Sick of Soot

Reducing the Health Impacts of Diesel Pollution in California

Union of Concerned Scientists

Citizens and Scientists for Environmental Solutions

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DON ANAIR

PATRICIA MONAHAN

Union of Concerned Scientists
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Don Anair is a vehicles engineer in the UCS Clean Vehicles Program. **Patricia Monahan** is a senior analyst in that program.

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Executive Summary

Diesel soot, or particulate matter (PM), is a dangerous pollutant that can penetrate deep into the lungs. People exposed to diesel soot can suffer from severe respiratory and cardiovascular illnesses, chronic bronchitis, cancer, and premature death. In 2000, the California Air Resources Board (CARB) estimated that diesel PM was responsible for 70 percent of the state's risk of cancer from airborne toxics (CARB, 2000c). Diesel engines often remain in operation for decades, with the older engines releasing the greatest amount of pollution.

California has made some progress in reducing diesel emissions, but state retrofit regulations designed to equip existing diesel vehicles with better pollution controls have yet to address 85 percent of diesel pollution sources. In addition, California's successful voluntary incentive programs to clean up diesel pollution are chronically underfunded.

This study evaluates the human health impacts of diesel exhaust in California and estimates the number of people that will suffer serious health problems from exposure to diesel PM.[1] Using financial data from the U.S. Environmental Protection Agency (U.S. EPA, 2003), the Union of Concerned Scientists (UCS) evaluates the economic impact of these diesel-related health problems and compares the costs to the benefits of reducing diesel pollution. UCS finds that the relatively modest costs of pollution cleanup can pay off in reduced hospitalizations, fewer asthma cases, and saved lives. This analysis represents a conservative estimate because many potential health and welfare impacts—such as smog-related respiratory problems, increasing asthma rates (especially for children), and damage to agricultural crops and forest habitats—are not quantified.

[1] Our analysis includes both PM directly emitted from diesel engines and formed secondarily from nitrogen oxides (NOx). We base our health impacts analysis on epidemiological studies that use real-world data to estimate the human health consequences of pollution. These studies provide mathematical formulas (called concentration-response, or C-R, functions) that provide a range of results within a 90 percent confidence interval. In the Executive Summary, we present the "mean" or middle value of these results, while the body of the report includes the 90 percent confidence range. Because of the uncertainties associated with epidemiological studies, the number of health effects presented should be viewed as estimates within a range, and not the actual number of incidences.

Statewide results

Today's impacts: More diesel-related deaths than homicides

In 2004 alone, diesel pollution will cause an estimated 3,000 premature deaths in California—greater than the estimated 2,300 annual homicides in the state.[2] In addition, diesel exhaust will cause an estimated 2,700 cases of chronic bronchitis and about 4,400 hospital admissions (including emergency room, or ER, visits) for cardiovascular and respiratory illnesses every year. **The cost of these health impacts is $21.5 billion per year.**

Future impacts: More than 38,000 diesel-related deaths by 2020

By 2020, stricter emission standards for new engines should reduce the number of annual diesel-related health problems about 50 percent.[3] But tens of thousands of premature deaths will occur while we wait for old, polluting engines to be replaced by new, cleaner engines. Implementing the state's plan to reduce diesel pollution, which calls for reducing emissions from engines on the road today, would prevent an estimated 11,000 premature deaths and 16,000 hospital admissions (including ER visits) by 2020. **Cutting pollution from existing diesel engines would result in a cumulative savings of $48 billion to $70 billion between 2004 and 2020.**

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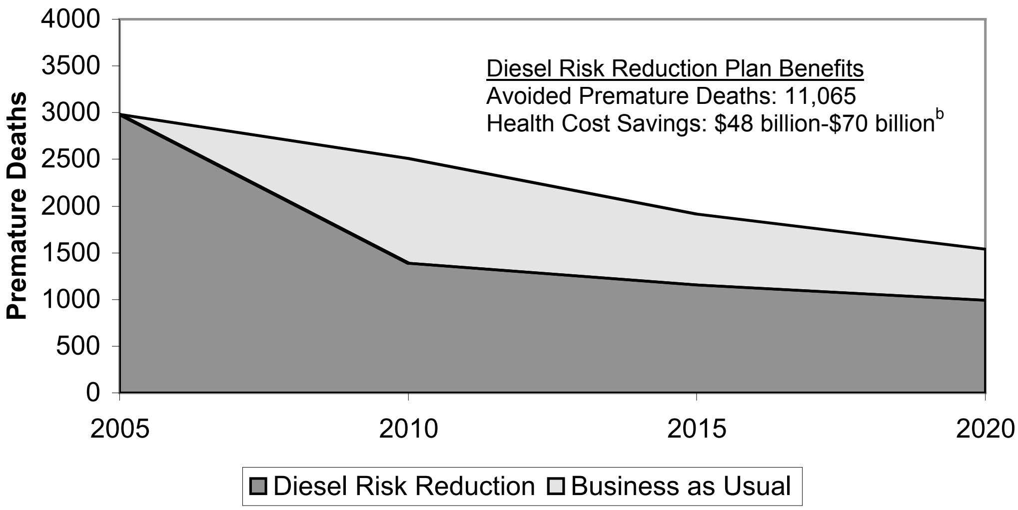
[2] Number of homicides is for 2001, based on data from the California Department of Health Services.

[3] Our projections of the health impacts of diesel pollution in 2020 do not account for emission reductions that may be achieved through retrofit regulations recently adopted (but not yet finalized) by California. Since these rulemakings were not final as of May 2004, we did not have sufficient information to evaluate their emissions inventory impacts.

Figure ES-1. Premature Deaths from Diesel Pollution[a]

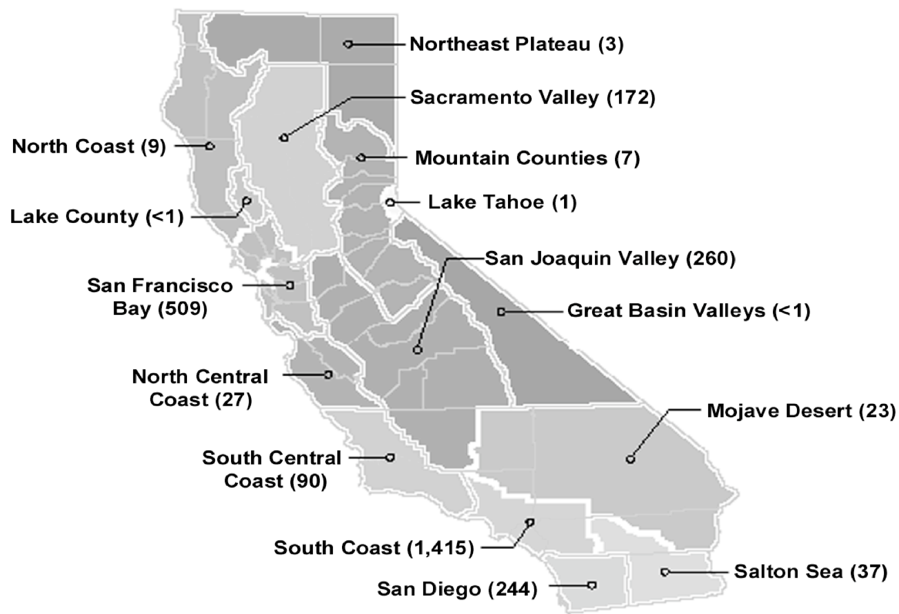


NOTES:
a. Our projections of the health impacts of diesel pollution through 2020 do not account for emission reductions that may be achieved through retrofit regulations recently adopted (but not yet finalized) by California. Since these rulemakings were not final as of May 2004, we did not have sufficient information to evaluate their emissions inventory impacts.
b. Health cost savings are based on all health endpoints evaluated in this study and are presented in year 2004 dollars. Both a three percent and seven percent social discount rate are applied to health incidences occuring from 2005 through 2020, resulting in a range of cost savings.

Air basin results

While Californians in every corner of the state are exposed to diesel pollution, the most densely populated and polluted air basins have the highest number of health problems (Figure ES-2). Roughly 90 percent of California's population, and 80 percent of the state's diesel pollution sources, are found in 5 of the 15 air basins: Sacramento Valley, San Diego, San Francisco Bay Area, San Joaquin Valley, and South Coast (Table ES-1).

Figure ES-2. 2004 Estimated Premature Deaths by Diesel Exposure by Air Basin



NOTE: Premature deaths are a result of exposure to diesel particulate matter, both direct from the tailpipe and from the conversion of NOx emissions to particulates in the atmosphere. Estimates for indirect particulate exposure for each air basin are based on a conversion of NOx emissions to particulates.
SOURCE: Image courtesy of CARB.

Table ES-1. Health Incidences from Diesel Exhaust in 2004 by Air Basin

Health Endpoint	Estimated Mean No. of Incidences in 2004					
	Sacramento Valley	San Diego	San Francisco Bay Area	San Joaquin Valley	South Coast	Statewide
Premature Mortality	172	244	509	260	1,415	2,980
Chronic Bronchitis	154	219	459	234	1,273	2,682
Hospital Admissions						
COPD	34	49	102	52	282	595
Cardiovascular Illness	101	143	299	153	831	1,751
Asthma Admissions	18	26	54	27	149	314
Asthma ER Visits	100	142	296	151	822	1,731
Total Estimated Health Costs (millions of 2004$)	$1,242	$1,763	$3,688	$1,884	$10,241	$21,575

NOTE: Estimates include effects of both indirect PM formed from NOx emissions and direct PM emissions. COPD is chronic obstructive pulmonary disease.

South Coast: Highest amount of diesel-related illnesses and deaths in California

Nearly half of the state's health incidences from diesel pollution occur in the South Coast Air Basin, where 45 percent of the state's population breathes more than 30 percent of California's emissions of diesel PM and nitrogen oxides (NOx). In 2004, diesel pollution will cause an estimated 1,400 premature deaths, 1,300 cases of chronic bronchitis, and 2,100 hospitalizations for cardiovascular and respiratory illnesses. **The cost of these health impacts is $10.2 billion per year.**

San Francisco Bay Area: Second highest of 15 air basins

With 20 percent of the state's population breathing 17 percent of California's diesel PM and NOx pollution, the Bay Area has more diesel-related illnesses than 13 other air basins in California. Diesel pollution released in 2004 will cause an estimated 500 premature deaths, 460 cases of chronic bronchitis, and 750 hospitalizations. **The cost of these health impacts is $3.7 billion per year.**

San Joaquin Valley: Third in diesel-related illnesses and deaths

With 10 percent of the state's population and 17 percent of California's diesel PM and NOx pollution, the San Joaquin Valley has the third most diesel-related health problems in the state. In 2004, diesel exhaust will cause an estimated 260 premature deaths, 230 cases of chronic bronchitis, and 380 hospitalizations. **The cost of these health impacts is $1.9 billion per year.**

San Diego: Fourth of 15 air basins

Eight percent of the state's population live in the San Diego Air Basin and breathe six percent of California's diesel PM and NOx pollution. In 2004, diesel pollution will cause an estimated 240 premature deaths, 220 cases of chronic bronchitis, and 360 hospitalizations. **The cost of these health impacts is $1.8 billion per year.**

Sacramento Valley: Fifth of 15 air basins

The fifth highest number of diesel-related health problems occurs in the Sacramento Valley, which has about six percent of the state's population and nine percent of its diesel PM and NOx pollution. Diesel exhaust emitted in 2004 will cause an estimated 170 premature deaths and more than 150 cases of chronic bronchitis. Hospital admissions for cardiovascular and respiratory illnesses exceed 250. **The cost of these health impacts is $1.2 billion per year.**

Federal new engine standards

New engine standards do not clean up the biggest polluters: existing diesel engines.

Thousands of premature deaths can be avoided by accelerating the replacement of diesel engines and retrofitting existing diesel equipment with the latest emission controls.

Until recently, the EPA focused primarily on cleaning up gasoline-powered vehicles. Now, new highway trucks and buses, as well as off-highway (also called "nonroad") heavy equipment, will be required to cut soot and smog-forming pollution by a factor of approximately 10. These regulations only apply to new engines and do not address two major categories of diesel engines: trains and ships.

Due to the longevity and durability of the diesel engine, as well as the toxicity of particulate emissions, new engine standards alone are not enough to protect Californians today from the health consequences of diesel pollution. The bulk of diesel pollution now and for the next decade or more will come from engines already in use. Thousands of premature deaths can be avoided by accelerating the replacement of diesel engines and retrofitting existing diesel equipment with the latest emission controls.

California's Diesel Risk Reduction Plan

The plan sets aggressive goals, but is in jeopardy.

California has been on the forefront of state efforts to reduce diesel pollution. In 2000, CARB developed the Diesel Risk Reduction Plan, which calls for reducing diesel PM 75 percent by 2010 and 85 percent by 2020 (from the base year 2000 level). UCS finds that implementing the Risk Reduction Plan could cut diesel-related health incidences and health costs by more than half from 2004 levels, and reduce cancer risk from exposure to diesel exhaust by 80 percent (Figure ES-1, p.x).

To meet these goals, the plan calls for stronger emission standards, retrofit regulations, and voluntary incentives. But the plan is in jeopardy of falling short of its goals due to regulatory gridlock and a lack of funding. This report finds that unless additional action is taken, diesel PM will only be cut about 30 percent by 2010, rather than the 75 percent target.[4]

State retrofit regulations

Regulatory development is on the slow track.

In the last few years, CARB approved new regulations for certain diesel fleets that together account for about 15 percent of California's diesel PM pollution.[5] As a result of these regulations, CARB estimates that PM emissions from these fleets will be halved by 2010, and about 1,200 premature deaths will be avoided. CARB has faced considerable industry opposition to these rules, many of which took years to be developed and finalized.

[4] UCS's evaluation included the impact of recent diesel cleanup regulations passed by CARB but not yet finalized, federal highway tailpipe standards, and the federal highway nonroad rule passed in May.

[5] Based on 2010 emission estimates (see Table 2-1, p.18).

Now the state needs to develop cleanup regulations to address the remaining 85 percent of California's diesel soot. But regulatory development is hampered by the diverse array of engines and ownership patterns. Furthermore, small businesses, individual owners and operators, and public agencies may not be able to afford the costs of pollution controls or early engine retirement. For example, an already financially strapped school district can ill afford the costs of cleaner buses. While regulations are the cornerstone to achieving the goals of the Risk Reduction Plan, incentive programs can fill the gap where regulations fall short.

To put these figures into perspective, the total cost to each Californian over 10 years would be about two cents for each premature death avoided.

Costs and benefits of diesel cleanup: Evaluating the Moyer Program

This program saves lives at a low cost, but is running out of funding.

In 1999, California created the Carl Moyer Memorial Air Standards Attainment Program (often simply referred to as the "Moyer Program"), which provides funding for diesel equipment owners to replace or rebuild high-polluting diesel engines. Though the focus of the program is reducing NOx, significant PM benefits have been achieved as well. The Moyer Program has had to struggle every year for funding, with state investment plummeting from a high of $50 million in 2001 to $18 million in 2004.

Investing in the Moyer Program pays off in public health benefits (Table ES-2):

- UCS estimates that for every dollar invested, the Moyer Program has reduced public health costs by $9 to $16.
- If the Moyer Program were funded for the next 10 years at $100 million per year, the resulting health benefits would include an estimated 1,200 avoided premature deaths, 1,100 avoided cases of chronic bronchitis, and the reduction of more than 1,800 hospitalizations and ER visits. Even as the cost of achieving pollution control rises over time, benefits outweigh costs by about 10 to 1.
- To put these figures into perspective, the total cost to each Californian over 10 years would be about two cents for each premature death avoided.

Table ES-2. Estimated Health Benefits from Future Moyer Program (2005 through 2014)[a]

Health Endpoint	Estimated Cumulative Mean No. of Incidences Avoided 2005 through 2020[b,c]					
	Sacramento Valley	San Diego	San Francisco Bay Area	San Joaquin Valley	South Coast	Statewide
Premature Mortality	152	56	153	208	498	1,223
Chronic Bronchitis	137	51	137	187	448	1,101
Hospital Admissions						
COPD[d]	30	11	30	42	99	244
Cardiovascular Illness	89	33	90	122	293	718
Asthma Admissions	16	6	16	22	52	129
Asthma ER Visits	88	33	89	121	289	710
Total Cumulative Benefits at 3% discount rate (millions of 2004$)	$996	$371	$1,003	$1,363	$3,273	$8,031
Total Cumulative Benefits at 7% discount rate (millions of 2004$)	$701	$261	$709	$958	$2,309	$5,661

NOTES:
a. Estimates are based on Moyer Program funding of $100 million per year from 2005 through 2014.
b. Emission reductions and health benefits accrue for seven years after the final year of funding due to an average estimated project life of seven years.
c. Emission reductions in each air basin are based on the percentage of total statewide Moyer reductions achieved in the past (CARB, 2002b).
d. COPD is chronic obstructive pulmonary disease.

School Bus Program

This program protects California's most vulnerable population, but is facing the budget axe.

California's other diesel cleanup incentive program, the Lower Emission School Bus Program, is suffering from budget cuts, with state funds reduced to less than $5 million in 2004 from a high of $50 million in 2000. The program provides funds for cash-strapped school districts to replace their oldest, dirtiest, and least safe buses with new, cleaner buses, and to retrofit existing buses with pollution controls.

The third largest fleet in the country, California's school buses are among the oldest and most polluting in the nation, exposing the most vulnerable population to the toxic impact of diesel emissions. In a study of tailpipe pollution, California's school buses received the poorest score in the country for smog-forming emissions, toxic soot, and global warming pollution (UCS, 2002). Without additional funds for the School Bus Program, California's schoolchildren will continue to ride on the dirtiest buses in the country.

Policy Recommendations

California

The state should fully implement its Diesel Risk Reduction Plan by requiring early retirement of the worst polluting vehicles and advanced pollution control retrofits where possible. Key sectors including ports, ships, trains, construction equipment, agricultural engines, and most highway trucks and buses need to be cleaned up. California's successful incentive programs should receive sufficient and sustainable funding, rather than struggling every year with reduced budgets. In addition, the Moyer Program should be strengthened by allowing state funds to be used for projects that reduce PM only and by targeting funding to high-risk areas and populations.

EPA and Congress

For new engines, the EPA should develop regulations that hold trains and ships accountable to the same standards that other diesel engines face. To clean up the existing fleet, the EPA should develop retrofit regulations that require pollution controls or early engine retirement, and should work with Congress to develop a well-funded voluntary incentive program. To ensure emission controls are functioning at their full potential and to prevent tampering with exhaust controls, the EPA should develop an inspection and maintenance program. And finally, there needs to be more research into the real-world emissions from diesel engines and the health impacts of ultrafine particles.

CHAPTER 1

DIESEL POLLUTION AND PUBLIC HEALTH: QUANTIFYING THE IMPACTS

The exhaust emitted from conventional diesel-powered engines may cause or exacerbate serious public health problems such as asthma, bronchitis, and cancer, and can even lead to premature death. In addition to its public health toll, diesel exhaust exacts enormous social costs, with escalating health care expenditures, loss of work and school days, and the most costly impact of all: the loss of human lives.

This study evaluates the human health impacts of diesel exhaust in California and estimates the number of people that will suffer serious health problems from exposure to diesel particulate matter (PM) released directly from the tailpipe or formed indirectly from emissions of nitrogen oxides. We translate these health impacts into dollars to evaluate the economic costs of diesel pollution. This chapter describes the basic steps of our analysis; for more details, see the Technical Support Document for this report.

Our ability to quantify the public health and welfare impacts of diesel exhaust is limited (Table 1-1, p.2). There are many potential impacts of diesel exhaust—such as smog-related respiratory problems, increasing asthma rates (especially for children), and damage to agricultural crops and forest habitats—that are not quantified. Thus, the true costs of diesel pollution are likely higher than our baseline estimates.

Table 1-1. Diesel Health and Welfare Impacts

	Pollutant	Quantified Impacts	Key Non-Quantified Impacts
Health	PM	Premature mortality Chronic bronchitis Hospital admissions -Asthma (including ER visits) -COPD -Cardiovascular illness Cancer cases	Lower and upper respiratory illness Chronic respiratory disease other than bronchitis Other hospital admissions such as pneumonia or non-asthma respiratory illnesses Minor restricted-activity days Work loss days Asthma attacks Respiratory symptoms in asthmatic population Infant mortality Low birth weight Allergic responses
Health	Ozone		Premature mortality—acute exposure Asthma attacks Inflammation in the lung Chronic respiratory damage Premature aging of the lungs Increased susceptibility to respiratory infection ER visits—respiratory Hospital admissions—respiratory Chronic asthma
Welfare	PM Ozone		Visibility Agricultural and forest commercial productivity Recreational demand Ecosystem damage Decreased worker productivity

NOTE: For a more complete list of the potential health and welfare impacts of diesel exhaust, see EPA, 2003 Table 9-1.

UCS analysis

Dr. Alan Lloyd, chairman of CARB, and Thomas Cackette, CARB's chief deputy executive officer, developed California-specific concentration-response (C-R) functions[6] for a number of serious health impacts, relying on epidemiological studies that estimate the relationship between a population's exposure to a pollutant and increased incidences of certain health problems. Using the California-specific data, we estimate the number of premature deaths, chronic bronchitis cases, and hospitalizations for certain respiratory and cardiovascular illnesses caused by diesel PM. We evaluate the current and future impacts of two scenarios: "Business as usual" and "diesel risk reduction." In addition, we use cost-benefit analysis to evaluate California's landmark diesel cleanup incentive program, the Carl Moyer Memorial Air

[6] Lloyd and Cackette (2001) utilized population-weighted diesel PM exposure estimates based on a previous analysis by CARB (1998).

Standards Attainment Program (often simply referred to as the "Moyer Program").

To evaluate the health impacts of diesel toxicity, we estimated the cases of cancer that would result from exposure to current and future levels of diesel PM. Since a fraction of the premature deaths are due to lung cancer, cancer cases are not translated into dollar impacts to avoid the possibility of double-counting. Other health impacts were excluded from this analysis for three primary reasons: (1) lack of established concentration-response relationships; (2) possibility of double-counting, and; (3) lack of California-specific data from peer-reviewed sources.

PM health effects

Diesel particles may be released directly from exhaust or may form indirectly, as nitrogen oxides (NOx) and sulfur oxides (SOx) react in the atmosphere.[7] The particles released directly from exhaust are often composed of a carbon core with an array of toxic compounds, including metals, polycyclic aromatic hydrocarbons (PAHs), and dioxins, adsorbed to the particle's surface (Cuddihy, 1984). Nearly all diesel particles fall in the fine and ultrafine size range (Table 1-2). These tiny particles can travel deep into the lungs and lodge in the alveoli, the delicate sites where oxygen exchange normally occurs (Bagley, 1996).

Table 1-2. Size Categories for Particulate Matter

	Diameter in microns
Coarse (PM_{10})	Less than 10
Fine ($PM_{2.5}$)	Less than 2.5
Ultrafine	Less than 0.1
Nanoparticles	Less than 0.05

Our polluted urban air has unfortunately provided researchers with ample evidence that human health is harmed by exposure to PM (for a list of these studies, see EPA, 2003). These epidemiological studies have found statistically significant associations of PM, especially fine particles, with a variety of illnesses (Table 1-3, p.4). Fine particles are linked with mortality and hospitalization for respiratory symptoms and cardiovascular illnesses, while coarse PM is associated with the aggravation of respiratory conditions such as asthma. These studies have targeted certain age ranges and thus do not account for all incidences in the general population. According to a U.S. Environmental Protection Agency review of recent studies (EPA, 2003), there is no health impacts threshold for PM, and even small amounts can have negative health impacts.

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[7] UCS only evaluated the secondary formation of PM from NOx, though SOx may contribute more than half the secondary PM from diesel engines. With the advent of low-sulfur diesel fuel in 2006, SOx emissions–and secondary PM from SOx–will plummet.

Table 1-3. Health Impact Studies for $PM_{2.5}$

Health Endpoint	Health Study[a]	Age Group	Description
Premature Mortality	Krewski et al., 2000	30 and older	Premature death arising from exposure to PM, including cardiopulmonary and lung cancer mortality.
Chronic Bronchitis	Abbey et al., 1995	27 and older	A form of bronchitis characterized by excess production of mucus, leading to a chronic cough and obstruction of air flow.
Hospital Admissions			
Chronic Obstructive Pulmonary Disease	Samet et al., 2000[b]	65 and older	Hospital admissions for a group of diseases including chronic bronchitis and emphysema, which result in decreased expiratory flow in the airways of the lung.
Cardiovascular	Samet et al., 2000[b]	65 and older	Hospital admissions for cardiovascular conditions including heart attacks and hypertension.
Asthma	Sheppard et al., 1999	64 and younger	Hospital admissions for asthma-related symptoms.
Asthma ER Visits	Schwartz, 1993	64 and younger	Emergency room (ER) visits attributed to asthma-related symptoms.

NOTES:
a. For a complete list of the Health Impact Studies used by the EPA to evaluate its recent proposal for new fuel and emission standards for nonroad engines, see EPA, 2003 Table 9-6.
b. According to HEI (2003), the Samet et al. (2000) study may have overestimated impacts by about 10 percent. UCS reduced the results for chronic obstructive pulmonary disease and cardiovascular hospitalizations by 10 percent to provide a more accurate accounting of impacts.

Premature mortality

The premature mortality data is based on a reanalysis by Krewski et al. (2000) of two seminal studies linking PM and premature death: The American Cancer Society study (Pope et al., 1995), which tracked more than half a million people in 151 cities; and the Harvard six-city study (Dockery et al., 1993), which followed the health of more than 8,000 people in six small cities for a period of 14 to 16 years. Adjusting for socioeconomic status, medical care, and other factors, Krewski et al. confirmed key conclusions of the earlier studies regarding the linkage between fine particles and premature mortality.

The premature mortality data include all causes of death, such as lung cancer, heart disease, and stroke, resulting from exposure to $PM_{2.5}$. Only people aged 30 and older were evaluated, with the elderly more likely to experience premature mortality than younger people. The EPA (2003) postulates that there may be a time lag between changes in PM exposures and changes in mortality rates, and the full benefits of cleaner air on reduced mortality may be delayed for several years.

Chronic bronchitis

Abbey et al. (1995) examined the relationship between chronic respiratory symptoms and $PM_{2.5}$ in about 1,900 Californians aged 27 and older. Over the 10-year study, Abbey et al. found that particulate matter was significantly associated with chronic bronchitis, an inflammation of the air passages (bronchi) connecting the windpipe with the lungs. Chronic bronchitis, which is marked by excessive mucus production and coughing, can continue for months and returns each year, generally lasting slightly longer each time. In the early stages of the disease, people suffering from chronic bronchitis may experience breathlessness on exertion. As the disease progresses, shortness of breath may be caused by very ordinary activities such as casual walking or getting dressed in the morning.

Hospitalizations

A number of studies have linked exposure to $PM_{2.5}$ with hospital admissions for various respiratory and cardiovascular illnesses. In a study covering 14 cities across the country, Samet et al. (2000) examined the relationship between air pollution and hospital admissions for people aged 65 and older. Samet et al. identified concentration-response relationships for $PM_{2.5}$ and hospitalizations for heart diseases, such as heart attacks and hypertension, as well as for chronic obstructive pulmonary disease (COPD). COPD is actually a group of diseases that lead to decreased flow in the airways of the lung, such as chronic bronchitis and emphysema. A recent study by the Health Effects Institute (2003) found that Samet et al. may have overestimated hospitalizations of these illnesses by an average of about 10 percent. Our results have been adjusted downward 10 percent to account for this new information.[8]

Schwartz (1993) evaluated emergency room (ER) visits for asthma in Seattle, and found statistically significant linkages between fine particles and asthma-related ER visits for people younger than 65. Asthma-related hospital admissions are based on another Seattle study by Sheppard et al. (1999) of non-elderly (under 65 years) hospital admissions for asthma.

Cancer

At least nine agencies, including the EPA, the Agency for Toxic Substances Control, and the State of California, have identified diesel exhaust as a likely, probable, or known cancer-causing agent (Table 1-4, p.6). According to its analysis of more than 30 epidemiological studies, CARB (1998) found that people who are routinely exposed to diesel exhaust through their work on railroads, docks, or trucks have a greater risk of lung cancer. On average, these studies found long-term occupational exposure to diesel exhaust was associated with a 40 percent increase in the relative risk of lung cancer. CARB developed a cancer risk assessment based on these studies and found that diesel exhaust is responsible for an alarming 70 percent of the state's risk of cancer from airborne pollution (CARB, 2000).

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[8] The exact C-R function parameters used by Lloyd and Cackette are not available, limiting our ability to adjust the hospitalizations for cardiovascular illnesses and COPD with specific findings from the HEI reanalysis.

Table 1-4. Agency Designations of Diesel Exhaust and Cancer

Year	Organization	Conclusion
2002	U.S. Environmental Protection Agency	Likely human carcinogen
2001	American Council of Government Industrial Hygienists (proposal)	Suspected human carcinogen
2001	U.S. Department of Health and Human Services	Reasonably anticipated to be a human carcinogen
1998	California Air Resources Board	Toxic air contaminant
1996	World Heath Organization International Programme on Chemical Safety	Probable human carcinogen
1995	Health Effects Institute	Potential to cause cancer
1990	State of California	Known to cause cancer
1989	International Agency for Research on Cancer (IARC)	Probable human carcinogen
1988	National Institute for Occupational Safety and Health (NIOSH)	Potential occupational carcinogen

We utilized CARB's cancer risk factor to estimate the number of cancer cases resulting from a 70-year exposure to diesel exhaust. However, our estimate does not account for changes in emissions, ambient concentrations, and toxicity over time. Diesel emissions will drop over the next several decades, as stronger emission standards for new equipment come into effect, and the number of cancer cases should fall as a result. In addition, sophisticated pollution controls such as PM traps appear to cut not just the mass of particulate emissions, but also the toxicity. Over time, California's cancer risk factor will need to be revised to reflect the changing profile of diesel exhaust.

Monetizing impacts

To estimate the economic value of health outcomes, we rely on the EPA's (2003) cost-effectiveness analysis for its proposed nonroad emission standards (Table 1-5). For premature mortality and chronic bronchitis, the EPA utilizes "willingness to pay" (WTP) data, which estimate the amount society is willing to pay to avoid a specific health impact. The more severe the health impact, the greater the willingness to pay to avoid the outcome. As real income increases, WTP also rises, though the adjustment factors differ based on the severity of the outcome. The EPA estimated that the value of a premature death avoided in 1990 was a little more than $6 million (in year 2000 dollars), while in 2020, society will be willing to pay $8 million to avoid a death.

Table 1-5. Economic Value of Health Impacts[a]

Health Endpoint	1990	2020	Description
Mortality[b] (Ages 30+)	$6,300,000	$8,000,000	Value is the mean of value-of-statistical-life estimates from 26 studies (5 contingent valuation and 21 labor market studies) reviewed for Section 812 Cost and Benefits of the Clean Air Act, 1990-2010 (EPA, 1999). Costs are discounted assuming the benefits of reduced exposure occur over five years (EPA, 2003).
Chronic Bronchitis (CB)	$340,000	$430,000	Value is the mean of a generated distribution of WTP (willingness to pay) to avoid a case of pollution-related CB. WTP to avoid a case of pollution-related CB is derived by adjusting WTP to avoid a severe case of CB for the difference in severity and taking into account the elasticity of WTP with respect to severity.
Chronic Obstructive Pulmonary Disease (COPD) (ICD codes 490-492, 494-496)	$12,378	$12,378	COI (cost of illness based on lost earnings plus direct medical costs) estimates are based on ICD-9 code level information (e.g., average hospital care costs, average length of hospital stay, and weighted share of total COPD category illnesses) reported in Agency for Health Care Research and Quality, 2000 (*www.ahrq.gov*).
Cardiovascular (ICD 390-429)	$18,387	$18,387	COI estimates are based on ICD-9 code level information (e.g., average hospital care costs, average length of hospital stay, and weighted share of total cardiovascular illnesses) reported in Agency for Health Care Research and Quality, 2000 (*www.ahrq.gov*).
Asthma (ICD 493)	$6,634	$6,634	COI estimates are based on ICD-9 code level information (e.g., average hospital care costs, average length of hospital stay, and weighted share of total asthma category illnesses) reported in Agency for Health Care Research and Quality, 2000 (*www.ahrq.gov*).
Asthma ER Visits	$286	$286	Simple average of two unit COI values: (1) $311.55, from Smith et al. (1997) (2) $260.67, from Stanford et al. (1999)

NOTES:
a. All monetary valuations are presented in year 2000 dollars.
b. In the cost-benefit analysis, the value of avoiding premature deaths is discounted over five years to account for a lag time between reduced exposure to PM and when the premature deaths are avoided.
SOURCE: EPA, 2003.

Placing a dollar value on a human life is rife with controversy, raising serious ethical issues about the appropriateness of such valuation. When making policy, federal agencies are often forced to place a value on human life, but there is little consistency across different federal agencies on the appropriate valuation technique. In 2003, the Office of Management and Budget (OMB) recommended that the lives of older people should be worth less than the lives of young adults.[9] That suggestion created controversy across the country, with seniors leading the charge against the new valuation.

[9] According to the OMB's calculation, saving the life of someone 70 or older may be worth only 63 percent as much as saving the life of someone younger. This is based on the principle that it is fairer to count the years of life saved by a government regulation than the number of lives.

By relying on baseline EPA estimates, this analysis does not make any assertion about the value of life at various ages.

For hospital admissions, the EPA relied on the cost of illness (COI). The EPA acknowledges that COI estimates generally understate the true value to society of avoiding an illness, since the cost data do not account for pain and suffering. In addition, COI estimates do not increase over time to reflect the escalating cost of medical services and hospitalization.

Study limitations

There are inherent uncertainties in estimates of health incidences obtained by applying concentration-response (C-R) equations. Many of these epidemiological equations are established by studying certain age groups in particular locations and exposed to a small range of pollutant concentrations. When applying these C-R functions, we assume that the relationships identified in the studies are consistent for other populations, geographic regions, and pollutant concentrations.

The C-R functions themselves also contain inherent uncertainties that can be quite large. In our results for the estimated number of health incidences, we present the mean value and a 90 percent confidence interval. A narrower confidence interval implies that the results may be more precise, while wider intervals imply less precision. In light of these uncertainties, estimates of health impacts should be viewed as representative of the magnitude of the effects and not the actual number of incidences.

Our projections of the health impacts of diesel pollution in the "business as usual" scenario for 2020 do not account for emission reductions that may be achieved through retrofit regulations recently passed (but not yet finalized) by CARB. Since these rulemakings were not final as of May 2004, CARB has not included them in its emissions inventory projections. Emission information at the level of detail required to include these reductions in our analysis was not available. As a result, future health incidences as calculated in the "business as usual" scenario may be overestimated.[10]

Emission reductions expected from the recently enacted EPA regulation to reduce pollution from new nonroad (or "off-highway") engines are included in this analysis. However, California-specific emission reductions were not available from the EPA. Therefore, estimated emission reductions used in this analysis are based on the national average percent reduction from marine, locomotive, and land-based nonroad diesel engines (EPA, 2004).

Lastly, we evaluated air basin impacts and did not account for variability in risk and exposure at the local geographic scale within an air basin. For direct PM, risk scales with the distance from the pollution source

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[10] Based on the limited information available from the Initial Statement of Reasons for a number of recent rulemakings (CARB 2004b, 2003a, 2003b, 2003c), we estimate that reductions in PM may result in a four percent decrease in 2010 and an eight percent decrease in 2020 over our "business as usual" projections. These preliminary emission reduction estimates are subject to change because the rules have not been finalized. Also, some double-counting is possible because emission reduction estimates were based on emissions inventory projections that were not updated to reflect the EPA's final nonroad diesel rule (EPA, 2004a).

(NESCAUM, 2003). Thus, the farther people are away from the polluting diesel engine, the fewer health risks they face. Conversely, people living in densely populated areas will face higher risks. Estimating health impacts based on air basin averages may overestimate the actual benefits for diesel cleanup in rural areas, and underestimate the impacts of cleaning up urban sources.

Non-quantified impacts

It is not clear how significantly non-quantified health and welfare impacts affect the cost of diesel pollution on Californians. Since some impacts, such as asthma attacks or work days lost, could number in the hundreds of thousands, many more Californians are affected by diesel pollution than our analysis indicates. We can safely assume that our estimate of the costs of diesel pollution is conservative. In addition, our analysis does not address sensitive populations, such as children, that may experience the harmful effects of pollution more acutely.

Other PM health impacts

Many other PM-related health impacts are not included in our analysis, such as asthma attacks, work loss days, and minor restricted-activity days that do not lead to hospital visits. These impacts can be very significant, since they can affect hundreds of thousands of people. For example, CARB estimates that reducing ambient concentrations of PM_{10} to meet the California State Standards would prevent more than 300,000 asthma attacks per year (CARB, 2002).

Smog-related health impacts

Smog, or ozone, is formed when NOx and hydrocarbons react in the presence of sunlight. Smog can make people more susceptible to respiratory infection and can aggravate pre-existing respiratory disease. Premature aging of the lungs and chronic respiratory illnesses such as bronchitis, asthma, and emphysema are all linked with exposure to ozone (EPA, 2002). On smoggy days, hospital admissions, especially for asthma, escalate (Koren, 1995; White, 1994).

Most of California's urban areas, and a growing number of rural locations, fail to meet the national air quality standards for ozone. In the spring of 2004, the EPA announced that 36 California counties—including San Diego, San Francisco, San Joaquin, and Los Angeles—are in violation of the new eight-hour smog standard.[11] The smoggiest region of the country is Los Angeles, with 120 violations in 2003; not far behind are the San Joaquin Valley and the Sacramento metropolitan area.

[11] The eight-hour ozone standard is 0.08 parts per million (ppm), averaged over eight hours. The older one-hour standard (in effect from 1979 to 1997) was 0.12 ppm, measured in hourly readings. The newer, stricter standard was issued in 1997 after a significant body of research showed that longer-term exposure to lower levels of ozone is harmful to human health.

Welfare impacts

Welfare impacts from diesel pollution include decreased worker productivity, poor visibility, decreased recreational demand, decreased commercial forest productivity, lower agricultural yields, and damage to sensitive ecosystems. There may also be profound and irreversible impacts to the health and stability of agricultural, forest, and natural ecosystems.

Children's sensitivity to air pollution

Outdoors more often and breathing at higher rates than adults, children (and their developing lungs) may experience greater exposure to harmful air pollutants (Wiley, 1993). Studies suggest that children, especially those with asthma, may be more susceptible to the harmful respiratory effects of particulate pollution than adults (Pope et al., 1991; Ostro, 1995). Children raised in heavily polluted areas have reduced lung capacity, prematurely aged lungs, and increased risk of bronchitis and asthma compared with peers living in less urbanized areas (Dockery, 1989; Peters, 1999).

While numerous studies have found that air pollution exacerbates asthma in children, a new study in Southern California suggests that air pollution may actually cause asthma in otherwise healthy children (McConnell et al., 2002). In communities with the highest ozone levels, children who participated in sports were more than three times as likely to become asthmatic compared with less active children.

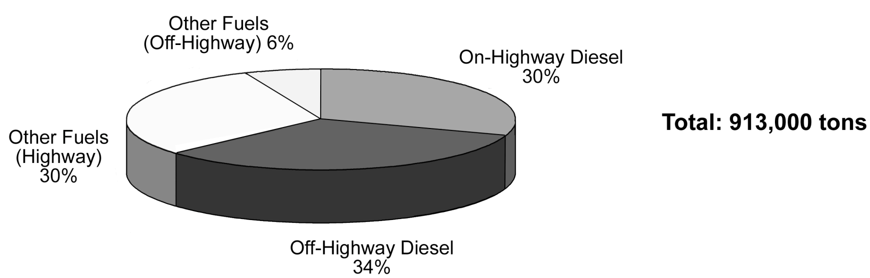
CHAPTER 2

DIESEL CLEANUP

California's diesel pollution

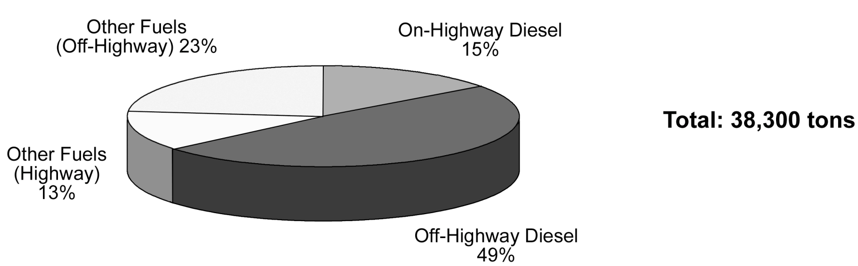
California's diesel engines are expected to release about 65 percent of the NOx and PM emissions from mobile sources statewide in 2005 (Figures 2-1 and 2-2). Off-highway engines, including construction and agricultural equipment, trains, ships, stationary engines, and other heavy equipment, release almost half of the PM and about 35 percent of the NOx from the state's mobile sources. Diesel trucks and buses account for only six percent of the total miles traveled on California's roads, yet they are responsible for about two-thirds of the pollution from highway vehicles.

Figure 2-1. California's 2005 Mobile Source Pollution: NOx



SOURCE: CARB 2004 Air Quality Almanac.

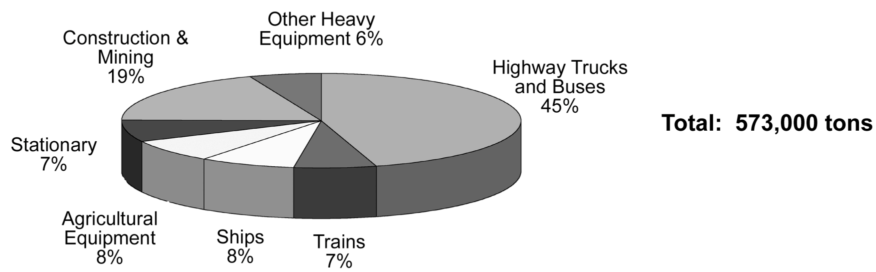
Figure 2-2. California's 2005 Mobile Source Pollution: PM_{10}



NOTE: Mobile source PM emissions exclude tire and brake wear.
SOURCE: CARB 2004 Air Quality Almanac.

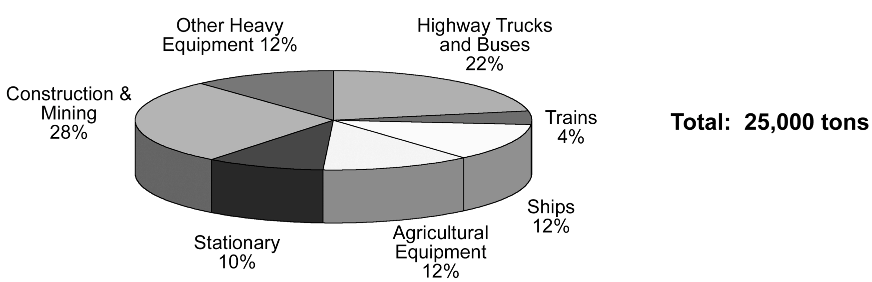
In 2005, CARB projects that diesel PM_{10} emissions will be 25,000 tons, while NOx emissions are projected at 573,000 tons (Figures 2-3 and 2-4). The biggest single source of diesel PM is construction and mining equipment, which release 28 percent of the state's total. For NOx pollution, highway trucks and buses release 45 percent of the state's total from diesel engines.

Figure 2-3. California's 2005 Diesel Pollution: NOx



NOTE: All of the diesel sources are mobile with the exception of stationary diesel engines, which are used primarily for the generation of electrical power. Other off-road diesel equipment includes lawn and garden equipment, airport ground support vehicles, and mobile refrigeration units.
SOURCE: 2004 CARB Air Quality Almanac.

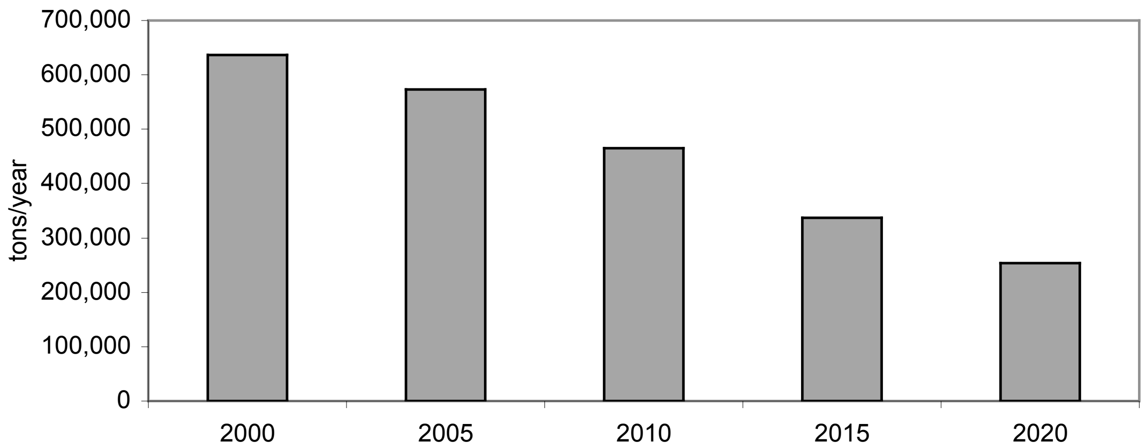
Figure 2-4. California's 2005 Diesel Pollution: PM_{10}



NOTE: All of the diesel sources are mobile with the exception of stationary diesel engines, which are used primarily for the generation of electrical power. Other off-road diesel equipment includes lawn and garden equipment, airport ground support vehicles, and mobile refrigeration units. Brake dust and tire wear are not included in diesel PM emissions.
SOURCE: 2004 CARB Air Quality Almanac.

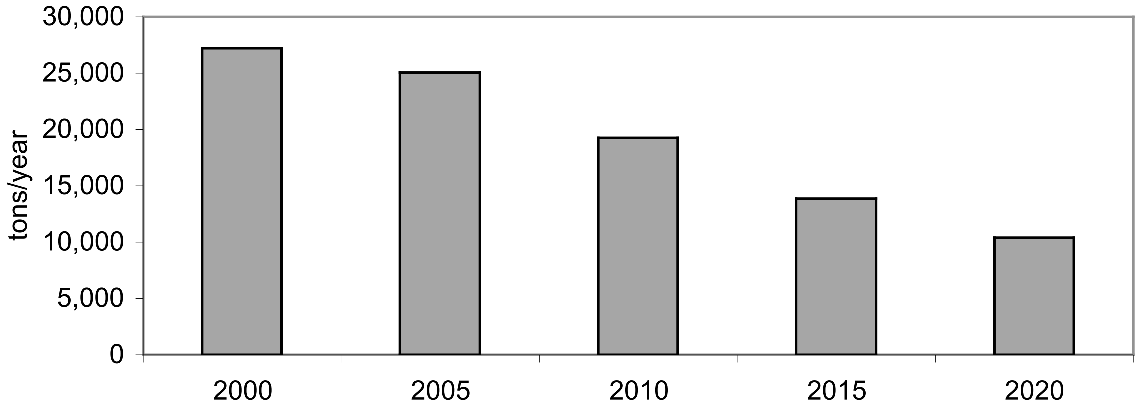
In the next 10 to 20 years, PM and NOx pollution from diesel engines will drop as stricter emission standards for new engines take effect (Figures 2-5, below, and 2-6, p.14). But this progress will be mitigated by increases in the number of heavy-duty vehicles, which are projected to grow 12 percent statewide and 23 percent in the South Coast Air Basin alone between 2000 and 2010 (CARB, 2002). In addition, the long lifetime of diesel engines means that they can remain in operation for decades. The oldest diesel engines release the greatest amount of harmful pollution—and pose the largest public health risks.

Figure 2-5. California's Diesel NOx Emission Projections



NOTE: Our projections of the health impacts of diesel pollution in 2020 do not account for emission reductions that may be achieved through retrofit regulations recently adopted (but not yet finalized) by California. Since these rulemakings were not final as of May 2004, we did not have sufficient information to evaluate their emissions inventory impacts.
SOURCE: CARB 2003 Air Quality Almanac.

Figure 2-6. California's Diesel PM_{10} Emission Projections



NOTE: Our projections of the health impacts of diesel pollution in 2020 do not account for emission reductions that may be achieved through retrofit regulations recently adopted (but not yet finalized) by California. Since these rulemakings were not final as of May 2004, we did not have sufficient information to evaluate their emissions inventory impacts.
SOURCE: CARB 2003 Air Quality Almanac.

Luckily, there are a wide variety of diesel cleanup technologies and clean fuel alternatives available today (UCS, 2004, 2003, 2002). In addition, new pollution controls are under development as manufacturers prepare to meet new tailpipe standards for highway trucks and buses.

Federal cleanup actions

Until recently, the EPA focused primarily on cleaning up gasoline-powered vehicles, letting diesel engines off the regulatory hook. Off-highway equipment such as bulldozers and tractors did not have to meet any emission standards until 1996. Highway trucks and buses did not have to meet any standards for soot particles until 1988. And diesel cars and light trucks have historically been held to weaker standards than their gasoline counterparts. Diesel cars may continue to pollute more until 2007 (for cars) and 2009 (for light trucks), when new tailpipe standards are fully implemented.

But for new engines, diesel's free ride may be coming to an end. In the next 10 years, most new diesel engines will face stricter fuel and emission standards.

Fuel standards

The most advanced pollution controls need low-sulfur diesel fuel (less than 15 parts per million, ppm) in order to function properly. The performance of these advanced controls can be impaired or completely compromised by sulfur contamination. The EPA has decided that, starting in mid-2006, nearly all highway diesel fuel must be low-sulfur diesel. For heavy diesel equipment (so called "off-highway" engines), the EPA has set a 2010 deadline for the conversion to low-sulfur, while locomotives and marine vessels have a 2012 deadline.

New vehicle emission standards

In 2000, the EPA issued its first in a series of rulemakings to strengthen tailpipe standards for new diesel engines. The new standards for highway trucks and buses reduce PM and smog-forming pollution (NOx plus non-methane hydrocarbons) by 90 percent or more. These standards will be phased in between 2007 and 2010. In 2004, the EPA finalized similar standards for most heavy diesel equipment, with full implementation occurring in 2015. Two major categories that can continue to pollute unnecessarily are trains and ships, and the EPA is just beginning to evaluate cleanup opportunities for these engines. The long phase-in for these emission standards and the long life of diesel engines means that their full impact on cleaner air will not be felt for decades.

Retrofit and replacement programs

The EPA is just beginning to address the pollution problem posed by the oldest (and dirtiest) diesel engines. It has two fledgling programs to reduce pollution from the existing diesel fleet: The Voluntary Retrofit Program (often simply referred to as the "Retrofit Program") and Clean School Bus

USA. The Retrofit Program verifies retrofit equipment for use, provides information about retrofit technologies, and offers limited economic incentives from a small pot of grant funding.[12] Clean School Bus USA was launched in 2003 to help school districts clean up high-polluting diesel school buses through replacement, retrofits, and reduced idling.[13]

California's cleanup actions

California has been on the forefront of state efforts to reduce diesel pollution. As part of the state's Diesel Risk Reduction Plan, CARB is in the process of issuing new regulations to reduce PM and NOx from certain fleets. The state has also developed incentive programs that fund the incremental costs of replacing older diesel engines with cleaner equipment.

Diesel Risk Reduction Plan

In 1998, CARB designated diesel exhaust a toxic air contaminant after an exhaustive, 10-year scientific assessment process (CARB, 1998). Using the newly developed cancer risk assessment for diesel, CARB estimated that diesel PM was responsible for 70 percent of the state's risk of cancer from airborne toxics (2000). These alarming statistics spurred CARB in 2000 to develop the Diesel Risk Reduction Plan, which calls for reducing diesel PM 75 percent by 2010 and 85 percent by 2020 (from the base year 2000 level).

The plan has three major components: first, to require low-sulfur diesel fuel (no more than 15 ppm); second, to develop or implement emission standards for new diesel engines that will reduce PM by 90 percent; and third, to require that existing engines use pollution controls where technically feasible and cost-effective. In addition, the plan recognizes the important role of voluntary incentive programs in reducing diesel pollution.

Fuel standards

In 2003, CARB passed the strictest diesel fuel regulations in the country, with low-sulfur diesel fuel required for all highway vehicles, non-highway heavy equipment, and stationary diesel generators starting in 2006. Two significant source categories—locomotives and marine vessels—were exempted from the requirements. These exempted engines often have the ability to refuel out of state, requiring a regional or national approach to ensure the use of low-sulfur diesel.

Regulations

Between 2001 and May 2004, CARB approved new regulations for five diesel fleets: transit buses, refuse haulers, transportation refrigeration units,

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[12] In 2003, the EPA distributed about $560,000 in funds for retrofit projects. For 2004, the EPA is offering $1.5 million for retrofit demonstration projects that reduce diesel pollution exposure among sensitive populations such as children and the elderly.

[13] The Clean School Bus USA program may soon have a larger infusion of funding. The 2005 President's Budget proposes a $60 million investment in the program, up from $5 million in 2004.

stationary engines, and portable engines (CARB 2004a, 2003a, 2003b, 2003c). Together, these fleets account for about 15 percent of California's diesel PM pollution (Table 2-1, p.18). As a result of these regulations, CARB estimates that PM emissions from these fleets will be halved by 2010, and about 1,200 premature deaths will be avoided. The cost-effectiveness of PM reductions ranges from $18,000 to $64,000 per ton. While not the primary focus, the regulations often reduce NOx emissions.[14] The average cost-effectiveness of these regulations for NOx pollution is $2,000 to $4,000 per ton, well below the maximum cost-effectiveness criteria of $13,600 per ton set by the Moyer Program guidelines.[15]

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[14] Only the transit bus regulation has required reductions in NOx.

[15] While CARB is not required in its regulations to meet a cost-effectiveness level of $13,600 per ton, CARB has used the Moyer Program guidelines as a benchmark for evaluating cleanup costs. Because the regulations simultaneously reduce NOx and PM, CARB allocates the cleanup costs between the two pollutants, in effect lowering the per-ton costs for each.

Table 2-1. California Diesel Cleanup Regulations: Current and Future

Current Rules

Rule/Subject	Summary of Control Measure	Key Regulatory Dates	PM Emissions Without Control Measure in Tons per Year (TPY) in 2010	Direct PM Emission Reductions (in TYP) from Control Measure 2010	2020	Premature Deaths Avoided	Cost-Effectiveness ($/ton direct PM)	Cost-Effectiveness ($/ton NOx)
Portable Engines	Requires engines larger than 50 hp meet specific PM emission standards	Approved 2004	1,000	292	584	768 (by 2037)	$18,000	$4,000
Stationary Diesel Engines	Requires new and existing engines meet specific PM emission standards	Approved 2004	1,000	146	55	121 (by 2020)	$16,000	$2,000
Transportation Refrigeration Units (TRUs)	Requires new and existing engines meet specific PM emission standards and operating-hour limitations	Approved 2004	900	219	192	211 (by 2020)	$30,000	N/A
Refuse Haulers	Requires new and existing engines meet specific PM emission standards	Approved 2003	200	121	30	80 (by 2020)	$64,000	$3,600
Transit Buses	Requires new and existing engines meet specific PM and NOx emission standards	Adopted 2001	50	27	12	N/A	$35,800	$3,600
Totals			**3,150**	**805**	**873**	**At least 1,180**	**$18,000 to $64,000 per ton**	**$2,000 to $4,000 per ton**

Future Rules

Rule/Subject	Summary of Control Measure	Target Regulatory Dates	PM Emissions Without Control Measure in Tons per Year (TPY) in 2010
Off-Road Vehicle Fleets	Anti-idling	2004	9,000
	Other cleanup: not defined	2005	
On-Road Vehicle Fleets	Anti-idling	2004	4,000
	Public fleet cleanup: new and existing engines to meet PM emission standards	2004	
	Private fleet cleanup: not defined	2005	
Ships (ocean transit, coastal waters)	Not defined	N/A	2,400
Ships/Boats (in and near CA ports)	Harbor craft fuel	2005	1,300
	Other measures: not defined	N/A	
Locomotives	Fuel requirements	2004/5	900
Fuel Tanker Trucks	Requires new and existing engines meet specific PM emission standards	2004	20
TOTAL			**17,620**

NOTE: The emission impacts, premature deaths avoided, and cost-effectiveness data are based on CARB's Initial Statement of Reasons (ISOR) for each proposed rule. Since the final rulemaking may differ from the staff proposal, these data should be considered general estimates only. Except for the TRU calculations, premature deaths avoided includes the benefits from reducing both direct and indirect PM through NOx reductions. The ISOR for TRUs only evaluated premature deaths avoided from PM reductions. For all cost-effectiveness data except TRUs and transit buses, CARB allocates some of the compliance costs to each pollutant reduced, resulting in lower costs per ton of pollutant reduced. Only the TRU cost-effectiveness data are exclusive to PM. For transit buses, CARB only evaluated the costs of retrofits for its PM calculation, and the costs of bus replacement for its NOx calculation.

CARB has had to overcome significant barriers to develop these regulations. These programs have often faced vigorous opposition from regulated industries and diesel vehicle manufacturers. The process of developing regulations can last years, as regulators evaluate technical options for reducing pollution, controlling costs, minimizing impacts on small businesses, and other issues.

California still has a long way to go to clean up diesel pollution. By 2010, California will only achieve about a 30 percent reduction in diesel PM compared with the 2000 level, rather than the Risk Reduction Plan target of 75 percent. The regulations approved so far target captive fleets and do not address 85 percent of California's diesel sources. The state is evaluating cleanup regulations for these remaining sectors, which are composed of a diverse array of engines and ownership patterns. Some are owned by small businesses and individual owners and operators, who may not be able to afford the costs of pollution controls. Regulations must be the cornerstone of California's strategy to clean up diesel pollution, but where regulations fall short, incentive programs can help fill the gap.

Incentive programs

California has two landmark incentive programs: The Moyer Program and the Lower Emission School Bus Program.

Moyer Program

In 1999, California created the Moyer Program to reduce smog-forming NOx from diesel engines and replace diesel with cleaner alternatives such as natural gas and electricity. The program helps offset the incremental costs of purchasing or retrofitting a cleaner engine. Each project must meet a specific cost-effectiveness level for NOx, currently set at $13,600 per ton. However, the average project cost-effectiveness—around $3,000 per ton—falls far below the maximum.

For the first four years, the Moyer Program reduced smog-forming NOx emissions by about 5,000 tons per year, equivalent to about one percent of the state's diesel NOx emissions from heavy-duty engines. Though the focus of the program is NOx, significant PM benefits have been achieved as well. The first four years of funding have resulted in PM reductions of 235 tons per year. As of 2002, the Moyer Program had replaced nearly 2,800 older diesel engines with new, cleaner diesel engines, primarily in marine vessels, off-road equipment, and agricultural irrigation pumps. The Moyer Program had also funded more than 2,000 alternatively fueled vehicles, especially transit buses and refuse trucks.[16]

Under current program guidelines, state funds cannot be used for projects that reduce PM only. To promote projects that simultaneously reduce PM and NOx, CARB has set a 25 percent PM emission reduction target for the

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[16] Information on the first four years of funding was obtained by personal communication with CARB staff.

statewide program.[17] In districts that fall well below the federal PM standard (San Joaquin Valley and South Coast), CARB has established a requirement that PM be reduced by 25 percent.

An advisory council for the Moyer Program recommended that the program be funded at $100 million for 10 years. However, the program has been historically funded far below this level, and may completely run out of money by July 2004.

School Bus Program

With the nation's third largest school bus fleet, California maintains some of the oldest and dirtiest school buses on the road. In a study of tailpipe pollution, California's school buses received the poorest score in the country for smog-forming emissions, toxic soot, and global warming pollution (UCS, 2002). Almost half of California's 24,000 school buses are more than a decade old. In a single year, the average state school bus emits as much soot as 170 cars. In addition, up to 1,000 of California's school buses were built before 1977, predating safety standards for passenger seating and crash protection, rollover protection, body joint strength, and fuel system integrity. These buses are safety hazards as well as major polluters.

To address these problems, CARB started the Lower Emission School Bus Program in December 2000. This incentive program provides funds for replacing older buses, especially those built before 1977, with new, cleaner buses. The program also provides funding for advanced retrofit equipment to reduce soot.[18] As of September 2003, California's School Bus Program had replaced about two percent of the state's older high-polluting school buses with cleaner alternatives, and retrofitted about six percent of the state's fleet with particulate traps (NRDC, 2003). But like the Moyer Program, this successful effort is hampered by a lack of funds. Without a new source of funding, the program will be completely out of money in July 2004.

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[17] Baseline emissions are the estimated "pre-project" PM. State PM reduction goals are not project-specific; rather, they are based on cumulative emissions. Thus, each project does not necessarily have to meet this target, as long as the 25 percent target is met overall.

[18] Historically, CARB has allocated 75 percent of the total funds for new bus purchases. Of this amount, two-thirds was designated for alternative-fuel school bus and infrastructure purchases, and one-third for new lower-emission diesel school buses. The remaining 25 percent of the funds was used for particulate trap retrofits.

CHAPTER 3

CALIFORNIA RESULTS

UCS has quantified key health impacts of diesel exhaust in California, including cases of premature death, chronic bronchitis, and hospitalizations, and estimated the economic costs of these health impacts. Our baseline analysis is for the year 2004, and analysis of future impacts in 2020 is based on two emissions scenarios. The first scenario is "business as usual," with no additional diesel cleanup measures taken. The second scenario assumes full implementation of California's Diesel Risk Reduction Plan, which calls for an 85 percent reduction in diesel particulate pollution. Finally, we evaluate the cost-effectiveness of California's landmark diesel cleanup incentive program, the Moyer Program.

Today

Our analysis indicates that diesel PM released in 2004 will cause an estimated 3,000 premature deaths and 2,700 cases of chronic bronchitis (Table 3-1, p.22). Hospital admissions and asthma-related visits to the emergency room average nearly 4,400. In addition, diesel emissions cause numerous other minor health impacts, including asthma attacks, acute bronchitis, and upper and lower respiratory symptoms in children and adults. Direct PM is responsible for about 70 percent of the health impacts, while indirect PM, formed from NOx pollution, is responsible for the remaining 30 percent.

Table 3-1. 2004 Statewide Health Incidences from Diesel Exhaust

Health Endpoint	Estimated No. of Incidences		
	5th Percentile	Mean	95th Percentile
Premature Mortality	1,462	**2,980**	4,492
Chronic Bronchitis	-26	**2,682**	5,446
Hospital Admissions			
COPD	39	**595**	1,169
Cardiovascular Illness	1,427	**1,751**	2,061
Asthma Admissions	106	**314**	621
Asthma ER Visits	1,147	**1,731**	2,318

NOTE: The 90 percent confidence interval is presented to show the range of statistical uncertainty in the epidemiological estimates. The mean value is the average estimate for each health endpoint and is used to evaluate the associated health costs. COPD is chronic obstructive pulmonary disease.

Premature deaths

By far the most serious consequence of breathing diesel PM is the risk of premature death. Diesel pollution ranks similarly to homicides and heart failure as a cause of premature death in California (Table 3-2). Some of the more common causes of premature death, such as heart disease, cancer, and heart failure, include deaths from diesel pollution.

Table 3-2. Deaths in California: Selected Causes (2001)[a,b]

Cause of Death[c]	No. of Incidences in CA
Heart Attack	16,210
Lung Cancer	14,061
Breast Cancer	4,253
Motor Vehicle Accidents	4,091
Heart Failure	3,400
Homicides	2,282
HIV	1,510
Accidental Drowning	441
Motorcyclist Accidents	294
Bicyclists in Motor Vehicle Collisions	89
Accidental Firearm Discharge	60
Lightning Strikes	2
Diesel Exposure (2004 Estimate)[d]	**2,980**

NOTES:
a. Table only shows a fraction of the causes of premature deaths in California. For a complete list of the leading causes of death, see California Department of Health Services, 2004.
b. 2001 statistics are based on place of occurrence and include all age groups.
c. Diesel exposure deaths include lung cancer, heart attacks, and heart failure. Causes of lung cancer, heart attacks, and cardiovascular and respiratory illnesses leading to premature death are not identified and could not be adjusted for diesel exposure, resulting in double-counting.
d. UCS estimate of premature deaths from exposure to diesel emissions. Includes population over 30.
SOURCE: California Department of Health Services, Vital Statistics Query System, 2001.

Economic costs

For 2004, the societal cost of diesel pollution, based only on the limited health endpoints evaluated, is nearly $22 billion (Table 3-3, p.24). The vast majority of these costs are associated with the most severe health consequence: premature death. And since many health and welfare impacts are not quantified, there are additional costs beyond our baseline analysis.

Table 3-3. Annual Cost of California's Diesel Pollution

Health Endpoint	Estimated Mean No. of Incidences	Estimated Health Cost (millions of 2004$)
Premature Mortality	2,980	$20,420
Chronic Bronchitis	2,682	$1,109
Hospital Admissions		
COPD	595	$8.0
Cardiovascular Illness	1,751	$34.8
Asthma Admissions	314	$2.3
Asthma ER Visits	1,731	$0.5
Unquantified Health and Welfare Impacts	U	$U
Total Estimated Cost		**$21,575 + U**

NOTE: Some health and welfare impacts not quantified include smog-related respiratory problems, increasing asthma rates, damage to agricultural crops and forest habitats, reduced visibility, and others. COPD is chronic obstructive pulmonary disease.
SOURCE: Based on UCS estimates of 2004 annual health incidences and EPA health endpoint valuations.

Future impacts

"Business as usual"

Under a "business as usual" scenario,[19] more than 1,500 premature deaths and 2,200 hospitalizations are expected from exposure to diesel pollution in 2020 (Table 3-4). The annual cost associated with these health incidences is estimated at $12.5 billion (in undiscounted 2004 dollars[20]). Though diesel emissions will drop over the next two decades, the number of annual health incidences remains high because of population growth.[21] By 2020, California's population is expected to grow by more than 20 percent, from about 37 million people today to more than 45 million people (CDOF, 2001).

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[19] The "business as usual" scenario is based on current emission projections from the 2003 CARB Air Quality Almanac. These projections include new diesel fuel and engine emission requirements for highway trucks and buses starting in 2006 and 2007. They also include estimates for the latest federal nonroad diesel engine standards, which were adopted in May 2004 and will be phased in between 2008 and 2014. The most recently approved state regulations targeting diesel PM, which have not yet been adopted in final form, are not included in the projections.

[20] When evaluating costs in a single year, the EPA does not apply a social discount rate.

[21] Even though NOx emissions are expected to decline by 55 percent and PM emissions by 60 percent, the number of health incidences associated with these emissions declines by only 48 percent.

Table 3-4. "Business as Usual" Scenario: 2020 Statewide Health Incidences Attributable to Diesel Exhaust

Health Endpoint	Estimated No. of Incidences		
	5th Percentile	Mean	95th Percentile
Premature Mortality	756	**1,542**	2,324
Chronic Bronchitis	-13	**1,387**	2,817
Hospital Admissions			
COPD	20	**308**	605
Cardiovascular Illness	738	**906**	1,066
Asthma Admissions	55	**162**	321
Asthma ER Visits	593	**896**	1,199

NOTE: The 90 percent confidence interval is presented to show the range of statistical uncertainty in the epidemiological estimates. The mean value is the average estimate for each health endpoint and is used to evaluate the associated health costs. COPD is chronic obstructive pulmonary disease. Our projections of the health impacts of diesel pollution in 2020 do not account for emission reductions that may be achieved through retrofit regulations recently adopted (but not yet finalized) by California. Since these rulemakings were not final as of May 2004, we did not have sufficient information to evaluate their emissions inventory impacts.

Diesel risk reduction

The Diesel Risk Reduction Plan calls for a 75 percent reduction in diesel PM emissions over year 2000 levels by 2010 and an 85 percent reduction by 2020. With full implementation of the plan, UCS estimates the annual health incidences from diesel exhaust would drop by more than 35 percent by 2020 over the "business as usual" scenario (Table 3-5, p.26). Annual premature deaths and cases of chronic bronchitis would drop from more than 1,500 to below 1,000 incidences per year, while hospital visits would also fall from more than 2,000 to less than 1,500**.** In 2020, the annual cost associated with these impacts is estimated at $8 billion (in undiscounted 2004 dollars), more than $4.5 billion less than in the "business as usual" scenario.

Implementation of the Diesel Risk Reduction Plan will produce significant reductions in health incidences and associated costs between 2004 and 2020, including an estimated 11,000 fewer premature deaths and 10,000 fewer cases of chronic bronchitis. This represents a 30 percent reduction in cumulative health incidences from the "business as usual" scenario (Figure 3-1, p.26). Fully implementing the Diesel Risk Reduction Plan would result in a cumulative cost savings of $48 billion to $70 billion between 2004 and 2020.[22]

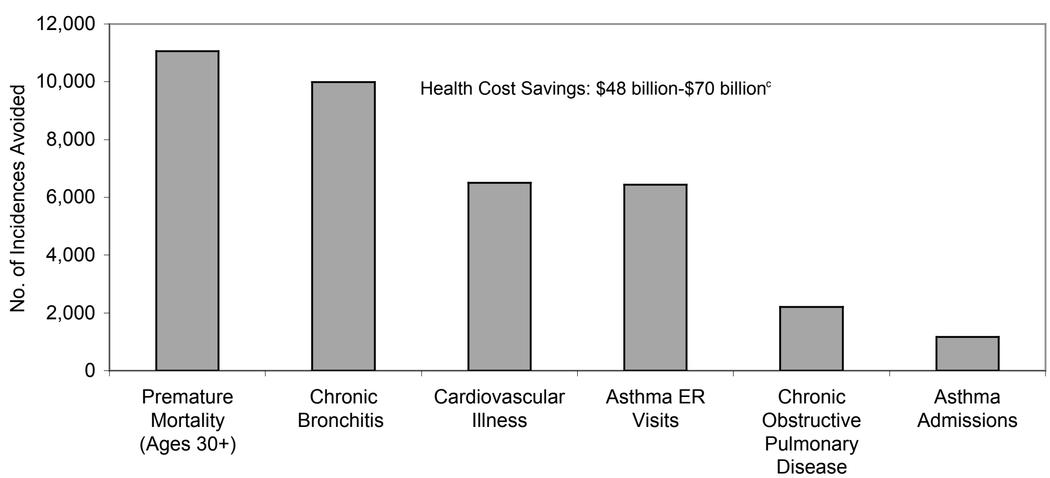
[22] Cumulative cost savings are in year 2004 dollars and future year benefits have been discounted using both a three percent and seven percent social discount rate.

Table 3-5. Diesel Risk Reduction Scenario: 2020 Statewide Health Incidences from Diesel Exhaust

Health Endpoint	Estimated No. of Incidences		
	5th Percentile	Mean	95th Percentile
Premature Mortality	485	**989**	1,491
Chronic Bronchitis	-9	**888**	1,800
Hospital Admissions			
COPD	13	**197**	387
Cardiovascular Illness	473	**581**	683
Asthma Admissions	35	**104**	206
Asthma ER Visits	380	**574**	768

NOTE: The 90 percent confidence interval is presented to show the range of statistical uncertainty in the epidemiological estimates. The mean value is the average estimate for each health endpoint and is used to evaluate the associated health costs. COPD is chronic obstructive pulmonary disease. Emissions inventory estimates for 2020 for the diesel risk reduction scenario are based on an 85 percent reduction from year 2000 estimates.

Figure 3-1. Comparing "Business as Usual" to Diesel Risk Reduction: Cumulative Health Incidences Avoided from 2004 to 2020[a,b]



NOTES:
a. Assumes goals of the Diesel Risk Reduction Plan are met in 2010 and 2020. Linear interpolation was used to calculate reductions for interim years.
b. Our projections of the health impacts of diesel pollution in 2020 for the "Business as Usual" scenario do not account for emission reductions that may be achieved through retrofit regulations recently adopted (but not yet finalized) by California. Since these rulemakings were not final as of May 2004, we did not have sufficient information to evaluate their emissions inventory impacts.
c. Health cost savings are presented in year 2004 dollars. Health costs calculated from incidences occurring between 2005 and 2020 are discounted using both a three percent and seven percent social discount rate, resulting in a range of cost savings.

Toxic risk

The health endpoints evaluated in the previous section do not specifically account for the toxicity of the components that comprise diesel PM.[23] Using the latest available diesel emissions inventory data, UCS estimated the statewide lifetime cancer risk from exposure to outdoor ambient concentrations of diesel PM. The lifetime cancer risk estimates are based on exposure to a specific diesel PM concentration over 70 years.

For the estimated outdoor concentration of diesel PM in 2005, we estimate there will be 519 excess cancer cases per million individuals, or about 19,000 cancer cases for California's estimated population of 37 million people (Table 3-6). By 2020, without implementation of the diesel risk reduction plan, this risk will only fall to 215 excess cancers per million. With aggressive implementation of the Diesel Risk Reduction Plan, toxic risk from diesel PM could be reduced 85 percent over year 2000 levels by 2020, to 85 excess cancers per million.

Table 3-6. Statewide 70-Year Lifetime Cancer Risk Estimates[a]

Year	Business as Usual[b]			Diesel Risk Reduction Plan[c]		
	Outdoor Population-Weighted Diesel PM Concentration (μg/m^3)	70-Year Cancer Risk (excess cancers per million)	Estimated Cancer Cases in CA from 70-Year Exposure	Outdoor Population-Weighted Diesel PM Concentration (μg/m^3)	70-Year Cancer Risk (excess cancers per million)	Estimated Cancer Cases in CA from 70-Year Exposure
2005	1.73	519	19,457	1.73	519	19,457
2010	1.33	399	16,074	0.47	141	5,674
2015	0.96	287	12,267	0.38	113	4,816
2020	0.72	215	9,857	0.28	85	3,875

NOTES:
a. Cancer case estimates are based on population projections from California Department of Finance (CDOF, 2001).
b. Our projections of the health impacts of diesel pollution in 2020 do not account for emission reductions that may be achieved through retrofit regulations recently adopted (but not yet finalized) by California. Since these rulemakings were not final as of May 2004, we did not have sufficient information to evaluate their emissions inventory impacts.
c. Emissions inventory estimates for the diesel risk reduction scenario in 2010 are based on a 75 percent reduction in PM emissions over year 2000 levels; 2020 estimates are based on an 85 percent reduction from year 2000 estimates.
SOURCE: Based on CARB (2000c) calculations with updated concentration estimates calculated by UCS.

[23] Causes of premature death were not specified in the original epidemiological study and may have included some deaths related to lung cancer.

Evaluating the Moyer Program

Current success

In 2004, projects funded through the Moyer Program will reduce about 6,000 tons of NOx, or one percent of statewide diesel NOx emissions.[24] Cumulatively, 58,000 tons of NOx and more than 3,000 tons of PM will be eliminated by 2012 from projects funded from 1999 through 2004.[25]

The resulting health benefits of the Moyer Program are impressive. Emission reductions from the current funding are expected to prevent between 240 and 340 premature deaths, about 250 incidences of chronic bronchitis, and at least 160 asthma-related hospital visits from 1999 through 2012 (Table 3-7).

These reduced incidences of illness and death translate to more than $2 billion in benefits, at a cost of less than $200 million. For every dollar spent on the Moyer Program, California has received benefits worth $9 to $16.[26]

The wide range of health benefits and benefit-to-cost ratios presented for the current Moyer Program is a result of agricultural (ag) pump PM emission reductions. The lower estimate assumes that reduction of PM emitted from ag pumps results in no associated health benefits. This would be the case if no people lived or worked close to the pumps. The upper estimate assumes that health benefits from ag pump PM reductions are equivalent to reducing PM from the average diesel source in the state. Ag pump PM emission reductions will likely result in some health benefits to agricultural workers and residents who live nearby. Therefore, the best estimate lies somewhere between the lower and upper bounds. Not enough information is available on the location of ag pumps or the populations affected by these emissions to arrive at a more precise estimate.

Other important factors affecting the health benefit estimates of the Moyer Program include assumptions about the average life of the projects funded and the conversion of NOx emissions to particulates. More information about the cost-benefit analysis of the Moyer program can be found in the accompanying Technical Support Document.

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[24] Estimated diesel NOx emissions for 2004 are 585,462 tons/year and estimated reductions attributed to the Moyer Program are 6,459 tons/year based on UCS calculations and information obtained from CARB.

[25] Actual funding is based on the state fiscal year, which is July 1 through June 30, so first-year funding actually occurred from July 1998 through June 1999. The average lifetime of projects funded through the Moyer Program has historically been about nine years. For example, emission reductions from a project funded in 2004 will occur from 2004 through 2012. The guidelines for the Moyer Program (CARB, 2000) provide details on required project life and information on calculating emission reductions.

[26] Per EPA guidance, costs and benefits accruing in different years are discounted using a three percent and seven percent discount rate.

Table 3-7. Costs and Benefits of the Current Moyer Program (1999-2004)

Health Endpoint	Cumulative Incidences Avoided (1999-2012)[a,b]	Monetary Benefits (millions of 2004$)[c]	
		High	Low
Premature Mortality	239 - 346	$2,505	$1,567
Chronic Bronchitis	215 - 312	$128	$85
Hospital Admissions			
COPD	48 - 69	$0.9	$0.6
Cardiovascular Illness	140 - 203	$4.0	$2.7
Asthma Admissions	25 - 36	$0.3	$0.2
Asthma ER Visits	139 - 201	$0.1	$0.04
Unquantified Health and Welfare Impacts	Not evaluated	$U	$U
Total Benefits		$2,638 + U	$1,656 + U
Total Costs		$164	$183
Benefit-to-Cost Ratio		**16**	**9**

NOTES:
a. Emission reductions and health benefits from funding in 2004 will obtain benefits through 2012 due to an average nine-year project life currently achieved through the program.
b. Benefits are presented as a range. The lower end of the range assumes that no health benefits are gained from reducing PM from ag pumps. The upper end of the range assumes that ag pump PM reductions achieve the average health benefits of reducing diesel PM.
c. In performing cost-benefit analyses, the EPA uses both a three percent and seven percent social discount rate for benefits and costs that occur in the future. A three percent discount rate and the higher health incidences estimate is used for the "High" estimates. A seven percent discount rate and the lower health incidences estimate is used for the "Low" estimates. This results in the largest range of cost-benefit ratios.

Future Moyer Program

UCS evaluated the potential benefits of a 10-year, $100 million per year funding level for the Moyer Program.[27] The results show that the Moyer Program will continue to be highly cost-effective, avoiding hundreds of premature deaths and maintaining a 10 to 1 benefit-to-cost ratio.

Reductions of more than 150,000 tons of NOx and nearly 10,000 tons of PM between 2005 and 2020 could be achieved. By 2010, an annual reduction of 20,000 tons of NOx, the equivalent of more than four percent of projected

[27] In 2000, the Moyer Program Advisory Board suggested that the Moyer Program could successfully utilize funding at $100 million per year for at least 10 years (CARB, 2000a). We assume that projects funded through the Moyer Program will become increasingly more expensive over time, with the cheaper projects funded in the first few years of the program. Also, the average project life is shortened to seven years, from an average of nine years currently achieved through the program. Choosing a seven-year project life lowers the expected emission reductions for each project funded, resulting in a higher cost per ton of reductions. The cost-benefit analysis assumes the Moyer Program starts receiving $100 million per year from 2005 to 2014. Emission reductions and health benefits accrue through the year 2020 due to the final year of funding in 2014 and the seven-year average project life.

statewide diesel NOx emissions, and 1,000 tons of PM, equivalent to five percent of statewide diesel PM emissions, could be achieved.[28]

The resulting health benefits of Moyer Program funding at this level include more than 1,200 avoided premature deaths and 1,100 avoided cases of chronic bronchitis, and the reduction of more than 800 asthma-related hospital visits (Table 3-8). Even with the projected higher costs of future emission reductions, benefits still outweigh costs by about 10 to 1. For less than $800 million in costs, the program would result in benefits valued between $5.5 billion and $8 billion (in discounted 2004 dollars). To put these figures into perspective, the resulting cost to each Californian would be about two cents for each premature death avoided.[29]

Table 3-8. Costs and Benefits of the Future Moyer Program (2005-2014)

Health Endpoint	Cumulative Incidences Avoided (2005-2020)[a,b]	Monetary Benefits (millions of 2004$)[c]	
		3% discount	7% discount
Premature Mortality	1223	$7,627	$5,359
Chronic Bronchitis	1101	$389	$291
Hospital Admissions			
COPD	244	$2.6	$2.0
Cardiovascular Illness	718	$11.5	$8.6
Asthma Admissions	129	$0.7	$0.6
Asthma ER Visits	710	$0.2	$0.13
Unquantified Health and Welfare Impacts	Not evaluated	$U	$U
Total Benefits		$8,031 + U	$5,661 + U
Total Costs		$753	$625
Benefit-Cost-Ratio		**11**	**9**

NOTES:
a. Emission reductions and health benefits from funding in 2014 will obtain benefits through 2020 due to an assumed average seven-year project life.
b. Ag pumps are excluded from future emission reduction projections because the majority of ag pumps in the state have been funded. Thus, we do not neglect a fraction of the PM savings from the future Moyer Program, as was the case for the current program's lower bound estimates.
c. In performing cost-benefit analyses, the EPA uses both a three percent and seven percent social discount rate for benefits and costs that occur in the future.

[28] Projected NOx emissions for 2010 are 465,586 tons/year and expected Moyer Program annual reductions are 20,239 tons/year. Projected PM emissions for 2010 are 19,275 and expected Moyer Program annual reductions are 1,079 tons/year.

[29] Assuming year 2004 population and a $1 billion program over 10 years, adjusted for inflation, the cost to each Californian is less than two cents per premature death avoided.

Conclusions

Without an aggressive effort to clean up existing diesel vehicles, public health impacts will mount while new engine standards slowly start to take effect. Between 2004 and 2020, tens of thousands of Californians may die prematurely as a result of diesel exhaust emissions. Thousands of individuals may take trips to the hospital for severe cardiovascular and respiratory ailments.

The health impacts of diesel are alarming, but cleaning up diesel pollution is not only possible, it also makes economic sense. Both regulations and incentive programs can cost-effectively reduce diesel emissions and improve air quality and public health. Our results indicate that the health benefits of reducing diesel pollution through the Moyer Program far outweigh the economic costs of cleaning up diesel engines, and will continue to do so for at least the next 10 years.

CHAPTER 4

AIR BASIN-SPECIFIC RESULTS

UCS analyzed the health impacts of diesel pollution exposure in the air basins with the largest amounts of diesel emission sources. For each air basin, the annual health incidences from exposure to diesel exhaust were estimated for 2004. The sources of diesel emissions were determined for each air basin and the health benefits from continued funding of the Moyer Program were evaluated.

Roughly 90 percent of California's population, and 80 percent of California's diesel pollution sources, are found in five of California's 15 air basins (Table 4-1). These air basins are the Sacramento Valley, San Diego, San Joaquin Valley, San Francisco Bay Area, and South Coast Air Basins. Air basins are generally defined by the topography of the region, being delineated both by mountain ranges and county boundaries.

Table 4-1. Diesel Sources by Air Basin (as a Percent of Air Basin Total)

Diesel Sources	Sacramento Valley		San Diego		San Francisco Bay Area		San Joaquin Valley		South Coast	
	NOx	PM_{10}	NOx	PM_{10}	NOx	PM_{10}	NOx	PM_{10}	NOx	PM_{10}
Highway Trucks and Buses	43%	22%	49%	26%	49%	25%	43%	21%	52%	24%
Trains	10%	6%	1%	1%	3%	2%	5%	3%	5%	3%
Ships	0%	0%	11%	17%	6%	11%	0%	0%	10%	17%
Ag Equipment	16%	24%	4%	6%	2%	3%	21%	30%	2%	2%
Stationary	10%	13%	6%	5%	7%	7%	14%	23%	5%	7%
Construction & Mining	15%	23%	22%	34%	27%	40%	11%	14%	20%	33%
Other Heavy Equipment	7%	12%	6%	12%	6%	13%	5%	8%	6%	14%
Total (tons/year)	**50,341**	**2,256**	**37,683**	**1,726**	**97,805**	**4,351**	**94,634**	**4,431**	**187,362**	**7,545**

NOTE: All of the diesel sources are mobile with the exception of stationary diesel engines, which are used primarily for the generation of electrical power. Other off-road diesel equipment includes lawn and garden equipment, airport ground support vehicles, and mobile refrigeration units.
SOURCE: CARB 2003 Air Quality Almanac.

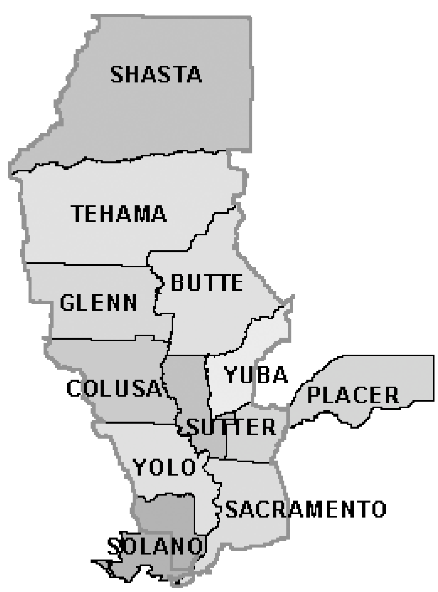
Our analysis assumes that the health impacts of PM and NOx emissions occur in the air basin where the pollutants are released. However, in some cases, air pollution can travel hundreds of miles, affecting multiple air basins. Generally, this is more of a concern with NOx emissions than PM emissions. Understanding how air pollution travels between air basins is an ongoing area of research, but modeling sufficient to account for interbasin pollution transport was beyond the scope of this analysis.

Each air basin comprises one or more air districts that are responsible for administering state Moyer Program funds. In addition to selecting projects eligible for Moyer funds, air districts must also provide their own matching funds. Currently, air districts are required to provide up to $25 million annually for projects that reduce PM and NOx and to cover administrative expenses. The following air basin-specific results do not include emission reductions achieved through air district matching funds and therefore may underestimate Moyer Program benefits.

Sacramento Valley

The Sacramento Valley Air Basin consists of 11 California counties and covers the northern Central Valley from Sacramento north to Mt. Shasta (Figure 4-1). This area accounts for approximately nine percent of California's diesel PM and NOx emissions and contains six percent of the population.[30]

Figure 4-1. Sacramento Valley Air Basin



SOURCE: California Air Resources Board.

[30] Based on 2005 inventory projections and Department of Finance interim 2005 population projections.

Health impacts

More than 170 premature deaths and more than 150 cases of chronic bronchitis are expected from 2004 diesel pollution exposure in the Sacramento Valley. Hospital admissions resulting from COPD and cardiovascular disease are expected to exceed 130 while asthma-related ER visits and hospital admissions are expected to top 100 (Table 4-2).

The societal cost associated with these health incidences is $1.2 billion.

Table 4-2. 2004 Health Impacts from Diesel Pollution: Sacramento Valley

Health Endpoint	Estimated Mean No. of Incidences	Estimated Health Costs (millions of 2004$)
Premature Mortality	172	$1,176
Chronic Bronchitis	154	$64
Hospital Admissions		
COPD	38	$0.51
Cardiovascular Illness	112	$2.23
Asthma Admissions	18	$0.13
Asthma ER Visits	100	$0.03
Unquantified Health and Welfare Impacts	U	$U
Total Estimated Cost		**$1,243 + U**

NOTE: Some health and welfare impacts not quantified include smog-related respiratory problems, increasing asthma rates, damage to agricultural crops and forest habitats, reduced visibility, and others. COPD is chronic obstructive pulmonary disease.
SOURCE: Based on UCS estimates of 2004 annual health incidences and EPA health endpoint valuations.

Diesel sources

There are numerous categories of engines responsible for diesel emissions in the Sacramento Valley. The largest source of diesel PM is from off-road and construction equipment, making up 35 percent of the total. Highway trucks and buses make up the largest portion of diesel NOx emissions at 42 percent. Agricultural equipment comprises a larger share of diesel emissions than in most other air basins due to the large amount of agriculture in the air basin. Agricultural equipment accounts for 24 percent of PM emissions and 16 percent of NOx emissions (Table 4-1, p.32).

Moyer success

The current Moyer Program will eliminate nearly 600 tons of PM and 10,000 tons of NOx from the air in the Sacramento Valley by 2012.[31]

[31] Estimated from funding available through 2004.

Continued funding of the Moyer Program would significantly add to these benefits. With a $100 million per year program for the next 10 years, the resulting emission reductions in the Sacramento Valley would be substantial. About 30,000 tons of NOx and more than 1,500 tons of PM would be eliminated by 2020. We estimate that these reductions would prevent 152 premature deaths and 137 cases of chronic bronchitis. More than 130 hospital admissions for respiratory, asthma, and cardiovascular illnesses could also be avoided (Table 4-3).

The economic savings associated with these benefits totals between $700 million and $1 billion.

Table 4-3. Future Benefits from the Moyer Program: Sacramento Valley

Health Endpoint	Cumulative No. of Incidences Avoided (2005-2020)[a,b]	Monetary Benefits (millions of 2004$)[c]	
		3% discount	7% discount
Premature Mortality	152	$946	$664
Chronic Bronchitis	137	$48	$36
Hospital Admissions			
COPD	30	$0.33	$0.24
Cardiovascular Illness	89	$1.43	$1.07
Asthma Admissions	16	$0.09	$0.07
Asthma ER Visits	88	$0.02	$0.02
Unquantified Health and Welfare Impacts	Not evaluated	$U	$U
Total Benefits		**$996 + U**	**$701 + U**

NOTES:
a. Emission reductions and health benefits from funding in 2014 will obtain benefits through 2020 due to an assumed average seven-year project life.
b. Ag pumps are excluded from future emission reduction projections because the majority of ag pumps in the state have been funded. Thus, we do not neglect a fraction of the PM savings from the future Moyer Program, as was the case for the current program's lower bound estimates.
c. In performing cost-benefit analyses, the EPA uses both a three percent and seven percent social discount rate for benefits and costs that occur in the future.

San Diego

The San Diego Air Basin consists of the County of San Diego, which includes the coastal area of California from the Mexico border to Orange and Riverside Counties (Figure 4-2, p.36). This area accounts for approximately six percent of California's diesel PM and NOx emissions and contains eight percent of California's population.[32]

[32] Based on 2005 inventory projections and Department of Finance interim 2005 population projections.

Figure 4-2. San Diego Air Basin

SOURCE: California Air Resources Board.

Health impacts

More than 240 premature deaths and more than 200 cases of chronic bronchitis are expected from diesel pollution exposure in 2004. Hospital admissions resulting from COPD and cardiovascular disease are expected to approach 200, while asthma-related ER visits and hospital admissions are expected to top 150 (Table 4-4).

The associated societal cost associated with these health incidences is estimated at $1.7 billion.

Table 4-4. 2004 Health Impacts from Diesel Pollution: San Diego

Health Endpoint	Estimated Mean No. of Incidences	Estimated Health Costs (millions of 2004$)
Premature Mortality	244	$1,669
Chronic Bronchitis	219	$91
Hospital Admissions		
COPD	54	$0.72
Cardiovascular Illness	159	$3.16
Asthma Admissions	26	$0.18
Asthma ER Visits	142	$0.04
Unquantified Health and Welfare Impacts	U	$U
Total Estimated Cost		**$1,764 + U**

NOTE: Some health and welfare impacts not quantified include smog-related respiratory problems, increasing asthma rates, damage to agricultural crops and forest habitats, reduced visibility, and others. COPD is chronic obstructive pulmonary disease.
SOURCE: Based on UCS estimates of 2004 annual health incidences and EPA health endpoint valuations.

Diesel sources

The largest source of diesel PM is off-road and construction equipment, accounting for 45 percent of total PM emissions. Highway trucks and buses make up the largest portion of diesel NOx emissions at about 50 percent. As a result of San Diego's coastal location and lax federal emission standards for large marine vessels, ships contribute a larger share of PM and NOx emissions than in some other areas of the state. Ships account for 17 percent of PM emissions in San Diego and 11 percent of NOx emissions (Table 4-1, p.32).

Moyer success

The current Moyer Program will eliminate approximately 120 tons of PM and 1,700 tons of NOx from the air in the Sacramento Valley by 2012.[33] Continued funding of the Moyer Program would significantly add to these benefits. About 5,500 tons of NOx and more than 400 tons of PM would be eliminated by 2020. These reductions would prevent 56 premature deaths and 51 cases of chronic bronchitis. The number of hospital admissions for respiratory, asthma, and cardiovascular illnesses would be reduced by 50 (Table 4-5).

The economic savings associated with these benefits totals between $260 million and $370 million.

Table 4-5. Future Benefits from the Moyer Program: San Diego

Health Endpoint	Cumulative No. of Incidences Avoided (2005-2020)[a,b]	Monetary Benefits (millions of 2004$)[c]	
		3% discount	7% discount
Premature Mortality	56	$352	$247
Chronic Bronchitis	51	$18	$13
Hospital Admissions			
COPD	11	$0.12	$0.09
Cardiovascular Illness	33	$0.53	$0.40
Asthma Admissions	6	$0.03	$0.03
Asthma ER Visits	33	$0.01	$0.01
Unquantified Health and Welfare Impacts	Not evaluated	$U	$U
Total Benefits		**$371 + U**	**$261 + U**

NOTES:
a. Emission reductions and health benefits from funding in 2014 will obtain benefits through 2020 due to an assumed average seven-year project life.
b. Ag pumps are excluded from future emission reduction projections because the majority of ag pumps in the state have been funded. Thus, we do not neglect a fraction of the PM savings from the future Moyer Program, as was the case for the current program's lower bound estimates.
c. In performing cost-benefit analyses, the EPA uses both a three percent and seven percent social discount rate for benefits and costs that occur in the future.

[33] Estimated from funding available through 2004.

San Francisco Bay Area

The San Francisco Bay Area Air Basin consists of numerous counties around San Francisco Bay (Figure 4-3). This area accounts for approximately 17 percent of California's diesel PM and NOx emissions and 20 percent of California's population.[34]

Figure 4-3. San Francisco Bay Area Air Basin

SOURCE: California Air Resources Board.

Health impacts

More than 500 premature deaths and more than 450 cases of chronic bronchitis are expected from diesel pollution exposure in 2004. Hospital admissions resulting from COPD and cardiovascular disease are expected to top 400. Asthma-related ER visits and hospital admissions are expected to reach 350 (Table 4-6).

The societal cost associated with these health incidences is $3.7 billion.

[34] Based on 2005 inventory projections and Department of Finance interim 2005 population projections.

Table 4-6. 2004 Health Impacts from Diesel Pollution: San Francisco Bay Area

Health Endpoint	Estimated Mean No. of Incidences	Estimated Health Costs (millions of 2004$)
Premature Mortality	509	$3,491
Chronic Bronchitis	459	$190
Hospital Admissions		
COPD	102	$1.36
Cardiovascular Illness	299	$5.96
Asthma Admissions	54	$0.38
Asthma ER Visits	296	$0.09
Unquantified Health and Welfare Impacts	U	$U
Total Estimated Cost		**$3,688 + U**

NOTE: Some health and welfare impacts not quantified include smog-related respiratory problems, increasing asthma rates, damage to agricultural crops and forest habitats, reduced visibility, and others. COPD is chronic obstructive pulmonary disease.
SOURCE: Based on UCS estimates of 2004 annual health incidences and EPA health endpoint valuations.

Diesel sources

Off-road and construction equipment account for 53 percent of total PM emissions in the Bay Area—more than double the next largest source. These off-road sources also account for 33 percent of diesel NOx emissions, while highway trucks and buses are responsible for about 50 percent. As in other coastal areas with port operations, ships and marine vessels contribute to the PM and NOx emissions in the air basin. More than 10 percent of PM emissions in the Bay Area are associated with maritime activity (Table 4-1, p.32).

Moyer success

The current Moyer Program will eliminate approximately 400 tons of PM and 6,700 tons of NOx from the air in the Bay Area by 2012.[35] Continued funding of the Moyer Program would significantly add to these benefits. With a $100 million per year program for the next 10 years, the resulting emission reductions in the San Francisco Bay Area Air Basin would be substantial. About 77,000 tons of NOx and more than 1,300 tons of PM would be eliminated by 2020. These reductions could prevent 153 premature deaths and 137 cases of chronic bronchitis. The number of hospital admissions for respiratory, asthma, and cardiovascular illnesses could be reduced by more than 130 (Table 4-7, p.40).

[35] Estimated from funding available through 2004.

The economic savings associated with these benefits totals between $700 million and $1 billion.

Table 4-7. Future Benefits from the Moyer Program: San Francisco Bay Area

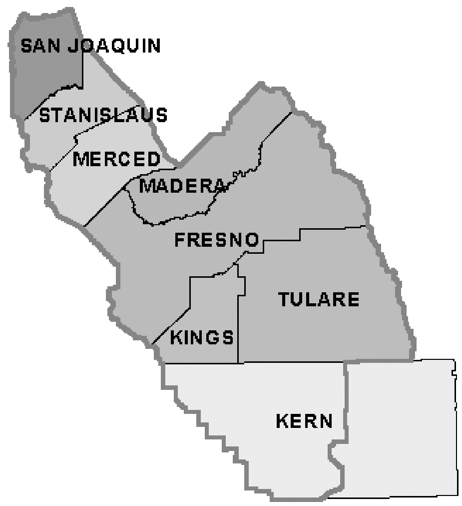
Health Endpoint	Cumulative No. of Incidences Avoided (2005-2020)[a,b]	Monetary Benefits (millions of 2004$)[c]	
		3% discount	7% discount
Premature Mortality	153	$953	$671
Chronic Bronchitis	137	$49	$36
Hospital Admissions			
COPD	30	$0.33	$0.25
Cardiovascular Illness	90	$1.44	$1.08
Asthma Admissions	16	$0.09	$0.07
Asthma ER Visits	89	$0.02	$0.02
Unquantified Health and Welfare Impacts	Not evaluated	$U	$U
Total Benefits		**$1,003 + U**	**$709 + U**

NOTES:
a. Emission reductions and health benefits from funding in 2014 will obtain benefits through 2020 due to an assumed average seven-year project life.
b. Ag pumps are excluded from future emission reduction projections because the majority of ag pumps in the state have been funded. Thus, we do not neglect a fraction of the PM savings from the future Moyer Program, as was the case for the current program's lower bound estimates.
c. In performing cost-benefit analyses, the EPA uses both a three percent and seven percent social discount rate for benefits and costs that occur in the future.

San Joaquin Valley

The San Joaquin Valley Air Basin consists of the southern counties of the Central Valley (Figure 4-4). More than 10 percent of California's population lives in this air basin, which accounts for nearly 17 percent of California's diesel PM and NOx emissions.[36]

Figure 4-4. San Joaquin Valley Air Basin



SOURCE: California Air Resources Board.

Health impacts

More than 250 premature deaths and more than 230 cases of chronic bronchitis are expected from diesel pollution exposure in 2004. Hospital admissions resulting from COPD and cardiovascular disease are expected to top 200. Asthma-related ER visits and hospital admissions are expected to reach 170 (Table 4-8, p.42).

The associated societal cost associated with these health incidences is $1.9 billion.

[36] Based on 2005 inventory projections and Department of Finance interim 2005 population projections.

Table 4-8. 2004 Health Impacts from Diesel Pollution: San Joaquin Valley

Health Endpoint	Estimated Mean No. of Incidences	Estimated Societal Cost (millions of 2004$)
Premature Mortality	260	$1,783
Chronic Bronchitis	234	$97
Hospital Admissions		
COPD	52	$0.70
Cardiovascular Illness	153	$3.04
Asthma Admissions	27	$0.20
Asthma ER Visits	151	$0.05
Unquantified Health and Welfare Impacts	U	$U
Total Estimated Cost		**$1,884 + U**

NOTE: Some health and welfare impacts not quantified include smog-related respiratory problems, increasing asthma rates, damage to agricultural crops and forest habitats, reduced visibility, and others. COPD is chronic obstructive pulmonary disease.
SOURCE: Based on UCS estimates of 2004 annual health incidences and EPA health endpoint valuations.

Diesel sources

Agriculture-related diesel equipment makes up the largest portion of diesel PM emissions in the San Joaquin Valley. This is a result of the large amount of agriculture that occurs in the Central Valley as well as the slow adoption of more stringent off-road engine standards.[37] Stationary sources, construction and heavy equipment, and highway trucks comprise an equal share of most of the remaining PM emissions. Stationary PM emissions are a larger percent of the total in the San Joaquin Valley than in other air basins because of the large number of stationary irrigation pumps used for agriculture. NOx emissions are predominantly from highway trucks and buses, accounting for more than 40 percent of NOx emissions, and agricultural equipment is the second largest at 21 percent (Table 4-1, p.32).

Moyer success

The Moyer Program is successfully reducing diesel pollution in the San Joaquin Valley Air Basin. Approximately 1,000 tons of PM and 16,000 tons of NOx will be eliminated from the air in the San Joaquin Valley by 2012 through projects funded by the Moyer Program to date.[38] These emission

[37] California is prohibited from regulating engine standards on agricultural equipment, and off-road emission standards have lagged on-road standards.

[38] Estimated from funding available through 2004.

reductions are among the largest of all the air basins participating in the Moyer Program.[39]

Continued funding of the Moyer Program would significantly add to these benefits. With a $100 million per year program for the next 10 years, the resulting emission reductions in the San Joaquin Valley Air Basin would be substantial. About 53,000 tons of NOx and more than 3,200 tons of PM would be eliminated by 2020. These reductions would prevent 208 premature deaths and 187 cases of chronic bronchitis. The number of hospital admissions for respiratory, asthma, and cardiovascular illnesses would be reduced by more than 180 (Table 4-9).

The economic savings associated with these benefits totals between $960 million and $1.4 billion.

Table 4-9. Future Benefits from the Moyer Program: San Joaquin Valley

Health Endpoint	Cumulative No. of Incidences Avoided (2005-2020)[a,b]	Monetary Benefits (millions of 2004$)[c]	
		3% discount	7% discount
Premature Mortality	208	$1,294	$907
Chronic Bronchitis	187	$66	$49
Hospital Admissions			
COPD	42	$0.45	$0.33
Cardiovascular Illness	122	$1.95	$1.46
Asthma Admissions	22	$0.13	$0.09
Asthma ER Visits	121	$0.03	$0.02
Unquantified Health and Welfare Impacts	Not evaluated	$U	$U
Total Benefits		**$1,363 + U**	**$958 + U**

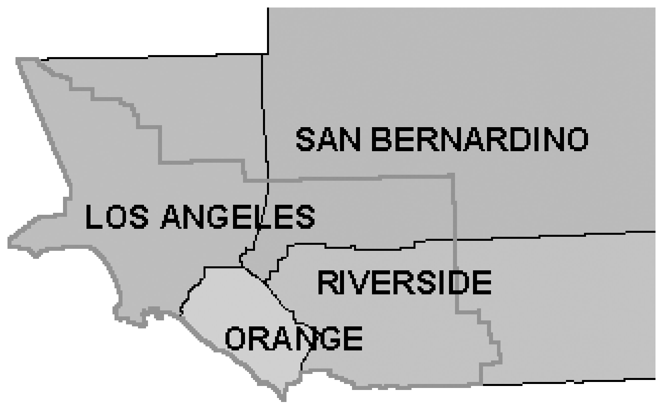
NOTES:
a. Emission reductions and health benefits from funding in 2014 will obtain benefits through 2020 due to an assumed average seven-year project life.
b. Ag pumps are excluded from future emission reduction projections because the majority of ag pumps in the state have been funded. Thus, we do not neglect a fraction of the PM savings from the future Moyer Program, as was the case for the current program's lower bound estimates.
c. In performing cost-benefit analyses, the EPA uses both a three percent and seven percent social discount rate for benefits and costs that occur in the future.

[39] The South Coast Air Basin and the San Joaquin Valley Air Basin have each achieved approximately 30 percent of the Moyer Program emission reductions.

South Coast

The South Coast Air Basin consists of Orange County and parts of Los Angeles, San Bernardino, and Riverside Counties (Figure 4-5). The South Coast Air Basin is home to more than 45 percent of Californians and accounts for more than 30 percent of the state's PM and NOx diesel emissions.[40] Consequently, the South Coast makes up the largest portion of diesel emissions in the state and suffers the highest number of diesel-related health incidences.

Figure 4-5. South Coast Air Basin



SOURCE: California Air Resources Board.

Health impacts

The health consequences of these emissions are staggering. More than 1,400 premature deaths and about 1,275 cases of chronic bronchitis are expected from diesel pollution exposure in 2004. Hospital admissions resulting from COPD and cardiovascular disease are expected to exceed 1,000. Asthma-related ER visits and hospital admissions are expected to reach 950 (Table 4-10).

The associated societal cost associated with these health incidences is overwhelming, estimated at $10 billion.

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[40] Based on 2005 inventory projections and Department of Finance interim 2005 population projections.

Table 4-10. 2004 Health Impacts from Diesel Pollution: South Coast

Health Endpoint	Estimated Mean No. of Incidences	Estimated Societal Cost (millions of 2004$)
Premature Mortality	1,415	$9,693
Chronic Bronchitis	1,273	$526
Hospital Admissions		
COPD	282	$3.78
Cardiovascular Illness	831	$16.54
Asthma Admissions	149	$1.07
Asthma ER Visits	822	$0.25
Unquantified Health and Welfare Impacts	U	$U
Total Estimated Cost		**$10,241 + U**

NOTE: Some health and welfare impacts not quantified include smog-related respiratory problems, increasing asthma rates, damage to agricultural crops and forest habitats, reduced visibility, and others. COPD is chronic obstructive pulmonary disease.
SOURCE: Based on UCS estimates of 2004 annual health incidences and EPA health endpoint valuations.

Diesel sources

Construction and heavy equipment account for approximately 50 percent of diesel NOx and PM emissions in the South Coast Air Basin, while highway vehicles make up about 25 percent. Ships are a significant source of diesel emissions as well, accounting for 17 percent and 10 percent of PM and NOx, respectively. This is a result of the large amount of port operations in the air basin and the high emissions from port vessels (Table 4-1, p.32).

Moyer success

The Moyer Program has been an integral part of South Coast efforts to reduce diesel emissions. Approximately 750 tons of PM and 19,000 tons of NOx will be eliminated from the air in the South Coast Air Basin by 2012 through projects funded by the Moyer Program to date.[41] The reduction in number of health incidences is the largest of all the air basins.

Continued funding of the Moyer Program would significantly add to these benefits. With a $100 million per year program for the next 10 years, the resulting emission reductions in the South Coast Air Basin would be substantial. About 62,000 tons of NOx and more than 2,400 tons of PM would be eliminated by 2020. These reductions would prevent nearly 500 premature deaths and 450 cases of chronic bronchitis. The number of

[41] Estimated from funding available through 2004.

hospital admissions for respiratory, asthma, and cardiovascular illnesses would be reduced by more than 400 (Table 4-11).

The economic savings associated with these benefits totals between $2.3 billion and $3.3 billion.

Table 4-11. Future Benefits from the Moyer Program: South Coast

Health Endpoint	Cumulative No. of Incidences Avoided (2005-2020)[a,b]	Monetary Benefits (millions of 2004$)[c]	
		3% discount	7% discount
Premature Mortality	498	$3,109	$2,186
Chronic Bronchitis	448	$158	$119
Hospital Admissions			
COPD	99	$1.07	$0.81
Cardiovascular Illness	293	$4.69	$3.52
Asthma Admissions	52	$0.30	$0.23
Asthma ER Visits	289	$0.07	$0.05
Unquantified Health and Welfare Impacts	Not evaluated	$U	$U
Total Benefits		**$3,273 + U**	**$2,309 + U**

NOTES:
a. Emission reductions and health benefits from funding in 2014 will obtain benefits through 2020 due to an assumed average seven-year project life.
b. Ag pumps are excluded from future emission reduction projections because the majority of ag pumps in the state have been funded. Thus, we do not neglect a fraction of the PM savings from the future Moyer Program, as was the case for the current program's lower bound estimates.
c. In performing cost-benefit analyses, the EPA uses both a three percent and seven percent social discount rate for benefits and costs that occur in the future.

CHAPTER 5

CLEANER AIR IN CALIFORNIA

Concerted actions to reduce harmful diesel pollution can save lives and prevent serious illnesses—all at a low cost. The relatively modest costs of pollution cleanup can pay off in reduced hospitalizations, fewer asthma cases, and avoided premature deaths.

The growing body of evidence that diesel pollution poses serious health risks for Californians spurred CARB to adopt the Diesel Risk Reduction Plan, which sets an impressive target of reducing diesel soot by 75 percent in 2010 and 85 percent in 2020 (from year 2000 levels). But California will not achieve these targets without aggressive state and federal action over the next 10 to 15 years.

California action

Strengthen incentive programs

California needs to strengthen its diesel cleanup incentive programs: the Moyer Program and the Lower Emission School Bus Program. The critical near-term need is to provide sufficient and sustainable funding for these successful programs. With a $100 million per year investment for the next 10 years, we estimate that the Moyer Program can provide health benefits that outweigh costs by at least 10 to 1. And with the oldest, dirtiest school buses in the nation, California must prioritize children's health and safety by investing in new, cleaner school buses and pollution controls. These successful programs should not have to fight every year for funding and face continued budget cuts.

State funds for the Moyer Program should target particulates as well as NOx. Currently, state Moyer funds can be used only for programs that reduce NOx, and any reductions of soot are an ancillary benefit. While CARB has set a goal of reducing diesel particulates by 25 percent on a per-project average, state law prohibits spending dollars on projects that only reduce PM. But the overwhelming evidence that diesel particulates are harmful to human health highlight the importance of including PM in the Moyer Program.

The Moyer Program should target emission reductions that achieve the greatest health benefits. The current cost-effectiveness criteria, which is based on project cost per ton of pollutant reduced, does not evaluate public health impacts. Other criteria, such as whether the project reduces pollution in heavily populated areas, affects sensitive communities, or provides worker protection, should be included in project evaluation.

Develop regulations for existing fleet cleanup

In the last three years, CARB has developed diesel cleanup regulations for a variety of fleets. These regulations begin to address the emissions from existing diesel engines, but CARB is far from achieving the goals of the Diesel Risk Reduction Plan. CARB's regulatory actions and new federal highway tailpipe standards reduce diesel PM about 30 percent by 2010 from year 2000 levels, while the goal of the plan is a 75 percent reduction. High-polluting sectors such as ports, ships, trains, construction equipment, agricultural engines, and highway trucks and buses still need to be cleaned up. CARB should continue to develop regulations that reduce PM and NOx from existing engines.

Coordinate regionally

California cannot tackle diesel cleanup alone; the state must work in concert with other western states, the federal government, Canada, and Mexico to address interstate and international diesel pollution problems. Reducing pollution from trains, ships, and long-haul trucks requires regional and, in some cases, global solutions. Specifically, California needs to work with other governments to promote the widespread availability of low-sulfur diesel, harmonize new engine emission standards, and develop coordinated cleanup approaches.

Federal action

Stricter emission standards

The EPA also needs to turn its attention to stronger standards for locomotives and commercial marine vessels. Trains and ships currently contribute about 12 percent of all emissions from mobile sources, and their share will grow as other highway and off-highway engines become cleaner. These engines should be held to the same standards facing highway and off-highway engines.

Expand voluntary programs

While states such as California and Texas[42] have developed incentive programs to clean up diesel vehicles, the EPA has only a fledgling voluntary retrofit program that is poorly funded. Congress should designate a federal diesel cleanup program modeled after the successful state programs, and provide sufficient funding to support extensive cleanup across the country. In addition, the EPA needs to work closely with California to develop streamlined criteria for verifying pollution control technologies. Finally, the EPA's Clean School Bus USA program should support goals that improve

[42] The Texas Emission Reduction Program (TERP) was passed by the state legislature in 2003. The primary purpose of the TERP is to provide voluntary incentives to reduce NOx in the Dallas/Fort Worth and Houston/Galveston areas. The program provides eligible projects with grants that help offset the incremental cost of reducing NOx from high-emitting mobile diesel sources.

children's health and safety by replacing buses built before 1991 with cleaner, safer vehicles.

National retrofit regulations

The EPA should follow California's lead and develop national retrofit regulations that require the existing fleet to reduce pollution. The agency's recent rulemakings for stronger emission standards for diesel engines have found that the benefits of reducing diesel pollution far outweigh the costs. Given the body of evidence that diesel is harmful to human health and the low compliance costs of retrofit regulations, the EPA should be mandating that certain fleets reduce their emissions. In addition, the EPA is uniquely positioned to develop regulations for reducing pollution from engines that travel across state lines.

Monitor real-world performance

Finally, the EPA must ensure that new engines held to stricter emission standards remain clean over their full lifetime. If historical experience is a guide, real-world emissions from new aftertreatment technologies may spike in the first few years, and systems that require more maintenance, such as active particulate filters and selective catalytic reduction, may have higher rates of degradation and failure. In-use testing, onboard diagnostics, and enforcement are necessary to translate stronger standards into public health gains.

Research and development

More research needs to be conducted on in-use vehicle emissions by particle size, number, and toxicity. Our current federal tailpipe standards only regulate particle mass, but there is increasing evidence that particle size, number, and toxicity are important factors for public health. Fine particles, for example, may contain more of the reactive substances linked to health impacts than coarse particles and penetrate more deeply into the respiratory tract, where they can cause greater damage. Some European countries, including Sweden and Germany, are exploring the possibility of adding particle number to tailpipe regulations.

One of the biggest challenges of monitoring real-world pollution is that today's primary evaluation method is an expensive chassis dynamometer test. There should be incentives and research on developing an in-use inspection and maintenance test to provide an affordable and widely accessible alternative to chassis dynamometer testing.

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Sick of Soot

Reducing the Health Impacts of Diesel Pollution in California

Californians continue to suffer from the adverse health effects of diesel pollution despite state and federal efforts to reduce these harmful emissions. New regulations requiring cleaner diesel fuel and lower tailpipe emissions for new diesel engines will eventually take hold over the coming decades. But, Californians waiting for existing diesel engines to be replaced by cleaner engines will pay a high price.

This report's analysis highlights the impact of diesel pollution on public health in California today and its potential impact during the next two decades. Though state officials have adopted an aggressive plan to reduce the risks associated with existing diesel engines, the health costs of diesel pollution will continue to mount unless this plan is fully implemented. Timely investment in "clean diesel" incentive programs and mandatory use of cost-effective retrofit technology on existing diesel engines could save thousands of lives and billions of dollars over the next 15 years, while setting an important clean air precedent for the U.S. Environmental Protection Agency and other states to follow.

National Headquarters
Two Brattle Square
Cambridge, MA 02238-9105
Phone: (617) 547-5552
Fax: (617) 864-9405

West Coast Office
2397 Shattuck Ave., Ste. 203
Berkeley, CA 94704
Phone: (510) 843-1872
Fax: (510) 843-3785

Washington, DC Office
1707 H St. NW, Ste. 600
Washington, DC 20006-3962
Phone: (202) 223-6133
Fax: (202) 223-6162

Website www.ucsusa.org **Email** ucs@ucsusa.org

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