CALIFORNIA AIR RESOURCES BOARD

Improving Air Quality in a Growing Economy: Lessons for Hong Kong & the Pearl River Delta

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CIVIC EXCHANGE

ABOUT CIVIC EXCHANGE

Civic Exchange is a Hong Kong-based not-for-profit public policy think tank that was established in October 2000. It is an independent organization that has access to policy makers, officials, businesses, media and NGOs – reaching across sectors and borders. Civic Exchange has solid experience is air quality, energy, water, urban planning, nature conservation and climate change research, as well as economic and governance issues.

ABOUT THE AUTHOR

Lynne Curry is an independent environmental consultant located in Los Angeles. She has worked for the Natural Resources Defense Council on a project basis. In addition, she lived in Hong Kong, Beijing, and Taipei for over 25 years and contributed to a variety of publications, including *CFO Asia*, published by the Economist Group, *Business Week*, and *TOPICS*, the monthly magazine published by the American Chamber of Commerce in Taipei.

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PREFACE

In 2007, Civic Exchange published a report entitled *Lessons for Hong Kong: Air Quality Management in London and Los Angeles*, which examined best practice in two cities that have achieved notable success in reducing air pollution. Despite various efforts, Hong Kong has made little progress in tackling air pollution that continues to threaten public health. The need to do more is growing. The broader economic development of the city is increasingly being constrained by the legacy of Hong Kong's failure to bring pollution under control - as evidenced by determined public opposition to the Hong Kong-Zhuhai-Macau Bridge and the proposed third runway for the airport.

On a more positive note the Central People's Government's plans to re-imagine the Pearl River Delta (PRD) as a *Quality Living Area* are aiming to realign the region's development priorities along more environmentally-responsible lines. Various consultation documents published from late 2008 have called for pilot studies and examples of global best practice to be considered for adoption in the PRD.

A useful example is that of Los Angeles, and the California Air Resources Board – CARB – the state's air quality regulator. Despite the tremendous growth in population, industry and cars on the road, CARB has been remarkably successful in controlling and reducing pollution in California. CARB has in fact been so successful that its initiatives are hugely influential in shaping the future direction of US national air policy and that of other jurisdictions including the European Union.

This report comes in two parts. The first sets out the key elements that have made CARB so successful. The second part provides a sample of mini case studies which demonstrate the wide variety of approaches CARB has adopted to address the threats from different types and sources of air pollution. Both are presented so that officials in Hong Kong and the PRD may have easy access to a proven approach that could contribute significantly towards the air pollution that is such a blight on the health of people in Hong Kong and the PRD.

Civic Exchange is grateful to Lynne Curry for putting together this introduction to the California Air Resources Board, to ADM Capital Foundation for assisting our overall air quality research, to Mike Kilburn for managing the project and to Michelle Wong for laying out the report.

Christine Loh
Chief Executive Office

1. California Air Resources Board (CARB): Introduction

California is the state that seemingly has it all – from the glamour of Hollywood and IT moguls in Silicon Valley to "A-list" sports teams and excellent universities. Yet, despite its magnificent mountains, sandy beaches, and redwood forests, the state is also known for another trait – it has some of the worst air pollution in the United States (US), and this is not confined only to the city of Los Angeles. With California's nearly year-round summers, high temperatures, many mountain ranges, valleys, and large population, air pollution has been a problem for decades. Indeed, according to the American Lung Association, eight of the top ten cities in the US with the highest level of ozone pollution and five of the top ten cities that have year-round particle pollution are in California.[1]

> *In the thirties and forties, you couldn't even see a city block the smog was so thick in LA, the regulatory agency responsible for improving the state's air quality. California had the most serious air pollution problem of all the states. Major industry was not the only source of air pollution. The state has lots of valleys, and heat energy was trapped in temperature inversions in the valleys of LA, San Francisco, and San Diego. This became smog at low (elevation) levels.*
>
> Dimitri Stanich, Information Officer, CARB

Because of the scale of the pollution, the state has developed some of the toughest air quality standards in the country for vehicles, factories, ships, and consumer products. It also has some of the strictest tailpipe emission standards required for cars in the country.

CARB is the regulatory agency that sets those standards. A highly autonomous science-driven agency, its eleven-member board comprises experts in various air quality-related fields. It's stated mission is: "To promote and protect public health, welfare and ecological resources through the effective and efficient reduction of air pollutants, while recognizing and considering the effects on the state's economy."[2]

After World War II, urban sprawl began in California, with more people moving to the state, building homes and factories, buying cars and trucks, and constructing freeways at an unprecedented rate. The population exploded from 11 million in 1950 to about 37 million in 2010, while the number of registered vehicles soared nearly 8 times from 4.5 million to 35 million vehicles[3] during the same period.

Responding to this staggering growth rate in people and vehicles, California has passed increasingly stringent laws to curb air pollution. This legislation eventually became the foundation for the creation of CARB. Today, the agency is an air quality regulatory powerhouse respected throughout the US and around the world.

2. Structure and Functions

2.1 Relationships with Federal and State Governments

CARB is an independent state agency that reports directly to the US Environmental Protection Agency (USEPA) under the terms of the Clean Air Act. That act acknowledges California's severe pollution problem and allows the state to obtain a waiver exempting it from federal laws, enabling it to enact its own more stringent regulations instead. Under this act, the USEPA reviews CARB proposals and generally grants the waiver.

> *Our regulations are some of the most far-reaching regulations that California adopts and serve as models for what would be done in any jurisdiction to reduce emissions from particular industries and processes.*
>
> John Swanton, Public Information Office, CARB

In contrast with its more official, clearly defined relationship with the USEPA, CARB's ties with the state branch of the California EPA (CalEPA) are less informal – it does not report directly to the CalEPA. Although the CalEPA has a cabinet level position in the state government and reports to the governor, it has no statutory authority to regulate CARB or any other state agency.

> *California EPA has no legal authority to oversee what CARB does. California EPA is an umbrella organization that is charged with better coordinating environmental activities. While it may work to influence CARB, there is no formal process of oversight. California EPA coordinates processes to make them work better, find areas of commonalities, and pool administrative tasks.*
>
> John Swanton, Public Information Office, CARB

CalEPA's responsibilities are primarily limited to overseeing and coordinating environmental activities among different agencies such as CARB, those regulating water quality, pesticides, hazardous materials, or other areas. The CalEPA is, however, informally kept abreast of CARB's initiatives.

However, like other state agencies, CARB must comply with both state regulatory laws and California's Environmental Quality Act, which determines whether a proposal or project can be implemented after an environmental assessment.

While it operates administratively like other states agencies, CARB's power stems not only from federal support, but from the Mulford-Carrell Act signed into law by Governor Ronald Reagan in 1967. With the passage of this bill, the California legislature created the CARB and gave it the authority to enact regulations with the force of law behind them.

2.2 Nationwide and International Impact

Although CARB is only a state agency, its impact is felt nationwide. It is unique among the 50 states. While other states have air quality authorities, none has the ability to adopt its own state air pollution control measures. California is the only state that can create and enforce its own stringent air quality standards – an acknowledgement of the state's decades-old efforts to curb air pollution with its own regulations that were already in place when the federal Clean Air Act was passed in 1970.

Apart from supporting California's own air pollution control regulations, the Clean Air Act broadened California's influence when it also gave other states the right to adopt federal or California laws to reduce their emissions. States that have selected California's more stringent regulations include some Northeastern states, and Washington and Oregon on the west coast. Indeed, many other states look to California for leadership and even press it to adopt measures sooner. Among the

measures that CARB has enacted, the ones that receive a high priority are those involving vehicles. The agency has pushed car manufacturers to design vehicles that pass California's tougher standards, and car makers have done so, knowing that other states will adopt California's rigorous requirements.

In addition, other cities and countries with similar emission sources, including Australia, Japan, and the European Union, monitor CARB's policies and its results. CARB officials are aware that others watch closely how California produces regulations and the effects and benefits from the process it goes through.

2.3 The Board

CARB's board members are appointed by the state governor with the consent of the state senate and serve their terms at the governor's discretion.[4] Members must meet specifications required by law: five must be chosen from the boards of local air quality management districts of the San Francisco Bay area, the greater Los Angeles region, the San Joaquin Valley, San Diego, and one to represent any other district of the state. Three are appointed by the governor in various fields, including medicine, chemistry, physics, meteorology, engineering, business, and law. The remaining two are public members.

The governor also appoints a chairperson. The chairperson is the only full time employee – the remaining ten members work part time and the board meets monthly in various parts of the state.[5] All meetings are open to the general public and a transparent process allows interested parties to make comments and observations.

The current 11-member board has evolved over the years from an original membership of seven. It functions with a fair degree of autonomy, but it also works with the state legislature on specific issues that need to be addressed.

Based in Sacramento, CARB has 1,200 employees consisting of a staff of scientists, engineers, lawyers, policy specialists, and other professionals. The CARB also operates a motor vehicle testing and analysis laboratory in El Monte, a suburb of Los Angeles.

2.4 Relationship with Air Quality Management Districts

CARB oversees the activities of the state's 35 local and regional air quality management districts. These districts regulate industrial pollution sources. They issue permits, develop local plans to attain healthy air quality, and ensure industries adhere to air quality mandates.[6] Five of the 35 air pollution control districts have 80%-90% of the state's population[7]. These districts are the South Coast,[8] San Diego, Sacramento, Bay Area, and San Joaquin Air Quality Management Districts.

CARB divides its oversight of pollutants into two basic categories: mobile and stationary sources. CARB is primarily responsible for defining emission standards for vehicles, gas, and consumer products, while the air quality management districts regulate stationary sources such as factories, dry cleaners, gas stations, bakeries, refineries, and power plants.

Each AQMD has the authority to create its own board and sets its own standards with some, like the South Coast[9] and Bay Area air quality management districts, imposing more stringent regulations than those set by CARB or other districts because of different local, meteorological and topographical conditions. Although each AQMD designs its own emissions reduction plan for stationary sources in its area, it coordinates its plans with CARB before submitting it to the agency. While districts must develop their own plans, they must mesh with CARB's plans. CARB retains oversight authority of the district, but the district has day-to-day responsibility for implementation of control measures.

CARB decides whether the AQMD plans are stringent or effective enough. We can send it back if we think it needs more work, but usually we don't need to, because we work in concert with the AQMDs.

Dimitri Stanich, Information Officer, CARB

CARB then incorporates the AQMD plans into the state implementation plan (SIP), which describes how each area will attain and maintain national ambient air quality standards. The SIP is then submitted to the federal EPA for approval.

Local plans are part of the structure dictated by federal law. In the case of the US, local control is very important. Federal law provides for local control. Districts fulfill the role of local control.

John Swanton, Public Information Office, CARB

3. Funding

CARB's funding is a crucial element underpinning its success.

> *CARB has the resources and capability to perform well. An agency must have dedicated funding streams. It needs a solid financial foundation, so it doesn't get caught up in political battles.*
>
> *Daniel Sperling, CARB board member*
> *Director, Institute of Transportation Studies, UC Davis*

CARB derives most of its funding from a system of regulatory, license, and vehicle registration fees, permits, fines, investments, and voter-approved state bond money.[10] It derives no money from property taxes. The air quality management districts each have their own system for raising revenues.[11]

4. Enforcement of Regulations

CARB's regulations fall within the state's health and safety code and are spelled out in a manual called the *California Air Pollution Controls Law*. Penalties for failure to comply with these regulations are clearly defined.

> *Those who are producing the pollution are typically not suffering from it. You need strong policies and strong enforcement to clean the air. A fair and equitable policy and enforcement go hand-in-hand. You can't have one without the other. A patchwork of polices doesn't work.*
>
> Dr. Anupom Ganguli, SCAQMD

CARB outlines a hierarchy of penalties and fines for offenders, ranging from a first time violation to multiple times and intentional transgressions. Distributors, as well as manufacturers of polluting products (which can range from automotive refrigerants to fuel exhaust emissions control systems), are held accountable for ensuring that their products meet California's air quality standards and can be fined for non-compliance.

CARB teams do investigate whether manufacturers are complying with regulations or are intentionally skirting the law. Most companies violating the law are unintentionally doing so. They will often reach a financial settlement with the agency and take steps to correct their practices.

Some, however, will go to court. It is sometimes cheaper for a company to go to court in the hopes of being awarded a lesser fine than pay the amount that CARB imposes.[12] The system is designed to be a level playing field promoting clean air rather than non-compliance and companies will also often report non-compliance of their competitors. The resources from these fines help to fund much of the testing and research done by CARB[13].

5. Ten Milestones in California's Emission Controls Program

1	**1975**	Catalytic Convertors introduced as part of CARB's Motor Vehicle Emissions Control Program. A catalytic converter is a pollution control device designed to reduce emissions from motor vehicles. They have been required on all motor vehicles sold in California since 1979.[14]
2	**1976**	CARB limits lead in gasoline. This was followed by the introduction of clean-burning gasoline in 1992. [15]
3	**1984**	California Smog Check program implemented to identify and repair ineffective emission control systems in cars and light trucks on a biennial basis. In 1998, CARB implemented a revamped Smog Check II program.[16]
4	**1990**	CARB enacts the first phase of the Low Emission Vehicle (LEV) program, which required manufacturers to install emission control devices on new passenger vehicles from 1994 - 2003.[17] CARB tightened the emission standards with LEV II, which ended in 2010, and is seeking to make them even more stringent with LEV III.
5	**1999**	CARB adopts consumer rules to cut smog-forming emissions and volatile organic compounds (VOCs) from 2,500 consumer-household products, ranging from nail polish to glass cleaners.[18] In 2010, California regulations further reduced air pollution from 11 product categories, including bug sprays, household and professional products.[19]
6	**2000**	CARB enacts the Diesel Risk Reduction Plan to reduce the concentration of diesel particulate matter by 85% by 2020.[20] This required many steps, including adopting new diesel fuel standards in 2003, which cut the sulphur content by 95%.
7	**2001**	Upholds Zero Emission mandate with modified requirements. Automakers are required to produce 4,450 - 15,450 zero emission cars starting in 2003.[21]
	2008	CARB adopts Zero Emission Vehicle rules, which will put 65,000 cleaner vehicles on the road by 2012. [22]
8	**2005**	CARB requires engine manufacturers of heavy duty diesel trucks to install on-board diagnostic systems beginning in 2010.[23] When a problem arises, the dashboard light automatically comes on.
9	**2007**	CARB adopts regulations to reduce formaldehyde emissions from composite wood products (including plywood, particleboard, and fiberboard).[24]
10	**2007 | 2008**	Trucks (including port trucks), off-road vehicles, farm vehicles, and construction vehicles are required to upgrade to meet emission standards. CARB adopted two critical regulations aimed at cleaning up harmful emissions from the state's estimated one million diesel trucks. One required the installation of diesel exhaust filters or an engine replacement, and the other required the installation of fuel efficient tires and aerodynamic devices.[25]
	2008	CARB regulates the use of lower sulphur fuel, which will eliminate 15 tons of diesel exhaust daily from ocean-going vessels--among the world's most stringent marine regulations.[26]

6. Reasons for Success

CARB's remarkable success in improving air quality is due to a variety of factors. State and federal governments are the foundation supporting California's impressive achievement. Before the agency was established, California had decades of experience in fighting to curb air pollution. Then in 1963, the state received help from the federal government when the US Congress enacted the Clean Air Act, which stipulated that air quality criteria be based on scientific studies.[27]

The state reached a crucial turning point in 1967 when Governor Ronald Reagan signed the Mulford-Carrell bill into law creating CARB and giving it the legal authority to adopt air control regulations. The same year, the federal government amended the 1963 Clean Air Act with the Air Quality Act. It established a framework for defining "air quality control regions" based on meteorological and topographical factors of air pollution.

Then in 1970, in response to public pressure, the federal government aggressively tightened its regulation of air quality and enacted the Clean Air Act, surpassing the earlier Air Quality Act. The 1970 Clean Air Act established the basic US program for controlling air pollution. It also granted California the authority to set and enforce its own emission standards for new vehicles provided those standards are as stringent as federal ones. In addition, the act allowed other states to adopt California's stricter standards.

CARB has also benefited from the foresight of California's regional leaders, many of whom recognized the need for clean air regardless of their political affiliation.

> *They stated their vision for clean air and sacrifices by the government and industry were made to improve the air. The vision and leadership shown to create air quality districts, combined with air pollution control of cars has had a dramatic impact.*
>
> Dr. Anupom Ganguli SCAQMD

In 1947, Governor Earl Warren signed an Air Pollution Act authorizing the creation of an air pollution control district in every county of the state. LA County became the country's first to establish such a district. [28]

CARB has earned the public and industry's respect with its reliance on sound scientific data, beginning with its earliest days. Its first chairman, the Dutch scientist at CalTech, Dr. Arie J. Haagen-Smit, made the critical discovery that smog is the result of photochemistry. When exhaust (nitrogen oxides and hydrocarbons) from motor vehicles and industrial facilities reacts with sunlight, it creates ozone or smog. Dr. Haagen-Smit saw this was deleterious to public health and the economy, and realized that by reducing air pollution he could reduce its impact on public health and agriculture. CARB considers this breakthrough to be the foundation upon which today's nationwide air pollution standards are based, according to CARB.[29]

Indeed, all policy decisions and regulations today are based on empirical data and economic analysis that shows direct public health and economic benefits. This evidence served to mobilize state and federal elected officials to provide the tools and funding to implement measures to improve air quality.

CARB's success is also due to its relative political independence, stemming partially from its board member selection process. California law requires the governor to appoint members from specific scientific disciplines, and the state senate must confirm these members. This law prevents the governor from making partisan or politically-motivated appointments.[30]

CARB has also successfully attracted a highly talented staff that combines a deep and sophisticated understanding of science with expert policy-making skills. The staff includes professionals who are scientists, engineers, economists, lawyers, and policy makers, among others.

CARB know how to bring science and policy together to make it work. They are blessed with a high calibre of people. They have some real stars in policy and scientists who are devoted to doing the right thing. Indeed, its policy experts consistently exhibit an astute sense of timing, knowing when to implement new regulations, and avoiding becoming mired in political issues. CARB has also benefited from cross-training, with some of its scientists and engineers becoming policy makers, further adding to the agency's depth on various issues.

Kathryn Phillips, Director, California Transportation and Air Initiative
Environmental Defense Fund

With its relentless focus on science, CARB is a deadline and milestone-oriented organization. Over the years, the regulations have provided a road map guiding California towards its goal of clean air and CARB's aggressive reduction measures on mobile sources are having a dramatic impact on car and truck emissions.[31]

In addition, enforcement of its regulations is another important component of CARB's success. Huge fines are imposed when regulations are violated.[32] CARB's revenues from those fines help fund most of the agency's testing and research on technology to reduce emissions.

CARB's solid financial foundation is critical to its success as it has a large enough budget to hire some of the best scientists around.

David Pettit, Senior Attorney, Natural Resources Defence Council (NRDC)

Despite its high-calibre staff, the number of professional employees is limited, especially given CARB's large scope and depth of work. CARB awards grants to universities and then executes policies based on the research from those grants.

By using the universities, CARB can get access to some of the best research on air quality at a fraction of the cost

Dr. Annmarie Eldering, Deputy Manager, Earth Atmospheric Science Section
Jet Propulsion Laboratories, Pasadena, Ca.

Finally, CARB has also won public support for its method of operation. A transparent organization with a culture of engagement, its staff interacts with industry, NGOs, and various stakeholders. CARB conducts workshops and road shows, consults vehicle manufacturers and other stakeholders, and does much public outreach. Before CARB implements a regulation, the proposal undergoes a process that includes opportunities for public comment and input and hearings with staff members where changes may be considered.

Even when there's a lot of tension, they still get lots of respect because they do try engagement with all parties. It has a culture of testing out ideas, trying out different proposals and strategies, and soliciting inputs.

Daniel Sperling, CARB board member&
Director, Institute of Transportation Studies, UC Davis

7. California's Air Basins

With its wide variety of climates, physical features, and emission sources, improving air quality is a complex task. What works in one area may not be effective in another. To better manage air quality problems, California is divided into 15 air basins.[33]

An air basin generally has similar meteorological and geographical conditions throughout its designated area. Boundaries usually follow political boundary lines and are defined as including both the source area and the receptor area. However, air masses can move freely from basin to basin, with the result that pollutants such as ozone and PM, and their precursors, can be transported across air basin boundaries.[34] Depending on the size of the basin, each one can include from one to eleven counties and each is regulated by one or more AQMDs. If an air basin crosses districts, CARB will work with agencies on both sides of the fence.

Source: California Air Resources Board,
The California Almanac of Emissions and Air Quality, 2009 Edition, p. 1-15.

8. California and National Ambient Air Quality Standards

For most pollutants, California standards are more stringent than the national standards.[35] Generally, air quality standards are expressed as a measure of the amount of pollutant per unit of air.[36]

National, state, and local agencies have implemented many control measures during the past three decades to improve air quality. Standards continually evolve depending on the source of the pollutant. CARB conducts regular reviews of standards on a case-by-case basis to determine whether that standard remains adequate to protect public health. There are no pollutants that have set time frames for review standards. Rather the decision to review standards is driven by state-of-the-art health research and the need to achieve emissions reductions, not in compliance with the overall state implementation plan.

In addition, the board can adjust a strict standard in a tough economy. If an emission standard is being met because a particular type of equipment or vehicle is not being used due to an economic slowdown and the pollutant is not being generated, CARB can modify the standard, lessening the burden on industry.

Statewide Emissions (tons/day, annual average)										
Pollutant	**1975**	**1980**	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
NOx	4,886	4,898	4,744	4,940	4,387	3,972	3,513	2,981	2,476	2,173
ROG	7,058	6,566	5,990	4,733	383	3,141	2,455	2,127	1,993	1,950
PM_{10}	1,857	1,889	1,971	2,215	2,112	2,174	2,134	2,139	2,202	2,275
$PM_{2.5}$	713	687	685	751	686	693	686	682	690	707
SOx	1,277	953	534	511	303	297	301	294	337	394
CO	42,175	37,958	35,270	30,084	22,405	17,203	13,127	10,543	9,134	8,369

Source: California Air Resource Board, *The California Almanac of Emissions & Air Quality*, 2009 Edition.

9. CARB's Future and Its Challenges

Despite its strong scientific focus, CARB has still occasionally become embroiled in political firestorms. With the economic downturn, it has faced intense political pressure to moderate new regulations because they are deemed too costly to implement in a weak economic climate.

> *"CARB's mission isn't to deal with the economy, but to clean up the air. It is important to resist industry where it is appropriate. Industry periodically wants government to tell CARB to back off. Sometimes, we have discovered CARB has delayed implementation of the rules based in part on the state of the economy. But CARB hasn't totally caved in. It is hard to draw the line in a tough economy.*
>
> David Pettit, Senior Attorney, NRDC

In another ongoing case, CARB is entangled in a legal challenge by environmental justice groups. Although CARB is a global leader in combatting air pollution, a California judge ordered the agency to delay implementation of the climate change law passed in 2006 that would reduce greenhouse gas emissions.[37] Environmental justice groups sued CARB, contending that their constituents in lower economic areas would be hurt when local polluters simply paid for allowances rather than reduce pollution itself. The judge ruled that CARB failed to do an adequate assessment of alternatives to the cap-and-trade policy, which issues permits to polluters, according to a predetermined ceiling and then allows those polluters to trade them as needed.[38] The case is in the state court of appeal. CARB and the justice groups attempted to settle, but ultimately failed to reach an agreement.[39]

Despite a difficult economic environment, however, the agency has not stood still. CARB's role continues to evolve from the times when the agency focused solely on setting air quality standards. Now CARB is increasingly focusing on climate change, greenhouse gas and other issues affecting the broader economy." These future challenges notwithstanding, CARB has successfully raised public awareness of the importance of clean air, and the air is the cleanest it's been in 50-60 years.[40]

APPENDICES

This appendix will examine five key pollutants that highlight the success CARB has achieved by adopting different approaches to reducing different pollutants. These five mini-case studies show how CARB has progressively tightened standards where necessary and has adapted those standards as technology has evolved. The appendix concludes with a brief summary of two influential research papers discussing the harmful impact of air pollution on human health.

Appendix 1: Emission Sources

1a Criteria Pollutants

CARB has targeted the reduction of emissions of seven criteria pollutants. These are pollutants that are so pervasive across the country that the U.S. EPA must establish national health standards, including the characteristics, potential health, and welfare effects of these pollutants.[41] Of these seven pollutants, this report examines five compounds: ozone, particulates (PM_{10}) and fine particulates ($PM_{2.5}$), nitrogen dioxide (NO_2), and sulphur dioxide (SO_2). It also discusses emissions related to these criteria pollutants, including reactive organic gases (ROGs, a class of reactive hydrocarbons), oxides of nitrogen (NO_X), and oxides of sulphur (SO_X).[42]

While some pollutants, such as carbon monoxide, are directly emitted, others are formed in the atmosphere from precursor emissions. Ozone is an example of this process. It is formed in the atmosphere when ROGs and NO_X react in the presence of sunlight.[43] Particulate Matter, which includes PM_{10} and $PM_{2.5}$, is a complex pollutant that can either be directly emitted or formed in the atmosphere from precursor emissions. PM precursors include NO_X, ROG, sulphur oxides, and ammonia (NH_3).[44] Examples of directly emitted PM include dust and soot. The whole of California now meets state and national standards for all critical pollutants except ozone and particulate matter (PM).[45]

1b Toxic Air Contaminants

In addition to these criteria pollutants, California has designated 200 compounds as toxic air contaminants (TACs).[46] Of these, CARB closely monitors the ten TACS that pose the greatest known health risk in California.[47] Besides the ten selected TACs, CARB also tracks dioxins, which are considered to pose substantial health risk. However, this report discusses the most important—diesel particulate matter—which has a higher health risk than the other nine compounds combined.[48]

1c By Category

California has many sources of air pollution. To estimate the sources and quantities of pollution, CARB, in cooperation with local air districts and industry, maintains an inventory of California emission sources.[49] Sources are subdivided into four major emission categories: stationary, area-wide, mobile, and natural sources.

Stationary source emissions are based on estimates made by facility operators and local air districts.[50] Area-wide emissions are estimated by CARB and local air district staffs. Area-wide sources may be either small individual sources, such as residential fireplaces, or widely distributed sources that cannot be tied to a single location, such as consumer products and dust from unpaved roads.[51] Mobile source emissions are estimated by CARB staff with assistance from local air districts and other government agencies. Mobile sources include on-road cars, trucks, buses, boats, off-road recreational vehicles, aircraft, and trains. Natural sources, also estimated by CARB and the air districts, include biogenic and geogenic hydrocarbons, natural wind-blown dust, and wildfires.[52]

Appendix 2: Ozone

2a Ozone sources and characteristics

Ozone—a colorless gas, which is odorless at ambient levels, is the chief component of urban smog. Not directly emitted as a pollutant, it is a powerful oxidant that can be compared in strength to household bleach—it can kill lung cells upon contact. It has a pungent odor and can sometimes be detected after lightning strikes or during electrical discharges.[53]

Meteorology also plays a major role in ozone formation. Generally, stagnant air, warm temperatures, and cloudless skies provide optimum conditions for ozone formation. Consequently, summer is usually the peak ozone season.

2b Ozone Levels and Standards

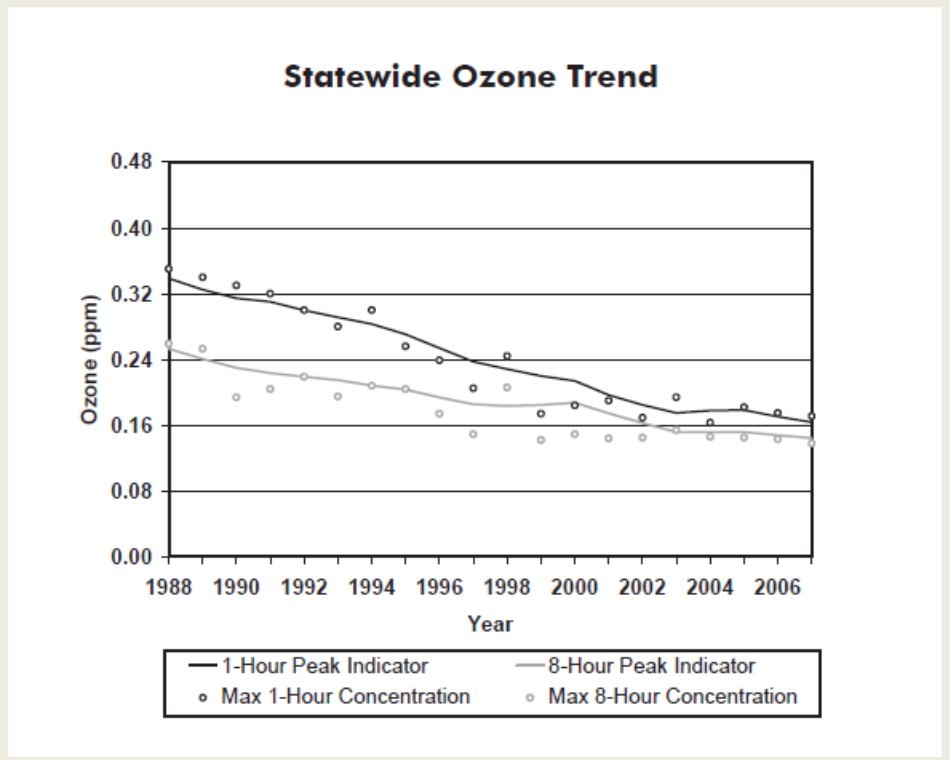
Although ozone levels have fallen significantly over the last few decades, ozone still poses a significant challenge to California. Despite aggressive emission controls, the maximum measured 1-hour and 8-hour ozone concentrations still exceed the state standard in 11 of the 15 air basins.[54] They were about twice the level of state standards during 2007.[55]

CARB's 8-hour ozone standards are designed to protect the public against the health effects of day-long exposures to unhealthy ozone concentrations.[56] The state's one-hour standard is aimed at protecting the public against acute exposures from elevated short-term ozone concentrations.

California's 8-hour ozone standard of 0.070 ppm is the most health-protective ozone standard in the country.[57]

These standards have meant that California's ozone levels have improved greatly over the last 20 years, despite significant population and vehicle growth.[58] The statewide trend shows that the peak 8-hour and 1-hour indicators declined by over 42% and over 49% respectively from 1988 to 2007.

On the federal level, in 2008, the US EPA completed a review of health studies and concluded the national ozone standard of 0.08 ppm was insufficiently protective of human health.[59] The government subsequently tightened it to the new standard of 0.075 ppm.[60] This new standard will build upon California's current efforts.



Source: California Air Resources Board,
The California Almanac of Emissions & Air Quality, 2009 Edition, p. 3-7.

2c Ozone Control Measures Adopted

From 1988 to 2007, California's population grew by 33% and the number of vehicle miles traveled daily rose by more than 46%.[61] Motor vehicles are the largest source of ozone precursor emissions, and reducing their emissions will continue to be the cornerstone of California's ozone control efforts.[62] New vehicles must meet CARB's low emission vehicle standards, which make about 95% fewer smog-forming emissions than vehicles produced in the 1970s.[63]

California will also continue to implement a comprehensive set of new programs. This will include new emission control standards and innovative incentive programs to accelerate clean air technologies and reduce emissions from goods movement.[64] CARB is also tackling ozone emissions by setting standards for NO_X precursors, one of the compounds that reacts in the presence of sunlight to form ozone.

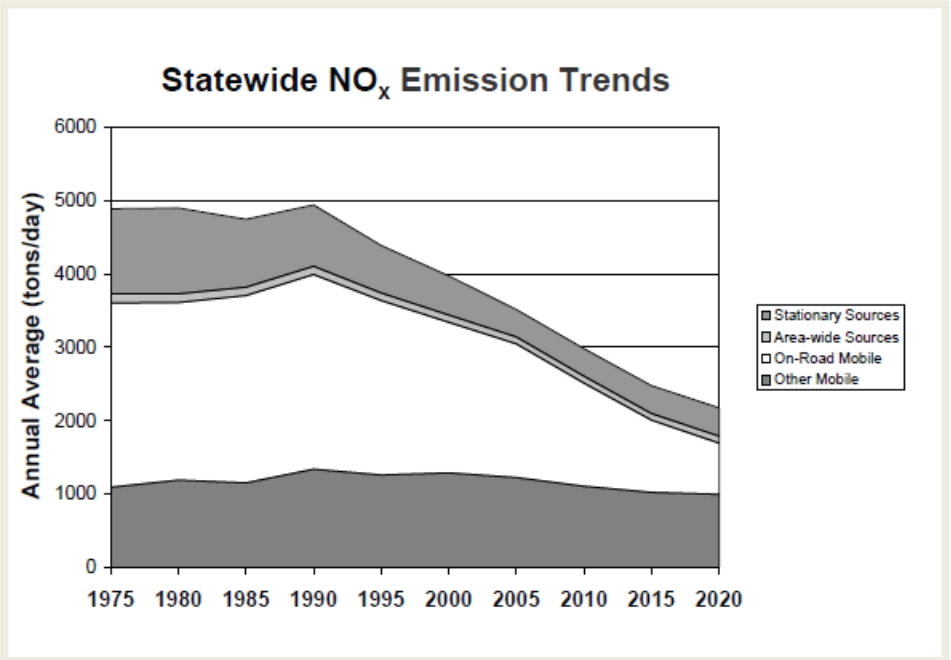
2d Ozone Precursor—Nitrogen Oxides: Sources, Standards, and Control Measures Adopted

Nitrogen Oxides—a group of gaseous compounds of nitrogen and oxygen, many of which contribute to the formation of ozone, PM_{10} and $PM_{2.5}$.

Most nitrogen oxide is produced by the combustion of fuels. Mobile sources make up about 85% of total statewide NO_X emissions.[65] NO_X emission standards for on-road motor vehicles were introduced in 1971 and followed with increasingly stringent standards and the introduction of three-way catalytic convertors. These standards resulted in a decline in NO_X emissions from on-road vehicles by 23% from 1990 to 2000.[66] CARB projects NO_X emissions will decrease by 66% between 2000 and 2020.[67] This continuing decline is due to vehicles meeting more stringent emission standards as they enter the fleet, and that all vehicles use cleaner-burning gasoline and diesel fuel or alternative fuels.[68]

Stationary source NO_X emissions also fell by 68% between 1980 and 2005.[69] This decrease is largely due to switching from fuel oil to natural gas and the implementation of combustion controls for boilers and catalytic converters for stationary sources.[70]

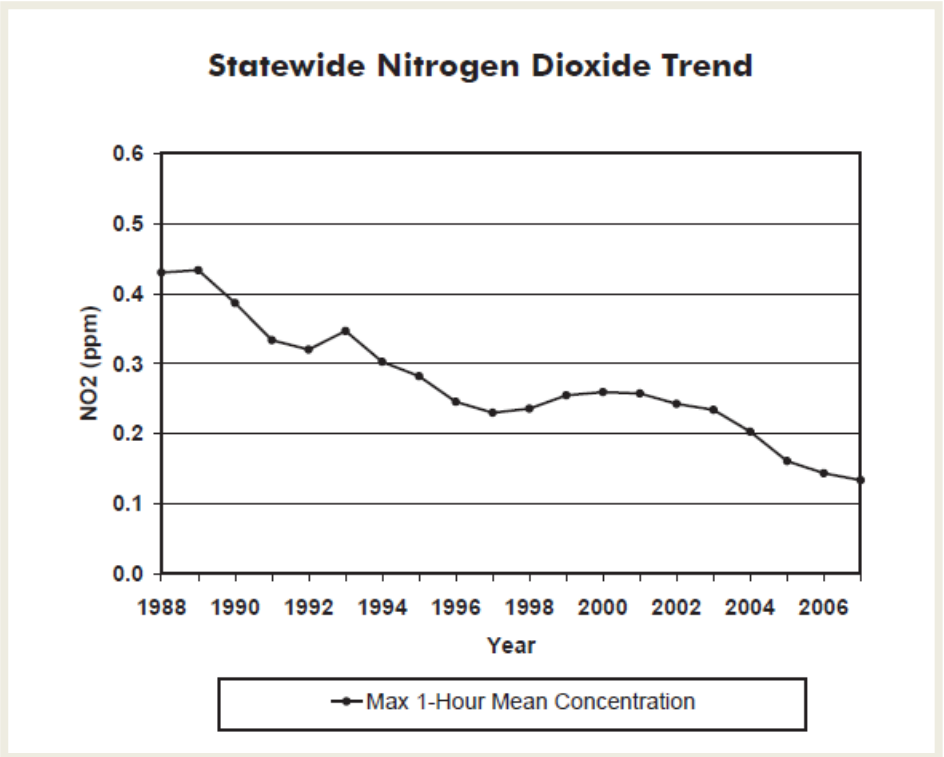
Total NO_X emissions from other mobile categories decreased from 1990 to 2020 with off-road equipment showing the largest decrease.[71] However, emissions from ships have risen, reflecting increased shipping activity.



Source: California Air Resources Board,
The California Almanac of Emissions and Air Quality, 2009 Edition, p. 3-20.

2e Ozone Precursor—Nitrogen Dioxide: Sources, Decreasing Emissions Trend, and Control Measures Adopted

Nitrogen Dioxide—a colorless, tasteless gas that can cause lung damage and respiratory infection. It is a component of NO_X and its presence in the atmosphere indicates emissions of NO_X. It is a by-product of combustion processes.[72] Since 1988 maximum NO_2 concentrations have decreased more than 76%, due primarily to tighter controls on both mobile and stationary sources.[73] Although many of these measures were implemented to reduce ozone, they also benefited NO_2.[74] All areas in California have reached the state and national NO_2 standards.[75]



Source: California Air Resources Board,
The California Almanac of Emissions and Air Quality, 2009 Edition, p. 3-21.

2f Ozone and Nitrogen Dioxide Health Risk

Ozone Health Risk

Exposure to this pollutant can damage the tissues of the respiratory tract, causing inflammation and irritation, and can result in coughing, chest tightness, and worsening of asthma symptoms.[76] Children, adolescents, and adults who exercise and work outdoors, where ozone concentrations are the highest, are at the greatest risk of harm from this pollutant.[77]

Nitrogen Dioxide Health Risk

NO_2 has short-term health effects at exposures, ranging from 30 minutes to 24 hours.[78] Adverse health effects include increased asthma symptoms and increased respiratory illnesses and symptoms.[79] Increased hospital admissions, particularly among children, asthmatics, and the elderly, are associated with short-term exposure.[80]

Nitrogen dioxide is becoming an increasing health concern in indoor events where the average person spends most of his or her time.[81] Indoor sources of this compound include gas appliances and unvented heating systems.

2g Ozone Precursor — Reactive Organic Gases (ROGs): Sources

Reactive Organic Gases (ROG) — Volatile Organic Compounds (VOCs) that are photochemically reactive and contribute to the formation of ozone.

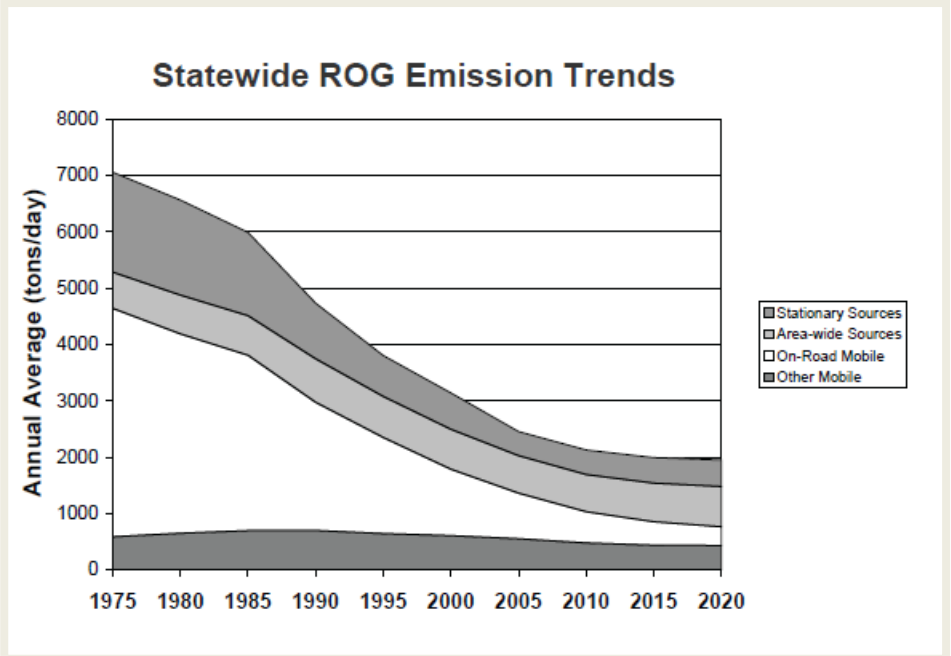
ROGs primarily come from incomplete fuel combustion and evaporation of chemical solvents and fuels.[82] On-road mobile sources are the largest contributor to statewide emissions. [83] Stationary sources include processes that use solvents, such as dry cleaning, degreasing, and coating, and petroleum-related processes such as petroleum refining and marketing. ROGs from petroleum marketing are evaporative emissions associated with activities like marine loading and unloading of

fuels, gasoline cargo tanks, and gasoline dispensing.[84] Area-wide ROG sources include consumer products, pesticides, aerosol and architectural coatings, asphalt, paving, and roofing, farming, and other evaporative emissions.[85]

2h ROG Decreasing Emissions Trend and Control Measures Adopted

ROG emissions are projected to decrease by over 72% between 1975 and 2020, largely due to CARB's on-road motor vehicle emission control program.[86] This program includes the use of improved evaporative emissions control systems, computerized fuel injection, engine management systems designed to meet increasingly stringent California emission standards, cleaner gasoline, and the Smog Check program.[87]

CARB projects ROG emissions from other mobile sources will decline between 1990 and 2020 as it implements tougher emission standards.[88] The vapor recovery program for area-wide sources such as service stations, bulk plants, and other fuel distribution operations has led to significant reductions in emissions.[89] Other on-going programs are aimed at reducing ROG emissions from coatings, consumer products, cleaning and degreasing solvents, and other substances used within California.[90]



Source: California Air Resources Board,
The California Almanac of Emissions & Air Quality, 2009 Edition, p. 3-5.

Appendix 3.
Particulate matter (PM_{10} and $PM_{2.5}$): Characteristics, Sources, and Standards

3a Characteristics: a mixture of particles and droplets of varying sizes and chemical composition.

All particles with a diameter of 10 microns or smaller (PM_{10}) are harmful.[91] By comparison, the diameter of a human hair is about 50 to 100 microns.[92] PM_{10} includes a subgroup of finer particles with a diameter of 2.5 microns or smaller.

3b Sources

Generally, combustion processes emit and form fine particles, whereas particles from dust sources tend to fall in the coarse range. Combustion sources include trucks, passenger cars, off-road equipment, industrial processes, residential wood burning, forest/agricultural burning.[93]Dust sources include paved and unpaved roads, construction, mining, and agricultural activities. Ammonia sources include livestock operations, fertilizer application, and motor vehicles.[94]

3c PM_{10} and $PM_{2.5}$ Standards

In 1982, CARB adopted 24-hour average and annual average PM_{10} standards,[95] five years ahead of the US EPA's decision to adopt national ambient air quality standards for PM_{10} in 1987. California's PM_{10} standards, however, are more health-protective.[96]

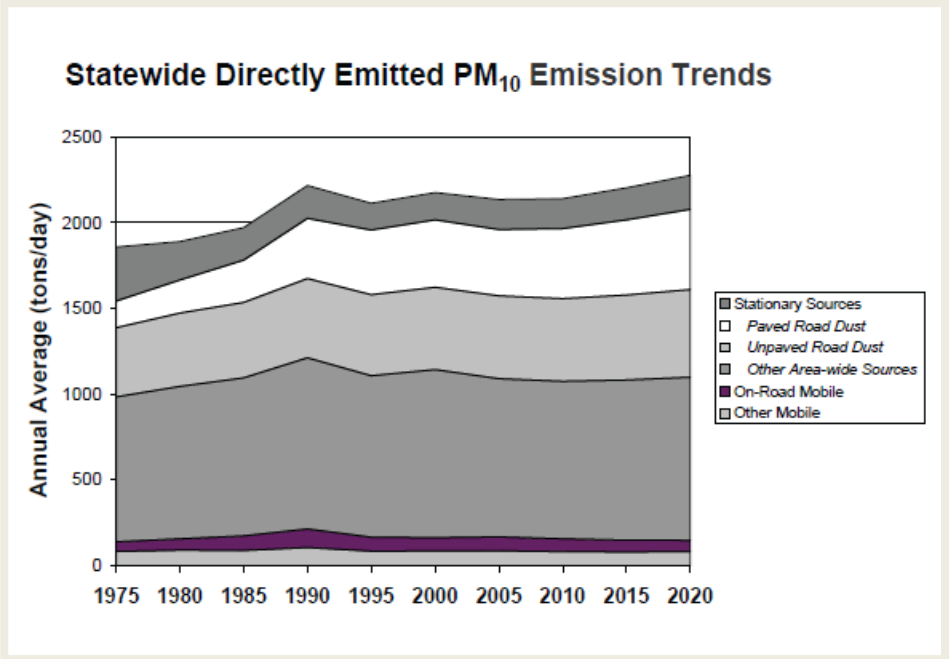
In June 2002, CARB lowered the level of the state PM_{10} annual standard again from 30 micrograms per cubic metre to 20 micrograms per cubic metre and established a new annual $PM_{2.5}$ standard of 12 micrograms per cubic metre.[97]

In 2006, the US EPA strengthened the 24-hour $PM_{2.5}$ standard to 35 micrograms per cubic metre from 65 micrograms in 1997.[98]

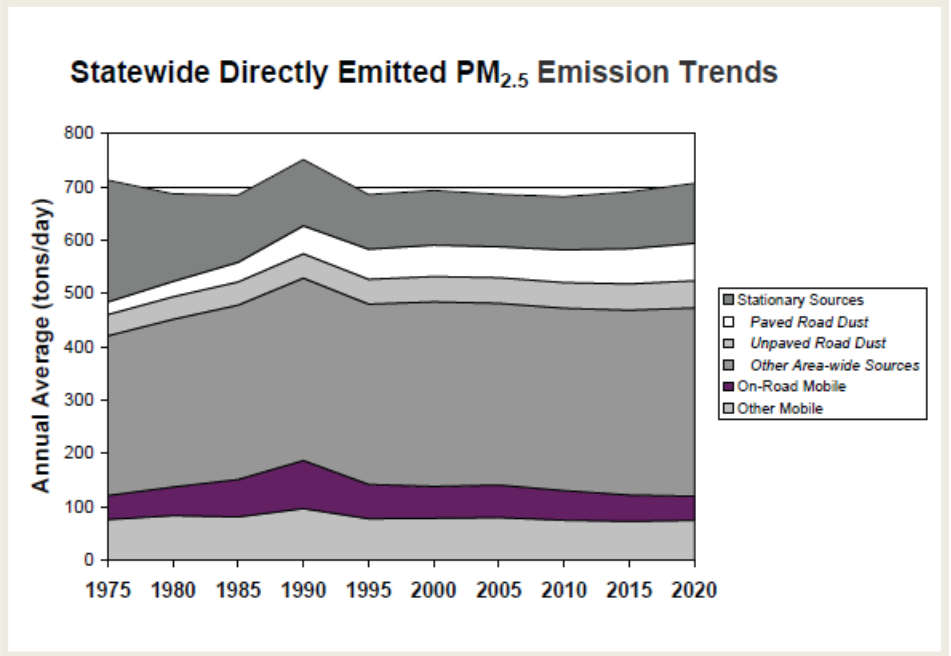
3d PM_{10} - Increasing Emissions and Control Measures Adopted

Despite the continuous strengthening of PM_{10} standards, emissions continued to increase between 1975 and 1990. Emissions from paved road and dust more than doubled between 1975 and 2000. Unpaved road dust emissions also generally increased through the same period.[99] The growth in emissions of paved and unpaved road dust are due to increases in the vehicle traffic traveling on the roads.[100]

Meanwhile, exhaust emissions from diesel mobile sources dropped by 38% from 1990 to 2000 due to more stringent emissions standards and the introduction of cleaner-burning fuel.[101] PM_{10} emissions from stationary sources are expected to increase slightly in the future due to industrial growth.[102]



Source: California Air Resources Board,
The California Almanac of Emissions & Air Quality, 2009 Edition, p. 3-12.



Source: California Air Resources Board,
The California almanac of Emissions & Air Quality, 2009 Edition, p. 3-13.

3e $PM_{2.5}$ – Increasing Emissions and Control Measures Adopted

$PM_{2.5}$ emissions decreased from 1975 to 1980 as a result of reduced stationary source emissions0.[103] Emissions rose slightly between 1980 and 1990, remained steady through 2010, and are projected to increase after 2010. Like PM_{10}, emissions from paved road dust more than doubled between 1975 and 2000, while unpaved road dust emissions increased as well during the forecast period.[104] Heavier vehicle traffic was responsible for the increase in emissions of unpaved and paved road dust.[105]

$PM_{2.5}$ emissions from stationary sources are expected to increase slightly in the future due to industrial growth.[106]

CARB has developed a list of over 100 control measures to reduce particulate matter emissions from a broad spectrum of mobile and stationary sources.[107] These include residential wood combustion and outdoor greenwaste burning, paved and unpaved roads and construction, combustion sources such as boilers and heaters, solvents and coatings, product manufacturing.

3f PM Research

Given CARB's projected increase in PM_{10} and $PM_{2.5}$ emissions--over 99% of Californians live in air basins with concentrations that violate state PM_{10} standards at least part of the year[108]--CARB and EPA scientists are actively researching alternative methods of measuring particulates. They are examining the health implications of measuring particulates by count (number) or by mass (weight). Fine particles don't have much mass but are especially prejudicial to health because they can penetrate deep into the lungs and circulatory system. Currently, particulate emissions in motor vehicle exhaust in the US are based on mass, while in Europe, they are measured by particulate count.[109]

> *CARB has no current plans to update the existing standard. However, if the scientists examining the issue determine it would be beneficial to public health and there is a logic to adopting another method, then, based on scientific evidence, the agency would make that recommendation. Before that step is taken a lot of evidence is pulled together and a rationale is established. It is not done overnight. It is a very democratic process that takes about a year.*
>
> Dimitri Stanich, Information Officer, CARB

If CARB were to move in that direction, the agency would follow its standard procedure of collecting data, holding workshops, and soliciting comments from all constituencies before writing a final report for the board. The board may then then approves or reject the proposal, or request more study.

3g Health Risk (PM_{10} and $PM_{2.5}$)

Exposure to PM exacerbates respiratory illnesses and may even cause early death in people with existing heart and lung conditions.[110] $PM_{2.5}$ poses a greater health risk than PM_{10} because the particles can be deposited deep in the lung and contain substances that are particularly harmful to human health.[111] $PM_{2.5}$ exposure is linked to emergency room visits and hospitalizations of persons with heart disease.[112] Long-term exposure to $PM_{2.5}$ may impair lung function and growth in children, produce respiratory symptoms, and even lead to the development of asthma.[113] Short-term PM_{10} exposure may cause lung inflammation, coughing, shortness of breath, and chest pain with inhalation. Studies also correlate deaths of people with heart disease during episodes of high PM concentrations.[114]

Appendix 4. Sulphur Dioxide

Sulphur dioxide - a strong smelling, colourless gas formed by the combustion of fossil fuels.

4a Sources

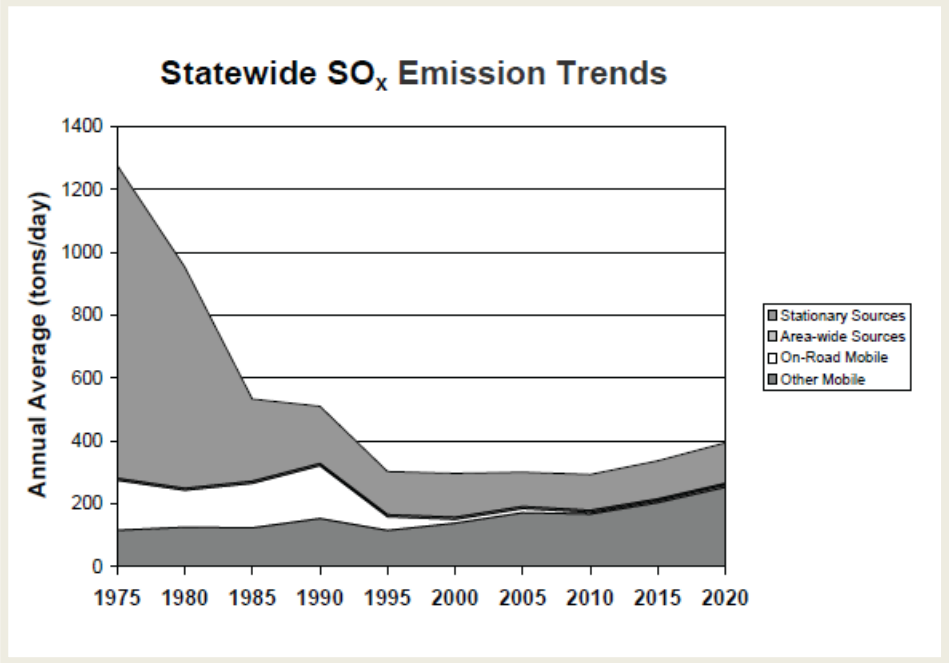
Power plants which use coal or oil with a high sulphur content can be a major source.

4b Sulphur Dioxide, Sulphur Oxide: Emissions Decreasing and Control Measures Adopted

A major constituent of sulphur oxide (SO_x) is sulphur dioxide (SO_2). SO_x emissions in 2005 plummeted 76% from emissions in 1975.[115] SO_2emissions from stationary sources decreased between 1975 and 2005 largely because of improved industrial source controls and switching from fuel oil to natural gas for electric generation and industrial boilers.[116] Lower sulphur content in the fuel for land-based on and off-road gasoline and diesel-fueled engines has also contributed to the decline in SO_X emissions. [117]

Beginning in 2006 CARB also enacted regulations to reduce the sulphur content in fuel used by commercial harbor craft such as tug boats and fishing vessels.[118]

However, SO_X emissions are expected to increase due to the growth in shipping activities especially ocean-going ships, which use high-sulphur fuels.[119] CARB recently adopted a regulation for fuels used in ship auxiliary engines that will help counter this trend.[120]



Source: California Air Resources Board,
The California Almanac of Emissions & Air Quality, 2009 Edition, p. 3-19.

4c Health Risk—Sulphur Dioxide

Short-term exposures, from five minutes to 24 hours, can lead to adverse respiratory effects, including coughing, pain on inhalation, breathing difficulty during exercise, and increased asthma symptoms.[121] Studies show a connection between short-term exposure and increased visits to emergency departments and hospital admissions for respiratory illnesses.[122]

Appendix 5. Toxic Air Contaminant (TAC) Emissions

Of the almost 200 compounds California has designated as TACs[123], this report discusses only diesel particulate matter, the one that poses the greatest health risk to California.

5a **Health Risk:** CARB assesses the health risk of the TACs on an individual basis as well as cumulatively with a focus on cancer risk.[124] CARB expresses the health risk of TACs in terms of number of excess cancer cases per million people exposed over a 70-year period.[125]

5b **Diesel Particulate Matter:** First on the list, this is a carcinogen that most researchers believe contributes the majority of the health risk because the particles in the exhaust carry many harmful organic compounds and metals.[126]

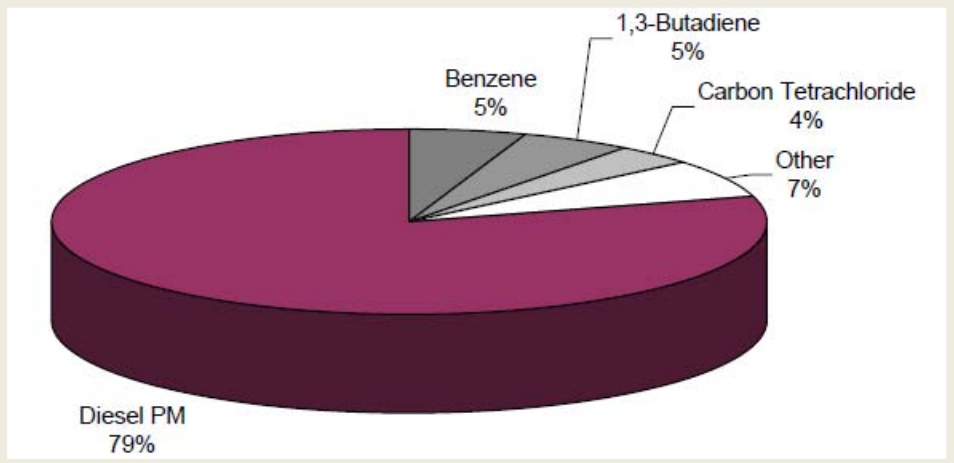
Sources: On-road diesel-fueled vehicles contribute approximately 38% of the statewide total, with an additional 60% attributed to other mobile sources, including construction and mining equipment, agricultural equipment, and refrigerated transport units.[127]

Health risk: Although there is no routine method for monitoring ambient concentrations of diesel PM—the monitoring technology does not yet exist to isolate this pollutant -- emissions and modeled ambient concentrations indicate that diesel PM has a higher health risk than all other TACs combined, and this poses the most significant risk to California's citizens.[128] CARB estimates that 79% of the known statewide cancer risk from the top 10 outdoor air toxics is attributable to diesel PM.[129]

Projected emissions decrease and control measures: The estimates for 2000 show a 40% drop from 1990, with a concentration of 1.8 micrograms per cubic metre and an associated health risk of 540 excess cancer cases per million people. The Diesel Risk Reduction Plan is expected to reduce concentrations by 85% by 2020.[130] Without implementing this plan, concentrations are estimated to drop by only 33% in 2020 from 2000 levels.[131]

However, the key elements of the plan are to clean up existing engines through engine retrofit emission control devices, to adopt stringent standards for new diesel engines, and to lower the sulphur content of diesel fuel to protect new, advanced technology emission control devices on diesel engines.[132] In addition, CARB continues to promote the use of alternative fuels and electrification.[133]

2007 Statewide Health Risks



Data for Diesel PM reflect 2000; carbon tetrachloride reflect 2003: "Other" only includes acetaldehyde, formaldehyde, para-dichlorobenzene, hexavalent chromium, perchloroethylene, and methylene chloride. This pie chart is based upon ambient monitoring for the top 10 TACs. The statewide number of excess cancer cases per million people over a 70-year, lifetime exposure is 680 for the year 2007.

Source: California Air Resources Board,
The California Almanac of Emissions & Air Quality, 2009 Edition, p. 5-5.

Appendix 6. Studies of Health Effects from Key Pollutants

Thousands of studies have documented the nature and extent of the harm poor air quality causes. This report presents a few highlights:

6a CARB Administers Active Research Program Involving Health Effects Linked with Air Pollution

CARB has an active research program to investigate the health effects associated with air pollution exposure, particularly in people that may be more sensitive to air pollution effects such as children and the elderly.[134] It does research in eight different areas—children's health, children's exposure, asthma/respiratory health, cardiovascular health, indoor health, particulate matter health effects, immune effects and exposure, and community health.

6b Children's Health Study Shows Clear Link between Air Pollution and Respiratory Illnesses

One of the most comprehensive studies done on the impact that air pollution has on human health is the Children's Health Study led by the Univ. of Southern California. Begun in 1992, it was a large, long-term study of the effects of chronic air pollution exposure on the health of children living in southern California. It documented about 5,500 children in 12 communities from when they were about 10 years old until they were 18. It is an extensive compilation of more than 10 years of community ambient air pollution measures and health outcomes related to lung function, growth, asthma, bronchitis, and acute respiratory illnesses.[135]

Researchers investigated the health impact, especially chronic respiratory conditions, of the following four pollutants: ozone, nitrogen dioxide, acid vapor, and particulate matter (PM_{10} and $PM_{2.5)}$. Later in the study, carbon monoxide and other oxides of nitrogen and ultrafine PM (with counts of particles smaller than 1 micrometre in diameter) were added to the study.[136]

A landmark study because of the duration of time it covered, it produced several significant results:

- Children exposed to higher levels of particulate matter, nitrogen dioxide, acid vapor, and elemental carbon had significantly lower lung function at age 18, an age when the lungs are nearly mature and lung function deficits are unlikely to be reversed.[137]
- Children exposed to current levels of air pollution had significantly reduced lung growth and development when exposed to higher levels of acid vapor, ozone, nitrogen dioxide, and PM.[138]
- Children living in high ozone communities who actively participated in three or more sports were more likely to develop asthma than children not participating in sports.[139]
- Children living in communities with higher concentrations of NO_2, PM, and acid vapor had lungs that both developed and grew more slowly and were less able to move air through them.[140] Decreased lung development may lead to chronic respiratory illness in adulthood.
- Days with higher ozone levels resulted in significantly higher school absences due to respiratory illnesses, more asthma incidences, and lower birth weights.[141] Children with asthma who were exposed to higher concentrations of particulate matter were much more likely to develop bronchitis.[142]

6c CARB Study Says PM2.5 Responsible for 9,200 Premature Deaths Each Year

Based on recent EPA methodology, a CARB report in 2010 said that approximately 9,200 people die annually due to exposure to fine particulate pollution in California's air.[143] CARB based its finding on scientific assessments completed by the US EPA. These assessments were required as part of the

federal agency's periodic review of national air quality standards for $PM_{2.5}$ every five years.[144] The US EPA concluded that exposure to $PM_{2.5}$ has a causal link to premature mortality[145]—the highest level of scientific certainty.

The US EPA review was followed by another related risk assessment report estimating premature deaths nationwide from exposure to $PM_{2.5}$. Those estimates were based on a study involving 500,000 people and 116 US cities, including Los Angeles and Fresno.[146]

CARB applied the same EPA methodology statewide using California-specific data to estimate the number of premature deaths linked to this pollution.

ENDNOTE

[1] The American Lung Association, "Most Polluted Cities," http://www.stateoftheair.org/2011/city-rankings/most-polluted-cities.html

[2] California Air Resources Board, "ARB Mission and Goals," http://www.arb.ca.gov/html/mission.htm.

[3] Personal Communication, Antonio Miguel, Air Pollution Specialist, Haagen-Smit Laboratory-M & L Division, CARB.

[4] California Air Resources Board, "Members of the Air Resources Board," http://www.arb.ca.gov/board/about.htm

[5] Ibid.

[6] California Air Resources Board, "Brief History of Air Resources Board," http://www.arb.ca.gov/knowzone/history.htm

[7] Personal communication. Dr. Anupom Ganguli, Assistant Deputy Executive Officer, of the South Coast Air Quality Management District.

[8] California's largest air quality management district, SCAQMD is the regional government agency responsible for air pollution control in Los Angeles and Orange counties and parts of Riverside and San Bernardino counties. It covers 40% of the state's population with nearly 17 million people.

[9] The SCAQMD's board has 13 members, 10 of whom are elected officials from the local counties and the city council officials. The remaining three are appointed by state-elected officials—the governor, the Speaker of the State Assembly, and by the State Senate Rules Committee.

[10] Governor's Budget 2011-12, "Entire Air Resources Budget," http://www.ebudget.ca.gov/StateAgencyBudgets/3890/3900/department.html.

[11] A significant portion of the South Coast budget comes from fees paid by businesses that pollute heavily, with the biggest polluters paying the most toward funding air pollution control. (www.aqmd.gov/finn/financialinformation.htm) Businesses must also pay annual fees for permits.

Approximately 73% of this district's revenues are generated by a system of fees—evaluation fees, annual operating fees, emission fees, penalties/settlements/investment, and hearing board fees. About 27% comes from federal grants, CARB, and state motor vehicle fees.

Although the South Coast focuses on emissions from stationary sources, motor vehicles account for more than two-thirds of this region's pollution problem. (www.aqmd.gov/finn/financialinformation.htm) Beginning in 1991, SCAQMD added a surcharge to this region's vehicle registration fees to help fund air pollution control efforts. The surcharge consists of a $4 per vehicle state fee and an additional $1 per vehicle district-wide fee. The SCAQMD uses a portion of the $4 fee to promote ride-sharing, to develop clean fuels, and fund programs that reduce vehicle emissions.

[12] Ibid.

[13] Personal communication. Dimitri Stanich, Information Officer, CARB

[14] "Key Events in the History of Air Quality in California," http://www.arb.ca.gov/html/brochure/history.htm, personal communication, Dimitri Stanich, California Air Resources Board.

[15] California Air Resources Board, "Key Events in the History of Air Quality in California," http://www.arb.ca.gov/html/brochure/history.htm

[16] California Air Resources Board, "Milestones in California's Emission Control Program," *the California Almanac of Emissions & Air Quality*, 2009 Edition, p. 1-41.

[17] Ibid.

[18] California Air Resources Board, "Key Events in the History of Air Quality in California, http://www.arb.ca.gov/html/brochure/history.htm

[19] Ibid.

[20] California Air Resources Board, "Chap. 5: Toxic Air Contaminant Emissions, Air Quality, and Health Risk," *The California Almanac of Emissions & Air Quality,* 2009 Edition, p. 5-45.

[21] California Air Resources Board, "Key Events in the History of Air Quality in California, http://www.arb.ca.gov/html/brochure/history.htm

[22] Ibid.

[23] Ibid.

[24] Ibid.

[25] "Key Events in the History of Air Quality in California," http://www.arb.ca.gov/html/brochure/history.htm

[26] Ibid.

[27] Ibid

[28] California Air Resources Board, "Key Events in the History of Air Quality in California," http://www.arb.ca.gov/html/brochure/history.htm

[29] California Air Resources Board, "Brief History of Air Resources Board," http://www.arb.ca.gov/knowzone/history.htm

[30] Personal communication. David Pettit, Senior Attorney, Natural Resources Defence Council

[31] Personal communication. Dr. Anupom Ganguli SCAQMD

[32] Personal communication. Dr. Antonio Miguel, air pollution specialist, CARB Haagen-Smit Laboratory, El Monte, CA.

[33] Ibid. p. 1-15.

[34] Ibid.

[35] Ibid., p. 1-18.

[36] Ibid., p. 1-19.

[37] Barringer, Felicity, "California Judge Calls Time Out for Climate Change Law," http://green.blogs.nytimes.com/2011/03/22/california-judge-calls-time-out-for-climate-change-law/?ref=californiaairresources

[38] Ibid.

[39] Personal communication. David Pettit, Senior Attorney, Natural Resources Defence Council.

[40] Personal communication. Dimitri Stanich, Information Officer, CARB.

[41] South Coast Air Quality Management District, "Air Quality," *Budget and Work Program, Fiscal Year 2010-2011*, www.aqmd.gov/finn/pdf/finalbudget1011.pdf, p. 11.

[42] California Air Resources Board, "Chapter 1: Introduction," *The California Almanac of Emissions & Air Quality, 2009 Edition*, p. 1-12.

[43] Ibid.

[44] Ibid.

[45] California Air Resources Board, "Chapter 1: Introduction," *The California Almanac of Emissions & Air Quality, 2009 Edition,* p. 1-5.

[46] Ibid, p. 5-2.

[47] Ibid.

[48] Ibid. p. 1-12

[49] Ibid.

[50] Ibid.

[51] Ibid.

[52] Ibid.

[53] Ibid., p. 1-19.

[54] Ibid., p. 2-16.

[55] Ibid., p. 1-7.

[56] Ibid.,

[57] Ibid.,

[58] Ibid., p. 3-7.

[59] Ibid.

[60] Ibid.

[61] Ibid.

[62] Ibid.

[63] Ibid.

[64] Ibid., p. 3-7.

[65] Ibid., p. 2-12.

[66] Ibid., p. 3-4.

[67] Ibid.

[68] Ibid.

[69] Ibid.

[70] Ibid.

[71] Ibid.

[72] Ibid., p. 3-20.

[73] Ibid., p. 3-21

[74] Ibid.

[75] Ibid.

[76] California Air Resources Board, "Facts about Ozone and Health," www.arb.ca.gov/research/aaqs/caaqs/ozone/ozone-fs.pdf, p. 1.

[77] Ibid.

[78] California Air Resources Board, "200 Emissions and Effects: 202.5 Nitrogen Dioxide," http://www.arb.ca.gov/cap/manuals/cntrldev/emissions_effects/200emission.htm#no2.
[79] Ibid.
[80] Ibid.
[81] Ibid.
[82] California Air Resources Board, "Current Emissions and Air Quality—Criteria Pollutants," *The California Almanac of Emissions & Air Quality, 2009 Edition, p*. 2-12.
[83] Ibid.
[84] Marketing means the distribution and transmission from retailer to consumer.
[85] California Air Resources Board, "Current Emissions and Air Quality—Criteria Pollutants," *The California Almanac of Emissions & Air Quality, 2009 Edition, p*. 2-12.
[86] Ibid., p. 3-5.
[87] Ibid.
[88] Ibid.
[89] Ibid.
[90] Ibid.
[91] California Air Resources Board, "Chapter 1: Introduction," *The California Almanac of Emissions & Air Quality, 2009 Edition*, p. 1-21.
[92] Ibid.
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[94] Ibid.
[95] Ibid.
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[101] Ibid.
[102] Ibid.
[103] Ibid., p. 3-13
[104] Ibid.
[105] Ibid.
[106] Ibid.
[107] California Air Resources Board, "Fact Sheet on SB 656, Reducing Particulate Matter in California," http://www.arb.ca.gov/pm/pmmeasures/pmmeasures.htm
[108] Ibid., p. 3-14.
[109] Personal communication. Karen Magliano, Chief, Air Quality Data Branch, CARB
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[111] Ibid.
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[113] California Air Resources Board, "200 Emissions and Effects: 202.2 Particulate Matter, Health Effects," http://www.arb.ca.gov/cap/manuals/cntrldev/emissions_effects/200emission.htm#no2.
[114] Ibid.
[115] California Air Resources Board, "Chapter 3: Statewide Trends and Forecasts—Criteria Pollutants," *The California Almanac of Emissions & Air Quality, 2009 Edition*, p. 3-19.
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[117] Ibid.
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[120] Ibid.
[121] California Air Resources Board, "200 Emissions and Effects: 202.6 Sulphur Dioxide," http://www.arb.ca.gov/cap/manuals/cntrldev/emissions_effects/200emission.htm#so2.
[122] Ibid.
[123] Ibid., p. 5-2.
[124] Ibid.
[125] Ibid., p. 5-3.
[126] Ibid., p. 5-42.
[127] Ibid., p. 5-44.

[128] Ibid.
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[130] Ibid., p. 5-45.
[131] Ibid.
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[133] Ibid.
[134] California Air Resources Board, "Health Effects of Air Pollution," http://www.arb.ca.gov/research/health/health.htm.
[135] California Air Resources Board, "Overview of the Children's Health Study," http://www.arb.ca.gov/research/chs/over.htm.
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[142] Ibid.
[143] 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, http://www.arb.ca.gov/research/health/pm-mort/pm-report_2010.pdf, p. 1.
[144] California Air Resources Board, "Fine Particle Air Pollution Responsible for 9,000 Premature Deaths in California Each Year, http://www.arb.ca.gov/newsrel/newsrelease.php?id=149.
[145] Note 143
[146] Ibid.

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