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Air Quality Planning and California's Changing Climate

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Summary

California is home to some of the worst air quality in the nation, notably in the San Joaquin Valley and South Coast air basins. Ninety percent of the state's population lives in areas that are out of attainment with at least one of the federal air quality standards, which are designed to be protective of human health.

Climate change will likely make it more difficult to meet air quality standards in the future. Emission reduction measures that appear sufficient to bring a region into attainment under current conditions could be insufficient in the future, necessitating additional emission reductions. These additional reductions and the associated cost are known as the "climate penalty."

Through a process known as air quality planning, state and regional agencies are responsible for demonstrating to the US Environmental Protection Agency how California will come into compliance with federal air quality standards. Air quality planning involves the quantification of the emission reductions necessary to bring a region into compliance, the identification and design of programs to achieve those reductions, and the demonstration of compliance through modeling.

Climate change will pose challenges for air quality planning because of the climate penalty as well as the potential increase in extreme events that could result in unhealthy air quality. Planners can become better prepared to face these challenges by proactively working to quantify the climate penalty for their regions and improving their understanding of the impact of extreme events on air quality.

However, limitations in regulatory authority could impede measures to improve preparedness. If additional emission reductions are needed to overcome the climate penalty, regional air quality planning agencies will likely have to look to state and federal programs to achieve additional emission reductions and design creative programs to achieve emission reductions from sources that fall outside of their traditional realm of responsibility. In addition, there are potential conflicts between emission reduction programs designed to address climate change and those needed to achieve air quality standards. If greenhouse gas emission restrictions are strictly regulated in the future, it could become more difficult to achieve additional reductions of emissions that are targeted for air quality. Finally, the current federal planning process is quite legalistic and bureaucratic, which could discourage air districts that would like to incorporate climate change into the planning process.

Despite these constraints, air quality planning appears to be in a better position than other sectors faced with climate-related challenges. Although meeting air quality standards will likely become more difficult and more expensive if additional emission reductions are needed, this does not look to be an impossible task. With appropriate preparation, state and regional agencies can position themselves to account for changes and to respond effectively to extreme events.

Acronyms

BAAQMD	Bay Area Air Quality Management District
CAPCOA	California Air Pollution Control Officers Association
CARB	California Air Resources Board
CCOS	Central California Ozone Study
CEQA	California Environmental Quality Act
GHG	greenhouse gas
NAAQS	National Ambient Air Quality Standards
NOx	oxides of nitrogen
NRC	National Research Council
PM	particulate matter
SB	Senate Bill
SIP	State Implementation Plan
USEPA	United States Environmental Protection Agency

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Introduction

California is home to two of the regions with the worst air quality in the nation – the San Joaquin Valley and the South Coast Air Basins. Although significant progress has been made over the past 25 years in reducing the number of days in violation of air pollution standards and the emissions that cause air pollution, these two regions are still far from being in attainment with air quality standards. Air quality problems plague other parts of the state as well: As of August 2007, 35 of California's 58 counties were designated non-attainment areas for the federal eight-hour ozone standard (United States Environmental Protection Agency, 2007). Climate change will likely pose additional challenges to state and regional air quality regulators as they work to attain air quality standards.

Thanks in part to the extent of existing air quality problems, California's state and local agencies are leaders in designing policies to reduce emissions. California's regulations have often served as a model for federal regulations. The California Air Resources Board (CARB), the state agency responsible for demonstrating compliance with federal air quality standards, is viewed as an international leader in air pollution science and policy. Many of the state's regional air districts, like the South Coast Air Quality Management District, have received international recognition for their leadership as well.

In addition to this leadership on air pollution, California has recently undertaken an ambitious effort to reduce greenhouse gas (GHG) emissions. In 2006, the governor signed the California Global Warming Solutions Act of 2006, which requires the state to reduce greenhouse gas emissions to 1990 levels by 2020. Much of the justification for this effort has been the potential impact that global warming could have on the state's already severe air quality problems and the associated public health effects (California State Legislature, 2002; Schwarzenegger, 2005; California State Legislature, 2006).

For the purposes of this report, the term *air quality planning* refers to the demonstration of compliance with federal air quality standards. The US Environmental Protection Agency (USEPA) sets standards for six "criteria" air pollutants: ozone, particulate matter (PM), nitrogen dioxide, sulfur dioxide, lead, and carbon monoxide. Among the six, ozone and PM pose the most widespread air quality problems. Ozone can lead to lung irritation, can exacerbate existing conditions such as asthma, and can lead to permanent lung damage. Exposure to ozone has also been shown to cause asthma in children (McConnell et al., 2002). Particulate matter is a mixture of small particles and liquid droplets in the air that are made up of a variety of compounds including acids, metals, organic compounds, and dust. Particulate matter can penetrate the lungs and aggravate existing conditions such as asthma and cause respiratory irritation and decreased lung function. Particulate matter pollution has also been linked to premature death in people with heart and lung disease.

Air quality planning is a formal exercise that ensues following the designation of an area in non-attainment with one of the criteria air pollution standards. Depending on the severity of the problem, a designated region is assigned an attainment deadline, with later deadlines for regions with more serious air quality problems. This report focuses on planning for attainment of the federal eight-hour ozone standard, as the majority of scientific analysis has focused on ozone pollution. Some of the findings are likely applicable to other pollutant standards as well, including particulate matter.

This report begins with an overview of the impacts that climate change could have on air quality in California and the challenges that this poses for air quality planners. This is followed by a discussion of ozone air quality conditions in the state and the relationship to temperature. The report concludes with a discussion of adaptation opportunities and constraints for the air quality planning process. An appendix provides an overview of the process for demonstrating attainment with federal air quality standards.

1. **Impacts of Climate Change on Regional Air Quality**

A changing climate will likely make it more difficult to meet air quality standards, particularly for ozone. Local air districts and CARB will need to identify additional emission reduction programs to overcome what is known as the "climate penalty" – the additional emission reductions and associated costs required to meet air quality standards in face of climate change. In addition, state and local agencies will need to reconcile programs to reduce greenhouse gas emissions with efforts to meet air quality standards when these goals conflict. The challenges fall into two categories: technical factors associated with climate change and institutional obstacles that can affect the ability to respond. We discuss each of these in turn.

Technical Challenges for Air Quality Planners

Analysis of the effects of climate change on air pollution have shown that climate change is likely to lead to an increase in the severity and duration of air pollution episodes (Mickley et al., 2004; Mickley, 2007). Air pollution levels can be affected by several direct and indirect effects of climate change: (i) increased temperature, (ii) changes in biogenic emissions (e.g., emissions from vegetation), (iii) changes in chemical reaction rates, (iv) changes in atmospheric conditions that affect pollutant mixing, and (v) changes in the atmospheric flows that affect pollutant transport (Hogrefe et al., 2004). In addition, behavioral responses to climate change could result in an increase in emissions, for instance through increased energy demand during heatwaves (Franco and Sanstad, 2008). There are also feedbacks between air pollution and climate change, as some local air pollutants also have an effect on the climate. To date, most studies have focused on the impact of climate change on ozone levels, though some analyses have also focused on particulate matter.

Ozone

Ozone is not emitted directly, but is formed in the atmosphere through a series of chemical reactions involving hydrocarbons and oxides of nitrogen (NOx) that are driven by sunlight. The production of ozone is highly non-linear; it depends on meteorological conditions as well as local concentrations of ozone precursors. Reductions in either NOx or hydrocarbon emissions could result in an *increase* in air pollution, depending upon local conditions.

Ozone is likely to be sensitive to changes in temperature, mixing depths, the frequency in stagnant air episodes, and changes in weather patterns as a result of climate change (Mickley et al., 2004). In addition, ozone levels are sensitive to changes in biogenic emissions (Bell and Ellis, 2004; Steiner et al., 2006). Studies have found that the cumulative effects of these factors are complex and vary by region (Hogrefe et al., 2004; Mickley et al., 2004; Leung and Gustafson, 2005; Steiner et al., 2006; Bell et al., 2007; Mickley, 2007; Tagaris et al., 2007). For example, one analysis predicts that climate change will have a negative impact on air quality in Texas, while there will be a negligible or positive impact on air quality in the Midwest (Leung and Gustafson, 2005). Another analysis finds climate change will negatively impact air quality in the eastern United States (Murazaki and Hess, 2006). Most of these analyses do not account for future changes in the emission levels (i.e., the emission inventory). Therefore, while they provide an estimate of the effect of climate change assuming current levels of criteria pollutant emissions, they are not likely to be representative of future conditions in terms of emissions and growth.

Another factor that influences ozone concentrations over the long-term is the level of the global background ozone concentration – the concentration of ozone that would exist in US cities even with no anthropogenic (or human-caused) emissions within the US. The concentration of background ozone in the United States appears to be increasing (Lin et al., 2000). The sources of background ozone are primarily natural production and transport from regions outside the United States (Asia and Europe).[1] If emissions continue to increase in developing countries as predicted, the contribution of background ozone concentrations to local air pollution levels in the United States will likely increase (Fiore et al., 2002a). Increases in global background ozone concentrations could prolong the ozone season in the United States (Fiore et al., 2002b). On balance, the increase in global background ozone levels will reduce the effectiveness of local emission reduction measures and make it more difficult to attain air quality standards (Lin et al., 2000; Fiore et al., 2002a; Fiore et al., 2002b).

Climate Impacts on Ozone Concentrations in California

Several analyses have found that climate change could increase ozone levels in California. Meteorology and, specifically, temperature have a large influence on ozone levels in the state. One such analysis, looking at high ozone episodes under past conditions, shows that higher temperatures, increased background ozone levels, and increased mixing depths – all phenomena expected with climate change - generally increased surface ozone concentrations (Kleeman, 2008). [2]

Another study has predicted ozone levels in central California in 2050 using a regional air quality model that takes climate change impacts (e.g., temperature change and increased biogenic emissions) into account as well as future reductions in ozone precursor emissions (e.g., NOx and hydrocarbons) (Steiner et al., 2006). Incorporating future levels of precursor emissions is important, because these emissions are expected to decrease under existing air quality plans. The study projects that on balance, ozone levels would decrease by 3 to 9 percent when both climate change and precursor emission reductions are factored in. However, this reduction is less than the approximately 10 to 15 percent reduction that would have occurred in the absence of climate change.

The reduction in the estimated improvements in future air quality as a result of climate change is known as the "climate penalty" (Mickley, 2007). To attain air quality standards in the future, additional emission reductions will be required beyond those predicted using historical meteorological conditions, which is standard practice in air quality planning today.

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[1] The contribution from the upper atmosphere appears to be negligible (Fiore et al., 2002a). It is important to distinguish between ozone in the lower atmosphere (tropospheric ozone) and the ozone layer (stratospheric ozone). In the troposphere, ozone is a pollutant that has negative impacts on human health. Air quality standards are set to limit the levels of tropospheric ozone. Stratospheric ozone, on the other hand, forms a protective layer in the upper atmosphere that protects the earth from the sun's harmful rays. Significant efforts have focused on protecting the stratospheric ozone layer and reducing the "ozone hole."

[2] This analysis is known as a "perturbation study," which allows re-analysis of past high ozone episodes, with adjustments of individual meteorological variables using complex air quality models.

Particulate Matter

Fewer studies have examined the effect of climate change on PM pollution levels than on ozone levels. PM can be emitted directly, but is also formed in the atmosphere through a series of reactions that involve a variety of compounds including, NOx, ammonia, and sulfates. The effects of climate change on PM concentrations are difficult to determine because there are a number of interactions at work. A recent analysis suggests that climate change will likely increase fine PM concentrations in California, but that more work is needed to verify the result (Kleeman, 2008). This study builds on an earlier analysis that had suggested that climate change could have little net effect on PM concentrations because the interacting effects would cancel one another out (Aw and Kleeman, 2003).

Feedback between Air Pollution and Climate Change

There is not a one-way relationship between climate change and air pollution. Ozone is itself a greenhouse gas, and increases in ozone levels in the lower atmosphere have contributed to global warming. It is estimated that increases in ground-level ozone since the pre-industrial era have contributed one-fourth to one-third of the warming effect of carbon dioxide (Forster et al., 2007; Mickley, 2007). Therefore, reducing ground-level ozone levels could result in climate benefits.

The relationship between PM and warming, on the other hand, is more complex. Some particulate matter, specifically black carbon (soot) from combustion (largely from diesel engines) contributes to global warming (Jacobson, 2002). Therefore, reducing black carbon levels could have a positive climate effect. On the other hand, other components of particulate matter, such as sulfates, have a net cooling effect. These aerosols reflect incoming solar and infrared radiation and affect cloud formation (Forster et al., 2007). Modeling has shown that an abrupt reduction in aerosol concentrations could enhance warming (Brasseur and Roeckner, 2005). Therefore, particulate matter poses an interesting challenge – from a public health standpoint, its reduction is necessary, but in some cases this reduction could aggravate global warming.

Extreme Events

Poor air quality is often correlated with the occurrence of certain extreme events. Extreme heat events, defined as days with temperatures above the 90^{th} percentile (T90) for a baseline period, occur about a total of six weeks a year (Drechsler et al., 2006). Table 1 shows the projected increase in days above T90 by the end of the century for several cities in California under three emission scenarios, compared to a baseline of 1961 to 1990. The range in the estimates for each scenario results from the use of different climate projection models (see Luers and Mastrandrea, 2008).

Table 1 - Projected Increases in Extreme Heat Events by the End of the Century (2070-2099) Under Three Emission Scenarios

City	T90 (°F, based on 1961-1990)	Low emissions (days)	Medium-high emissions (days)	High Emissions (days)
Statewide	95	39-52	53-76	69-88
Los Angeles	91	38-45	39-98	63-93
San Francisco	81	37-49	40-91	70-94
Sacramento	100	40-52	47-89	70-78
San Bernardino	104	36-45	36-87	63-78
Fresno	104	40-52	46-93	69-75

Source: (Miller et al., 2008).

Notes: The following emission scenarios used are: low emissions – B1, medium high emissions – A2, and high emissions – A1fi.

The increased likelihood of violating air quality standards with higher temperatures results from a combination of factors. One contributor is the increase in emissions associated with higher energy use on high temperature days (Franco and Sanstad, 2008). Analysis of power plant NOx emissions with temperature at several locations around the state shows a roughly 3 percent linear increase in NOx emissions from power plants per degree F increase in daily maximum temperature (Drechsler et al., 2006).[3] In addition, higher summer temperatures result in increased evaporative emissions from motor vehicles and vehicle refueling. Using projected temperature increases under four future emission scenarios, evaporative emissions from the on-road vehicle fleet were estimated to increase by up to 31 percent by the end of the century (Motallebi et al., 2008).[4] In addition to affecting air pollution, extreme heat events have a direct impact on human health (for more on health impacts, see Bedsworth, 2008).

Another extreme event that can affect air quality is wildfire. Wildfires can lead to increased concentrations of particulate matter. Climate change is predicted to alter the characteristic and extent of forests and increase the risk of wildfires (Cayan et al., 2006; Westerling and Bryant, 2006). Modeling that incorporates potential future climate conditions predicts that the probability of "large" fires could increase by 12 to 53 percent by the end of the century (Westerling and Bryant, 2006).[5]

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[3] This estimate is based on current power plant technology and does not account for any future technology changes.

[4] This estimation is based on the 2005 vehicle fleet and does not take into account any future change in vehicle technology or population. Therefore, it is not a prediction of what will happen in the future, but rather an illustration of the effect that increased temperature can have on vehicle emissions.

[5] A large fire is defined as one that is greater than 200 hectares (494 acres).

2. Ozone Air Quality in California

The National Ambient Air Quality Standards (NAAQS) established for ozone and the other five criteria pollutants are designed to be protective of human health. USEPA recently revised the NAAQS for ozone, making it more stringent and protective (USEPA, 2008b). CARB is responsible for preparing a State Implementation Plan (SIP), which shows how all regions of the state will come into compliance with the NAAQS.

California is divided into 35 air quality control or planning districts, the regional agencies responsible for air quality planning. Figure 1 shows boundaries of the regional air districts and the areas in California that are currently out of attainment with the federal eight-hour ozone standard.[6] These air districts are responsible for designing emission control programs for stationary sources within their jurisdictions and developing attainment plans to show how the region will comply with federal and state air quality standards. Most air districts develop an attainment plan for each pollutant individually, even if they are out of attainment with more than one pollutant. The plan includes an inventory of the emission reduction programs that are necessary to come into compliance. The magnitude of the necessary reductions is determined by modeling a past poor air quality episode that is considered "typical" for the region - in other words, excluding extreme events. In 2007, the South Coast prepared the first air quality plan that considered multiple pollutants – ozone and fine PM (PM 2.5) (South Coast Air Quality Management District, 2007). More plans of this type are expected in the future, but none currently account for any type of climate change. For more details on the process of demonstrating attainment, see Appendix A.

In addition to developing air quality attainment plans, the regional air districts play other important roles. As the front line actors in the effort to attain air quality standards, they often serve as incubators for new air quality improvement programs. In addition, they often adopt rules and regulations that pressure state and federal regulators to adopt new programs. The South Coast Air Quality Management District has done this in several areas, most recently adopting rules to control emissions from vehicle fleets. The San Joaquin Valley Air Pollution Control District and Bay Area Air Quality Management District have played similar roles.

[6] The EPA recently revised the federal eight-hour ozone standard to 0.075 ppm (down from 0.08 ppm) to be more protective of human health (USEPA, 2008b).

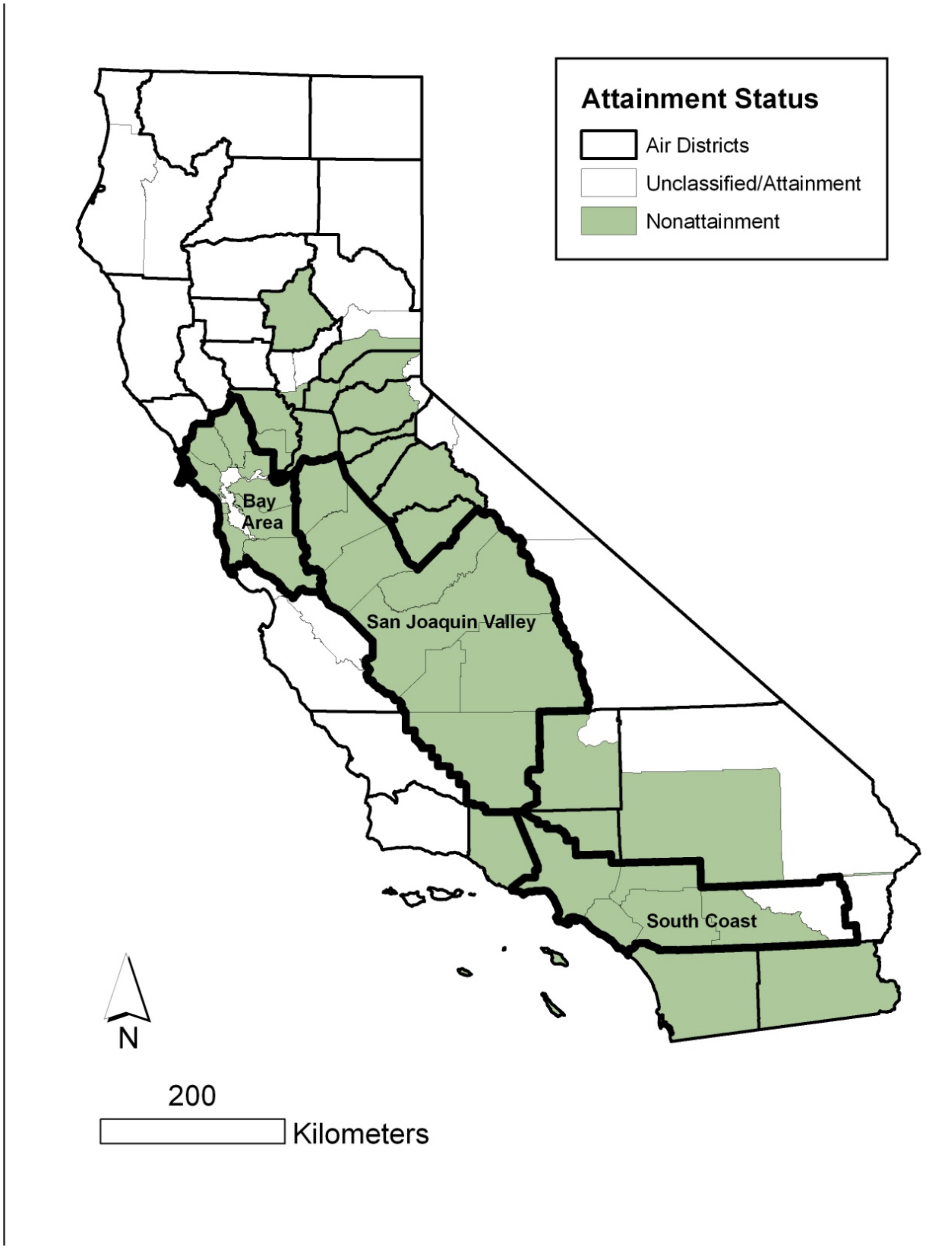

Figure 1- Federal 8-hour Ozone Non-attainment Areas in California

Source: (USEPA, 2008a)

Note: Attainment designations have not been made for the new federal eight-hour ozone standard. This map shows designations under the old standard.

Relationship Between Temperature and Ozone

The ozone season typically spans from May to September, as high ozone concentrations tend to be associated with warmer weather (Lin et al., 2001). Figure 2 shows the share of exceedances of the federal eight-hour ozone standard by month for three of the most populous air basins in California: the South Coast, the San Joaquin Valley, and the San Francisco Bay Area (see Figure 1 for basin boundaries). For each of these basins, over 80 percent of the exceedances occurred during the May to September season.

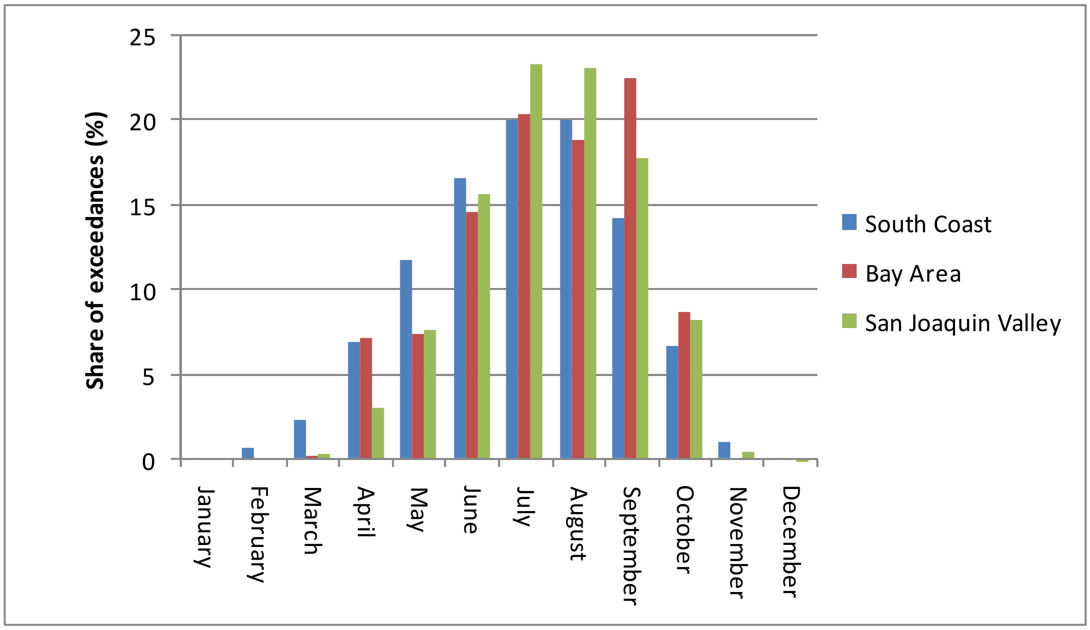

Figure 2 - Share of Exceedances of the Federal 8-hour Ozone Standard by Month for Three Air Basins, 1980-2005

Note: shows exceedances of the 2008 8-hour ozone standard

Using air quality data for these three basins, we determined the relationship between temperature and the probability of exceeding the federal eight-hour ozone standard during the ozone season. All three basins show a statistically significant, positive relationship between temperature and the probability of exceedance when controlling for site location and day of the week (Table 2). These results show that an increase in high temperature days could likely result in an increase in exceedances of the ozone standard.

Table 2 – Relationship Between Temperature and the Probability of Exceeding the Federal Eight-hour Ozone Standard

Air Basin	Increase in probability of exceedance for each one degree F increase in temperature (percentage point)
South Coast	1.8
San Joaquin Valley	2.4
San Francisco Bay Area	0.3

Note: Results determined using linear regression using air quality and temperature data for 1980 to 2005, holding location and day of the week constant. Regression performed for the 2008 8-hour ozone standard.

Current Trends in Ozone Air Quality

To characterize the impact of more frequent high heat events on the attainment of air quality standards, we examined trends in ozone air quality indicators in the three air basins. Figure 3 shows the trend in days in exceedance of the federal eight-hour ozone standard between 1980 and 2005 in each of the three air basins. Overall, the air basins show improvement in the most recent years. For both the San Francisco Bay Area and the South Coast, the trends are negative and statistically significant at the 95 percent level of confidence over the entire period (-1.2 and -4.0 exceedances per year, respectively). Although the trend in the San Joaquin Valley appears negative (-0.2 exceedances per year), it is not statistically significant.

To provide a sense of how conditions might change under higher temperatures, the charts in Figure 3 also display the trends in exceedances when the maximum daily temperature is greater than or equal to 95 °F.[7] Although the trends for the South Coast and the San Francisco Bay Area remain negative and statistically significant, the rate of improvement is lower (-0.5 exceedances per year for both). In the San Joaquin Valley, the trend in violations reverses sign, becoming slightly positive (0.3 exceedances per year), though still not statistically significant.

Overall, these trends affirm the significant progress that has been made in the effort to attain federal air quality standards in the two metropolitan coastal areas. The results at higher temperatures suggest that this progress could be slowed if there is an increase in the occurrence of days with higher temperatures.

[7] Ozone exceedances are more likely when the temperature is high. We chose 95°F for the cutoff for this analysis because it is a high temperature for each of the three air basins, but occurs with enough frequency each year that there were sufficient data for the analysis. Between 1980 and 2005, each air basin averaged the following number of days with a maximum temperature above 95°F at at least one location – San Francisco Bay Area: 46 days; South Coast: 63 days; San Joaquin Valley: 95 days.

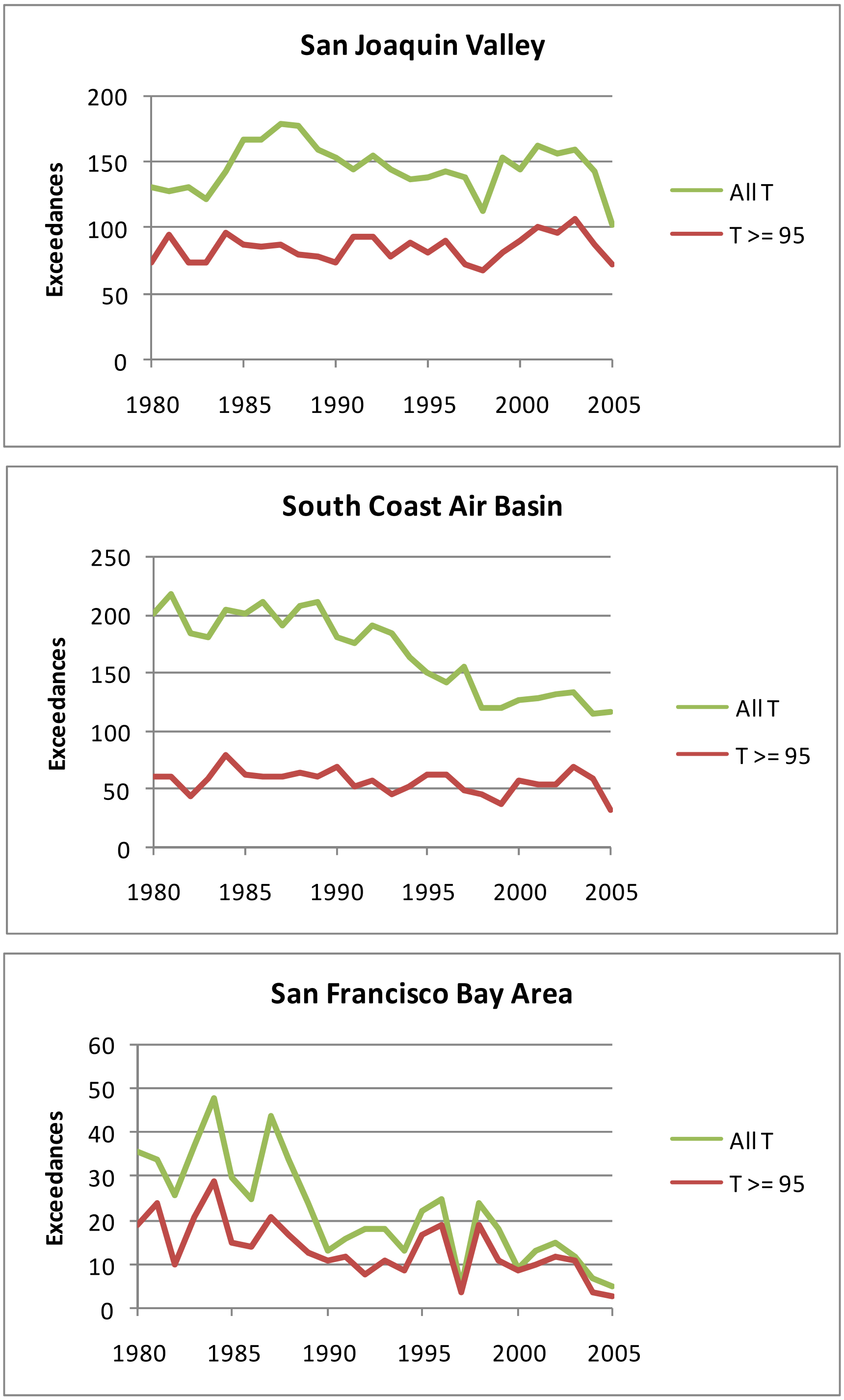

Figure 3 - Trends in Exceedances of the Federal 8-hour Ozone Standard in Three Air Basins, 1980 to 2005

Source: Air quality data from CARB, temperature data from Western Regional Climate Center

3. Adapting Air Quality Planning to Account for Climate Change

Air quality planners face two primary challenges from climate change: reduction in future air quality improvements (the climate penalty) and increased incidence of extreme events that result in more unhealthy air days. Although there are opportunities to prepare air quality planners to face these challenges, some technical and institutional constraints could hinder progress.

Adaptation Opportunities for Air Quality Planning

CARB has been mandated to address climate change alongside air quality. This mandate has not yet been extended to the local air districts, although some have begun to engage in climate change-related activities and programs. At the local level, the focus remains on meeting air quality standards. From the standpoint of public health, it is important not to divert attention and limited resources from the primary goal of improving air quality, given the public health impacts of current poor air quality. Nonetheless, local air districts should become aware of the relationship between air quality rules and regulations and climate change in order to insure that public health goals can still be met as the climate changes (for more on the adaptation in the public health sector, see Bedsworth, 2008). Measures include raising awareness and improving technical information on the climate penalty and the role of extreme events.

Raising Awareness of Climate-Related Policies and Impacts

Local air districts could benefit from becoming more aware of how climate change could affect local air quality as well as how California's GHG emission reduction policies might affect air quality. For instance, some climate change policies could have significant benefits for air quality (e.g., increased use of renewable sources of electricity), while others could potentially harm air quality (e.g., increased use of ethanol (Jacobson, 2007)). This type of work is already underway and is being led by the California Air Pollution Control Officers Association (CAPCOA), which provides a forum for coordination among local air districts and represents the perspective of local air district in state legislative and regulatory decisions.

The districts can also learn from programs underway in some regions to incorporate climate change considerations into air quality planning. For example, the Bay Area Air Quality Management District (BAAQMD) has developed a Climate Protection program (Table 3). This program was developed in 2005 to provide regional leadership on climate change issues and to maximize co-benefits between climate change, criteria pollutant, and air toxics emissions reductions. At this time, this program is the most developed district-level climate change program in the state.

Table 3 - BAAQMD Climate Protection Program Activities

Goals	Activities
Assistance to local governments	- Aid in developing emission inventories - Workshops for local government - Awarded $3 million in climate protection grants to local governments (2007)
Encouraging regional cooperation	- Organized regional climate summit (2006) - Coordinate with regional transportation planning and land use agencies
Integrating climate protection into district activities	- Include GHG emission criteria in distribution of clean air funds - Member of California Climate Action Registry - Becoming a carbon neutral organization
Outreach and education	- Developed a K-12 climate protection curriculum - Outreach through Spare the Air program
Foster statewide collaboration on climate change	- Working with state agencies to implement the Global Warming Solutions Act of 2006 - Working with CAPCOA to foster cooperation between air districts - Took lead to develop CAPCOA white paper on climate change and California Environmental Quality Act (2008)

Quantifying the Climate Penalty

Planning agencies would also benefit from efforts to quantify the magnitude of the climate penalty for each non-attainment area. The analysis by Steiner, et al. (2006) is a good start for this type of analysis. The next step would be to quantify the additional emission reductions that will be needed to meet air quality standards. Such an analysis would provide an estimate of each region's vulnerability to a changing climate and an estimate of the magnitude of the potential impact, both in terms of additional emission reduction and added cost. This action does not require fundamental changes in the planning process, and it will make the process more robust and better poised to anticipate changing conditions.

Broadening Episode Selection for Modeling

Similarly, steps to incorporate analysis of extreme events could be highly beneficial. As noted above, one of the likely effects of climate change on air quality is an increase in the frequency and severity of extreme events. Currently, the modeling prepared for air quality planning focuses on "typical" air pollution episodes. This allows districts to avoid the inclusion of emissions that they do not control, such as those from wildfires, as well as extreme meteorological conditions. However, this approach likely masks potential challenges that could arise under a changing climate.

Examination of poor air quality episodes that occur under extreme conditions can allow districts to better understand what type of emission reductions and strategies will be needed under a changing climate. Consideration of such episodes could provide a bounding case for modeling purposes. This type of analysis could point to episodic controls that are needed to address air quality issues during these episodes. Although this type of analysis would not require a fundamental change in the modeling process, some additional data gathering would be necessary. In addition, it is not clear how it would be incorporated into the federal air quality planning process, particularly if it demonstrates non-attainment of the federal air quality standards under certain conditions.

Constraints on Adaptation in Air Quality Planning

The air quality planning process also faces some constraints that could make it more difficult to meet air quality standards under a changing climate. These include the scope of regulatory authority, potential conflicts between air quality and climate change programs, and constraints arising from the attainment demonstration requirements under the Clean Air Act.

Limitations in Regulatory Authority

Under a changing climate, it is likely that additional emission reductions will be needed to overcome the climate penalty. If the distribution of emission sources remains similar to the current distribution, this could pose a challenge to local air districts because they do not have authority over the majority of emissions. Attainment will require large reductions from sources that fall under state and federal authority, notably "mobile source" emissions (e.g., from cars and trucks). Figure 4 shows the smog-forming emission inventory by regulatory responsibility for the South Coast and the San Joaquin Valley. In both cases, a large majority of the emission sources fall under the jurisdiction of state and federal agencies.

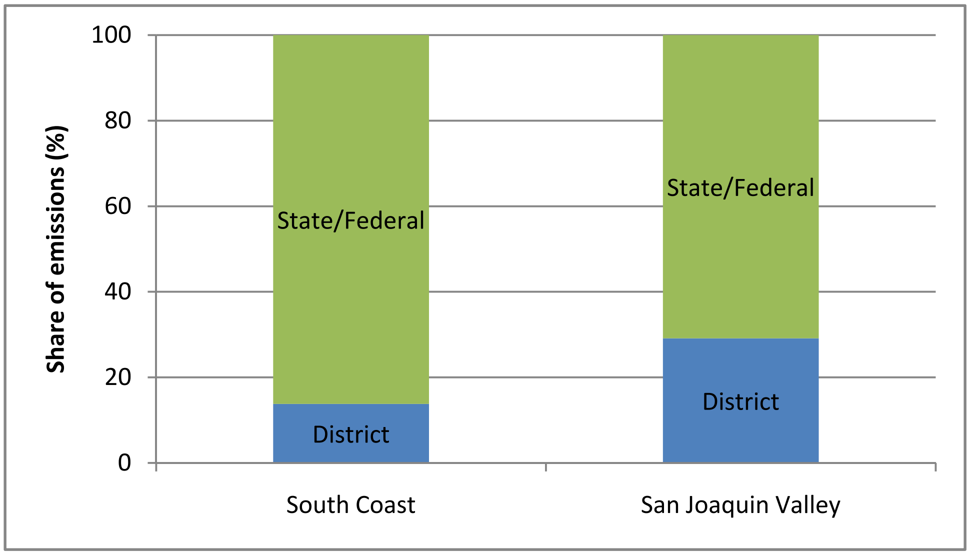

Figure 4 - Regulatory Responsibility for the Smog-Forming Emission Inventory, 2006

Source: Author's calculation based on California Air Resources Board data

Because they cannot use direct regulation to affect sources that do not fall under their jurisdiction, air districts will be pushed to take creative actions to reduce emissions from these sources. For example, the San Joaquin Valley Air Pollution Control District has recently adopted an Indirect Source Review rule, which requires emission reductions from the activities associated with the construction and operation of new development projects. Developers can achieve emission reductions through a variety of mechanisms, including locating near transit, developing mixed land uses, improving energy efficiency, raising density, and installing sidewalks and bike paths. If the developer is not able to meet the emission reduction requirements, they will be assessed fees that will be used to reduce emissions from other sources.

Districts can also adopt incentive programs to achieve similar goals. For example, while local air districts do not have the authority to regulate mobile source emissions, they are able to offer incentives for purchases of cleaner equipment or provide funding to upgrade and retrofit new equipment. Such programs are likely to require additional funding sources.

Recent attention has begun to focus on programs which simultaneously address reductions in criteria air pollutant and GHG emissions. Such programs require coordination between air districts and other local agencies including land use and transportation planning agencies. Several air districts have taken steps in this direction. For example, the Sacramento Metropolitan Air Quality Management District has recommended that California Environmental Quality Act (CEQA) documents include consideration of GHG emissions. Inclusion of GHG emissions in CEQA analyses can insure that projects do not have a negative impact on GHG emissions. Their inclusion also can help to capitalize on the criteria pollutant co-benefits of certain measures that result in reductions in vehicle miles travelled or smart land use. The San Joaquin Valley's Indirect Source Rule also is recognized as a tool for reducing GHG emissions as well as improving air quality (California Air Resources Board, 2008).

These types of programs will likely become more common under the implementation of Senate Bill (SB) 375, which was signed into law in September 2008. SB 375 links regional transportation planning to reductions in GHG emissions. Under SB 375, CARB will set regional GHG emission reduction goals. Regional transportation plans, developed by local and regional agencies, will outline how to meet these goals through a sustainable communities strategy.

Potential Conflicts between Control Strategies

Given that additional emission reductions will likely be needed to meet air quality standards in the future, it is important that actions undertaken to reduce greenhouse gas emissions take air quality into consideration. Some proposed strategies for reducing GHG emissions, especially from the transportation sector, could result in an increase in criteria pollutant emissions. For example, increased use of ethanol in gasoline could result in an increase in ozone (Jacobson, 2007). Other strategies could rely on technologies that might limit the potential for future criteria pollutant reductions. For example, light-duty diesel vehicles can reduce carbon dioxide emissions, but increased use of diesel vehicles could make future air quality improvements difficult to achieve. To avoid these potential conflicts, regulators should consider future air quality conditions when evaluating greenhouse gas emission strategies. This will ensure that the state avoids pursuing climate strategies that could end up locking into a technology pathway that prevents further air quality emission reductions should they become necessary

Constraints of the Federal Planning Process

The final constraint on agencies working to incorporate climate change into air quality planning is the bureaucratic and constrained federal requirements for developing and approving SIPs. A recent review of air quality management by the National Research Council (NRC) (2004) found that while the SIP process has likely been helpful in improving air quality, it has not led to many regions coming into attainment with the NAAQS. In addition, the review committee found that the process is overly legalistic and bureaucratic and likely stifles innovation and experimentation. The committee also found that the attainment demonstration process creates a false sense of security and fails to account for significant uncertainties that could affect attainment of the NAAQS.

These constraints and weaknesses could present difficulties as the planning process works to incorporate climate change, a factor not considered in the NRC review. In particular, inclusion of extreme events or quantifying the climate penalty could put the state and local air districts at risk of penalties from the federal government. For example, including the climate penalty in modeling could mean that attainment is not possible by a federal deadline because there are more violations of the standard than predicted by the modeling used in the attainment plan. Nonetheless, this information could be very valuable to local air quality planning organizations.

Similarly, understanding air quality impacts under extreme events would help local air quality planning agencies to be prepared to face a changing climate. The current process provides no incentive to quantify this uncertainty and is constructed around a deterministic, rigid modeling process. Increasing frequency of extreme events could also make episodic control programs attractive. Episodic controls, such as the Bay Area’s Spare the Air program, are programs that only go into effect when the probability of violating air quality standards is high. The current planning process does not provide means to receive credit for episodic control programs.

In the longer-term, it could be beneficial to integrate air quality planning for criteria air pollutants with planning to reduce greenhouse gas emissions. This could enable the full incorporation of feedbacks between air pollution and global warming and the consideration of potential conflicts between emission reduction strategies. The current federal air quality planning process is not compatible with this approach.

Conclusions

California faces significant air quality problems that pose risks to human health. The San Joaquin Valley and the South Coast are home to some of the worst air quality in the nation. While tremendous progress has been made over the past several decades in improving air quality, there is still a long way to go. Climate change could make it even more difficult to meet air quality standards.

Air quality planners can take several steps to gain a better understanding of the challenge that climate change poses. This includes quantifying the climate penalty and broadening episode selection in air quality modeling to better understand air quality under extreme events. Air quality planners will also have to overcome some constraints in the face of climate challenges. These include limitations in regulatory authority, potential conflicts between climate change and air quality control strategies, and constraints of the federal process for reviewing and approving state implementation plans under the Clean Air Act.

Despite these constraints, air quality planning appears to be in a better position than many other sectors faced with climate challenges. Although meeting air quality standards may become more difficult and more expensive if additional emission reductions are needed, this does not look to be an impossible task. With appropriate preparation, air quality planners can be in a position to account for changes and to respond effectively to extreme events.

Appendix: Demonstrating Attainment with the National Ambient Air Quality Standards

National Ambient Air Quality Standards (NAAQS)

The Clean Air Act directs the USEPA, in coordination with state and local agencies, to improve air quality, and it directs USEPA to set the NAAQS. The NAAQS set limits for six air pollutants known as criteria air pollutants: ozone, carbon monoxide, nitrogen dioxide, lead, particulate matter, and sulfur dioxide. Of these, ozone and particulate matter cause the most widespread pollution problems in the country. The primary standards are set to be protective of human health. In addition, for some criteria pollutants there are secondary standards set to limit environmental and property damage. For example, ozone can damage agricultural crops and building materials. Areas that are designated to be in non-attainment are required to demonstrate compliance with the primary standards.

Areas that are not in attainment with the NAAQS must develop a plan demonstrating the emission reduction strategies that will be employed to come into attainment with the standards. Each region is given a deadline by which to meet the standards, with later deadlines for basins where the air quality problem is more severe. Failure to meet these standards can result in sanctions by the federal government, notably the loss of federal highway funds.

State Air Quality Standards

In addition to the NAAQS, the state of California has set its own air pollution standards that are generally more stringent than the federal standards. The state sets standards for the following pollutants: ozone, particulate matter, lead, sulfur dioxide, nitrogen dioxide, sulfates, hydrogen sulfide, carbon monoxide, and visibility-reducing particles. Every three years, CARB updates the attainment status of regions in the state, indicating whether they are in or out of attainment with the state air quality standards. Regions that are not in attainment are required to implement all feasible measures to come into attainment, but there are no deadlines or penalties for failing to meet the standards.

Demonstrating Attainment with Federal Standards

CARB is responsible for coordinating the regional efforts to attain both state and federal air quality standards. The planning process generally originates in local air districts with the development of an attainment plan. Air districts develop attainment plans that outline proposed and existing federal, state, and local regulations that will be used to achieve emission reductions. These measures are combined to demonstrate that sufficient reductions will be made by the attainment deadline to achieve attainment. CARB then uses these attainment plans as contributors to the State Implementation Plan (SIP), which outlines the combination of federal, state, and local actions needed to bring all regions of the state into compliance with the NAAQS. The SIP addresses each pollutant individually.

Attainment is demonstrated using a model that simulates air pollutant formation. This modeling entails the selection of a typical poor air quality episode that has occurred in the past for which there are sufficient data to prepare a simulation. The model is first used to simulate that episode using base year data to ensure that the model can replicate the observed air pollution levels (model validation). Then, the model is used to simulate that ozone episode using base year meteorology, but with estimates of future emissions. The future emission inventory takes into account growth in emissions as well as future controls. If the modeled scenario does not demonstrate attainment, the district has to identify further emission reductions that will be undertaken to bring the region into compliance. The model is used to identify a combination of ozone precursor emissions that will allow the region to meet the air quality standard; this is called the "carrying capacity."

This technical component of the planning process has two important elements. The first is the selection of the episode to be modeled for attainment demonstration. The second is the identification of emission reduction programs to meet the standard. Each of these elements has implications for how well a district can respond to and incorporate climate change into the planning process.

Data Requirements and Episode Selection

The data used for modeling a typical poor air quality episode are obtained through extensive field studies that gather air quality data from a number of locations within a region over a period of time. For example, the Central California Ozone Study (CCOS) collected significant amounts of ozone measurement data in the summer of 2000. An episode from this study is used in the current attainment plan for the San Joaquin Valley. Because the data requirements are extensive, the number of episodes available for modeling tends to be limited and the data are usually at least several years old.

The episode to be modeled is selected to be representative of a "typical" poor air quality event. This means that these episodes do not include extreme conditions that could influence air quality, such as extreme heat or wildfire, both of which are expected to increase with climate change.

Identifying Emission Reduction Measures

The emission reductions needed to come into compliance are achieved through a combination of local, state, and federal programs. Emission reduction programs can focus on technological changes or social/behavioral changes that reduce emissions. To date, the majority of programs have focused on technological changes (National Research Council, 2004). Any emission reduction program that is included in the SIP is federally enforceable; if the targeted reductions are not attained, they must be achieved through other means (National Research Council, 2004).

Local air districts are primarily responsible for designing rules to reduce emissions from all stationary and most area-wide sources. These include factories, refineries, and residential sources such as fireplaces and water heaters. The state is responsible for developing programs to reduce emissions from mobile sources as well as consumer products and pesticides (through the Department of Pesticide Regulation). The federal government is responsible for developing standards for mobile sources that fall under federal jurisdiction, such as interstate trucks, trains, and marine vessels (California Air Resources Board, 2007).

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