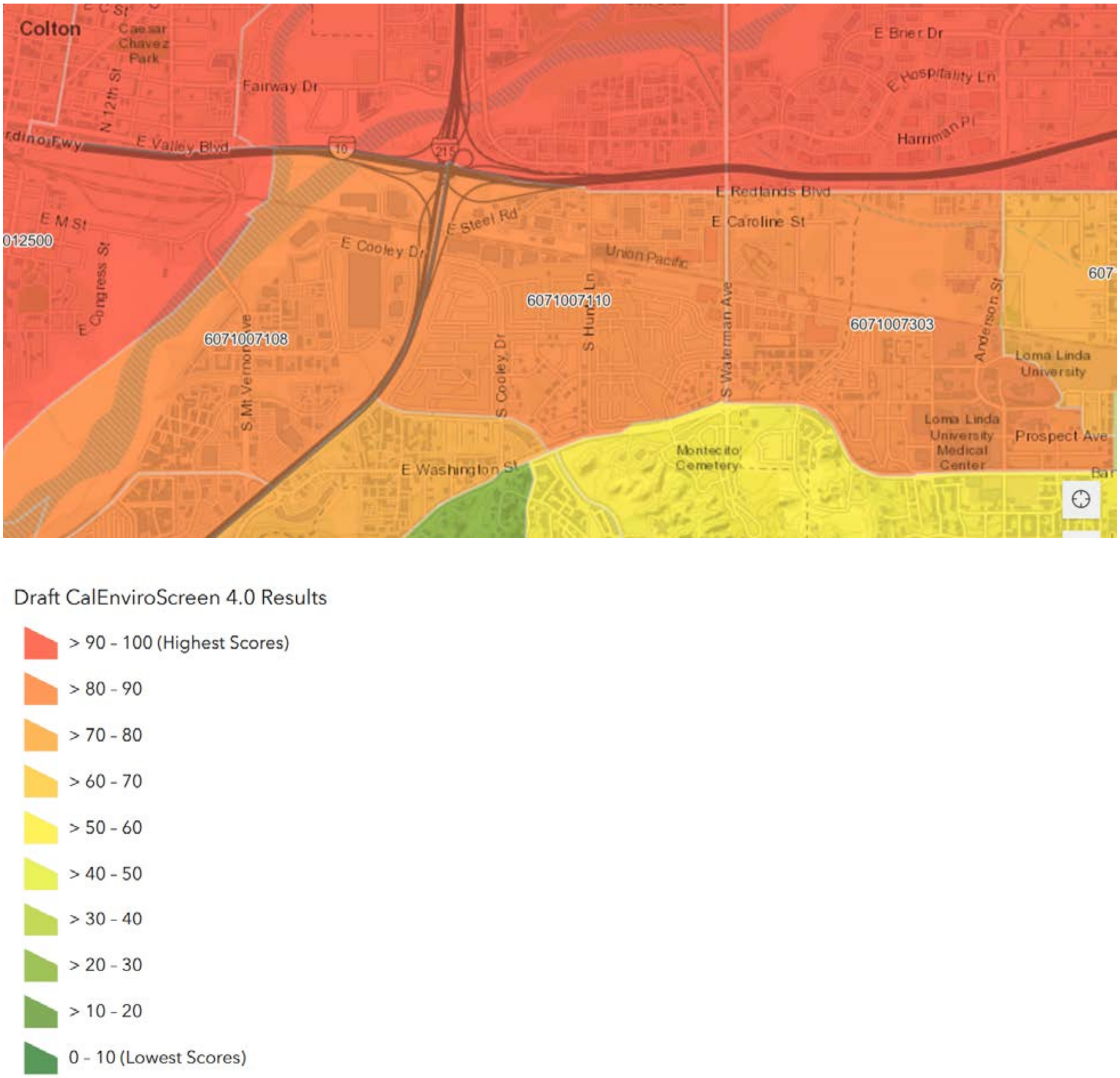
The Union Pacific (UP) Colton Railyard is a classification yard that primarily serves as a location for assembling and disassembling trains for delivery of items to various destinations (REF63). The railyard is roughly 5 ½ miles in length and 1/3 mile in width, and is physically located parallel to the I-10 Freeway. Based on the 2008 Health Risk Assessment, the UP Colton Railyard is among the top third of California railyards in terms of diesel emissions (tons per year). Locomotive operations accounted for 99% of on-site diesel PM emissions at the time of the CARB Health Risk Assessment, of which switcher locomotives were responsible for 62% of the diesel PM emissions (REF63). Other air contaminants associated with UP Colton Railyard operations include several organic gases of concern, such as 1,3 butadiene and formaldehyde, but the diesel emissions associated with locomotive operations are the predominant emissions for consideration.

The western edge of the UP Colton Railyard was roughly 350 feet from the nearest residential area at the time of the 2008 Health Risk Assessment, with a local high school located just south of the railyard. The railyard is in the South Coast Air Quality Management District, and the region is one prone to elevated levels of ozone and $PM_{2.5}$ and currently in non-compliance with NAAQS and California air quality standards for ozone and PM.

Figure 14 below depicts the cumulative environmental burdens facing the Colton community, and show the UP Colton Railyard to be in the 80^{th} to 100^{th} percentile of all California census tract areas with regard to environmental burden.

Figure 14: CalEnviroScreen 4.0 Visualization of Colton CA area.

As the Legend below the Figure shows, Colton is in the two highest designations (80 to 90th and 90th to 100th percentile) for environmentally-impacted census tract areas in California; Note that the UP Colton Railyard is in the lower-right center of the picture (FROM REF55).

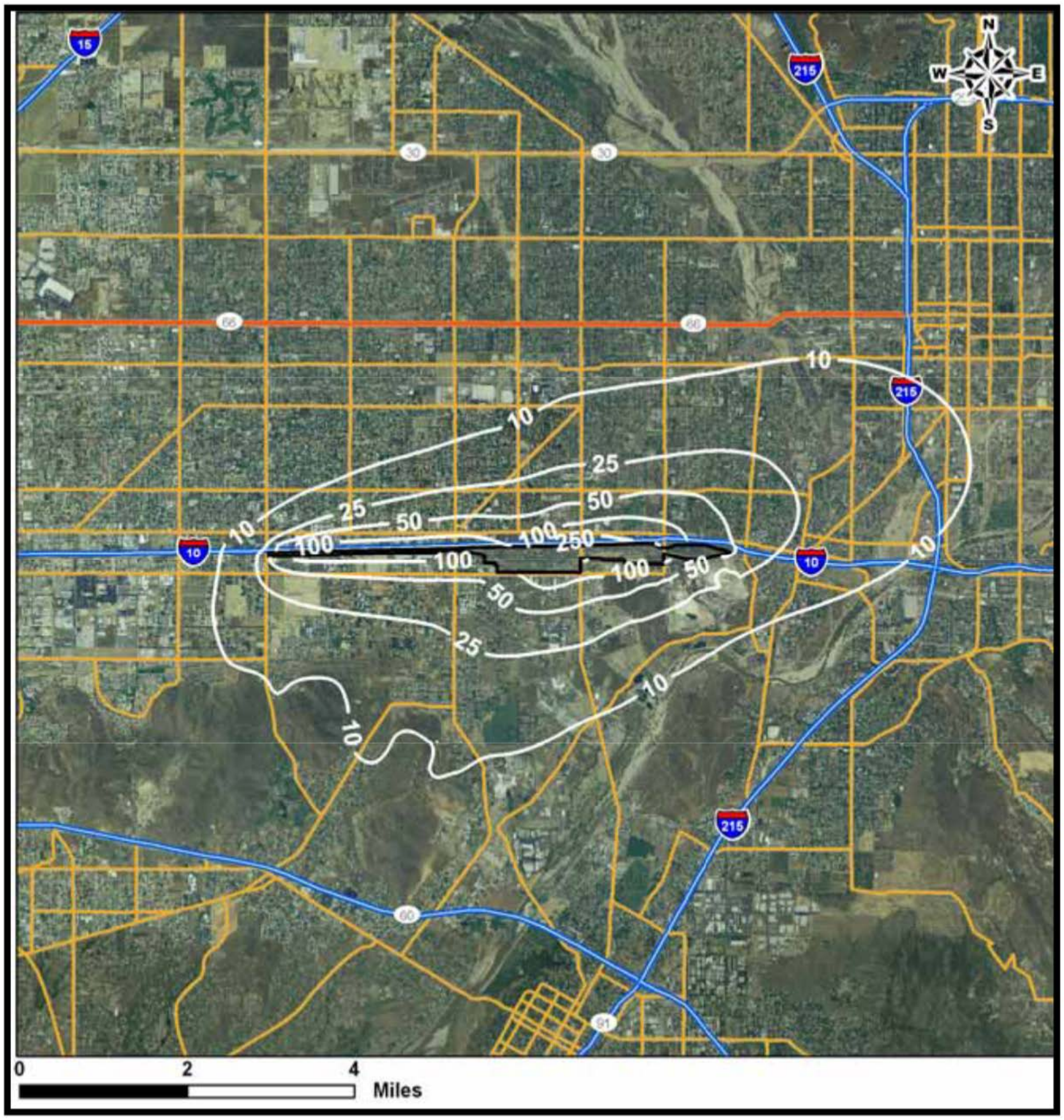


52. Please describe the health risks that CARB found related to the UP Colton Railyard in its 2008 Health Risk Assessment (HRA).

Cancer and non-cancer risks were estimated in the CARB HRA. At the Point of Maximal Impact (PMI). The cancer risk was estimated to be about 575 in a million (REF63). An illustration of the estimated near-source cancer risks is presented in Figure 15 below. These estimates are based on a 70-year lifetime exposure assumption.

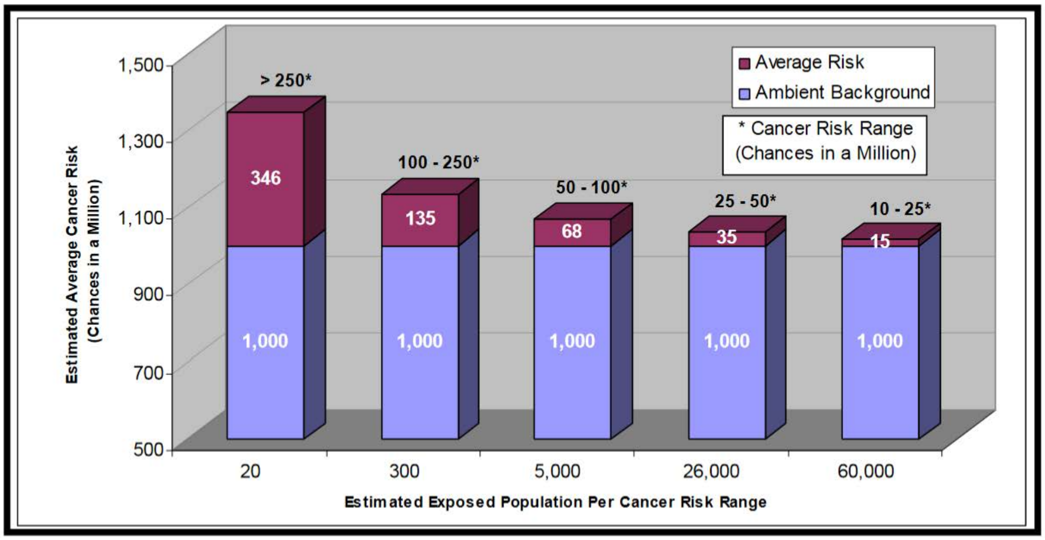
Figure 15: Cancer risk associated with the UP Colton Railyard Operations.

The black outline is the Railyard boundary, and the white curved lines around the railyard display the area of increased cancer risk at gradations as shown (250, 100, 50, ... chances in a million, respectively) (From REF63).



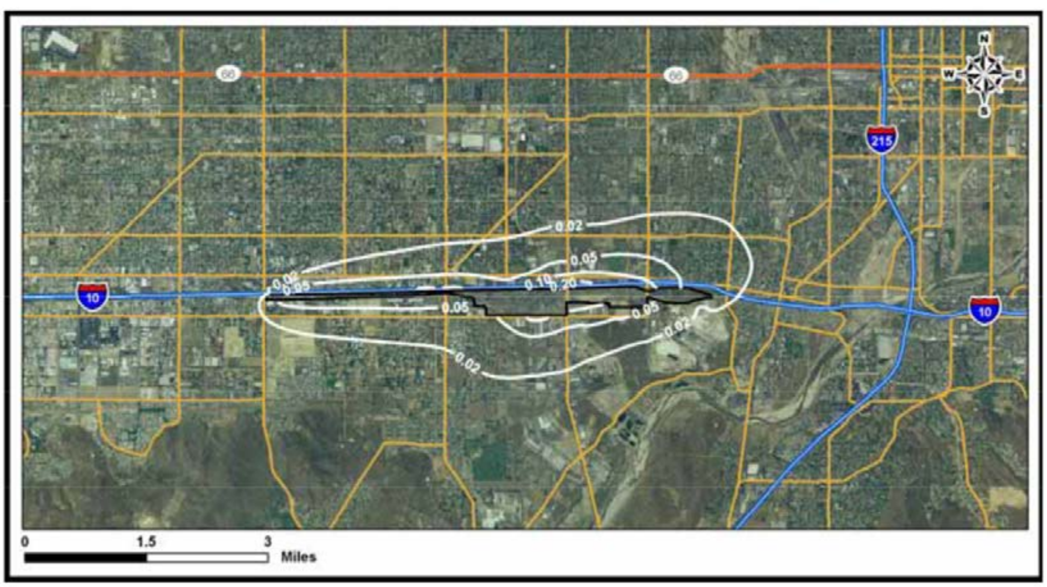
The comparative contribution of the UP Colton Railyard to regional cancer risk is shown in Figure 16 below. Due to the substantial air quality regional contributions, the contribution of the UP Colton Railyard was significant (accounting for a roughly 35% increase) for those most highly exposed but only a smaller portion (less than 13%) of the overall cancer risk for most of the population (REF63).

Figure 16: Comparison of regional and UP Colton Railyard operations estimated cancer risk (REF63)



Non-cancer risks reported in the CARB HRA for the UP Colton Railyard showed a Hazard Index ranging between 0.02 to 0.20 (see Figure 17). Because this index is below 1.0, this indicates that exposure is less likely to result in non-cancer effects. Due to uncertainties in methodology and calculations at the time, however, CARB recommended that cancer risk be focused upon as the primary risk driver. Since that 2008 assessment, additional research has led CARB to acknowledge that there are additional non-cancer health risks (including increased risk for asthma-related emergency room visits for children and adults, increased cardiopulmonary mortality, and increased hospitalizations for cardiovascular and respiratory illness (REF58).

Figure 17: Estimated non-cancer risk (Hazard Index) associated with diesel emissions at the UP Colton Railyard, according to the 2008 CARB HRA (REF63).



53. Please describe the health impacts from operations at the UP Colton Railyard.

The health impacts are summarized in the response to Question 52.

54. Please describe the communities that are bearing these health impacts from operations at the UP Colton Railyard.

From a demographic perspective, the percentage of African-American residents living in close proximity to the UP Colton Railyard was equivalent (roughly 9%) to the percentage of African-American residents in San Bernardino County (REF59). The percentage of Latinx residents living in close proximity to the UP Colton Railyard compared to County estimates was somewhat higher (roughly 68% vs. 40%, respectively) (REF59). For the proportion of low-income households, the percentage of low-income households was somewhat higher in close proximity to the UP Colton Railyard (roughly 43%) compared to the corresponding percentage for San Bernardino County (roughly 35%) (REF59). These differences suggest a closer look be given to environmental justice issues in the communities bearing the health impacts of railyard operations.

55. Please provide an assessment of the air pollution health impacts from the combined operations at the BNSF San Bernardino, BNSF Barstow, and UP Colton Railyards.

Air pollution impacts from the BNSF San Bernardino, BNSF Barstow, and UP Colton railyards is substantial to both the immediate surrounding community and the larger regional area. In the immediate vicinities of the respective railyards, their 2008 diesel exhaust emissions were estimated to be responsible for placing an estimated 2714 individuals into the increased cancer risk category of >100 in a million (see Figures 8, 12, and 16 above). The estimated diesel emissions from railyard operations for these three facilities alone accounted for roughly one-third of the total estimated Diesel PM emissions (66.4/210.1 tons per year) for all 18 railyards in the state of California. In a region struggling to meet the National Ambient Air Quality Standards (NAAQS) for $PM_{2.5}$ and ozone, these operations make achievement and ongoing compliance that much more difficult.

On the health impacts side, the communities of San Bernardino, Barstow, and Colton are home to census tracts identified by the State of California as being among the most disproportionately-environmentally-exposed locations in the entire state (see Figures 6, 10, and 14 above). Airborne exposures to the PM and gases associated with the respective railyard operations further stresses and exacerbates the environmental health of community residents.

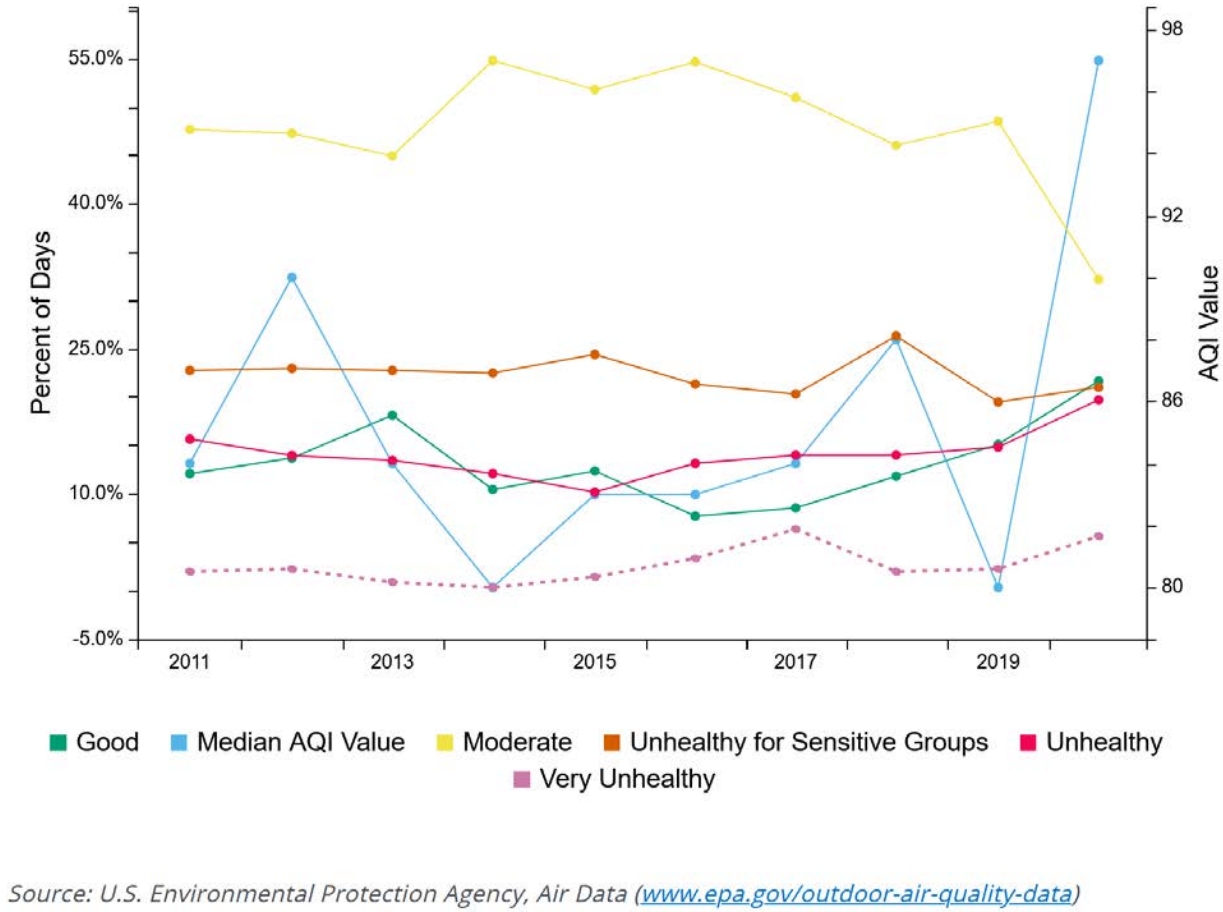
56. **Please describe the health risks of residing or working near these three railyards in San Bernardino County, and who bears those risks.**

As for the health risks of residing or working near these three railyards, please see the response to Question 55 above. As to who bears these risks, they both fall on all of the residents and workers in the San Bernardino, Barstow, and Colton, but disproportionately fall on a large number of susceptible sub-populations in the community. These include children, pregnant mothers, newborns and infants, those with pre-existing cardiovascular or respiratory conditions, outdoor workers, and people of color; Health research has repeatedly identified these sub-groups as being especially sensitive to poor air quality (REF 2,3,5).

57. **Please provide an assessment of the air pollution health impacts from operations at other large freight facilities like warehouses and diesel corridors in San Bernardino County.**

The topic of other large freight facilities like warehouses and diesel corridors in San Bernardino County has become one of increasing public concern in the past few years. The proliferation of large-footprint mega-warehouses, the growth of Amazon and similar home-delivery services, and the expansion of inland ports and redistribution centers have combined to bring increased pressure on communities for air quality and health considerations in the face of pressure to expand for economic and business pursuits. Increased consumer demand for next-day and home shopping services have led to increased truck activity in and through communities to accommodate that demand. Although there is an increase in the use of low-emissions or electric small delivery vans for intra-community delivery of goods and next-day type deliveries, the larger cargo delivery trucks that provide the bulk material goods to the mega-warehouses and the locomotives that deliver cargo remain largely diesel-fueled. This has the net result of increasing diesel emissions (with increased PM, nitrogen oxides, and organic gases) in local communities and throughout the region. In the face of other environmental shifts driven by climate change, this has resulted in increasing the number of days with elevated pollution levels in the area. As recent trends in county air quality data show (see Figure 18 below), the net effect has been no real improvements in overall air quality and an increase in the median Air Quality Index value. The "Moderate" days of air quality have been replaced by more days at the extremes (more "Good" days, but also more "Unhealthy" days, as well.

Figure 18: Ten-year trend (2011 to 2020) Air Quality Index values in each of the sub-categories (Good, Moderate, Unhealthy for Sensitive Groups, Unhealthy, and Very Unhealthy) (REF64).



The net air pollution health impacts of these operations on the health of San Bernardino residents have been negative; as the health research has shown, increased and continuing exposures to levels of $PM_{2.5}$, ozone, NO_2, and assorted gases and carcinogenic materials has lasting effects on respiratory, cardiovascular, neurocognitive, metabolic, and other system health outcomes (REF2,3,5).

58. Please describe the health impacts from goods movement from the Ports of Los Angeles and Long Beach (Ports) to San Bernardino County.

The health impacts from goods movements from the Ports of Los Angeles and Lon Beach to San Bernardino County have been broad, far-reaching, and largely negative. The physical footprint of the goods movement is decidedly regional and not just local. One needs to consider localized impacts adjacent to shipping terminals, railyards, trucking depots, and warehouses, but also be aware of regional impacts wrought by the connective links (freeways, roads, rail lines, and warehouse re-distribution centers). These cumulative effects – both local and regional – better capture the breadth of health impacts.

At the local level, noise, increased traffic and road safety, over-illumination, and vibration can have effects on stress, blood pressure, quality of sleep, mental focus, and pregnancies (REF65-67). Exposure to the airborne contaminants emitted from operations can lead to any number of system acute and chronic effects and result in emergency room visits for asthma events or other conditions (such as cardiovascular events) requiring hospitalization (REF2,3,5). Collectively, the health impacts from goods movement operations between the ports of Los Angeles and Long Beach and San Bernardino County have affected the health of the millions of residents who live in the greater Los Angeles metropolitan region.

Locomotive Electrification.

59. How does locomotive electrification relate to health outcomes?

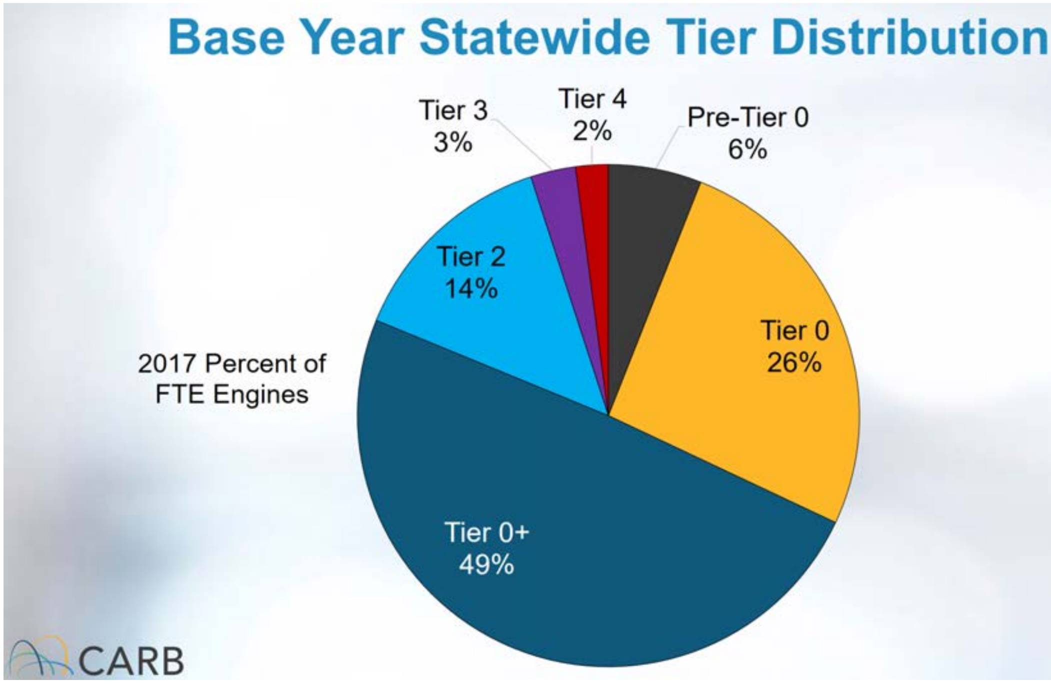
The major source of emissions associated with railyard operations, as have been described above, is with locomotive operations. There have been several successive TIER engine refinements and improvements in terms of reduced emissions of particles and gases of environmental health concern, and current TIER 4 locomotives do represent a significant improvement over their TIER 0 counterparts (see Table 4 above). However, the reality is that the working lifetime of locomotives is long, and the replacement turnover of the existing fleet has been very slow (see Figure 5 above).

Locomotive electrification could substantially reduce emissions in and around railyards (for switcher locomotives) and for short- and possibly longer line-hauls. This would improve both the local and regional air quality and reduce health impacts in very positive and productive ways.

60. Where in your assessment should locomotive electrification be focused to provide the most health benefits?

Major obstacles to locomotive electrification have included recurring stated concerns of duration of charge, time required for re-charge, lifetime of performance, and cost of purchase (REF69). For switcher locomotives that stay generally in the railyard or on short-haul operations, many of these issues seem more readily solvable and worthy of consideration. In California, relatively few of the switcher locomotives in operation are of a later Tier (in other words, most have relatively poor control of diesel emissions) (REF 32). Substantial reductions in localized diesel emissions for the surrounding community would be reflected in substantial health benefits for the surrounding population through a reduction in exposure. Accordingly, consideration should be focused on accelerated efforts to electrify switcher locomotives to provide the most health benefits.

Figure 19: California Tier Distribution of Switcher Locomotives, based on Calendar 2017 data (REF32).



References

1. World Health Organization. *Ambient Air Pollution*, Geneva Switzerland, World Health Organization, (2016).

2. U.S. Environmental Protection Agency, *Integrated Science (ISA) for Oxides of Nitrogen—Health Criteria (Final Report)*, (Jan. 2016), https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=310879, *last accessed* July 9, 2021.

3. U.S. Environmental Protection Agency, *Integrated Science Assessment for Ozone and Related Photochemical Oxidants*, (April 2020), https://www.epa.gov/isa/integrated-science-assessment-isa-ozone-and-related-photochemical-oxidants, *last accessed* July 11, 2021.

4. California Air Resources Board, *Ambient Air Quality Standards,* https://ww2.arb.ca.gov/sites/default/files/2020-03/aaqs2_0.pdf, *last accessed* July 13, 2021.

5. U.S. Environmental Protection Agency, *Integrated Science Assessment for Particulate Matter*, (Dec. 2019), https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=347534#tab-3, *last accessed* July 13, 2021.

6. Diana Younan et al., Particulate Matter and Episodic Memory Decline Mediated by Early Neuroanatomic Biomarkers of Alzheimer's Disease, Brain 143(1), at 289-302, (Jan. 1, 2020), https://pubmed.ncbi.nlm.nih.gov/31746986/.

7. Laura McGuinn et al., *Early Life Exposure to Air Pollution and Autism Spectrum Disorder: Findings from a Multisite Case-Control Study*, Epidemiology 31(1), at 103-14, (Jan. 3, 2020), https://pubmed.ncbi.nlm.nih.gov/31592868/.

8. Giulia Grande et al., *Association Between Cardiovascular Disease and Long-term Exposure to Air Pollution with Risk of Dementia*, JAMA Neurol. 77(7), at 801-09, (July 1, 2020), https://pubmed.ncbi.nlm.nih.gov/32227140/.

9. California Air Resources Board, *Overview: Diesel Exhaust and Health*, https://ww2.arb.ca.gov/resources/overview-diesel-exhaust-and-health, *last accessed* July 15, 2021.

10. Ibrahim Resitoglu et al., *The Pollutant Emissions from Diesel-engine Vehicles and Exhaust Aftertreatment Systems*, Clean Techn. & Environ. Policy (17), at 15-27, (June 11, 2014), https://link.springer.com/article/10.1007/s10098-014-0793-9.

11. Magdi Kahir et al., *Emission Formation in Diesel Engines*, DieselNet Technology Guide, https://dieselnet.com/tech/diesel_emiform.php, *last accessed* July 15, 2021.

12. World Health Organization, International Agency for Research on Cancer, *Diesel Engine Exhaust Carcinogenic*, (June 12, 2012), https://www.iarc.fr/en/media-centre/pr/2012/pdfs/pr213_E.pdf, *last accessed* July 15, 2021.

13. Chelsea Weitekamp et al., A Systematic Review of the Health Effects Associated with the Inhalation of Particle-filtered and Whole Diesel Exhaust, Inhalation Toxicology 32(1), at 1-13, (Jan. 2020), https://pubmed.ncbi.nlm.nih.gov/32100584/.

14. Haley Reis, et al., Diesel Exhaust Exposure, Its Multi-system Effects, and the Effect of New Technology Diesel Exhaust, Environment International 114, at 252-65, (May 2018), https://pubmed.ncbi.nlm.nih.gov/29524921/.

15. Prashant Kumar et al., *Ultrafine Particles in Cities*, Environ. Intl. (66), at 1-10, (May 2014) http://dx.doi.org/10.1016/j.envint.2014.01.013.

16. G Oberdorster et al., *Translocation of Inhaled Ultrafine Particles to the Brain*, Inhal. Toxicol. 16(7-7), at 437-45, (June 2004), https://pubmed.ncbi.nlm.nih.gov/15204759/.

17. Hank Cheng et al., *Nanoscale Particulate Matter from Urban Traffic Rapidly Induces Oxidative Stress and Inflammation in Olfactory Epithelium with Concomitant Effects on Brain*, Environ. Health Perspect 124 (10), at 1537-46, (Oct. 2016), http://dx.doi.org/10.1289/EHP134.

18. Eva Bongaerts et al., Translocation of Ultrafine Particles and Nanoparticles Across the Placentia; a Systematic Review on the Evidence of In Vitro, Ex Vivo, and In Vivo Studies, Part. & Fibre Toxicol. 17(1), at 56 (Nov. 2, 2020), https://particleandfibretoxicology.biomedcentral.com/articles/10.1186/s12989-020-00386-8.

19. Chris Lim et al., *Association Between Long-term Exposure to Ambient Air Pollution and Diabetes Mortality in the US*, Environ. Res. 165, at 330-36, (Aug. 2018), https://pubmed.ncbi.nlm.nih.gov/29778967/.

20. Ghassan Hamra et al., *Lung Cancer and Exposure to Nitrogen Dioxide and Traffic: A Systematic Review and Meta-Analysis* 123(11), at 1107-12 (April 14, 2015), https://pubmed.ncbi.nlm.nih.gov/25870974/.

21. Iona Cheng et al., *Association Between Ambient Air Pollution and Breast Cancer Risk: The Multiethnic Cohort Study*, Int. J. Cancer 146(3), at 699-711, (April 25, 2019), https://pubmed.ncbi.nlm.nih.gov/30924138/.

22. Wikipedia, *Switcher*, https://en.wikipedia.org/wiki/Switcher, *last accessed* July 18, 2021.

23. The Quarto Group, *Switcher Locomotives*, https://www.quartoknows.com/blog/quartodrives/switcher-locomotives, *last accessed* July 18, 2021.

24. U.S. Environmental Protection Agency, *Control of Emissions from Idling Locomotives*, https://nepis.epa.gov/Exe/ZyPdf.cgi?Dockey=P100HP4Q.pdf, *last accessed* July 18, 2021.

25. DieselNet, *Locomotive Test Cycles*, https://dieselnet.com/standards/us/loco.php, *last accessed* July 18, 2021.

26. Chris Lindhjem, *Intermodal Yard Activity and Emissions Evaluations*, (Jan. 2008), https://gaftp.epa.gov/AIR/nei/ei_conference/EI17/session11/lindhjem.pdf, *last accessed* July 18, 2021.

27. CSJ, *Line-haul Locomotive Definition*, https://www.csx.com/index.cfm/about-us/company-overview/railroad-dictionary/?i=L, *last accessed* July 18, 2021.

28. California Office of Environmental Health Hazard Assessment, *CalEnviroScreen 4.0 Mapping Tool*, https://experience.arcgis.com/experience/4af93cf9888a424481d2868391af2d82/page/home/, *last accessed* July 18, 2021.

29. Wikipedia, *Passenger Trains*, https://en.wikipedia.org/wiki/Train#Passenger_trains , *last accessed* July 18, 2021.

30. U.S. Environmental Protection Agency, *The Midwest Clean Diesel Initiative: Locomotive Switcher Idling and Idle Control Technology*, https://archive.epa.gov/midwestcleandiesel/web/pdf/switchers2.pdf, *last accessed* July 23, 2021.

31. U.S. Environmental Protection Agency, *EPA Finalizes More Stringent Emissions Standards for Locomotives and Marine Compression-Ignition Engines*, https://nepis.epa.gov/Exe/ZyPDF.cgi/P100094D.PDF?Dockey=P100094D.PDF, *last accessed* July 23, 2021.

32. California Air Resources Board, *2020 Locomotive Emissions* Inventory, Air Quality Planning and Science Division Public Workshop, (Sept. 3, 2020). https://ww2.arb.ca.gov/sites/default/files/2020-09/CARBlocoinvwebinar2020.pdf.

33. South Coast Air Quality Management District, *What is the SCAQMD?*, http://www.aqmd.gov/nav/about, *last accessed* July 23, 2021.

34. South Coast Air Quality Management District, *Chapter 5 Draft, Actions to Reduce Community Air Pollution*, (Aug. 2, 2019), http://www.aqmd.gov/docs/default-source/ab-617-ab-134/steering-committees/east-la/cerp/chapter-5c-draft-railyards-august-2019.pdf?sfvrsn=8, *last accessed* July 25, 2021.

35. ENVIRON International Corporation, *Los Angeles–Hobart Railyard TAC Emissions Inventory* (*Prepared for Burlington Northern and Santa Fe Railway*), (Dec. 2006), https://ww2.arb.ca.gov/sites/default/files/classic//railyard/hra/env_hob_ei122006.pdf, *last accessed* July 25, 2021).

36. Michelle Bergin et al., *Regional Atmospheric Pollution and Transboundary Air Quality Management*, Ann. Rev. Env. Resour. 30, at 1-37 (Nov. 21, 2005), https://www.annualreviews.org/doi/abs/10.1146/annurev.energy.30.050504.144138.

37. Meredith Franklin et al., *Predictors of Intra-community Variation in Air Quality*, J. Exp. Sci. Environ. Epidemiol. 22(2), at 135-47 (Jan. 18, 2012), https://www.nature.com/articles/jes201145.

38. U.S. Environmental Protection Agency, *Non-attainment Area for Criteria Pollutants (Green Book)*, https://www.epa.gov/green-book, *last accessed* July 25, 2021.

39. Los Angeles Metropolitan Authority, *Railyards: A Toolkit for Goods Movement*, (March 2009), http://media.metro.net/projects_studies/mcgmap/images/5-guidebook-chapter5_final.pdf.

40. Laura Maclachan et al., *Annoyance in Response to Vibration from Railways*, Int. J. Environ. Res. Pub. Health 15(9), at 1887, (Sept. 2018), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6163999/.

41. Alan Lex Brown et al., *WHO Environmental Noise Guidelines for the European Region: A systematic review of transport noise interventions and their impacts on health*, Int. J. Environ. Res. Public Health 14(8), at 873, (Aug. 2017), https://pubmed.ncbi.nlm.nih.gov/28771220/.

42. Ofer Amram et al., *Proximity of Public Elementary Schools to Major Roads in Canadian Urban Areas*, Int. J. Health Geogr. 10(68), (Dec. 21, 2011), https://ij-healthgeographics.biomedcentral.com/articles/10.1186/1476-072X-10-68.

43. Ulrike Gehring et al., *Impact of Noise and Air Pollution on Pregnancy Outcomes*, Epidemiology, 25(3), at 351-58, (May 25, 2014), https://journals.lww.com/epidem/Fulltext/2014/05000/Impact_of_Noise_and_Air_Pollution_on_Pregnancy.5.aspx.

44. Thomas Munzel et al., *Adverse Cardiovascular Effects of Traffic Noise with a Focus on Nighttime Noise and the New WHO Noise Guidelines*, Annu Rev Public Health, (April 2, 2020), https://pubmed.ncbi.nlm.nih.gov/31922930/..

45. California Air Resources Board, *Air Quality and Land Use Handbook: a Community Health Perspective*, (April 2005), https://www.arb.ca.gov/ch/handbook.pdf, *last accessed* July 28, 2021.

46. California Air Resources Board, *2021 Line-Haul Locomotive Emission Inventory*, (Feb. 2021), https://www.arb.ca.gov/ch/handbook.pdf, *last accessed* July 28, 2021.

47. Maria Helena Andersen et al., *Exposure to Air Pollution Inside Electric and Diesel-powered Passenger Trains*, Environ Sci Technol., 53(8), at 4579-87 (April 16, 2019), https://pubmed.ncbi.nlm.nih.gov/30917278/.

48. Christopher Lovett et al., *Commuting in Los Angeles: Cancer and Non-cancer Health Risks of Roadway, Light-rail and Subway Transit Routes*, Aerosol and Air Quality Research (2018), 18: 2363-2374. https://doi.org/10.4209/aaqr.2017.09.0331.

49. Wikipedia, *San Bernardino County, California*, https://en.wikipedia.org/wiki/San_Bernardino_County,_California, *last accessed* Aug. 1, 2021.

50. Caillie Roach, *Air Pollution in the Inland Empire*, (Dec. 1, 2020), https://storymaps.arcgis.com/stories/fe2811197ce1427db17a808593f1526e, *last accessed* Dec. 21, 2022.

51. American Lung Association, *2021 State of the Air Annual Report*, American Lung Association, https://www.lung.org/research/sota, *last accessed* Dec. 21, 2022.

52. Junhyeong Park, Non-Road Model Development Section, Mobile Sources Analysis Branch, Air Quality Planning and Science Division, California Air Resources Board, Private Communication, received July 27, 2021.

53. California Air Resources Board, *California Emissions Projection Analysis Model (CEPAM)*, https://ww2.arb.ca.gov/criteria-pollutant-emission-inventory-data, *last accessed* Dec. 21, 2022.

54. California Air Resources Board, *CEPAM Emissions Projection Tool*, https://www.arb.ca.gov/app/emsinv/fcemssumcat/fcemssumcat2016.php, *last accessed* Aug. 8, 2021.

55. California Office of Environmental Health Hazard Assessment, *CalEnviroScreen 4.0*, https://oehha.ca.gov/calenviroscreen/report/draft-calenviroscreen-40, *last accessed* Dec. 21, 2022.

56. California Air Resources Board, *Health Risk Assessment for the BNSF Railway San Bernardino Railyard*, (June 11, 2008), https://ww2.arb.ca.gov/sites/default/files/classic/railyard/hra/bnsf_sb_final.pdf, *last accessed* Aug. 9, 2021.

57. U.S. Dept of Housing, *Definition of an Environmental "Health Hazard Index,"* https://www.arcgis.com/home/item.html?id=c7e2c62560bd4a999f0e0b2f4cee2494, *last accessed* Aug. 9, 2021.

58. California Air Resources Board, *Concepts for In-use Locomotive Regulation Workshop Day 2*, at 28-32, (Oct. 30, 2020), https://ww2.arb.ca.gov/sites/default/files/2020-12/2020.10.28%20841AM%20Workshop%20Slides%20Day%202%20-%20Remediated.pdf, *last accessed* Aug. 9, 2021.

59. Andrea Hricko et al., *Global Trade, Local Impacts: Lessons From California on Health Impacts and Environmental Justice Concerns for Residents Living Near Freight Rail Yards*, Int.J. Environ. Res. Public Health, 11(2), at 1914-41 (Feb. 2014), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3945577/.

60. California Air Resources Board, *Health Risk Assessment for the BNSF Railway Barstow Railyard*, (June 9, 2008), https://ww2.arb.ca.gov/sites/default/files/classic//railyard/hra/bnsf_barstow_final.pdf *last accessed* Aug. 9, 2021.

61. U.S. Census Bureau, *QuickFacts, Barstow City, California*, https://www.census.gov/search-results.html?q=Barstow%2C+CA&page=1&stateGeo=none&searchtype=web&cssp=SERP&_charset_=UTF-8, *last accessed* Aug. 10, 2021.

62. U.S. Census Bureau, *QuickFacts, San Bernardino City, California*, https://www.census.gov/quickfacts/fact/table/sanbernardinocitycalifornia/RHI225219 *last accessed* Aug. 10, 2021.

63. California Air Resources Board, *Health Risk Assessment for the Union Pacific Railroad Colton Railyard*, (April 18, 2008), https://ww2.arb.ca.gov/sites/default/files/classic//railyard/hra/up_col_hra.pdf, *last accessed* Aug. 11, 2021.

64. San Bernardino County, *San Bernardino County Community Indicators: Environment—Air Quality*, https://indicators.sbcounty.gov/environment/air-quality/, *last accessed* Aug. 12, 2021.

65. Thomas Munzel et al., The Adverse Effects of Environmental Noise Exposure on Oxidative Stress and Cardiovascular Risk, Antioxid Redox Signal 28(9), at 873-908, (March 20, 2018), https://pubmed.ncbi.nlm.nih.gov/29350061/.

66. Clara Sears et al., *The Association of Traffic-related Air and Noise Pollution with Maternal Blood Pressure and Hypertensive Disorders of Pregnancy in the HOME Study Cohort*, Environ. Int. 121(Pt.1), at 574-81 (Dec. 2018), https://pubmed.ncbi.nlm.nih.gov/30300815/.

67. Lilian Tzivian et al., *Effect of Long-term Outdoor Air Pollution and Noise on Cognitive and Psychological Functions in Adults.* Int J Hyg Environ Health, 218(1), at 1-11 (Jan. 2015), https://pubmed.ncbi.nlm.nih.gov/25242804/.

68. U.S. Environmental Protection Agency, *Emission Factors for Locomotives*, https://nepis.epa.gov/Exe/ZyPDF.cgi/P100500B.PDF?Dockey=P100500B.PDF, *last accessed* Aug. 12, 2021.

69. Richard Nunno, *Electrification of US railways: pie in the sky or realistic goal?*, (May 30, 2018), https://www.eesi.org/articles/view/electrification-of-u.s.-railways-pie-in-the-sky-or-realistic-goal, *last accessed* Aug. 12, 2021.