

Clean Cars in California:

Four Decades of Progress in the
Unfinished Battle to Clean Up Our Air



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November 2010

Acknowledgments

Environment California Research & Policy Center would like to thank Wendy James at the Better World Group and Roland Hwang at the Natural Resources Defense Council for their review and insightful comments on drafts of this report. Additional thanks to Tony Dutzik and Elizabeth Ridlington at Frontier Group for editorial assistance.

The generous financial support of the Energy Foundation and the Arntz Family Foundation made this report possible.

The opinions expressed in this report are those of the authors and do not necessarily reflect the views of our funders or those who provided review. Any factual errors are strictly the responsibility of the authors.

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Cover Photo: Chris Hudson Design

Layout: To the Point Publications, www.tothepointpublications.com

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Executive Summary

California's efforts to reduce air pollution from cars and trucks have made the state's air cleaner than it has been in decades – and Californians are healthier as a result. **Clean car standards have helped cut total automobile air pollution in California by more than 85 percent since 1975**, despite rapid growth in population and vehicle travel.

However, many Californians are still exposed to some of the worst air pollution in the United States – contributing to high asthma rates and shortened life spans. Passenger cars and trucks produce nearly 2 million pounds of health-threatening air pollution statewide every day.

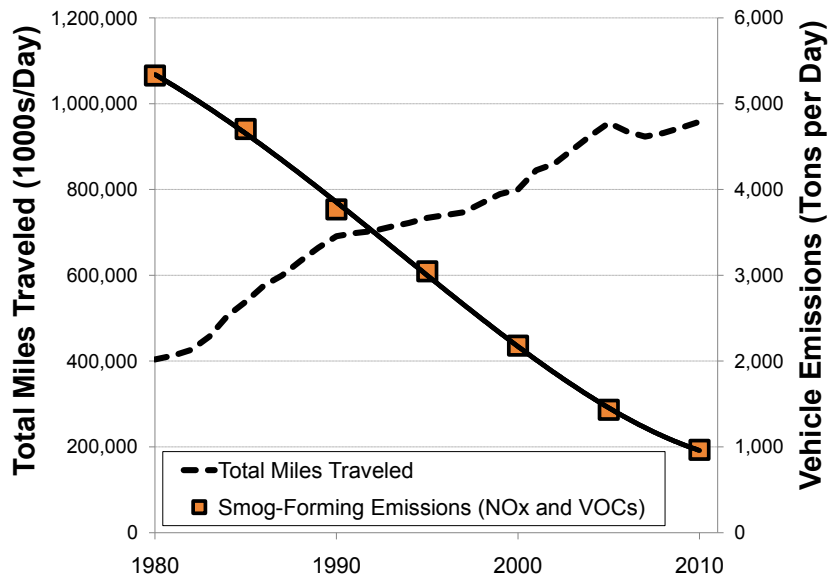
To continue progress, state officials should update California's vehicle emission standards and ensure that they remain strong and effective. Given the size of California's vehicle population, the state needs to make sure that new cars are as clean as possible – and to en-

courage auto manufacturers to rapidly commercialize vehicles that produce no pollution whatsoever.

Unhealthy air has been a life-or-death problem facing Californians for decades.

- During the summer of 1943, a cloud of smog cut visibility in the Los Angeles area to only three blocks. People exposed to the hazy, acrid cloud suffered from eye irritation, respiratory problems, nausea and vomiting. Eventually, scientists recognized that smog was caused by pollution from fossil fuel combustion and gases evaporating from fuels and solvents, reacting together in sunlight.
- As California's population grew and more cars were driven more miles each year, the state's smog problem

Figure ES-1: Even as Californians Drive More Miles Every Year, Overall Vehicle Emissions Have Declined



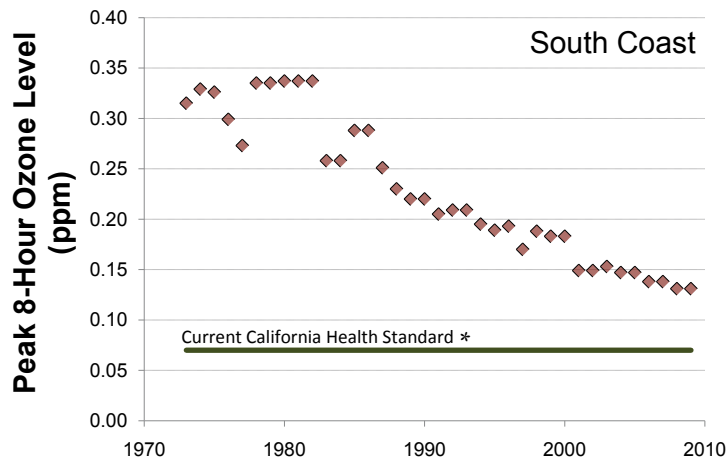
grew worse. In the 1970s and early 1980s, for example, peak smog levels in the Los Angeles area were routinely five times higher than the state’s current air quality standard. As state population grew, high smog levels expanded to other areas, including the Central Valley and the Inland Empire.

- Extreme smog levels caused serious harm to public health – including premature death, increased hospital admissions and emergency room visits, more asthma diagnoses and asthma attacks, and more frequent missed school and work days due to respiratory illness.

To protect public health, state officials required auto manufacturers to develop and install new technologies to control emissions from their vehicles.

- California created the world’s first tailpipe emission standards in 1966. State officials have regularly updated and strengthened the standards over the years, adding evaporative emission standards and requiring increased emission control system durability. In 1990, state officials added a requirement for automakers to develop and market advanced technologies, including “zero-emission vehicles” with superior emission control systems and even new kinds of fuels and engines.
- These standards forced automakers to innovate. In response to the requirements, automakers invented and refined the catalytic converter – now standard equipment on every gasoline-powered car in the United States and most in the world – and a variety of other enhanced emission control technologies. The standards

Figure ES-2: While Smog Levels in Los Angeles Have Declined, Pollution Still Reaches Unhealthy Levels



*Air quality violates the current California health standard when ozone levels exceed 0.07 ppm averaged over an 8-hour period. The federal health standard is 0.075 ppm ozone over an 8-hour period, although the U.S. EPA has proposed to strengthen the standard to the range of 0.06 to 0.07 ppm.

also spurred automakers to introduce super-clean gasoline-electric hybrid cars – such as the Toyota Prius.

California’s vehicle air pollution standards have been extremely effective. Today’s cars and trucks are much cleaner, and overall vehicle emissions have dramatically declined.

- A typical new car sold in California in the 1960s produced about one ton of smog-forming pollution for every 100,000 miles of driving. Today, under California’s Clean Car standards, a typical new car is more than 99 percent cleaner, producing about 10 pounds of smog-forming emissions driven over the same distance.
- Total annual emissions of smog-forming pollution from passenger

cars and trucks in California have dropped more than 85 percent since 1975, even as the number of miles driven in the state has more than doubled. (See Figure ES-1.)

- California’s Clean Car standards have cleaned up our air without crippling the economy or making cars too expensive. Automakers have tended to overestimate the cost of emission controls by a factor of two to 10.
- Investments in cleaner air have been worth it. According to the U.S. Environmental Protection Agency, the health benefits of clean air advances achieved since the 1970s exceed the cost of emissions controls by as much as 100 to 1.

Clean car standards have helped to reduce smog levels in major metropolitan areas, including Los Angeles, the San Francisco Bay Area, San Diego, and cities in the Central Valley – improving public health.

- Since 1980, peak smog levels¹ have dropped by 70 percent in the Los Angeles area (see Figure ES-2); 50 percent in the San Diego area and in the Sacramento Valley; 40 percent in the San Francisco Bay Area; and 33 percent in the San Joaquin Valley.
- Cleaner air prevents asthma attacks and cancers, reduces the burden of respiratory disease, and saves lives.

Despite the state’s tremendous progress, California still suffers from air that is unhealthy to breathe.

- California still has the worst smog pollution in the country. All 10 of

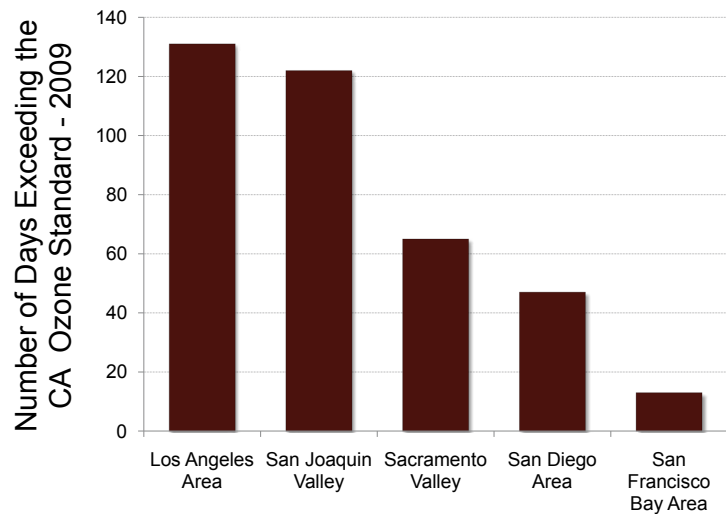
the most polluted counties nationwide are located in California. Smog levels still exceed state health-based standards for more than one-third of the year in the Los Angeles area and the San Joaquin Valley. (See Figure ES-3.)

- Passenger cars and trucks are still an important part of the problem. These vehicles emit nearly 2 million pounds of smog-forming pollution daily across the state – almost 20 percent of total smog-forming emissions.
- Scientists are also continually uncovering evidence that smog can harm our health at very low levels of exposure. New information may lead to tighter health standards, requiring greater emission reductions.

New technologies can make our cars even cleaner, and cleaner cars are a critical piece of reducing our exposure to unhealthy air. The California Air Resources Board should ensure that the next round of vehicle emission standards are strong and effective.

- Updated Clean Car standards should ensure that future cars are as clean as possible, requiring all internal combustion engines to meet “Super-Ultra Low Emission Vehicle” performance, with emission control systems durable up to 150,000 miles.
- The standards should also chart a course for widespread commercialization of next-generation cars with no tailpipes or emissions – such as electric cars.
- Finally, the standards should facilitate reducing vehicle global warming pollution in accordance with state goals to reduce overall emissions 80 percent below 2005 levels by 2050.

Figure ES-3: Most Californians Still Live in Areas with Unhealthy Air Quality



Introduction

Throughout the past 40 years, automakers have consistently opposed government efforts to reduce vehicle emissions and protect public health.

Faced with new requirements to control vehicle pollution in the 1970s, automakers – the same industry that heroically retooled its factories in a matter of months to supply airplanes, tanks and bullets for World War II – claimed that the technology wasn't there, that it was unaffordable, and that it would kill jobs and the economy.

In 1975, in the aftermath of the national crisis fueled by the Arab Oil Embargo, General Motors president Elliott Estes

“The industry has a dismal record of asserting what can't be done, and an admirable record of doing what it is forced to do.”

– *Washington Post* Columnist George Will, June 1977³

held greater vehicle efficiency hostage in a battle to roll back air pollution standards, saying, “We can't even begin to talk about mandatory fuel economy until we get some action on relaxing emission standards.”⁴

In September 1979, Chrysler chairman Lee Iacocca told Congress, “I don't think the country can afford this much clean air.”⁵

In 1995, the American Automobile Manufacturers Association surveyed Californians and found increasing consumer acceptance of electric vehicles as a way to clean up California's perpetually dirty air. Instead of working to build cars for that market, the automakers, in a confidential memo, announced their intention to “create a climate in which the state's mandate requiring automakers to produce a fixed percentage of electric vehicles ... can be repealed.”⁶

Fortunately, the automakers' fears were far overblown. While auto industry lobbyists and executives fought Clean Car standards, automotive scientists and engineers were hard at work developing solutions – and policy makers had the

wisdom to continue to push the industry toward innovation.

As this report reviews, new cars and trucks today are much, much cleaner than models built before 1970. Emission control systems in cars today perform at levels practically unimaginable even 20 years ago, much less 40 years ago.⁷ And California's air is measurably cleaner as a result.

California's leadership is at the heart of this progress. Over the decades, California has set the pace for the rest of the country with its pioneering vehicle emission standards and its zero emission vehicle program. These programs forced automakers to create and deploy the technology that has made reducing emissions feasible.⁸

Today, California faces the same challenge that we faced in the 1960s, 70s, 80s, 90s and 2000s. While our air is cleaner, most Californians are still exposed to unhealthy levels of air pollution. The burden of asthma, respiratory infections, hospital admissions and even deaths caused by air pollution remains unacceptably high.

And there are new challenges, as well. Unless we rapidly reduce emissions of global warming pollution, the state faces dramatic, disruptive impacts. According to U.S. Energy Secretary Steven Chu, "We're looking at a scenario where there's no more agriculture in California." Without rapid action to cut emissions, rising temperatures could fuel the loss of up to 90 percent of winter snowpack in the Sierra Nevada by the end of the century, leading to massive water shortages.⁹ Already, global warming pollution is acidifying

"Our experience in California shows that industry generally overstates its difficulties in meeting new standards and then makes a maximum effort to comply once the requirements are set. In 1973, when California adopted stringent 1975 standards, the industry warned of catastrophic fuel penalties and other problems. But when those 1975 cars came along, the first automobiles equipped with catalysts, we saw the greatest improvement in fuels and drivability ever achieved."

– Tom Quinn, Chairman of the California Air Resources Board, writing to President Jimmy Carter in February 1977²

California's coastal waters, driving heat waves and extreme weather events, and fueling drought.¹⁰

Cars and trucks remain a serious source of these problems. Continued progress will require stronger, updated emission standards – continuing California's long tradition of leadership.

Throughout the state's history, when faced with a choice between the promise of cleaner air or the short-term interests of the auto industry, citizens have opted for cleaner air. History shows that we've made the right choice every time.

California's Legacy of Dirty Air

Unhealthy air has been a fact of life in California for decades. Not long ago, unhealthy levels of smog persisted for half of every year in parts of California, occasionally reaching crisis levels. California's air pollution problem imposed heavy costs on public health and Californians' quality of life.

A Brief History of Air Pollution in California

"If they'd lower the taxes and get rid of the smog and clean up the traffic mess, I really believe I'd settle here until the next earthquake."

– Groucho Marx on 1950s Los Angeles¹¹

Mid-20th century comedians often cracked jokes about California's legendary smog problem. But to Californians, air

pollution was no laughing matter. Dangerous levels of smog were a near-daily occurrence in parts of California, and concentrations of smog in the air would occasionally spike to crisis levels.

As California considers how to address its air pollution problems for the future, it is worth recalling exactly how bad California's air was just a few decades ago.

Birthplace of Smog

California is uniquely sensitive to air pollution. Atmospheric inversions tend to trap rising pollution in a dirty brown layer above valleys – in particular, around the state's South Coast and the San Joaquin Valley. Infrequent rainfall aggravates the situation, allowing pollution to remain in the air for extended periods. And intense summer heat and sunlight cooks the toxic mixture, creating smog.



Smog levels in the 1970s and 1980s in Los Angeles were routinely five times higher than today's health standard for air quality. The noxious haze is clearly visible in this photo, taken during the filming of the helicopter chase scene in the movie Blue Thunder in December 1981.

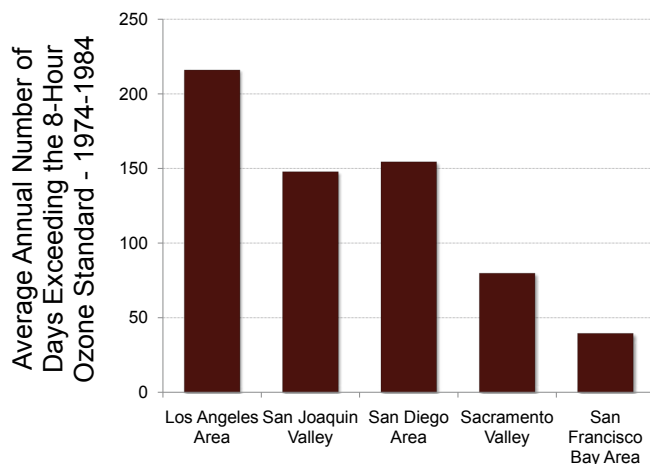
California's first recognized bout with smog came in the 1940s. During the summer of 1943, a cloud of smog cut visibility in the Los Angeles area to only three blocks. People exposed to the hazy, acrid cloud suffered from eye irritation, respiratory problems, nausea and vomiting.¹²

Within a decade, scientists – led by Cal Tech researcher Arie Haagen-Smit – began to recognize that smog was caused by man-made pollution. Burning fossil fuels – such as petroleum or coal – creates oxides of nitrogen (NOx). At the same time, volatile organic gases (VOCs) evaporate into the air from gasoline and from chemical solvents used in a variety of products such as cleaners or paints. When these two types of pollution mix in the presence of sunlight, they form

ozone – a powerfully reactive gas that is a principal component of California's smog problem. A natural layer of ozone exists high in the atmosphere, but when pollutants create ozone near the ground, it becomes a threat to public health.

During the 1950s and 1960s, the state's air pollution problems continued. In 1965, the Los Angeles area posted a maximum ozone concentration of 0.58 parts per million – nearly five times as high as the initial health based standard that would be adopted in 1971.¹³ In the summer of 1971, Los Angeles and Orange County experienced 17 consecutive smog alert days. The number of patients visiting doctors' offices doubled and people with respiratory problems were advised to leave the city.¹⁴

Figure 1: Unhealthy Levels of Smog Plagued the Air Across Much Of California in the 1970s and 1980s²³



In October 1980, a heat inversion in the air above the city trapped heavy smog within 800 feet of sea level for two weeks.¹⁵ Visibility plummeted, the air was thick and hazy, and the sun set in a red glow. Officials at Los Angeles International Airport closed runways because the thick smog reduced visibility to unsafe levels.¹⁶

During this episode, ozone levels were so high that a medical supply center in Los Angeles was inundated with calls from residents asking to buy or rent oxygen as relief from the constant smog. The state issued dozens of health alerts, public schools canceled physical education classes, and people with respiratory problems – such as asthma, bronchitis, and emphysema – were forced to stay inside and minimize strenuous activity so they would be able to breathe.¹⁷ At Hawthorne Community Hospital, the number of patients seeking medical help for smog-related complaints tripled.¹⁸

Throughout the 1970s and 1980s, the mountains were an infrequent sight for residents of Los Angeles. Acrid, polluted air and low visibility plagued most days

in the spring, summer and fall. Smog reached unhealthy levels on more than half of the days in a typical year.¹⁹ Peak smog levels in the Los Angeles area were routinely five times higher than the state’s current air quality standard.²⁰

But smog wasn’t just a Los Angeles problem. In August 1985, unhealthy smog levels worried officials managing the San Diego Half Marathon. Dr. Tom Mosher, medical director for the race, told the *Los Angeles Times*, “An athlete’s ability is significantly reduced during heavy smog days, especially if that runner suffers from any respiratory problems. I suspect that some runners may voluntarily drop out of the race all together.”²¹ Ozone levels in San Diego exceeded the state’s current health standard on more than 40 percent of the days in a typical year in San Diego during the 1970s and 1980s. The problem reached a similar level of severity in the San Joaquin Valley.²² Sacramento and the San Francisco Bay Area also had serious air quality problems, though not quite as bad as Southern California. (See Figure 1.)

Smog Harms Public Health

Citizens were well aware that smog was a nuisance as soon as it first appeared in Los Angeles in 1943. After initially causing citizens to think that they were under attack by the Japanese, yellow-brown clouds of pollution “sent cursing citizens, coughing, and crying, running for the sanctuary of air-conditioned buildings.”²⁴ The *Los Angeles Times* reported that “everywhere the smog went that day, it left a group of irate citizens [...]. Public complaints reverberated in the press.”²⁵

At a November 1949 football game at U.C. Berkeley, thousands of fans “experienced intense eye irritation.” A state committee investigating the incident found that “the cause of this particular eye irritation was in some way directly related to

automobile exhaust,” from the thousands of fans driving to the stadium – a situation with strong similarity to the smog problem in Southern California.²⁶

By the 1960s, fully 75 percent of the population of Los Angeles, when polled, reported that they were “bothered” by air pollution either at home or at work.²⁷

At the same time, scientists were accumulating evidence that automobile emissions and smog were not just a nuisance – but a serious threat to public health. Scientists found that during bouts of high ozone levels, people suffered more frequent coughing, eye and chest discomfort, and headaches. High school cross country runners ran slower. School children’s lungs didn’t work as well. College students were more likely to come down with upper respiratory infections.²⁸

California’s prized agriculture industry suffered as well. Reporting on the problem in 1986, the *Los Angeles Times* wrote:²⁹

Last year, smog cost the American public \$2.3 billion in lost crop yield. In Southern California, the annual damage is extensive. Lettuce, endive and spinach no longer can be grown commercially in Los Angeles County. Few orchids can tolerate the air south of Oxnard. In Riverside, once the home of the navel orange, only 2,000 acres of citrus groves remain, and commercial production of alfalfa and turnips is marginal. Smog no longer stops at the Tehachapi Mountains. Last year in Kern County, 20 percent – or \$61 million worth – of the grape crop was lost, and an acre of land that used to yield three bales of cotton produced only two and a half because of smog generated locally or blown south down the Central Valley from the San Francisco Bay area.

Today, We Know That Smog Is Deadly

Today, armed with more than 50 years of scientific evidence, we know much more about the deadly effects of smog. Repeated exposure to ozone can cause permanent lung damage and can even kill.³⁰ The California Environmental Protection Agency estimated that residents of Southern California in the 1990s were paying \$9 billion a year in health costs because of dirty air.³¹

Ozone quickly reacts with airway tissues and produces inflammation similar to a sunburn on the inside of the lungs. This inflammation makes lung tissues less elastic, more sensitive to allergens, and less able to ward off infections.³² Minor exposure to ozone can cause coughing, wheezing, and throat irritation. Constant exposure to ozone over time permanently damages lung tissues, decreases the ability to breathe normally, and exacerbates or even causes chronic diseases like asthma.³³ Children, adults who are active outdoors, and people with existing respiratory system ailments suffer most from ozone’s effects.

On days with elevated levels of ozone pollution:

- Hospitals admit increased numbers of patients for respiratory and cardiovascular disease.³⁴ Scientists have estimated that typical summertime smog pollution is responsible for up to half of all respiratory hospital admissions on bad air days.³⁵
- More people visit hospital emergency rooms for asthma, pneumonia and upper respiratory infections.³⁶
- Children and adults suffer more asthma attacks, increased respiratory difficulty, and reduced lung function.³⁷
- More adults miss work and more children miss school due to illness.³⁸

Beyond Smog: Other Air Pollutants

Smog is California's most high profile air pollution issue. But it isn't the only one. California has also faced other forms of air pollution that threaten our health.

- **Carbon monoxide** is a product of the incomplete combustion of fuel in automobile engines and other combustion sources. It interferes with the delivery of oxygen from the lungs to the body, causing headaches and dizziness – and it can be deadly at higher levels of exposure. More than 90 percent of monitoring sites in the United States in 1971, including many in California, recorded pollution levels that were in violation of carbon monoxide standards – but effective emissions controls have greatly reduced the severity of this problem today.³⁹
- **Particulate matter**, or soot, consists of extremely small and practically invisible particles in the air that result from fuel burning – especially in diesel engines. Particles can contain hundreds of toxic chemicals, some of which cause cancer, irritate lung tissues, or cause changes in the function of the heart that increase the risk of heart attacks.⁴⁰ Particulate pollution can cause irreversible damage to children, interfering with the growth and development of the lungs.⁴¹ Particulate pollution is also deadly, killing upwards of 9,000 Californians every year.⁴² In fact, according to the largest study of the effects of particulates on mortality, breathing the air in major U.S. cities is about as dangerous as living or working with a smoker.⁴³ Much of California still violates health-based air quality standards for particulate matter.⁴⁴
- Cars and trucks directly emit dangerous **toxic air contaminants** near roadways. Fuel combustion produces pollutants like nitrogen oxides, small particles, benzene, formaldehyde, and 1,3-butadiene. In sufficient amounts, these pollutants irritate airways and lungs, cause asthma, worsen asthma symptoms, and cause leukemia and other types of cancers.⁴⁵ Exhaust from highways and major roads poses a serious health hazard for anyone who lives, works or goes to school in or near heavy traffic. Children directly exposed to traffic pollution develop respiratory problems, including cough, wheezing, runny nose, and asthma.⁴⁶ People living near highways or highly traveled roads face an increased risk of death from stroke, lung disease and heart disease.⁴⁷ Many people assume that being inside a car offers some protection from exhaust—but pollution levels can be up to 10 times higher than in the air outdoors, especially in congested traffic.⁴⁸
- **Global warming pollutants** – including carbon dioxide, produced by fuel combustion in automobiles – are rapidly changing America's climate.⁴⁹ The country is becoming hotter.⁵⁰ Sea level is rising.⁵¹ Rainstorms and hurricanes are becoming more intense.⁵² Landscapes are changing – from Western forests ravaged by drought, bark beetles and fires, to shifts in the timing of seasons and in the habitable ranges of plant and animal species across the country.⁵³ Should our emissions of global warming pollutants continue unchecked, America and the world face catastrophic consequences. Global average temperatures could increase by as much as 11.5° F by the year 2100 (depending on the pace of the emissions increase).⁵⁴ Sea level could rise by as much as 6.5 feet by the end of the century, causing extensive coastal flooding.⁵⁵ And America could experience extended periods of hot weather and drought, punctuated by heavy downpours, interfering with water supplies and agriculture and exacerbating smog pollution.⁵⁶ The more global warming pollution that humanity emits into the atmosphere, the greater the warming – and the damage – that will become unavoidable.

California's Response to Air Pollution: The Clean Cars Program

Once scientists in the 1950s discovered how smog was formed, state officials began formulating a plan of action to cut air pollution levels. In response to the fact that more than 50 percent of smog-forming pollution in the state came from California's millions of passenger cars and trucks, California created the world's first vehicle tailpipe emission standards.

Over the years, California has strengthened and updated its Clean Car standards – the package of regulations and incentives that reduce pollution from automobiles. The state has added new requirements for higher performance emission control systems, more durable technologies, and new vehicle designs. These standards have forced automakers to innovate, developing and deploying new technologies that are now commonplace on highways throughout California – and around the world.

Passenger Cars and Trucks – A Leading Source of Pollution

California's love affair with the automobile – beginning with the rapid expansion of the suburbs after World War II – set the stage for passenger cars and trucks to become a major source of air pollution in the state.

In 1980, California was home to 12 million vehicles, which were driven more than 400 million miles every day.⁵⁷ Passenger cars and trucks produced seven times more NOx pollution than all power plants statewide.⁵⁸

Overall, vehicles in 1980 were responsible for:⁵⁹

- More than half of smog-forming volatile organic pollutant emissions;
- 40 percent of statewide smog-forming NOx emissions;

- About 80 percent of carbon monoxide emissions; and
- About 15 percent of particulate emissions from mobile sources, with the remainder coming from heavy duty diesel trucks and equipment, trains, ships, and other large vehicles.

Curbing Vehicle Pollution with Clean Car Standards

Faced with clear evidence that automobile emissions were polluting California's skies and harming public health, state officials took action. In 1959, legislators passed a law authorizing the Department of Public Health to set caps on automobile emissions.⁶⁰ In 1961, California required installation of the first automobile emission control device in the country – the positive crankcase ventilation (PCV) system. In 1966, California was the first state to adopt tailpipe emission standards for specific pollutants. Three years later, the state issued the first set of pollutant-specific air quality standards.⁶¹

Photo: iStockPhoto.com



In 1980, vehicles were responsible for about half of California's emissions of smog-forming pollution.

California continued to tighten automobile emission standards throughout the 1970s. Unlike California's initial emission reduction efforts, which focused on requiring automakers to install emission control technologies that already existed, the state's efforts in the 1970s focused on "technology forcing" – that is, enacting limits on the amount of air pollution that vehicles could produce and challenging automakers to develop and implement technologies that would meet those standards.

California's emission reduction efforts soon fell into a predictable pattern: the state would adopt ambitious emission standards, which automakers often claimed would be difficult or expensive to meet, automobile company engineers would meet the standards anyway, usually at reasonable cost, then the federal government would adopt similar standards. Figure 2 shows how California's standards have consistently been mimicked several years later by the federal government.

In 1990, California's emission control efforts took a major leap forward with adoption of the Low-Emission Vehicle (LEV) program. The LEV program was different from previous standards for several reasons. First, the LEV program dramatically ratcheted down the amount of smog-forming pollution permitted from cars over time. Second, instead of having to install specific emission control equipment – as the earliest emission control regulations required – or meet a targeted emission level for all cars, the LEV program set ambitious targets for the average emissions of the vehicle fleet, and gave automakers the flexibility to meet the standard with a mix of relatively dirty and super-clean vehicles. Finally, the LEV program included the Zero-Emission Vehicle (ZEV) program, which required that automakers place for sale a certain percentage of vehicles

that produced no tailpipe emissions, particularly electric vehicles.

In 1998, California took a further step forward, adopting the LEV II program, which further reduced allowable levels of pollution from vehicle tailpipes and from evaporative emissions. Meanwhile, the state updated the ZEV program to create more flexibility for automakers, enabling ultra-clean gasoline powered vehicles – called partial zero-emission vehicles (PZEVs) – to qualify for credit under the program.

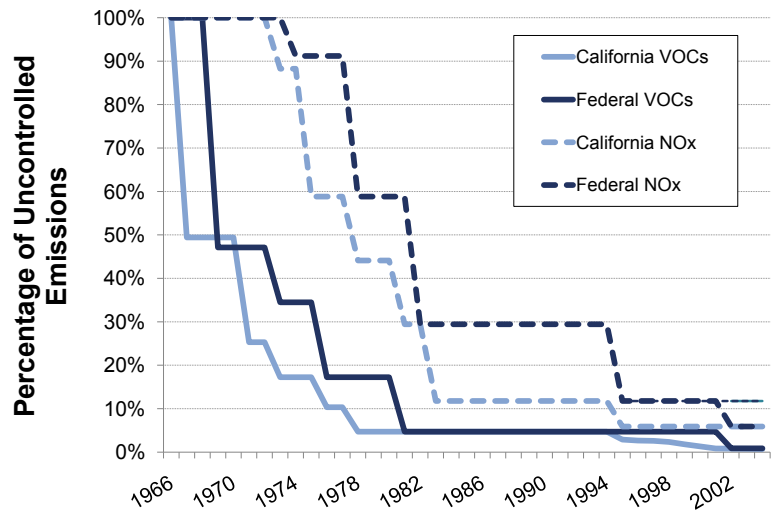
Then, in 2002, the California Legislature enacted a law (AB 1493) that required the California Air Resources Board to set standards to achieve the maximum cost-effective reductions in emissions of global warming pollutants from vehicles. The new rules, adopted by the Air Resources Board in 2004 and implemented with the 2009 model year, are expected to reduce global warming emissions from new California passenger vehicles by about 22 percent in 2012 and about 30 percent in 2016.⁶³ As with previous standards, California’s leadership paved the way for other states to take action, and ultimately led the federal government to adopt comparable standards in October 2010.

The Standards Have Forced Automakers to Innovate

At every step of the way, California’s automobile emission standards have forced automakers to innovate – driving improvements in technology that have made cars cleaner not just in California, but throughout the United States and even in much of the world. Among the technologies introduced into the marketplace by California emission standards are:

- **Catalytic converters** – Catalytic converters enabled major reductions in emissions of hydrocarbons

Figure 2 – Federal and California Tailpipe Emission Standards as Percentage Reduction from Uncontrolled Emissions⁶²



and carbon monoxide from vehicles when they were first required in California vehicles in 1975. Later, more advanced “three-way” converters came onto the market in the late 1970s that also addressed emissions of smog-forming nitrogen oxides.

- **Durable emission control systems** – Spurred by California’s regulations, automakers developed emission control systems that last, under warranty, for 100,000 and even 150,000 miles.
- **Control and diagnostic technologies** – Oxygen sensors, which were first included in Volvo cars sold in California in 1977, enable more precise control of the fuel-air mixture, which is critical to reducing the formation of pollutants during combustion. The emergence of on-board diagnostics provided an opportunity to further reduce pollution by warning the driver to seek maintenance when emission controls had failed.⁶⁴ Along with the addition of more durable emission systems,

these features helped drivers to get prompt service and extend the lifespan of their vehicles.

- **Evaporative emission controls** – California’s strict limits on evaporative emissions from cars have led to the development of improved fuel tanks, hoses and seals – as well as technologies to reduce emissions during refueling – that prevent volatile organic compounds from escaping from gasoline into the air.
- **Hybrid-electric vehicles** – While California’s original zero-emission vehicle requirement did not result in electric vehicles making immediate inroads into the state’s car market, it did spawn advances in battery technology that helped pave the way for the introduction of hybrid-electric vehicles in the late 1990s. Today, just over a decade later, hybrid-electric vehicles are common on California highways and are a leading strategy for reducing carbon dioxide pollution from automobiles.

The partial zero-emission vehicle – or PZEV – is a good example of how California’s standards have spawned innovation. The PZEV standard, established in 1998, is the world’s tightest emission standard for gasoline powered cars, requiring ultra-low tailpipe emissions, near-zero evaporative emissions,

and emission control systems capable of remaining effective for 150,000 miles (backed up by a warranty from the automakers).

Initially, vehicles meeting the PZEV standard were expected to cost an additional \$500 each. However, as PZEVs began to hit the road, automakers found ways to meet the standards less expensively, causing CARB to reduce its cost estimate for PZEVs to \$200 and finally \$100 per car.⁶⁵ Today, more than 1 million PZEVs have been delivered for sale in California and many more in states that have adopted California’s Clean Cars program for themselves.⁶⁶ What must have seemed impossible from the perspective of someone living just two decades ago – a gasoline car with emissions approaching zero – has now become routine.

California’s Clean Car standards have created no less than a revolution in automotive technology – a revolution that has benefited people around the world. The catalytic converter, for example, is estimated to have reduced air pollution in the United States by 10 billion tons since its introduction, and the device can now be found on 90 percent of all new vehicles worldwide, as well as many other types of fossil fuel-burning equipment.⁶⁷

But closer to home, those standards have also met their primary goal: making California’s air cleaner.

Figure 3: A New Car Today Is More than 99 Percent Cleaner than a 1960s-Era Car



California's Efforts Have Delivered Results: Cars Today Emit Less Pollution and Our Air Is Cleaner

California's vehicle air pollution standards have been extremely effective. Today's cars and trucks are much cleaner, and overall vehicle emissions have dramatically declined.

Cars Today Emit Less Pollution

California's Clean Car standards are reducing pollution. A typical new car sold in California in the 1960s produced about one ton of smog-forming pollution for every 100,000 miles of driving. Today, under California's Clean Car standards, a typical new car is more than 99 percent cleaner, producing about 10 pounds of smog-forming emissions driven over the same distance.⁶⁸ (See Figure 3.)

Overall Vehicle Emissions Are Down

Because cars are cleaner, overall emissions from passenger vehicles have dramatically declined – even as Californians buy more cars and drive more miles every year.

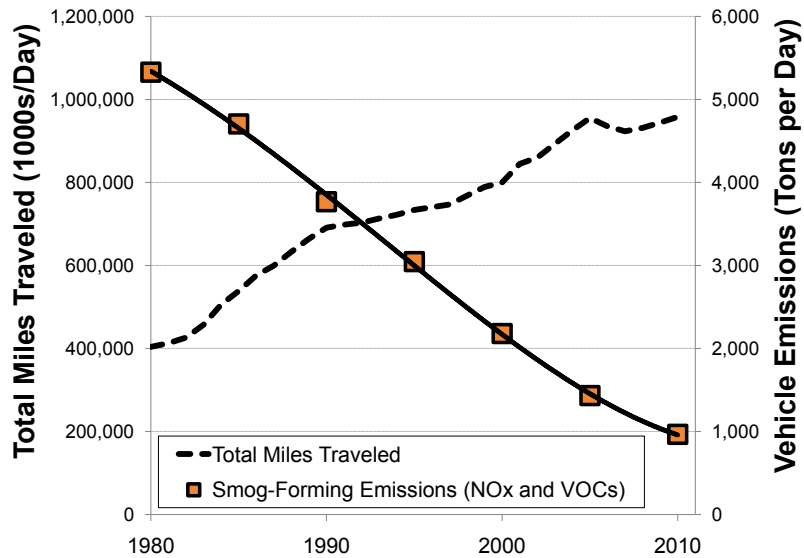
The amount of driving in California has more than doubled since 1980. In 1980, California had 11 million cars on the road, each driving an average of 33 miles per day. Today, California has 25 million cars on the road, each driving an average 35 miles per day.⁶⁹

Despite the trend toward more driving, total annual emissions of smog-forming pollution from passenger cars and trucks in California have dropped more than 85 percent since 1975. (See Figure 4.) NO_x emissions fell from 2,150 tons per day to 520 tons per day – a 76 percent drop.⁷⁰ Smog-forming VOC emissions similarly fell from 3,800 tons per day to 450 tons per day – a nearly 90 percent drop.⁷¹

Emissions per mile traveled have fallen even further. From 1980 to 2010, average per-mile NO_x emissions across the vehicle fleet fell 94 percent, and average per-mile VOC emissions fell 96 percent.⁷²

The standards have helped to reduce emissions of other key health-threatening pollutants as well:⁷³

Figure 4: Even as Californians Drive More Miles Every Year, Overall Vehicle Emissions Have Declined



- Carbon monoxide emissions are down 85 percent, and the whole state is in attainment of carbon monoxide standards; and
- Sulfur dioxide emissions are down more than 90 percent (thanks in large part to cleaner fuels, required by state law).

California's Air Is Cleaner

California's auto emission standards have helped to make the state's air cleaner.

Since 1980, peak 1-hour smog levels have dropped by 70 percent in the Los Angeles area, 50 percent in the San Diego area and in the Sacramento Valley, 40 percent in the San Francisco Bay Area; and 33 percent in the San Joaquin Valley.⁷⁴

Progress based on measuring peak smog levels over an 8-hour period has been slightly slower, but still substantial. Since 1980, peak 8-hour smog levels have

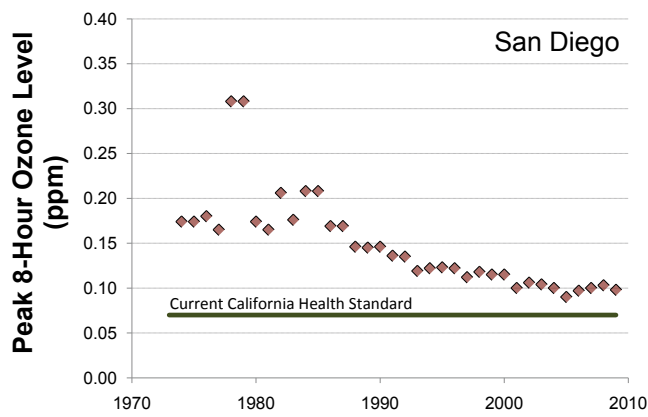
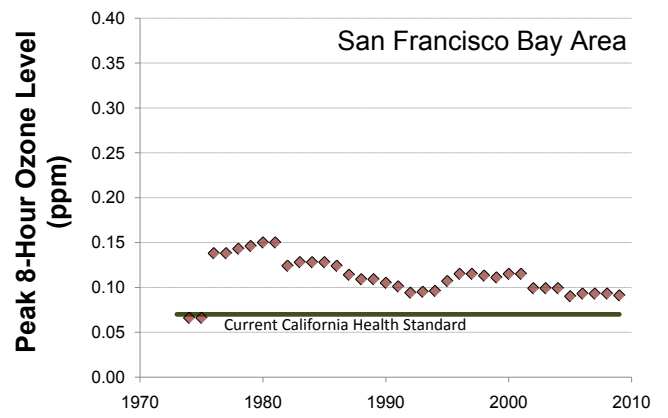
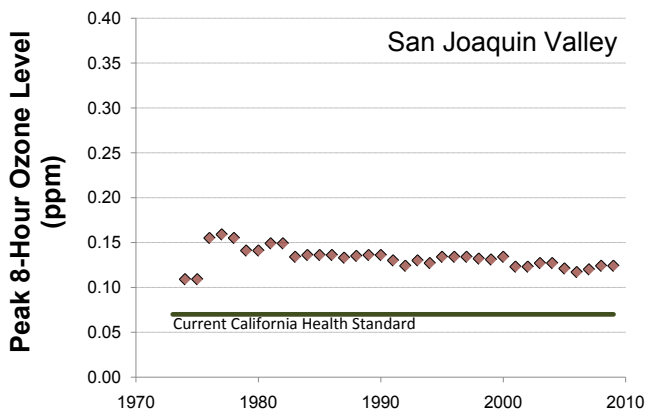
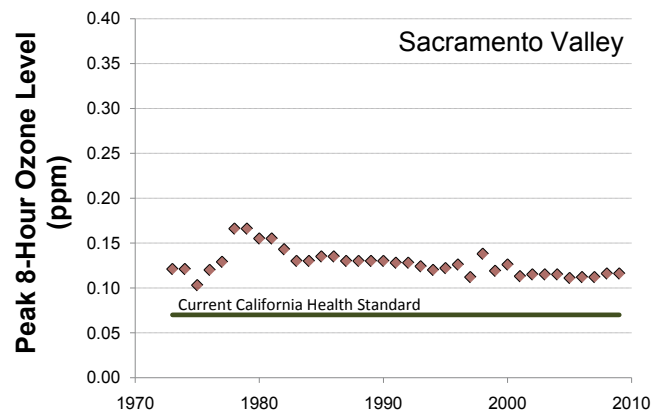
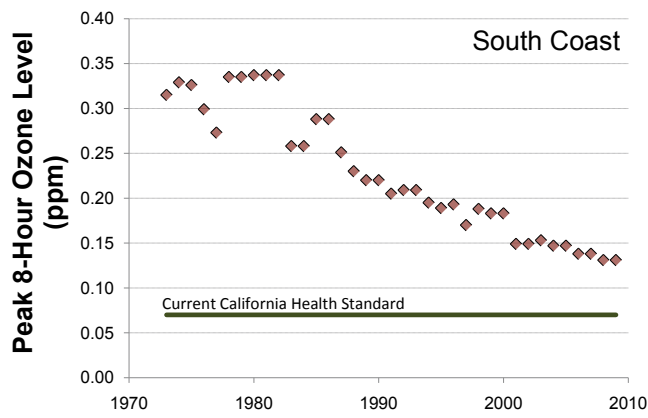
dropped 60 percent in the Los Angeles Area, about 40 percent in the San Diego and San Francisco Bay areas, about 25 percent in the Sacramento Valley, and just over 10 percent in the San Joaquin Valley. (See Figure 5.)

At the same time, the number of days with unhealthy air has fallen by on the order of 70 percent in San Diego and the San Francisco Bay Area; 35 to 40 percent in the Sacramento Valley and the Los Angeles area; and 17 percent in the San Joaquin Valley from 1980 to 2009.⁷⁶ (See Figure 6.)

But one doesn't need to look at statistics to understand the impact of California's falling smog levels. One just needs to ask someone who has experienced the change for themselves.

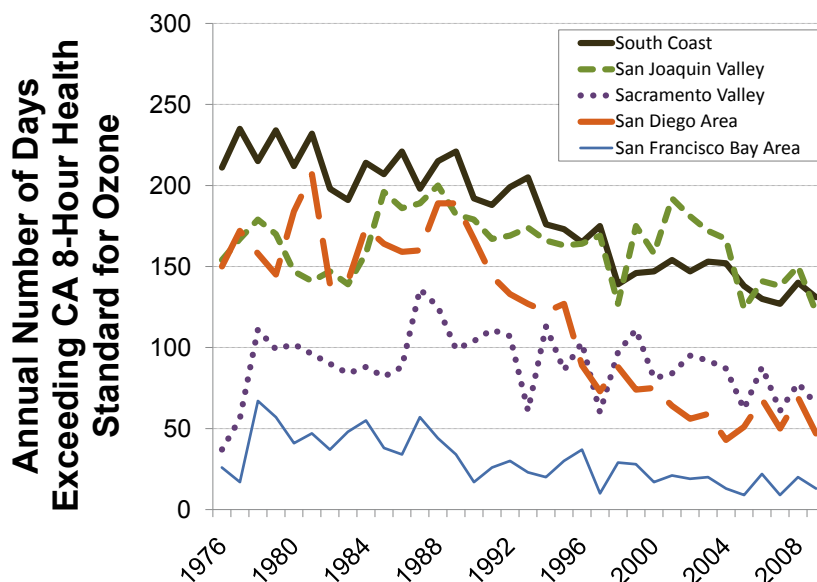
Speaking to the *New York Times* in 2005, Bob Wyman, a life-long resident of Los Angeles, noted that he no longer has to pant for air after running, unlike in his childhood. He told the paper, "Smog had a palpable impact on our daily lives.

Figure 5: Smog Levels in Los Angeles Have Declined 70 Percent Since 1980⁷⁵



Air quality violates the current California health standard when ozone levels exceeded 0.07 ppm averaged over an 8-hour period. The federal health standard is 0.075 ppm ozone over an 8-hour period, although the U.S. EPA has proposed to strengthen the standard to the range of 0.06 to 0.07 ppm.

Figure 6: The Number of Days with Unhealthy Air Is Declining⁷⁷



I'm 51. I'm not sure how conscious most people are of this."⁷⁸

In the 1970s, homeowners just five miles from the foot of the San Gabriel Mountains could not see the peaks through the dense summer smog.⁷⁹ Today, hikers on the Temescal Ridge Trail – 30 to 50 miles away – can often see the mountains.⁸⁰

Levels of other air pollutants have fallen in many parts of the state as well. For example:

- Since 1990, annual average particulate matter levels have declined more than 30 percent in the South Coast and in the Sacramento Valley, and more than 40 percent in the San Francisco Bay Area and in the San Joaquin Valley.
- Statewide, California is in attainment of federal and state health standards for carbon monoxide pollution. The South Coast area,

including Los Angeles, met the federal carbon monoxide health standard in December 2002 – a major achievement compared to pollution levels in the 1970s and 80s.⁸¹

Californians lead healthier, richer lives today because of the state's strong air pollution standards for cars. Moreover, cleaner air has come without the catastrophic economic impacts predicted time and time again by automakers.

The Benefits of Clean Cars Far Exceed Their Costs

California's cleaner cars – and our cleaner air – have come at a relatively low cost to auto buyers, belying the warnings of automakers that each new round of emission controls would make vehicles unaffordable. And the benefits

to our health have far exceeded the cost of achieving progress.

Since the 1970s, the auto industry has consistently overestimated the cost of complying with new pollution regulations by a factor of two to 10.⁸²

A 2004 study by researchers at UC Davis estimated that vehicles at that time cost buyers about \$1,000 more than a vehicle without emission controls (typical of vehicles of the mid-1960s). That \$1,000 increase was far less than the increase in prices resulting from other improvements to automobiles over that time. Interestingly, the difference in prices estimated in the early 2000s was roughly the same as it was in the early 1980s, despite the vast improvements in emission control technology over that period.⁸³ In other words, each successive round of emission

controls has been achieved *without* measurable increases in the cost of vehicles to buyers.

Efforts to control emissions have been unambiguously worth the cost. In 1999, the federal Environmental Protection Agency estimated that from 1970 to 1990, the nation's efforts to clean up air pollution produced \$6 trillion to \$50 trillion in benefits, while costing only \$500 billion to achieve – a benefit/cost ratio as high as 100 to one.⁸⁴ In 2010, the Small Business Majority and the Mainstreet Alliance commissioned an update, finding that the benefits of clean air regulations have exceeded costs on the order of 40 to 1, while creating more than 1.3 million jobs in pollution control industries between 1979 and 1991.⁸⁵

Despite Progress, California's Air Remains Unhealthy

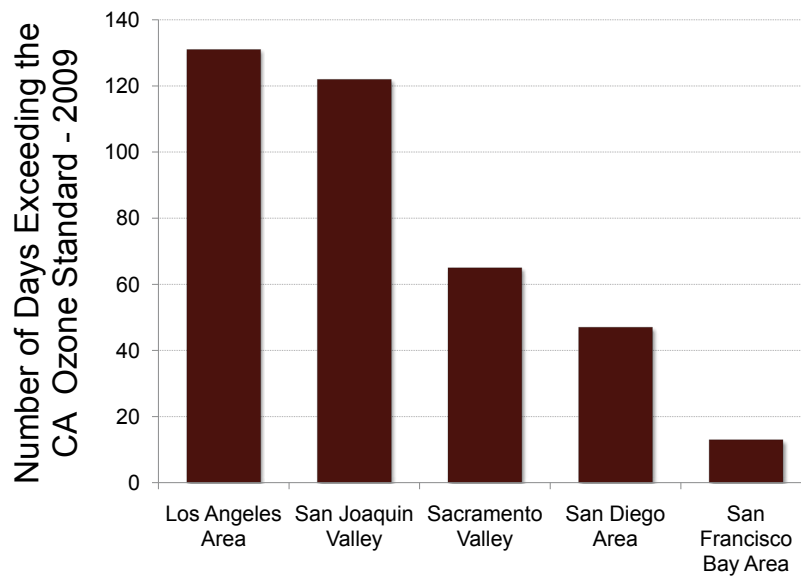
However, despite the significant progress made to date, most Californians still live in areas with unhealthy air quality. According to the American Lung Association, the 10 most polluted counties nationwide are located in California.⁸⁶

Most Californians Still Live in Areas with Dirty Air

Smog levels still exceed state health-based standards for more than one-third of the year in the Los Angeles area and the San Joaquin Valley. The Sacramento Valley and the San Diego area still have unhealthy air quality on about 50 days of the year. And even the San Francisco Bay Area violates health-based air quality standards on about 10 days every year. (See Figure 7.)

Moreover, scientists are continually revealing that smog has measureable impacts on public health – even at levels of exposure beneath California's current air quality standards. For example, in 2009, Dr. Michael Jerrett at the University of California Berkeley and his colleagues published research that concluded that every 10 part-per-billion increase in exposure to ozone increases the risk of death from respiratory causes by 4 percent.⁸⁸ In other words, residents of polluted California cities face more than triple the risk of dying from respiratory illness compared with people living in the least polluted cities.⁸⁹ In recognition of these facts, in January 2010 the U.S. Environmental Protection Agency proposed tightening the federal air quality standard for ozone.⁹⁰

Figure 7: Most Californians Still Live in Areas with Unhealthy Air Quality⁸⁷



Making California’s air clean will require reductions in pollution from all sources – not just cars. But it will also require automakers to use all of the clean car technologies available.

Vehicles Are Still a Significant Part of the Problem

Passenger cars and trucks are still an important part of the problem. These vehicles emit nearly 2 million pounds of smog-forming pollution daily across the state – almost 20 percent of statewide emissions.⁹¹

The California Air Resources Board has identified multiple technologies that automakers could deploy in the mid-2010s to achieve greater emissions control system performance and durability, including:⁹²

- Systems to improve emissions control performance when vehicles are started and while engines are running;
- Improved catalytic converter designs;
- New kinds of exhaust management systems; and
- Special paints on the front of cars designed to directly reduce pollutant concentrations in the air while the cars drive.

Finally, the California Air Resources Board has identified a series of technologies that increasingly point toward potential for zero-emission vehicles. In addition to reducing emissions of health-threatening pollution, these technologies will help California reduce global warming pollution from vehicles. (See “Global Warming – Another Air Pollution Challenge” on page 26.)

Global Warming – Another Air Pollution Challenge

Protecting California’s future from the most catastrophic impacts of global warming is another compelling reason to continue reducing pollution from our vehicles.

While state standards have effectively reduced health-threatening pollution from motor vehicles, global warming pollution remains inadequately controlled. Vehicles have been a growing source of global warming emissions since the 1970s – responsible for about a quarter of the state’s total emissions.⁹³ From 1990 to 2008, global warming emissions from passenger vehicles climbed 17 percent.⁹⁴

Controlling global warming pollution remains a major challenge for California’s future. Fortunately, many technologies are available now that could reduce global warming emissions from cars, including:⁹⁵

- More efficient drive systems, including better transmissions, turbocharged engines, and cylinder deactivation technology; and
- Better air conditioning systems, with higher efficiency, lower leak rates, and refrigerants that contribute less to global warming.

With a little development, automakers could also deploy:

- More advanced and efficient gasoline engine technology;
- More efficient hybrid and plug-in hybrid vehicle drive systems; and
- Lighter-weight vehicle components.

Finally, automakers could deploy fully electrified vehicles that could draw energy from zero-emission electricity sources – whether renewable electricity, or renewably-generated hydrogen – to drive vehicles that are truly emission-free.

To meet California’s commitment to reduce global warming pollution, these zero-emission vehicles should make up at least 80 percent of the vehicle fleet by 2050.

Policy Recommendations

To continue progress toward clean air, state officials should ensure that California builds on its legacy of leadership by adopting a new round of strong and effective vehicle emission standards.

Further progress can help the state to:⁶

- Continue to make progress in reducing smog pollution in our cities;
- Reduce exposure to traffic-related emissions – including toxic air pollutants such as formaldehyde and benzene, plus ultrafine particulate matter; and
- Do its part to prevent the most catastrophic impacts of global warming.

Given the size of California’s vehicle population, the state needs to make sure that new cars are as clean as possible – and

encourage auto manufacturers to rapidly commercialize vehicles that produce no pollution whatsoever. In addition to reducing air pollution, a shift towards zero emission vehicles can provide additional benefits, including promoting technological innovation in the auto industry and helping consumers save money on fuel.

Specifically, the California Air Resources Board should:

Update state Clean Car standards to ensure that future new cars are as clean as possible, requiring the average new vehicle to achieve “Super-Ultra Low Emission Vehicle” (SULEV) performance, with emission control systems durable up to 150,000 miles.

- The standards should require automakers to meet a fleet average performance equivalent to SULEV

Photo: Sandy Ridlington



A new round of strong and effective vehicle emission standards can reduce pollution in California's cities and promote continued technological innovation in the auto industry.

(defined as 0.02 grams of NO_x and 0.01 grams of VOCs per mile for light duty vehicles) by no later than the 2022 model year.

- The standards should include more stringent limits on ultrafine combustion particle emissions.
- The emission control systems should be under warranty for 15 years or 150,000 miles.

Chart a course for widespread commercialization of next-generation cars with no tailpipes or emissions – such as electric cars.

- The standards should ensure that next-generation cars powered by batteries or fuel-cells achieve commercial scale by 2025 at the latest. Zero emission vehicles should make up on the order of 20 percent of new vehicle sales by 2025, climbing to 100 percent by no later than 2050.⁹⁷ The standards should give a clear, unambiguous signal to automakers and help guide their investment in new technology.
- To support the commercialization of zero emission vehicles, the state should accelerate the installation of appropriate infrastructure, such as vehicle charging stations.

Reduce vehicle global warming pollution in accordance with state goals to reduce overall emissions 80 percent below 2005 levels by 2050.

- In addition to cleaning up unhealthy levels of smog and other health-threatening air pollution, the standards should guide the reduction of global warming pollution from California's vehicle fleet.

Other Actions to Reduce Vehicle Emissions

California can reduce air pollution from transportation through many tools in addition to stronger vehicle emission standards and measures to accelerate the introduction of new vehicle technologies. In particular, California should work to reduce the amount of vehicle travel through smart planning and the promotion of transportation alternatives, from cycling to bus lines to local trains and high speed rail. California should:

- **Promote alternatives to drive-alone work trips.** Commutes to work account for more than a quarter of all vehicle travel nationally and are a prime reason for congestion on our roadways. States such as Oregon and Washington have shown that creative programs designed to reduce drive-alone trips to work can reduce vehicle travel and ease congestion and California should follow their lead.
- **Build high-speed rail.** Air travel is a large source of global warming and other pollution in California. Yet, for many long-distance trips within the state, high-speed rail could provide service that is just as quick and convenient as air or car travel, but with far less pollution. The state should provide adequate funding for the voter-approved high-speed rail line linking Sacramento, the Bay Area, Los Angeles and San Diego.
- **Expand the state's transit systems.** There are many portions of the state – even in the largest metropolitan areas – where residents do not have easy access to high-quality transit service. California should invest in transit to ensure that most residents of the state's largest metropolitan areas have access to good transit service by 2030.
- **Stop sprawl and expand transit-oriented development.** The state should work with local governments to ensure that our growing population is housed not in sprawl-style developments that demand more driving, but rather in compact developments where residents can walk, bike or take transit to get most of the places they need to go.

Notes

1. Measured as the highest concentration of ground-level ozone recorded in any one-hour period during the noted year and the previous two years, excluding any peaks that may have been caused by an exceptional event, such as stratospheric ozone intrusion.
2. As quoted in Jack Doyle, *Taken for a Ride: Detroit's Big Three and the Politics of Pollution*, (New York: Four Walls, Eight Windows) 2000.
3. Ibid.
4. Ibid.
5. Guy Dart, "Imports Rising. Profits Falling. Executives Moaning About Regulations," *Associated Press*, 16 December 1979.
6. See note 2.
7. Ibid.
8. Bill Sessa, California Air Resources Board, September 1990, as quoted in Jack Doyle, *Taken for a Ride: Detroit's Big Three and the Politics of Pollution*, (New York: Four Walls, Eight Windows) 2000.
9. Jim Tankersley, "California Farms, Vineyards in Peril from Warming, U.S. Energy Secretary Warns," *Los Angeles Times*, 4 February 2009.
10. United Nations Environment Programme, *Impacts of Climate Change Coming Faster and Sooner: New Science Report Underlines Urgency for Governments to Seal the Deal in Copenhagen* (press release), 24 September 2009; United Nations Environment Programme, *Climate Change Science Compendium 2009*, September 2009.
11. Speaking to a contestant on "You Bet Your Life," a 1950s radio and TV quiz show that Groucho hosted. Stefan Kanter, *The Essential Groucho*, Penguin Books Ltd., 2000.
12. California Air Resources Board, *Key Events in the History of Air Quality in California*, downloaded from www.arb.ca.gov/html/brochure/history.htm, 10 September 2010.
13. Ibid.
14. "Article on Extreme Impact of Smog on Quality of Life in Riverside, Calif," *New York Times*, 3 August 1972.
15. "Forecasters Say Two-Week Smog Siege at an End," *The Associated Press*, 13 October 1980.
16. Tamara Jones, "No Relief in Sight for Smog-Struck Los Angeles," *The Associated Press*, 8 October 1980.
17. Tom Harrigan, "Los Angeles Doctors Report Increase in Respiratory Ailments," *The Associated Press*, 9 October 1980.
18. Ibid.
19. California Air Resources Board, *Air Quality Trends Summaries*, downloaded from www.arb.ca.gov/adam/trends/trends1.php on 22 September 2010.
20. Ibid. California's air quality standards are 0.07 ppm ozone averaged over any 8-hour period and 0.09 ppm ozone averaged over any 1-hour period.
21. Michele Norris, "Above Clean Air Level; Hold Your Breath! Smog Fouls Air this Weekend," *Los Angeles Times*, 24 August 1985.
22. See note 19.
23. Number of days exceeding California's ambient air quality standard for ozone of 0.07 ppm averaged over an 8-hour period. California Air Resources Board, *Air Quality Trends Summaries*, downloaded from www.arb.ca.gov/adam/trends/trends1.php on 22 September 2010.
24. See note 2.
25. Ibid.
26. Ibid.
27. United Nations Environment Programme and the World Health Organization, International Program on Chemical Safety, *Environmental Health Criteria 7: Photochemical Oxidants*, 1979.
28. Ibid.
29. David Devoss, "New Strategies Against an Old Enemy . . ." *Los Angeles Times*, 20 July 1986.
30. Lung Damage: U.S. EPA, *Smog—Who Does it Hurt? What You Need to Know About*

Ozone and Your Health, July 1999; Kill: Michael Jerrett et al., "Long Term Ozone Exposure and Mortality," *The New England Journal of Medicine* 360: 1085-1095, 12 March 2009; K. Ito, S.F. de Leon and M. Lippmann, "Associations Between Ozone and Daily Mortality," *Epidemiology* 16: 446-57, July 2005.

31. James M. Strock, California Secretary for Environmental Protection, *Rules of the Road on the Drive for Clean Air* (presentation), before the Institute of Business Law, Los Angeles, CA, 14 November 1995, as cited in note 2.

32. M. Lippman, "Health Effects of Ozone: A Critical Review," *Journal of the Air Pollution Control Association* 39: 672-695, 1989; I. Mudway and F. Kelley, "Ozone and the Lung: A Sensitive Issue," *Molecular Aspects of Medicine* 21: 1-48, 2000; M. Gilmour et al., "Ozone-Enhanced Pulmonary Infection with *Streptococcus Zooepidemicus* in Mice: The Role of Alveolar Macrophage Function and Capsular Virulence Factors," *American Review of Respiratory Disease* 147: 753-760.

33. Kendall Powell, "Ozone Exposure Throws Monkey Wrench Into Infant Lungs," *Nature Medicine*, Volume 9, Number 5, May 2003; R. McConnell et al., "Asthma in Exercising Children Exposed to Ozone: A Cohort Study," *The Lancet* 359: 386-391, 2002; N. Kunzli et al., "Association Between Lifetime Ambient Ozone Exposure and Pulmonary Function in College Freshmen – Results of a Pilot Study," *Environmental Research* 72: 8-16, 1997; I.B. Tager et al., "Chronic Exposure to Ambient Ozone and Lung Function in Young Adults," *Epidemiology* 16: 751-9, November 2005.

34. Joel Schwartz, "Air Pollution and Hospital Admissions for the Elderly in Birmingham, Alabama," *American Journal of Epidemiology* 139: 589-98, 15 March 1994; Joel Schwartz, "Air Pollution and Hospital Admissions for the Elderly in Detroit, Michigan," *American Journal of Respiratory Critical Care Medicine* 150: 648-55, 1994; Joel Schwartz, "PM₁₀, Ozone, and Hospital Admissions for the Elderly in Minneapolis-St.

Paul, Minnesota," *Archives of Environmental Health* 49: 366-374, 1994; Joel Schwartz, "Short-Term Fluctuations in Air Pollution and Hospital Admissions of the Elderly for Respiratory Disease," *Thorax* 50: 531-538, 1995; J. Schwartz and R. Morris, "Air Pollution and Hospital Admissions for Cardiovascular Disease in Detroit, Michigan," *American Journal of Epidemiology* 142: 23-25, 1995; Joel Schwartz, "Air Pollution and Hospital Admissions for Respiratory Disease," *Epidemiology* 7: 20-28, 1996; Joel Schwartz, "Air Pollution and Hospital Admissions for Cardiovascular Disease in Tucson," *Epidemiology* 8: 371-377, 1997.

35. George Thurston et al., "Respiratory Hospital Admissions and Summertime Haze Air Pollution in Toronto, Ontario: Consideration of the Role of Acid Aerosols," *Environmental Research* 65: 271-290, 1994; R. Burnett et al., "The Role of Particulate Size and Chemistry in the Association Between Summertime Ambient Air Pollution and Hospitalization for Cardio-respiratory Disease," *Environmental Health Perspectives* 105: 614-620, 1997; R. Burnett et al., "Association Between Ozone and Hospitalization for Respiratory Diseases in 16 Canadian Cities," *Environmental Research* 72: 24-31, 1997.

36. R. Cody et al., "The Effect of Ozone Associated with Summertime Photochemical Smog on the Frequency of Asthma Visits to Hospital Emergency Departments," *Environmental Research* 58: 184-194, 1992; C. Weisel et al., "Relationship Between Summertime Ambient Ozone Levels and Emergency Department Visits for Asthma in Central New Jersey," *Environmental Health Perspectives* 103, Supplement 2: 97-102, 1995; Jennifer Peel et al., "Ambient Air Pollution and Respiratory Emergency Department Visits," *Epidemiology* 6: 164-174, March 2005.

37. George Thurston et al., "Summertime Haze Air Pollution and Children with Asthma," *American Journal of Respiratory Critical Care Medicine* 155: 654-660, February 1997; A. Whittemore and E. Korn, "Asthma and Air Pollution in the Los Angeles Area," *American*

- Journal of Public Health*, 70: 687-696, 1980; J. Schwartz et al., "Acute Effects of Summer Air Pollution on Respiratory Symptom Reporting in Children," *American Journal of Respiratory Critical Care Medicine* 150: 1234-1242, 1994; M. Friedman et al., "Impact of Changes in Transportation and Commuting Behaviors During the 1996 Summer Olympic Games in Atlanta on Air Quality and Childhood Asthma," *Journal of the American Medical Association* 285: 897-905, 2001; Janneane Gent et al., "Association of Low-level Ozone and Fine Particles with Respiratory Symptoms in Children with Asthma," *Journal of The American Medical Association* 290, 1859-1867, 8 October 2003; E.W. Triche et al., "Low Level Ozone Exposure and Respiratory Symptoms in Infants," *Environmental Health Perspectives* doi:10.1289/ehp.8559 (available at dx.doi.org), online 29 December 2005.
38. B. Ostro and S. Rothschild, "Air Pollution and Acute Respiratory Morbidity: An Observational Study of Multiple Pollutants," *Environmental Research* 50: 238-47, 1989; F. Gilliland et al., "The Effects of Ambient Air Pollution on School Absenteeism Due to Respiratory Illness," *Epidemiology* 12: 43-54, 2001; H. Park et al., "Association of Air Pollution with School Absenteeism Due to Illness," *Archives of Pediatric and Adolescent Medicine* 156: 1235-1239, 2002.
39. National Academy of Sciences, National Research Council, *Managing Carbon Monoxide Pollution in Meteorological and Topographical Problem Areas*, ISBN: 0-309-08923-9, 2003.
40. J. Pekkanen et al., "Daily Variations of Particulate Air Pollution and ST-T Depressions in Subjects with Stable Coronary Heart Disease: The Finnish ULTRA Study," *American Journal of Respiratory Critical Care Medicine* 161: A24, 2000.
41. W.J. Gauderman et al., "The Effect of Air Pollution on Lung Development from 10 to 18 Years of Age," *The New England Journal of Medicine* 351: 1057-67, 9 September 2004.
42. California Air Resources Board, *Estimate of Premature Deaths Associated with Fine Particle Pollution (PM2.5) in California Using a U.S. Environmental Protection Agency Methodology*, 31 August 2010.
43. C. Pope et al., "Lung Cancer, Cardiopulmonary Mortality, and Long-Term Exposure to Fine Particulate Air Pollution," *Journal of the American Medical Association* 287: 1132-1141, 2002.
44. California Air Resources Board, *Ambient Air Quality Standards for Particulate Matter*, 24 November 2009, downloaded from www.arb.ca.gov/research/aaqs/pm/pm.htm.
45. Asthma: Ralph Delfino et al., "Asthma Symptoms in Hispanic Children and Daily Ambient Exposures to Toxic and Criteria Air Pollutants," *Environmental Health Perspectives* 111(4), 647-656, April 2003; I.L. Bernstein, M. Chan-Yeung, J.L. Malo, and D.I. Bernstein, *Asthma in the Workplace*, (New York, NY: Marcel Dekker), 1999; Cancer: D. Glass et al., "Leukemia Risk Associated with Low-Level Benzene Exposure," *Epidemiology* 14: 569-577, 2003; A. Blair and N. Kazerouni, "Reactive Chemicals and Cancer," *Cancer Causes Control* 8: 473-490.
46. P. van Vliet et al., "Motor Vehicle Exhaust and Chronic Respiratory Symptoms in Children Living Near Freeways," *Environmental Research* 74:122-32, 1997; T. Nicolai et al., "Urban Traffic and Pollutant Exposure Related to Respiratory Outcomes and Atopy in a Large Sample of Children," *European Respiratory Journal* 21: 956-63, June 2003; W.J. Gauderman et al., "Childhood Asthma and Exposure to Traffic and Nitrogen Dioxide," *Epidemiology* 16: 737-43, November 2005; Cough: U. Gehring et al., "Traffic-Related Air Pollution and Respiratory Health During the First 2 Yrs of Life," *European Respiratory Journal* 19: 690-8, April 2002; More asthma evidence: J.J. Kim et al., "Traffic-Related Air Pollution Near Busy Roads: the East Bay Children's Respiratory Health Study," *American Journal of Respiratory Critical Care Medicine* 170: 520-6, September 2004.

47. R. Maheswaran and P Elliott, "Stroke Mortality Associated With Living Near Main Roads in England and Wales," *Stroke* 34: 2776-80, December 2003; G. Hoek et al., "Association Between Mortality and Indicators of Traffic-Related Air Pollution in the Netherlands: a Cohort Study," *Lancet* 360: 1203-9, 19 October 2002.
48. Bob Weinhold, "Don't Breathe and Drive? Pollutants Lurk Inside Vehicles," *Environmental Health Perspectives* 109: A422-27, September 2001.
49. Intergovernmental Panel on Climate Change, *Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, 2007.
50. Ibid.
51. Ibid.
52. Ibid.
53. Ibid. See also Paul R. Epstein and Evan Mills, eds., The Center for Health and the Global Environment, Harvard Medical School, *Climate Change Futures: Health, Ecological and Economic Dimensions*, November 2005; United Nations Environment Programme, *Climate Change Science Compendium 2009*, September 2009.
54. A.P. Sokolov et al., Massachusetts Institute of Technology, Joint Program on the Science and Policy of Global Change, "Probabilistic Forecast for 21st Century Climate Based on Uncertainties in Emissions (without Policy) and Climate Parameters," *Journal of Climate* 22: (19): 5175-5204, in press (doi: 10.1175/2009JCLI2863.1), 2009; Vicky Pope, United Kingdom Met Office, Head of Climate Change Advice, "Met Office Warn of 'Catastrophic' Rise in Temperature," *The Times Online* (London), 19 December 2008.
55. 6.5 feet: W.T. Pfeffer et al., Institute of Arctic and Alpine Research, University of Colorado, Boulder, "Kinematic Constraints on Glacier Contributions to 21st-Century Sea-Level Rise," *Science* 321: 1340-1343, September 2008.
56. E.J. Burke, S.J. Brown, and N. Christidis, "Modeling the Recent Evolution of Global Drought and Projections for the Twenty- First Century with the Hadley Centre Climate Model," *Journal of Hydrometeorology* 7: 1113-1125, 2006; Susan Solomon et al., U.S. National Oceanic and Atmospheric Administration, "Irreversible Climate Change Due to Carbon Emissions," *Proceedings of the National Academy of Sciences* 106: 1704-1709, 10 February 2009; Richard Seager et al., "Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America," *Science* 316: 1181-1184, 25 May 2007; U.S. Global Change Research Program, *Global Climate Change Impacts in the United States*, Cambridge University Press, 2009.
57. California Air Resources Board, *CEPAM: 2009 Almanac – Population and Vehicle Trends Tool*, download from www.arb.ca.gov/app/emsinv/trends/ems_trends.php, 16 September 16, 2010.
58. Including Passenger Cars, Light-Duty Trucks 1 (<3,750 lbs), Light-Duty Trucks 2 (3,751-5,750 lbs), and Medium-Duty Trucks (5,751-8,500 lbs). California Air Resources Board, *CEPAM; 2009 Almanac – Standard Emissions Tool*, downloaded from www.arb.ca.gov/app/emsinv/cepam_emssumcat_query.php, 16 September 2010.
59. Ibid.
60. California Air Resources Board, *Key Events in the History of Air Quality in California*, downloaded from www.arb.ca.gov/html/brochure/history.htm, 10 September 2010.
61. Ibid.
62. U.S. National Academy of Sciences, *State and Federal Standards for Mobile Source Emissions*, ISBN: 0-309-10151-4, 2006, p. 92. Figure does not fully capture subtle differences in the California and federal standards involving certification methods and fleet averaging. Lines that split reflect the fact that the emissions standard varies depending on certification levels (for example, low-emission and ultralow-emission vehicles).

63. California Air Resources Board, *Clean Car Standards - Pavley, Assembly Bill 1493*, downloaded from www.arb.ca.gov/cc/ccms/ccms.htm, 4 October 2010.

64. 1977: Kevin Clemens, "A History of the Oxygen Sensor - On the Line; A Part of the Whole Building Better Widgets at Bosch," *European Car Magazine*, July 2004.

65. \$200, \$100: California Air Resources Board, *ARB Staff Review of Report Entitled "Impacts of Alternative ZEV Sales Mandates on California Motor Vehicle Emissions: A Comprehensive Study,"* 31 October 2001.

66. California Air Resources Board, *White Paper: Summary of Staff's Preliminary Assessment of the Need for Revisions to the Zero Emission Vehicle Regulation*, 25 November 2009.

67. Manufacturers of Emission Controls Association, *Clean Air Facts: The Catalytic Converter: Technology for Clean Air* (factsheet), February 2006.

68. California Air Resources Board, *LEV II - Amendments to California's Low-Emission Vehicle Regulations* (factsheet), downloaded from www.arb.ca.gov/msprog/levprog/levprog.htm on 10 September 2010.

69. 11 million cars in 1980 and 25 million cars in 2010 determined by adding together vehicle populations for Passenger Cars, Light-Duty Trucks 1 (<3,750 Ibs), Light-Duty Trucks 2 (3,751-5,750 Ibs), and Medium-Duty Trucks (5,751-8,500 Ibs). Data from: California Air Resource Board, *CEPAM: 2009 Almanac - Population and Vehicle Trends Tools* (database), downloaded from www.arb.ca.gov/app/emsinv/trends/ems_trends.php, 16 September 2010; 33 miles per day in 1980 and 35 miles per day in 2010 determined by dividing the total miles traveled by all cars (determined by adding the vehicles miles traveled for Passenger Cars, Light-Duty Trucks 1 (<3,750 Ibs), Light-Duty Trucks 2 (3,751-5,750 Ibs), and Medium-Duty Trucks (5,751-8,500 Ibs) for 1980, per California Air Resource Board, *CEPAM: 2009 Almanac - Population and Vehicle Trends Tools* (database), downloaded from <http://www.arb.ca.gov/>

[app/emsinv/trends/ems_trends.php](http://www.arb.ca.gov/app/emsinv/trends/ems_trends.php), 16 September 2010) by the vehicle populations.

70. Including Passenger Cars, Light-Duty Trucks 1 (<3,750 Ibs), Light-Duty Trucks 2 (3,751-5,750 Ibs), and Medium-Duty Trucks (5,751-8,500 Ibs). Data from California Air Resource Board, *CEPAM: 2009 Almanac - Standard Emissions Tool* (database), downloaded from www.arb.ca.gov/app/emsinv/fcemssumcat2009.php, 16 September 2010.

71. Ibid.

72. Emissions per note 70 divided by VMT per note 69.

73. See note 70.

74. Measured as the highest concentration of ground-level ozone recorded in any one-hour period during the noted year and the previous two years, excluding any peaks that may have been caused by an exceptional event, such as stratospheric ozone intrusion. California Air Resources Board, *iADAM Air Quality Data Statistics*, downloaded from www.arb.ca.gov/adam/ on 16 September 2010.

75. California Air Resources Board, *iADAM Air Quality Data Statistics*, downloaded from www.arb.ca.gov/adam/ on 16 September 2010.

76. Based on the California 8-hour ozone standard of 0.07 ppm. California Air Resources Board, *iADAM Air Quality Data Statistics*, downloaded from www.arb.ca.gov/adam/ on 16 September 2010. Progress based on the 1-hour ozone standard of 0.09 ppm has been greater: the number of days with unhealthy air has fallen by on the order of 90 percent in San Diego, 75 percent in the San Francisco Bay Area, 60 percent in the Sacramento Valley, 50 percent in the Los Angeles area, and 33 percent in the San Joaquin Valley from 1980 to 2009.

77. Based on the California 1-hour ozone standard of 0.09 ppm. California Air Resources Board, *iADAM Air Quality Data Statistics*, downloaded from www.arb.ca.gov/adam/ on 16 September 2010.

78. Felicity Barringer, "California Air Is Cleaner, But Troubles Remain," *The New*

York Times, 3 August 2005.

79. Ibid.

80. Ibid.

81. South Coast Air Quality Management District, *2007 Air Quality Maintenance Plan*, October 2006, available at www.aqmd.gov/aqmp/07aqmp/draft/07aqmp.pdf.

82. Roland Hwang and Matt Peak, NRDC and CALSTART, *Innovation and Regulation in the Automobile Sector: Lessons Learned and Implications for California's CO₂ Standards*, April 2006.

83. Daniel Sperling et al, University of California at Davis, *The Price of Regulation*, Fall 2004, available at www.its.ucdavis.edu/publications/2004/UCD-ITS-RR-04-32.pdf.

84. U.S. Environmental Protection Agency, *Final Report to Congress on Benefits and Costs of the Clean Air Act, 1990 to 2010*, Document # EPA 410-R-99-001, 15 November 1999.

85. The Mainstreet Alliance and the Small Business Majority, *The Clean Air Act's Economic Benefits: Past, Present and Future*, October 2010.

86. American Lung Association, *State of the Air 2010*, April 2010.

87. Based on the CA 8-hour ozone standard of 0.07 ppm. California Air Resources Board, *iADAM Air Quality Data Statistics*, downloaded from www.arb.ca.gov/adam/ on 16 September 2010.

88. Measured in terms of average daily 1-hour maximum ozone level. Michael Jerrett et al., "Long Term Ozone Exposure and Mortality," *The New England Journal of Medicine* 360: 1085-1095, 12 March 2009.

89. Ibid.

90. U.S. Environmental Protection Agency, *Proposal to Revise the National Ambient Air Quality Standards for Ozone* (factsheet), 6 January 2010.

91. California Air Resources Board, *CE-PAM; 2009 Almanac – Standard Emissions Tool*, downloaded from www.arb.ca.gov/app/emsinv/cepam_emssumcat_query.php, 16 September 2010.

92. California Air Resources Board, *Public Workshop on Proposed Revisions to the Low-Emission Vehicle Program* (presentation), El Monte, California, 2 March 2010.

93. 1970s: Anne Choate et al., ICF Consulting, Sonoma Technology, Inc. and California Energy Commission, *California's Greenhouse Gas Emissions and Trends over the Past Decade*, downloaded from www.epa.gov/ttn/chief/conference/ei11/ghg/choate.pdf on 1 October 2010. From 1990: California Air Resources Board, *California Greenhouse Gas Emission Inventory, 1990-2004 and 200-2008*, downloaded from www.arb.ca.gov/cc/inventory/inventory.htm, 28 May 2010.

94. California Air Resources Board, *California Greenhouse Gas Emission Inventory, 1990-2004 and 2000-2008*, downloaded from www.arb.ca.gov/cc/inventory/inventory.htm, 28 May 2010.

95. Nic Lutsey, California Air Resources Board, *Technologies and Trends for Reducing Automobile Greenhouse Gas Emissions in the 2025 Timeframe* (presentation), 2 March 2010, available at www.arb.ca.gov/msprog/levprog/leviii/leviii.htm.

96. Tom Cackette, California Air Resources Board, *Advanced Clean Vehicles Program: Setting the Course for Cleaner Vehicles: 2014-2050*, presented at public meeting on amendments to California's Low Emission Vehicle Regulations for passenger cars - LEV III, 18 May 2010.

97. California Air Resources Board, *ZEV Regulation Workshop* (presentation), Byron Sher Auditorium, Sacramento, 3 May 2010.