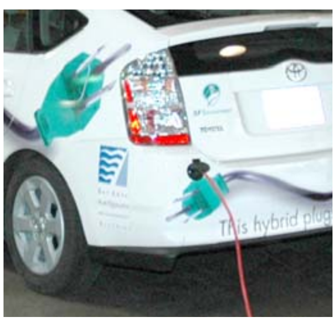
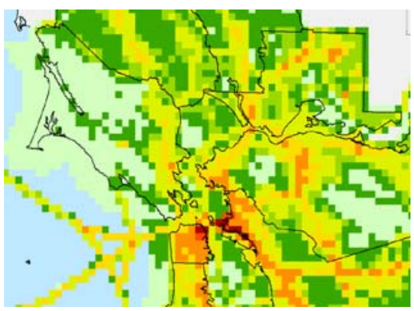
Bay Area Air Quality Management District

Draft Bay Area 2010 Clean Air Plan





Appendices

Association of Bay Area Governments

bcdc

Metropolitan Transportation Commission

March 2010

Appendix A – Bay Area Air Pollution Burden: Past & Present

Analysis of trends in monitoring data shows that in recent decades Bay Area air quality has improved dramatically. This has been accomplished even as regional population, the number of motor vehicles and miles driven, and the value of the region's economic production have grown significantly. Our progress in improving air quality is due to a comprehensive program to reduce emissions from both stationary and mobile sources of air pollutants.

The purpose of this analysis is to estimate the health and social impacts of air pollution in the Bay Area today compared with the earliest period for which reliable ambient air quality measurements were available. The analysis presented here is based upon a methodology which is described in detail in the Air District's June 2009 *Multi-Pollutant Evaluation Method Technical Document* (MPEM).[1] For purposes of this analysis, to facilitate comparison between earlier years and today, we have calculated the benefit of pollutant reductions based upon the current Bay Area population. That is, the health burden is analyzed as if today's population were exposed to the pollution levels that prevailed in earlier years, and then compared that to the health burden associated with current air pollution levels.

The good news is that exposure to unhealthy concentrations of local air pollutants in the Bay Area - ozone, particulate matter (PM), and air toxics - and hence their health effects, have been reduced by more than half since the 1970 Clean Air Act was enacted.[2] However, despite this progress, a variety of health effects, including premature mortality, are still associated with exposure to air pollution in the Bay Area today, and these health effects result in direct and indirect economic impacts to the region that are valued in billions of dollars per year.

Air Toxics

The air toxic health effects considered here are limited to cancer. The Air District and CARB began regular air toxics monitoring in the late 1980s. However, some toxics such as formaldehyde and acetaldehyde were not monitored until several years later. Except

[1] See Draft Multi-Pollutant Evaluation Method Technical Document at www.baaqmd.gov/Divisions/Planning-and-Research/Plans/Clean-Air-Plans/Resources.aspx.

[2] By contrast, emissions of greenhouse gases that contribute to global warming have increased significantly during this period. However, after years of steady increase, emissions of greenhouse gases should begin to decline in California in coming years as a result of AB 32 and regulations that will be adopted to implement the Air Resources Board's AB 32 Climate Change Scoping Plan.

for diesel PM, estimates were made of the annual mean for the earliest year available and for 2008.

Diesel PM, the air toxic with the greatest health impact, cannot presently be measured directly. Indirect estimates were made for recent years using elemental carbon measurements for various Air District sites. For earlier years, Coefficient of Haze measurements[3] were used. The Addendum below presents details of which toxics were considered and how the risks were calculated.

Ozone

The Air District has monitored ozone since the 1950s and since 1968 has had a spatially dense set of ozone measurements. These measurements were used to estimate population exposure for 2008 and what the exposure would have been if the ozone levels had not been reduced since 1970. For purposes of this analysis, we assumed that ozone health effects occurred for hourly ozone concentrations at or above 50 parts per billion (ppb), but not below.

$PM_{2.5}$

$PM_{2.5}$ consists of many components, some man-made, some natural. The health burden of $PM_{2.5}$ was based on the amount of anthropogenic (man-made) $PM_{2.5}$, subtracting natural background $PM_{2.5}$ (sea salt, windblown dust, etc.) which is estimated to average about 3 micro-grams per cubic meter ($\mu g/m^3$). $PM_{2.5}$ has been measured routinely only since 1999. To estimate $PM_{2.5}$ concentrations prior to 1999, other PM measurements made since the late 1980s and early 1990s were used to approximate $PM_{2.5}$ concentrations in 1990. The Addendum provides details of how this was done.

Diesel PM is a key component of $PM_{2.5}$ and warrants separate treatment. Therefore, anthropogenic $PM_{2.5}$ is divided into diesel PM and non-diesel PM. Diesel PM cannot be measured directly, but is approximated from other measurements. See the Addendum below for details.

Health Summary

Figure A-1 shows the number of cases of selected health effects that are related to population exposure to current Bay Area air pollution levels (2008, labeled "now") compared to the estimated number of cases that would have occurred if the quantifiable air quality improvements had not been made (labeled "then"). The “then” data is based on the earliest data available – 1970 for ozone, and the late 1980s for toxics and PM.

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[3] Coefficient of Haze (COH) was a measurement of PM that is highly correlated with elemental carbon (EC). A regression relation was established between COH measurements and EC from the few Air District sites with simultaneous measurements of both.

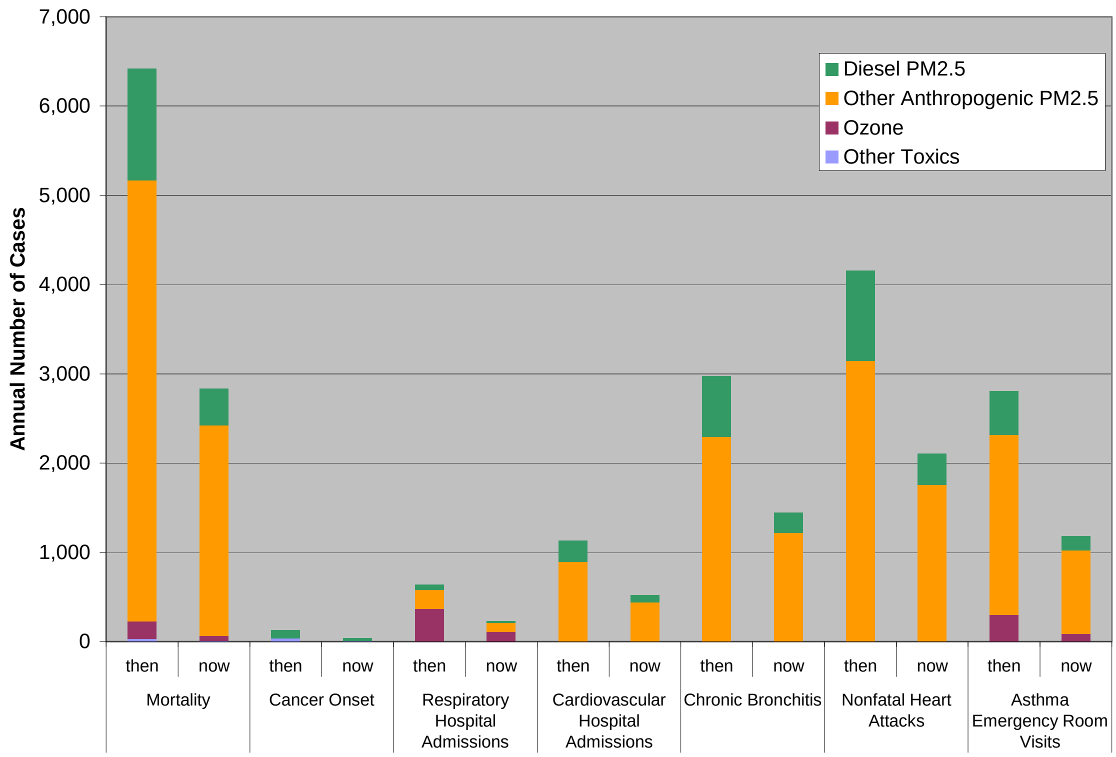

Figure A-1. Incidence of selected health effects among Bay Area residents from air pollution today versus without air quality improvements. "Then" is 1970 for ozone, and the late 1980s for toxics and PM2.5. "Now" is 2008.

Table A-1 shows the reduction in the estimated number of annual cases; i.e., the difference between "then" and "now" for each of the health effects shown in Figure A-1. Table A-1 provides the "best estimate" as well as the lower bound (10th percentile) and upper bound (90th percentile) for an 80% confidence interval. The range of values is provided in Table A-1 in order to emphasize that all the health effects figures provided in this analysis are estimates; the numbers in this analysis are intended to convey a sense of overall trends and relative magnitudes, but they are not precise figures.

Table A-1. Reductions in annual cases, "then" to "now" including an 80% confidence interval.

	Mortality	Cancer Onset	Respiratory Hospital Admissions	Cardiovascular Hospital Admissions	Chronic Bronchitis	Nonfatal Heart Attacks	Asthma Emergency Room Visits
Best Estimate	3,600	90	200	700	1,900	2,700	1,400
10th Percentile	1,400	40	100	500	600	1,300	900
90th Percentile	6,400	170	300	900	3,000	3,800	1,900

Figure A-1 shows that the annual numbers of health effects associated with exposure to air pollutants in the Bay Area has dropped dramatically, by more than half. Of particular interest, premature mortality related to air pollution has decreased from an estimated 6,400 per year to an estimated 2,800 per year. For purposes of comparison, the total number of annual deaths in the Bay Area is about 45,000, and the annual number of transportation-related deaths in the Bay Area is 600 to 700.

Life expectancy is widely regarded as an indicator of the overall health of a given population. Life expectancy measures the average number of years a baby born today would live given the present distribution of age-specific probabilities of death. Premature mortality is a measure of unfulfilled life expectancy. The reduction in mortality risk as shown in Figure A-1 and Table A-1 can be expressed in terms of increased life expectancy. Over the past 20 years, Bay Area life expectancy has increased by almost 5 years, from 75.7 in 1990 to 80.5 today, due to a variety of factors. Of the overall increase in life expectancy during this period, we estimate that the improvements in air quality can be credited with extending average life expectancy in the Bay Area by 6 months. Thus, approximately 10% of the improvement in Bay Area average life expectancy over the past decade and a half can be attributed to cleaner air. (See Addendum below for details.)

The vast majority of the mortality risk related to air pollution is correlated with exposure to fine particulate matter ($PM_{2.5}$), shown as the combination of diesel $PM_{2.5}$ and other anthropogenic $PM_{2.5}$ in Figure A-1. Several robust epidemiological studies have shown that $PM_{2.5}$ concentrations in a given area affect the death rate. The studies are based on data sets where the health and health-relevant information for a set of people from different areas has been collected for an extended period. These records allow the estimation of mortality rates for various areas, where the rates are adjusted for key factors such as age, gender, smoking, and obesity. The adjusted death rate for each area is compared with the average PM concentrations in the area, showing clear correlations.

After reviewing the literature, we use a risk factor based on the assumption that every 1.0 $\mu g/m^3$ reduction in $PM_{2.5}$ concentration results in a 1% reduction in mortality rate for individuals over 30 years old.[4] For the MPEM, the change in premature mortality from $PM_{2.5}$ was calculated by estimating the percentage change in mortality from a given change in $PM_{2.5}$ concentration and applying that to the annual deaths to persons over 30 years old. Currently, Bay Area $PM_{2.5}$ concentrations average about 9.5 $\mu g/m^3$, or about 6.5 $\mu g/m^3$ above natural background levels. Thus, we estimate that total

[4] The key study serving as the basis of our estimate is the *Expanded expert judgment assessment of the concentration-response relationship between $PM_{2.5}$ exposure and mortality*, prepared for OAQPS-EPA by Industrial Economics Inc, September 21, 2006. A summary of this study is provided in Roman, HA et al., *Environ. Sci. Tech.* 2008, *42*, 2268-2274.

elimination of anthropogenic $PM_{2.5}$ would reduce the death rate by about 6.5% for those over 30, or about 2,800 deaths per year.

Although research is still on-going to determine the precise biological mechanisms through which $PM_{2.5}$ is associated with increased mortality, it appears that cardiovascular problems, such as heart attacks, are the leading cause (EPA 2009). Although diesel PM is the leading air toxic in the Bay Area, it should be noted that perhaps only 10-20% of these PM-related deaths are linked to diesel exhaust. Other sources of PM, such as wood smoke, cooking, and secondary formation of PM from precursors such as NOx, SO2, and ammonia, collectively account for most of the ambient PM, and PM-related mortality, in the Bay Area. To the extent that diesel PM does contribute to premature mortality, it appears to be primarily due to the mechanisms mentioned above. Cancer accounts for a smaller number of total deaths related to air pollution. The total annual number of cancer deaths, including lung cancer, related to exposure to diesel PM in the Bay Area, is approximately 80-90 per year. Thus, mortality related to exposure to fine PM (including diesel particles) appears to be associated much more with cardiovascular problems than with cancer.

Summary of Costs and Disbenefits

Air pollution imposes costs on society in terms of public health, the environment, and the economy. Approximations can be made for the direct costs of treatment for pollution-related health effects, as well as indirect costs based upon people's willingness to pay to avoid those health effects. Table A-2 presents a list of health effects and the estimated dollar value of these effects on a per-case basis. For greenhouse gases, we use an estimate of $28 per metric ton of CO2-equivalent emitted for the overall social cost of anticipated impacts of climate change. Chapter 5 of the MPEM Technical Document provides more detailed explanations for these cost estimates.

Figure A-2 summarizes the figures for health burden associated with exposure to ozone, $PM_{2.5}$, and air toxics, and also the social cost of GHG emissions. The cost estimates in Figure A-2 are based upon individual case values shown in Table A-1. Note that the data in Figure A-2 is based upon a wider range of health effects than the subset of health effects portrayed in Figure A-1 above. In each case, estimates for the earliest reliable period are compared with the present. The data in Figure A-2 indicates that, in aggregate, annual health and social costs have declined by roughly 50%, from approximately $50 billion to approximately $24 billion per year. It should be emphasized that the numbers in Figure A-2 are estimates only; they should not be seen as precise values. Nonetheless, we can conclude with a high degree of confidence that the benefits of air pollution reductions run in the billions of dollars annually.

Table A-2. Estimated dollar value per case for key health effects related to Bay Area air pollution.

Health Effect	Unit Value (Cost per Incident, 2009 dollars)
Mortality (all ages)	$6,900,000
Chronic Bronchitis Onset	$409,189
Respiratory Hospital Admissions	Age 65 < : $35,228 Age 65 > : $33,375
Cardiovascular Hospital Admissions	Age 65 < : $43,889 Age 65 > : $38,759
Non-Fatal Heart Attacks	$84,076
Asthma Emergency Room Visits	$468
Acute Bronchitis Episodes	$534, for a 6 day illness period
Upper Respiratory Symptom Days	$35
Lower Respiratory Symptom Days	$22
Work Loss Days	Daily Median Wage by County ($168 to $243)
School Absence Days	$91
Minor Restricted Activity Days	$61
Cancer	$1,750,000
Greenhouse Gases	$28 per metric ton ($CO_2$ equivalent)

In contrast to ozone, PM, and air toxics, emissions of GHGs have risen steadily since 1980. The estimated costs presented in Figure A-2 are a few billion dollars a year, but this represents a median estimate, not an upper bound. The potential effects from global warming could be catastrophic.

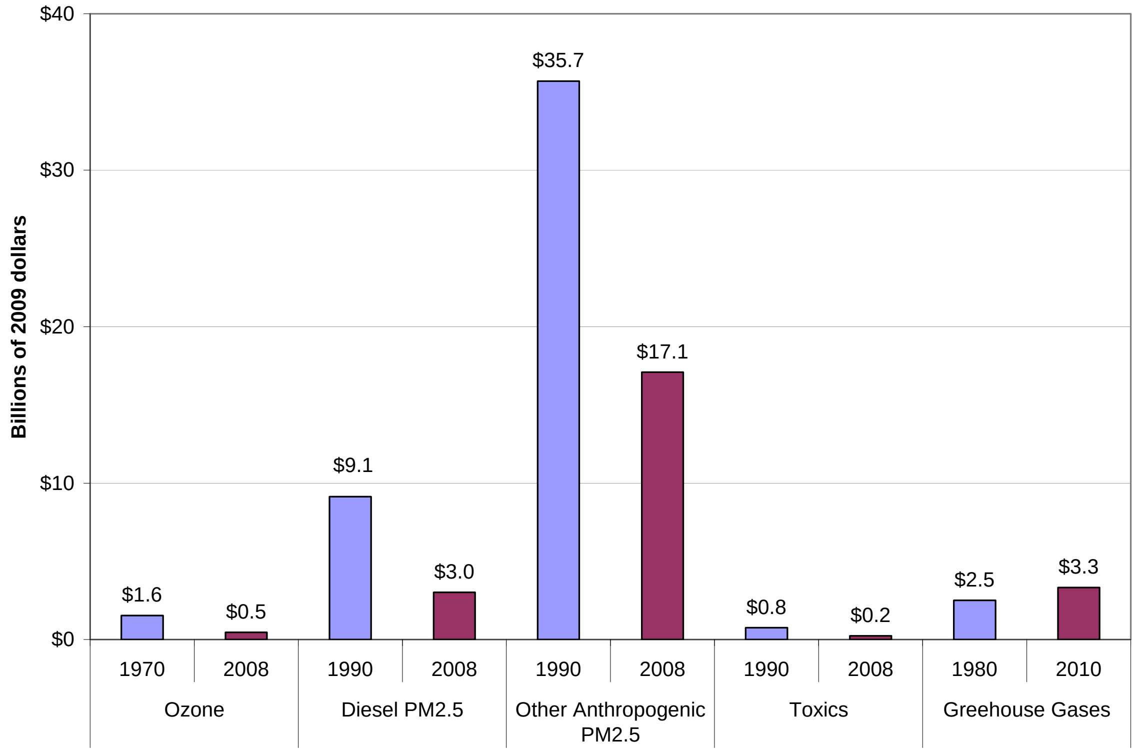

Figure A-2. Estimated current annual health and other social costs of Bay Area air pollution: prior years compared to 2008.

Summary of Key Findings

The analysis described in this appendix indicates that, due to improved air quality in the Bay Area, annual health effects, and the related social and economic cost of these health effects, have declined by at least 50% over the past several decades. The estimated number of premature deaths related to air pollution in the Bay Area decreased from approximately 6,400 per year in 1990 to about 2,800 per year in 2008. The reduction in premature mortality related to air pollution over the past two decades has contributed to an increase in average life expectancy. We estimate that improved air quality has extended average life expectancy on the order of six months per Bay Area resident. However, despite this substantial progress, Bay Area residents continue to experience significant health effects from exposure to air pollution. These health effects impose on-going costs to the individuals who experience these impacts and to the region as a whole.

Additional detail describing the methodology used in this analysis is provided in the Addendum below.

Addendum to Appendix A

Air Toxics

Table A-3 shows the estimated annual means for the carcinogenic toxics that the Air District or CARB measures. These are annual, District-wide means. The earliest available means are presented along with the means for 2008 (or the most recent available year).

The table also shows the cancer risk factors and the lifetime risks from each of the toxics. To facilitate comparison, the arithmetic mean for each toxic was linearly interpolated or extrapolated to 1990. We assume exposure is spatially constant, that is, that all Bay Area residents are exposed to the mean concentration of each toxic. The lifetime risk from these 1990 concentrations is shown in the table compared with the risk for 2008. The reductions in risk are shown in the last column. With the exception of carbon tetrachloride,[5] the reductions are statistically significant. The overall reduction in risk has been 69%, i.e., two-thirds.

Table A-3. Estimated annual mean values of carcinogenic toxics & lifetime risk factors.

	1st year	Most recent year	Estimated Annual Bay Area Mean (µg/m^3)		Lifetime Risk per million per ug/m3	Lifetime Risk per million Bay Area Residents		
Compound			Earliest	2008		1990	2008	Reduction
Diesel	1987	2008	3.50	1.06	300.0	933.2	318.0	66%
Benzene	1987	2008	1.80	0.23	29.0	146.1	20.9	86%
1,3-butadiene	1989	2008	0.37	0.04	170.0	131.5	14.0	89%
Formaldehyde	1996	2008	2.11	1.37	6.0	18.2	10.1	44%
Acetaldehyde	1996	2008	0.84	0.69	2.7	4.5	3.4	25%
Carbon tetrachloride	1987	2006	0.10	0.10	42.0	27.0	26.2	3%
Methylene dichloride	1987	2006	0.83	0.31	1.0	2.6	1.1	59%
Perchloroethylene	1987	2008	0.39	0.02	5.9	13.1	0.7	95%
PAHs (risk-weighted)	1995	2004	0.15	0.09	1320.0	0.2	0.1	57%
Hexavalent chromium	1991	2006	0.28	0.07	150000.0	43.3	10.9	75%
Lifetime cancer risk	1990	2006				1318.7	405.3	69%

Figure A-3 compares lifetime cancer risk from air toxics in the Bay Area for 1990 versus 2008 on a cases per million population basis. The estimated number of lifetime cases has declined from approximately 1,300 per million people to approximately 400 per million, a decrease of roughly 70% over this relatively short time period.

[5] The use of carbon tetrachloride was banned in the United States in 1996. It has a long atmospheric residence time. Thus, the concentrations experienced in the Bay Area derive from a persistent global background.

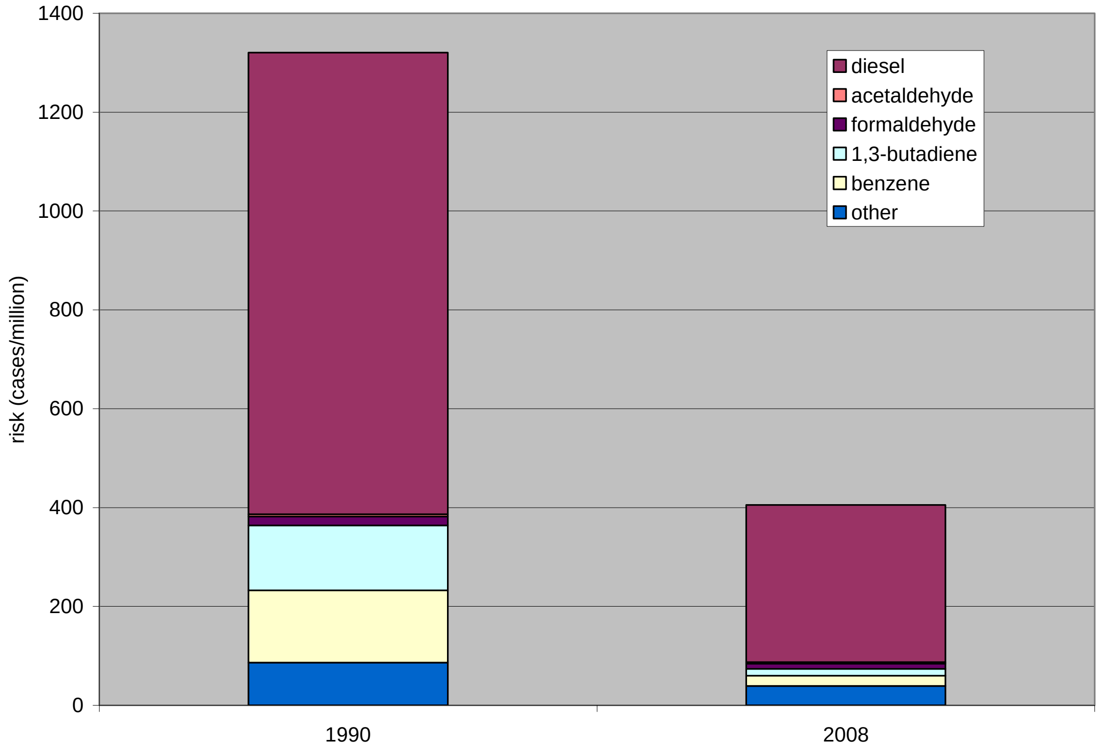

Figure A-3. Lifetime cancer risk per million people from air toxics in the Bay Area: 1990 versus 2008.

Ozone

For this analysis, 50 ppb was used as the ozone health effects threshold; that is, we assume that health effects may occur above 50 ppb.[6] Daily maximum 1-hour ozone values were interpolated to each census tract and any excess above 50 ppb was multiplied times the (year 2000) population for the tract. This was done for every year from 1968 to 2008. Five-year annual averages of these values were computed for 1968-1972 and 2004-2008, and the results summed for each county. The MPEM health effects were then calculated using present population data.

Figure A-4 shows the results. Overall, there has been a significant reduction in the health burden related to ozone. This includes an estimated reduction of 134 deaths per year, from 193 in the 1968-72 period to 59 in the 2004-08 period. There is still a substantial impact from ozone today, but exposure to high concentrations has been reduced by more than two-thirds since 1970. Compared to an annual cost of less than

[6] The decision to use an ozone health effects threshold of 50 ppb is based on several health studies. In their ozone health benefit analysis, Ostro et al. (2006) stated "…no clear threshold for effects has been reported…" They used their estimate of 40 ppb for ozone background as their threshold. In this analysis for the 2010 CAP, we use a somewhat higher concentration at the upper end of background ozone levels.

$500 million for the 2004-2008 period, the impact of ozone in the 1968-72 period would have been almost $1.6 billion for today's population in 2009 dollars.

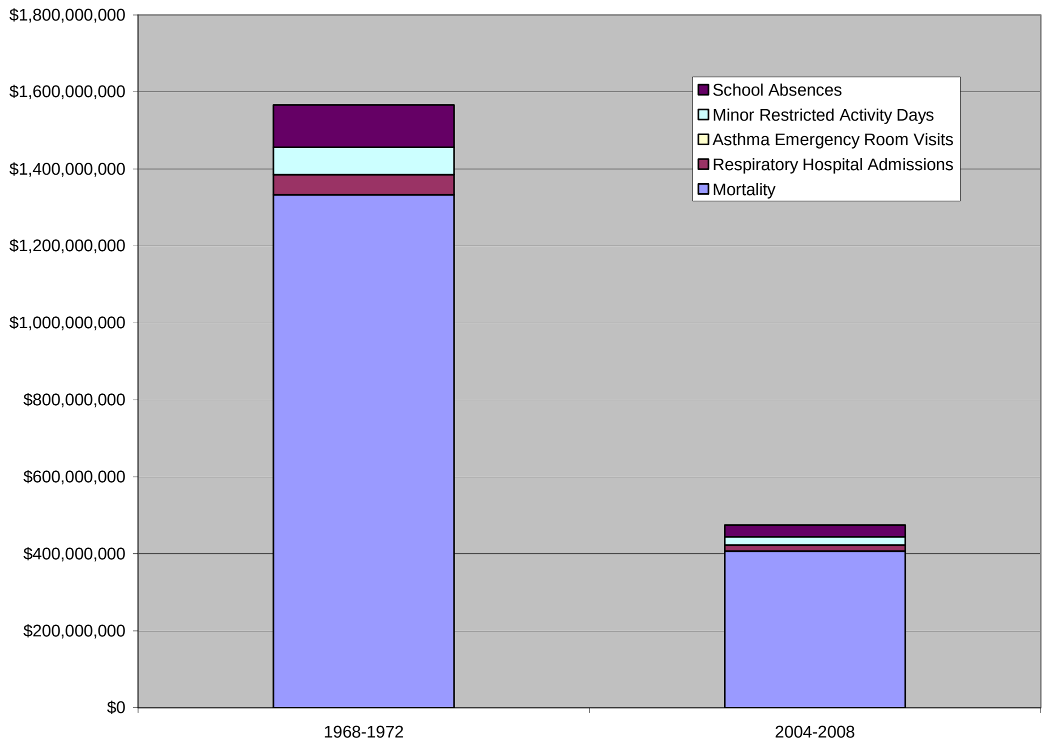

Figure A-4. Estimated health burden from exposure of Bay Area residents to ozone: 1968-72 v. 2004-08.

$PM_{2.5}$

This section explains how we analyzed the trend in anthropogenic $PM_{2.5}$. Estimating $PM_{2.5}$ trends is more complex than analyzing ozone and toxics trends for several reasons. Total $PM_{2.5}$ has been measured routinely only since 1999, so analyzing $PM_{2.5}$ trends prior to 1999 required using other measurements. Analysis of $PM_{2.5}$ is also complicated by the fact that it consists of many components, some man-made, some natural. Thus, we need to analyze the various components, as explained below. And finally, diesel PM, one of the key components of $PM_{2.5}$, cannot be measured directly; as explained in the Diesel $PM_{2.5}$ section below, it must therefore be estimated using elemental carbon as a proxy.

In what follows, we attempt to estimate $PM_{2.5}$ trends since the late 1980s by analyzing the trends in the major components of $PM_{2.5}$ – nitrate, sulfate and carbonaceous $PM_{2.5}$. Nitrate and sulfate have been measured since the early 1990s. Coefficient of Haze (COH), a key measurement which is well-correlated with total carbon, was measured for decades; however, COH measurements ended in 2002. We also have PM10 measurements starting in 1987. $PM_{2.5}$ trends are equivalent to the average of trends in its components.

Table A-4 summarizes the trend information available for these different PM components. Because the PM2.5 measurements have only been available since 1999, whereas the COH measurements were unavailable after 2002, the table shows Bay Area mean concentrations for three periods: (A), the earliest available 5-year periods for PM_{10}, sulfate and nitrate, and parallel years for COH; (B), the earliest 3-year period for $PM_{2.5}$; and (C), the most recent data available. Averages were either 3- or 5-year, a longer period chosen to compensate for fewer data points.

Table A-4. Annual Bay Area mean concentrations (µg/m3 except coefficient of haze units for COH) for various PM measurements in 3 periods.

	Period			Annual Reduction %	
	A	B	C	A to B	B to C
	1988-92	2000-02			
COH	3.81	1.46		8.4%	
		2000-02	2004-08		
total carbon		6.39	5.24		3.9%
	1990-94	2000-02	2003-07		
PM10 nitrate	2.91	1.75	1.41	5.5%	5.2%
	1991-95	2000-02	2003-07		
PM10 sulfate	1.96	1.86	1.60	0.7%	3.7%
	1988-92	2000-02	2003-07		
PM10	31.41	22.57	19.21	3.0%	4.0%
		2000-02	2006-08		
PM2.5		11.94	9.47		3.8%

The last two columns show annual reductions.[7] Consider the reductions from period B to period C first, because $PM_{2.5}$ measurements are available as a benchmark. During this time, there was a reduction in $PM_{2.5}$ of 3.8% per year. This is a lower bound for the annual reduction in anthropogenic $PM_{2.5}$, however, because a fraction of the $PM_{2.5}$ is natural background. Thus, for example, if the background $PM_{2.5}$ were 3 µg/m^3 then the reduction in anthropogenic $PM_{2.5}$ would have been from 11.94 – 3 to 9.47 – 3 or 5.2%.

The major components of $PM_{2.5}$ – nitrate, sulfate and carbonaceous $PM_{2.5}$ – were all reduced by similar amounts from B to C, as was PM_{10}. Note that both sulfate and carbon have natural background: the former from marine air, the latter from forest fires

[7] Computed as follows: If x1 is the concentration in period A and x2 is the concentration in period B and there are y years between them, then the annual reduction was calculated by 1-(x2/x1)^(1/y). For example, PM2.5 went from x1 = 11.94 to x2 = 9.47 in 6 years (2001 to 2007), so the annual reduction is 1-(9.47/11.94)^(1/6) = .0379, or about 3.8%.

and secondary biogenic carbonaceous $PM_{2.5}$. Nitrate, with little natural background was reduced by a larger amount. Thus, the anthropogenic part of these components was reduced by more than 3.8%, consistent with the result for $PM_{2.5}$ as a whole.

The annual nitrate reductions from period A to period B were also around 5% per year, but there was little reduction in sulfate. The 3% annual reduction in PM_{10} was somewhat less than the 4% annual reduction since 2000. But the annual reduction in COH was large, 8.4% annually. Considered as a surrogate for carbonaceous $PM_{2.5}$, it suggests there were major reductions in this component.

Combining this information suggests that the assumption that anthropogenic $PM_{2.5}$ was reduced by 4% per year from 1990 through 2000 is, if anything, somewhat conservative.

To estimate natural background, we have measurements from two coastal national parks – Point Reyes and Redwood, in northern California. Mean annual $PM_{2.5}$ measurements were 5.5 $\mu g/m^3$ for Point Reyes and 3 $\mu g/m^3$ for Redwood National Park from data for 2005-06. At least 1 $\mu g/m^3$ of the difference is a greater Point Reyes ship component.

Taking the lower figure, 3 $\mu g/m^3$, as an estimate of natural background $PM_{2.5}$ and assuming that the reduction in anthropogenic $PM_{2.5}$ was 4% per year, this suggests the 1990 Bay Area mean $PM_{2.5}$ concentration from anthropogenic sources was about 14 $\mu g/m^3$.

Currently, the Bay Area mean $PM_{2.5}$ concentration is about 9.5 $\mu g/m^3$, so the anthropogenic component is about 6.5 $\mu g/m^3$ or somewhat less than half of what it was in 1990. Figure A-5 shows the estimated impact in dollars of $PM_{2.5}$ for 1990 and 2008. The figure is dominated by the costs of mortality; premature mortality is valued at $6.9 million per case, as explained in Chapter 5 of the MPEM Technical Document. Annual estimated deaths in 1990 were 6,200, dropping to about 2,800 annually in 2008.

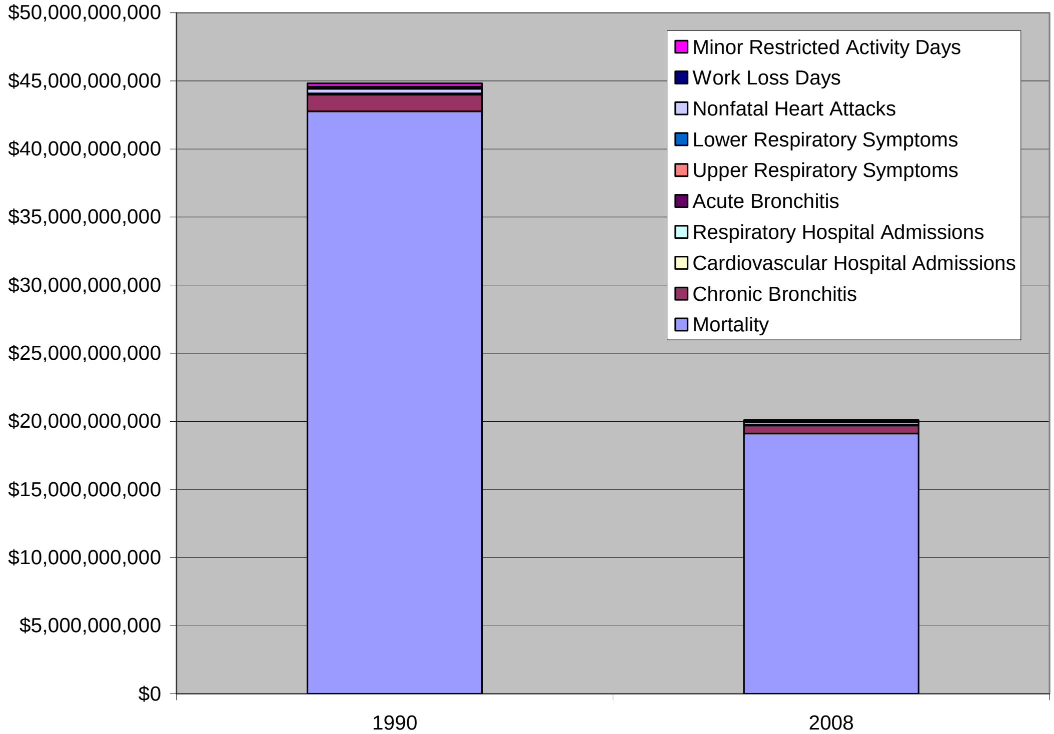

Figure A-5. Estimated annual health burden from PM2.5 exposure of Bay Area residents, 1990 vs. 2008.

Diesel $PM_{2.5}$

Diesel $PM_{2.5}$ cannot be measured directly. Soot, or elemental carbon (EC), is the main constituent, and this has been measured. Roughly 70% of diesel PM is EC and roughly 70% of EC derives from diesel. Thus, to a first approximation, EC concentrations are an estimate of diesel concentrations.

The District has made extensive EC measurements since mid-2004. Figure A-6 shows annual means for site-years with sufficient data in each quarter. Overall, EC concentrations average about 1 $\mu g/m^3$ in populated areas. Point Reyes measurements, from a network of National Park sites, are close to zero, indicating that marine background EC concentrations are very low.

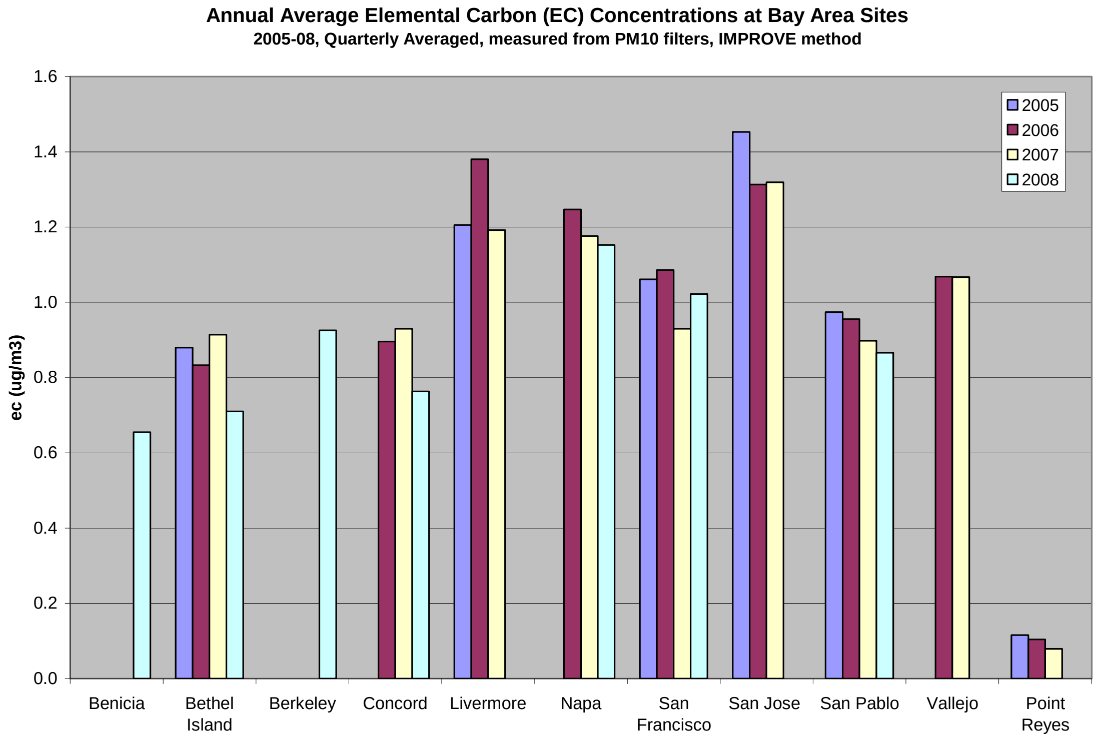

Figure A-6. Annual mean elemental carbon concentrations at Bay Area sites, 2005-08.

There is also data from the toxics modeling conducted for the CARE program, which included diesel. An analysis of concentrations for 2005 yielded a population-weighted diesel concentration of 1.3 $\mu g/m^3$.

To combine these to produce a single estimate, we note that the modeled estimate has the advantage of representing the Bay Area population, but is based on December and July, not the full year. Also, uncertainties in emissions and the modeling process itself cause significant uncertainties in the concentration estimates.

To provide an estimate of earlier diesel concentrations we rely on long-term measurements made with COH instruments. COH measurements are well-correlated with EC as noted earlier. An analysis comparing the measurements at several sites yielded a composite formula: EC = 0.75*COH.

District COH measurements have been collected for many years, with an extensive set commencing in 1967-68. These measurements continued through 2003, when COH monitoring was terminated for most District sites. There were 7 sites with measurements for most of the period and these were used to establish trends.

Figure A-7 shows annual COH means for these sites for years when sufficient data were available. Also shown with a thicker line is a 3-year moving average of these sites. The figure shows an increase in COH from the mid-1970s through 1990 then, starting in

1990, a steady downward trend. The reduction from 1990 to 2003 was large – a factor of 3 - with average COH reduced from 4.0 to 1.3. Applying the formula, this suggests a reduction in EC from 0.75*4 = 3 μg/m^3 to 0.75*1.3 = 1 μg/m^3. Thus, we conclude that average diesel concentrations were reduced from 3 μg/m^3 to 1 μ g/m^3 between 1990 and 2000.

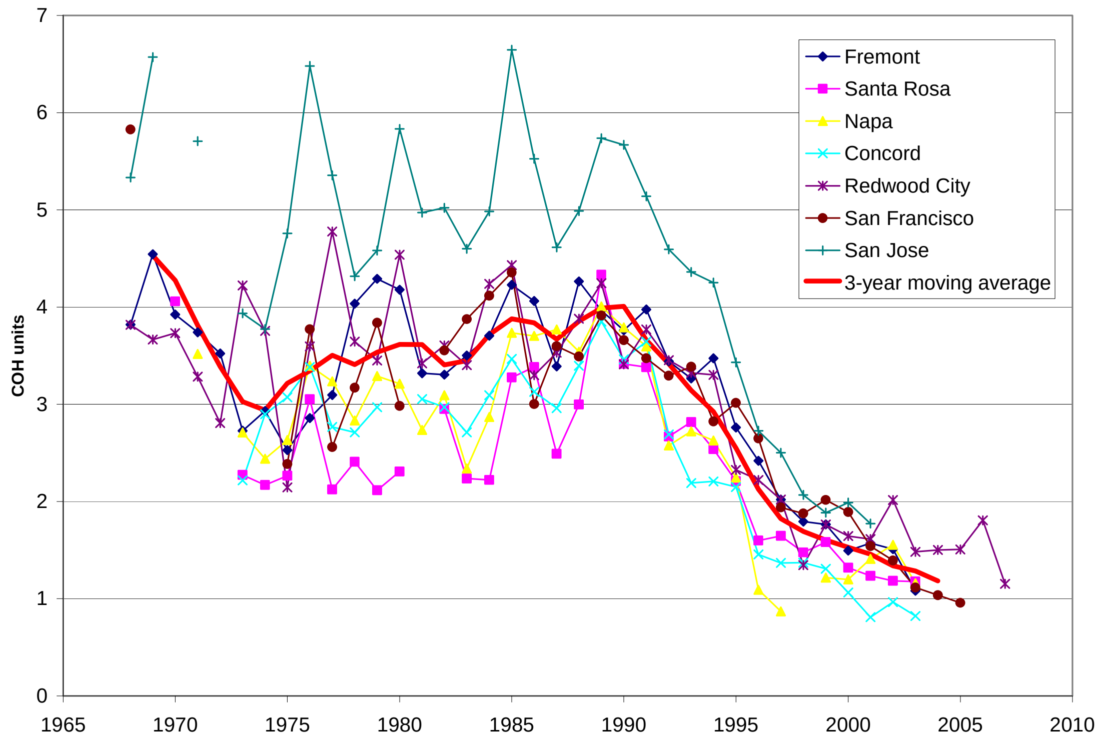

Figure A-7. Annual mean COH measurements for site-years with sufficient data in each quarter. A 3-year moving average is computed from all the measurements within a window of year y-1 to year y+1.

These estimates contain uncertainties. COH is not perfectly correlated with EC which, in turn, is not equal to diesel exhaust. Nevertheless, we believe that the estimates are a reasonable first approximation. For the burden analysis we assume that the current average diesel contribution is 1 μg/m^3 out of the anthropogenic total of 6.5 μg/m^3, and its 1990 contribution was 3 μg/m^3 out of an anthropogenic total of 14 μg/m^3.

Life Expectancy

Figure A-1 above shows that without the air quality improvements that have occurred over the last few decades, there would have been 6,400 deaths per year due to air pollution versus the current 2,800. But this difference would not necessarily be reflected in the raw death rate, because the lower probability of death from air pollution would cause people to live longer, resulting in an older population. Life expectancy can more accurately express the difference in raw death rates. This section compares Bay Area life expectancy today with that of 1990, and what part the reduction in air pollution may have played.

Computing life expectancies requires population and death data by age. We used individual California mortality data from 1989 through 2007. From this the number of deaths by age of Bay Area residents for 1989-91 and 2005-07 was compiled. Age-specific population data was available from the California Department of Finance. Combining these, and using the National Center for Health Statistics approach,[8] we estimated the probability of death at each age for 1990 and 2006.

Figure A-8 shows the results on a log scale. The probability of death has been reduced from 1990 to 2006 at every age. The population-weighted reduction is 40%, so that the probability of dying at a given age today is about 60% of what it was in 1990.

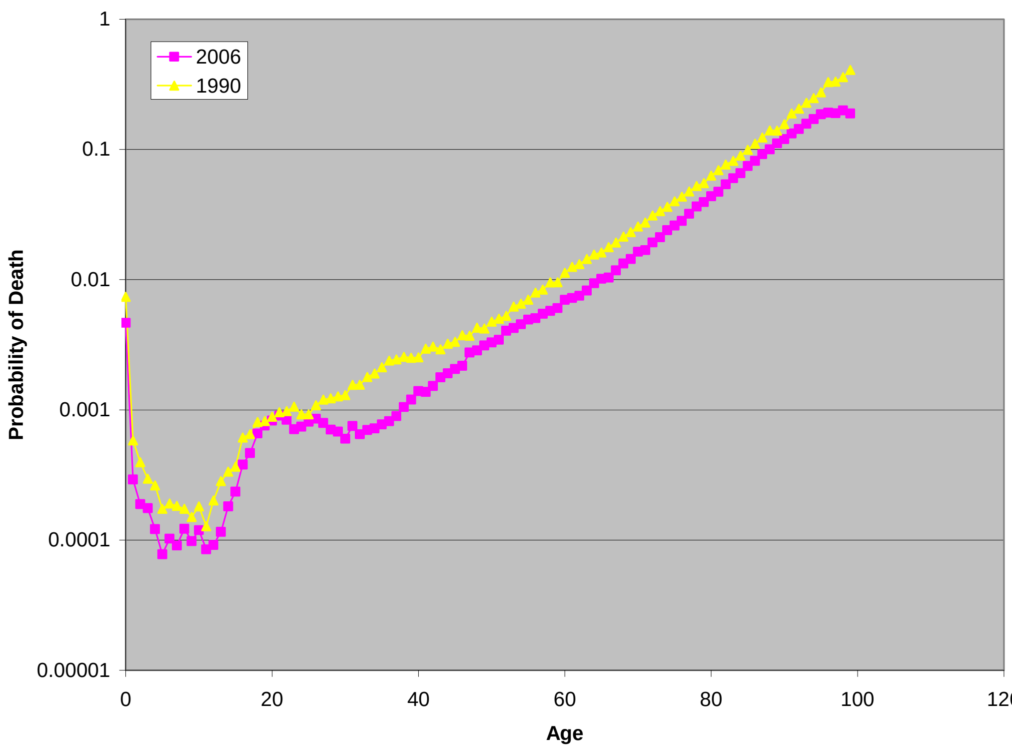

Figure A-8. Probability of death among Bay Area residents, 1990 and 2006. 3-year average deaths vs. population by age.

These probabilities can be translated into life expectancy. For example, starting with a population group of 100,000, the probabilities of death at each age are applied and the

[8] Arias E. United States life tables, 2000. National vital statistics reports; vol 51 no 3. Hyattsville, Maryland: National Center for Health Statistics. 2002.

survivors live to the next age and so on. Totaling the number of life-years and dividing by 100,000 yields the life expectancy, the average number of life-years lived.

For 1990, Bay Area life expectancy was 75.7 years. By 2006 it had increased to 80.5 years. How much of this improvement was due to reductions in $PM_{2.5}$? Using CARB's $PM_{2.5}$ factor of 1% reduction in mortality for each 1 µg/m^3 reduction in $PM_{2.5}$ (CARB 2008), the increment in the probability of death from anthropogenic $PM_{2.5}$ dropped from 15% in 1990 to 6.7% in 2006, a reduction of 8.3%.

This factor is specifically for those 30 and older, and for non-accidental mortality. So the number of deaths by age for this group for 2005-2007 was computed. Multiplying the death rate for this group by 1.083 results in a drop in life expectancy to 80.0, or 6 months. Thus, Bay Area residents can expect to live 6 months longer because of the reductions in $PM_{2.5}$ since 1990.

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Appendix B – Public Outreach for the Bay Area 2010 CAP

Air District staff reached out to inform and engage the general public, as well as key stakeholders, about the 2010 Clean Air Plan (CAP) throughout the plan development process. At the outset of the process, staff designed a public outreach strategy to foster sustained engagement and dialogue with a wide range of stakeholders in developing the Plan. Staff identified the following goals to guide CAP public outreach and engagement:

- *Inform* a wide range of stakeholders and members of the public about the scope and schedule of the plan and opportunities for comment.
- *Provide opportunities* for members of the public and stakeholders to offer input on the plan and outreach process.
- *Educate* the public about air quality and why the Air District and the CAP are relevant, by emphasizing the connection between air quality and health outcomes, and explaining the potential benefits of multi-pollutant planning focused on reducing health risk.
- *Engage impacted communities and multilingual communities* in developing the Plan.
- *Promote transparency* throughout the CAP preparation process.
- *Foster buy-in, ownership, and acceptance* of the Plan.

Public outreach for the CAP took place in three phases: introduction to the CAP and the planning process, development of the control strategy, and presentation of the draft and final plan. Primary outreach mechanisms utilized include the CAP website; notices sent to the CAP e-mail list serve; and CAP public workshops and community meetings and the associated materials and comment summaries that staff prepared. Additionally, in the interests of implementing the goals above, staff developed materials and outreach mechanisms to support education and outreach to Air District constituents for whom English is not the primary language, with a focus on Chinese, Vietnamese, and Spanish speakers. Additional outreach took place for the environmental review process and consultation with other air districts. A description of the full range of outreach mechanisms employed over the course of the CAP planning process is provided below.

CAP Web Pages - The CAP pages on the Air District's website features a description of the plan goals and purpose, regulatory framework, meeting schedule, meeting notices and materials, and key technical documents. Technical documents include multi-pollutant planning methodology and key analyses in regard to pollutant emissions and concentrations, exposure, health outcomes, costs, and pollutant weighting factors underlying the plan control strategy. The website has been used primarily to alert the public to meetings and workshops and to post meeting materials and CAP documents for public review prior to each workshop. The main CAP web page is at: www.baaqmd.gov/Divisions/Planning-and-Research/Plans/Clean-Air-Plans.aspx.

E-mail and paper mail database - The database was compiled from an existing outreach database, updated to reflect the most current information for contacts, augmented with additional health, NGO, and regulatory agency contacts, and converted to the extent possible from snail mail addresses to e-mail in keeping with the Air District's interest in reducing waste. It consists of approximately 1075 e-mail contacts with an additional 179 snail mail contacts, representing regional and state regulatory agencies, staff from other air districts, transportation agencies (including CMAs), environmental and health advocates and professionals, community members, representatives from regulated industries, local governments, and others. The list is refreshed and added to by meeting attendance lists and requests received via e-mail and the CAP website. The database was used to notify the public of meetings dates and locations, and to alert the public to meeting materials and planning and CEQA documents posted on the CAP website.

Outreach to Multilingual Communities – Air District staff developed a CAP informational FAQ sheet to educate and inform members of the public about how the CAP relates to air quality and health. The FAQ was translated into Spanish, Chinese, and Vietnamese languages, posted on the CAP website, and distributed at public meetings and workshops. Staff developed and maintained a phone response system in order to respond to any questions from Chinese, Spanish, and Vietnamese language speakers about the CAP. Directions for accessing this system in each of these languages were included on all CAP e-mails and workshop/meeting notices.

Public Workshops and Community Meetings - The Air District held public workshops and meetings at locations throughout the Bay Area during the CAP planning process to facilitate dialogue and collect input on the proposed control strategy and Plan. All meetings were held at accessible locations and in close proximity to transit, whenever possible. Notice of each meeting was provided at least three weeks in advance on the District website and by e-mail and snail mail to the CAP contact database. Public comments received during meetings were recorded, compiled in summaries of public comments and District responses, and posted on the CAP website for public review. As of February 2010, 14 public workshops and community meetings have been held by Air District staff at key intervals throughout the CAP planning process. A table summarizing CAP public workshops and meetings is provided in Table B-1.

Additional public workshops will be held after the release of the draft CAP.

Table B-1. Public workshops on Bay Area 2010 Clean Air Plan.

	Description and Purpose	Date and Location	Attendance
Introduction to the CAP planning process	Kick-off workshop	July 15, 2008 MetroCenter, Oakland	35
	Fall 2008 community meetings	October 6, 2008 West Oakland Public Library * October 8, 2008 San Jose City Hall * October 21, 2008 Petaluma Public Library October 23, 2008 Pleasanton Senior Center October 27, 2008 San Leandro Public Library * November 15, 2008 San Francisco * Bayview Opera House	16 6 8 7 14 42
Control Strategy Development	Public Workshop: • All Feasible Measures Review / Call for control measure ideas	January 28, 2009 Oakland MetroCenter	50
	Public Workshops: • Preliminary Control Measures • Draft control measure review • 2005 Ozone Strategy Implementation Update	April 27 2009 Redwood City Public Library April 29, 2009 Oakland City Hall April 30, 2009 Petaluma Public Library	22 23 11
	Public Workshop: • Multi-pollutant Methodology	June 11, 2009 MetroCenter, Oakland	37
	Public Workshops: • Draft Control Strategy	September 2, 2009, Mountain View City Hall September 3, 2009, MetroCenter in Oakland	12 38
	CEQA Scoping Meetings	September 2, 2009, Mountain View City Hall September 3, 2009, MetroCenter in Oakland	12 38

*These meetings were held in Community Air Risk Evaluation (CARE) impacted communities to address the District's CARE program and the CAP, with the aim of soliciting input on the CAP planning process from communities most directly impacted by air pollution.

In addition to formal workshops and community meetings, staff made presentations about the CAP to interested stakeholders in other venues as opportunities arose. These presentations were made, often upon request, in order to build partnerships, increase understanding of the scope of objectives of the CAP, and solicit feedback on innovative aspects of the CAP.

Staff pursued opportunities to make presentations about the CAP in other venues, including:

- Richmond resource team meeting, September 25, 2008.
- CAPCOA Engineering Managers symposium, June 16, 2009
- US EPA conference call, July 23, 2009
- California Council for Environmental and Economic Balance:
  - July 13, 2009 and October 6, 2009
- Contra Costa Council: September 4, 2009
- CAPCOA Planning Managers symposium, September 30, 2009
- Urban Heat Island Mitigation Conference, September 21, 2009

Consultation with Neighboring Air Districts: Air District staff held two conference calls to solicit input on the CAP control strategy on September 1, 2009 and September 15, 2009, as described in transport mitigation section in Appendix C.

Collaboration with Regional Agencies: The CAP was developed in collaboration and consultation with MTC, ABAG, and BCDC, the Air District's regional agency partners. MTC staff and ABAG staff provided important input to the Transportation Control Measures, and MTC staff played a key role in developing emission reduction and cost estimates for the TCMs. In addition, the CAP was informed by regional agency plans, including *Transportation 2035: Change in Motion* and *Projections and Priorities 2009*.

Air District Staff made presentations about the CAP at the following regional agency meetings:

Joint Policy Committee:
November 7, 2008
September 18, 2009

MTC Planning Committee:
May 8, 2009
July 10, 2009

The Draft CAP will be presented to the MTC Planning Committee on March 12, 2010 and to the Joint Policy Committee on March 19. 2010.

Reports to Air District Board of Directors and Board Committees: District staff provided several briefings to the Board of Directors and Board Committees in the course of developing the draft CAP.

BAAQMD Executive Committee:
September 26, 2008
June 29, 2009

BAAQMD Climate Protection Committee:
October 8, 2009

BAAQMD Board of Directors:
September 16, 2009

CEQA Review: Pursuant to the California Environmental Quality Act (CEQA), the Air District prepared and issued a Notice of Preparation (NOP) and Initial Study (IS) and held two public scoping meetings on September 2 in Mountain View at the Mountain View City Hall and on September 3 at the Metro Center Auditorium in Oakland. The purpose of these meetings was to identify the range of actions, alternatives, mitigation measures, and significant effects to be analyzed in depth during the environmental review. The public comment period for the NOP ended on September 21, 2009.

Appendix C – State Air Quality Planning Requirements

For the past 20 years, the 1988 California Clean Air Act (CCAA), along with subsequent amendments, as codified in the California Health & Safety Code, has guided efforts throughout California to achieve State ambient air quality standards. The basic goal of the CCAA is to achieve health-based State ambient air quality standards by the earliest practicable date. The CCAA requires regions that violate the State ozone standard to prepare attainment plans that identify a strategy to attain the standard. Regional air quality plans are required to achieve a reduction in district-wide emissions of 5 percent per year for ozone precursors (California Health & Safety Code Section 40914).[1] If an air district is unable to achieve a 5 percent annual reduction, adopting a control strategy that includes all feasible measures on an expeditious schedule is acceptable, as an alternate strategy (Sec. 40914(b)(2)).

California classifies ozone nonattainment areas based on their "expected peak day concentration," which is an ozone reading that the region should not exceed more than once per year, on average, excluding exceptional or extreme readings. Legal requirements vary according to the severity of a region's ozone problem. The Bay Area is subject to CCAA requirements for "serious" areas. (Secs. 40921.5(a)(2), 40919).

This Appendix describes CCAA air quality planning requirements and how the Bay Area 2010 Clean Air Plan (CAP) fulfills all requirements.

All Feasible Measures

No non-attainment area in the state has been able to demonstrate a 5% reduction in ozone precursor pollutants each year. Consequently, air districts throughout the state, including the Bay Area, have opted to adopt “all feasible measures” as expeditiously as possible to meet the requirements of the CCAA. The CCAA does not define “feasible,” but the Health and Safety Code provides some direction to assist the District in making this determination. Sec. 40406 defines a related term, Best Available Retrofit Control Technology (BARCT), as “an emission limitation that is based on the maximum degree of reduction achievable, taking into account environmental, energy and economic impacts by each class or category of source.” CARB defines “all feasible measures” in the Transport Mitigation Regulation, Section 70600 *et seq,* Title 17 California Code of Regulations, as “air pollution control measures, including but not limited to emissions standards and limitations, applicable to all air pollution source categories under a district's authority that are based on the maximum degree of reductions achievable for emissions of ozone precursors, taking into account technological, social, environmental, energy and economic factors, including cost-effectiveness.” Section 40922(a) requires an assessment of the cost effective of each proposed control measure, including a

[1] All references to Section numbers are for the California Health and Safety Code, unless otherwise noted.

ranking of measures from the least cost-effective to the most cost-effective. Section 40922(b) lists additional criteria that air districts should consider in reviewing potential control measures, including technological feasibility, total emission reduction potential, the rate of reductions, public acceptability, and enforceability.

The process by which the Air District reviewed and evaluated potential control measures in relation to these criteria is described in Appendix F. An overview of the 2010 CAP control strategy is provided in Volume I, Chapter 4; detailed descriptions of control measures are provided in CAP Volume II.

Transport Mitigation Requirements

The CCAA requires CARB to periodically assess transport of ozone and ozone precursors from upwind to downwind regions, and to establish mitigation requirements for upwind districts (Sec. 39610). The CCAA also requires air districts to address transport mitigation requirements in the triennial updates to strategies to achieve the State ozone standard (Sec. 40912).

CARB first adopted transport mitigation requirements in 1990, amended them in 1993, and further strengthened them in 2003. CARB's 2003 amended Transport Mitigation Requirements are in Title 17, California Code of Regulations, Sections 70600 and 70601. The requirements for transport mitigation state that upwind districts "shall include sufficient emission control measures in their attainment plans for ozone…to mitigate the impact of pollution sources within their jurisdictions on ozone concentrations in downwind areas commensurate with the level of contribution." Specifically, the Bay Area is required to:

1) adopt and implement all feasible measures as expeditiously as practicable;
2) adopt and implement best available retrofit control technology (BARCT) on all existing stationary sources of ozone precursor emissions as expeditiously as practicable;
3) implement, by December 31, 2004, a stationary source permitting program designed to achieve no net increase in the emissions of ozone precursors from new or modified stationary sources that emit or have the potential to emit 10 tons or greater per year of an ozone precursor; and
4) include measures sufficient to attain the state ambient air quality standard for ozone by the earliest practicable date within the North Central Coast Air Basin, that portion of Solano County within the Broader Sacramento Area, that portion of Sonoma County within the North Coast Air Basin, and that portion of Stanislaus County west of Highway 33 during air pollution episodes, provided that:
    a) the areas are likely to violate the State ozone standard,
    b) the areas are dominated by transport from the Bay Area, and,

c) the areas are not affected by emissions of ozone precursors within their borders.

The 2010 CAP addresses all of the above requirements. The 2010 CAP control strategy, together with the Air District rule development and permitting processes, address the requirement to adopt all feasible measures, including measures sufficient to attain the State ozone standard in specified transport areas, and to implement BARCT on all existing stationary sources. With respect to the "no net increase" requirement, the Air District adopted a 10 ton/year no net increase requirement for ozone precursors in District Regulation 2, Rule 2: New Source Review on December 21, 2004. As adoption of all feasible measures represents the most stringent control strategy that can be accomplished, this requirement is met with the approval of each triennial plan.

In addition, the Air District is required to consult with downwind districts, review the list of control measures in the most recently approved attainment plan (in this case, Bay Area 2005 Ozone Strategy), make a finding as to whether the list of control measures meets the requirements of Section 70600 (b) and include the finding in the proposed triennial plan revision.

To fulfill this consultation requirement, the Air District consulted with downwind air districts to ensure that the CAP control strategy includes all feasible measures. The Air District hosted conference calls with downwind air districts on September 1 and September 15, 2009 to solicit comments and suggestions on the preliminary CAP control strategy. Air District staff also made presentations on the CAP to the CAPCOA (California Air Pollution Control Officers Association) Engineering Managers on June 16, 2009 and to the CAPCOA Planning Managers on September 20, 2009.

Other Requirements

In addition to requirements concerning all feasible measures and transport mitigation, the CCAA requires that strategies to attain the State ozone standard contain other elements, including the following:

<u>Emissions inventory system</u> (Sec. 40918(a)(5)). The Air District maintains an emissions inventory system. The emission inventory is included in the "Sources of Air Pollution – Emission Inventory" section of this document.

<u>A permitting program</u> [Sec. 40919(a)(2)] designed to achieve no net increase in emissions from permitted sources with a potential to emit greater than 15 tons per year of a nonattainment pollutant or their precursors and to require the use of best available control technology (BACT) on new and modified sources with a potential to emit greater than 10 pounds per day. The Air District's permitting program, as spelled out in BAAQMD Regulation 2, Rule 2 — New Source Review — complies with the requirements of Health and Safety Code Section 40919(a)(2). Sufficient offsets have been provided for

all permits that have been issued by the Air District. Furthermore, the Small Facility Banking account has sufficient credits to sustain withdrawals into the foreseeable future at the current withdrawal rate. The Air District's no net increase threshold was reduced to 10 tons per year to comply with transport mitigation requirements in December 2004.

<u>Best available retrofit control technology (BARCT) on all existing permitted stationary sources</u> **[**Sec. 40919(a)(3)]. BARCT is implemented through the Air District's rule development, enforcement and permit review programs. Air District staff perform an assessment of BARCT requirements when proposing new rules or rule amendments and ARB reviews Air District rules and proposed rule amendments to insure that BARCT standards are implemented. Additionally, the Air District evaluates existing sources during the annual permit review process to ensure BARCT requirements are being met. Finally, the Air District issues facility advisories, and implements compliance assistance and enforcement programs help to ensure compliance with BARCT standards in rules.

<u>Measures to achieve use of a significant number of low-emission vehicles in motor vehicle fleets</u> [Sec. 40919(a)(4)]. Proposed mobile source control measures MSM A-1, MSM A-2, and MSM A-3 promote the use of low-emission vehicles to reduce motor vehicle fleet emissions. TCM A-1 addresses clean fuel transit and school buses. The Air District's Transportation Fund for Clean Air, Carl Moyer and Low Emission School Bus programs provide funding for projects to promote the purchase and use of low-emission vehicles.

<u>Transportation control measures</u> (TCMS) to substantially reduce the rate of increase in passenger vehicle trips and miles traveled per trip [Sec. 40918(a)(3)]. Pursuant to Sections 40233 and 40717, each TCM must include the following:

- A schedule for implementation
- Identification of potential implementing agencies
- Procedures for monitoring the effectiveness of and compliance with the measures in the plan; and

In addition, Section 40233 directs the Air District to estimate the quantity of emission reductions from transportation sources necessary to attain and maintain State and national ambient air quality standards. Section 40233 requires MTC to prepare and adopt a TCM plan to achieve the specified quantity of emission reductions. The TCM plan is then incorporated into the overall strategy for achieving the State ozone standard. The statute also requires MTC to develop and adopt a revised TCM plan whenever the Air District revises the emission reduction target.

The Air District and MTC complied with the requirements of Section 40233 when preparing the first Bay Area plan for the State ozone standard, the 1991 Clean Air Plan, by adopting a TCM emission reduction target and plan in 1990. Section 40233 leaves it to the Air District's discretion as to whether and when to revise the emission reduction target for transportation sources set in 1990. This triennial update to the strategy for the State ozone standard does not include a revised emission reduction target for transportation sources, and therefore, does not trigger a TCM plan revision. The Air District and MTC have, however, comprehensively reviewed and augmented the TCMs during preparation of the 2010 CAP to maximize their effectiveness.

<u>Indirect source and area source programs</u> [Sec. 40918(a)(4)] Several measures in the 2010 CAP are intended to reduce emissions from indirect sources. LUM 2 calls for the District to develop an indirect source review regulation pursuant to Section 40716. LUM 3 describes updated CEQA guidelines that should also help to reduce emissions from new indirect sources of emissions. Also, TCM D-3 includes actions by the District and partner agencies to promote focused development that should also reduce emissions from indirect sources. Management of area source emissions is addressed through existing Air District regulations for ROG in Regulation 8 and NOx in Regulation 9. In addition, PM is addressed by Regulation 6, including the District's wood smoke rule (Reg. 6, Rule 3, adopted in July 2008) and complementary wood smoke public education program.

<u>Regional public education programs</u> [Sec. 40918(a)(6)] The Air District administers several public education programs that encourage the public to reduce air pollution both year round and on an episodic basis. The Air District's "Spare the Air" public education program, described in TCM C-4, is aimed at curbing emissions from motor vehicles and other ozone precursor sources on days when weather conditions are conducive to high ozone levels. The *Winter Spare the Air* program, described in Chapter 3, complements the regulatory Wood Burning program that reduces emissions of particulate matter from wood burning. Other ongoing educational programs include grassroots resource teams located throughout the Bay Area; a Smoking Vehicle Assistance Program; outreach and presence at public events throughout the year; a suite of youth education programs including the Clean Air Challenge, Cool the Earth and Protect Your Curriculum; and a Speakers Bureau that delivers talks on air quality to a variety of audiences throughout the region.

<u>An assessment of cost-effectiveness of proposed control measures</u> (Sec. 40922). Information regarding cost-effectiveness CAP control measures is provided in Chapter 4 of CAP Volume I.

Periodic requirements include the following:

<u>An annual regulatory schedule</u> (Sec. 40923). The Air District produces a regulatory schedule each December, listing regulatory measures that may be scheduled for adoption or amendment during the following year. A proposed regulatory schedule for years 2010 through 2012 is provided Chapter 4 of the 2010 CAP.

An annual progress report on control measure implementation and, every third year, an assessment of the overall effectiveness of the program (Sec. 40924). The Air District has submitted annual progress reports to CARB nearly every year since 1993. Previous triennial assessments of overall plan effectiveness were submitted in 1994, 1997, 2000, and 2005. The latest triennial assessment is provided in Chapter 3 of the 2010 CAP.

A review and update of the plan every three years to correct for deficiencies and to incorporate new data and projections (Sec. 40925). The 2010 CAP incorporates new data and projections and updates the control strategy.

Appendix D – Ecosystem Impacts of Air Pollution

In addition to impacts on human health, air pollutants can also have impacts on the terrestrial and aquatic ecosystems and the flora and fauna that sustain human life. In many cases, air pollutants such as reactive organic gases (ROG), nitrogen oxides (NOx), sulfur dioxide (SO2), ammonia (NH3), and particulate matter (PM) are ultimately deposited on land and water, where they cause a variety of impacts. Air pollutants can be deposited directly onto the surface of a water body, or they can be deposited on to land and then carried to water bodies through run-off.

This appendix summarizes some of the key ecosystem impacts of air pollution, including damage to crops and vegetation, acid deposition, and eutrophication of waterways. As shown in the table below, multiple pollutants may contribute to each specific impact, and certain pollutants, such as NOX and NH3, may cause multiple impacts.

	Impacts on Terrestrial Systems		Impacts on Aquatic Systems		
	Damage to Crops & Vegetation	Deposition on Land	Acidification	Eutrophication	Water Pollution
ROG	X				
NOx	X	X	X	X	
SO2			X		
NH3		X	X	X	
PM & metals					X

Reactive Nitrogen

Concern about climate change has drawn attention to the consequences of human intervention in the carbon cycle. However, the impact of human intervention in another system of fundamental importance, the nitrogen cycle, has received much less attention. Reactive nitrogen (Nr) is one of the major causes of ecosystems impacts discussed below, including ozone damage to plants, acid deposition on land and on water, nitrogen deposition on land, and eutrophication of water bodies. Human activities produce five times more reactive nitrogen per year than natural processes (EPA Science Advisory Board 2009). The use of synthetic fertilizers is the leading source of anthropogenic Nr, but combustion of fossil fuels in motor vehicles, power plants and other sources is also a major source of Nr.

Nitrogen in its pure form is an inert (non-reactive) gas. However, nitrogen is chemically reactive and exists in many reactive forms. The reactive nitrogen compounds can have beneficial uses, such as fertilizer to increase crop production, but they can also be harmful to ecological systems. Once in a reactive form, nitrogen is easily transported between air, water, and soils in a process known as the "nitrogen cascade." This cascade is very complex, extending from initial emissions through atmospheric transport and chemical transformations; dry-deposition and wet-deposition; and downstream effects that involve plants, animals, fungi, and bacteria interacting in myriad ways. The primary forms of Nr that are released as air pollutants are NH3, NOx, and N2O.

Because it can move so easily from the atmosphere into soils and waterways, and back again, a single nitrogen-containing molecule can have a series of impacts on the environment. While airborne in the form of NOx, reactive nitrogen contributes to formation of ozone in the lower atmosphere, causing respiratory ailments in humans and damaging vegetation. NOx, NH3, and N2O may fall to the surface and contribute to acid deposition, pollution of groundwater and surface water, and eutrophication of estuaries and coastal ecosystems.

Ozone

Ozone is formed by a chemical reaction between ozone precursors, ROG and NOx, in the presence of sunlight. Emissions of these precursors are produced by a wide range of sources and processes, including combustion of fossil fuels, industrial processes, evaporative emissions from fuel tanks, and chemical solvents. Elevated concentrations of ozone can damage agricultural crops, trees and other forms of vegetation. Ozone oxidizes plant tissue, which reduces photosynthesis and interferes with the ability of sensitive plants to produce and store food. Impacts include:

- premature leaf loss, and reduced leaf and root weight;
- increased susceptibility to certain diseases, insects, other pollutants, competition and harsh weather;
- damage to the appearance of urban vegetation, as well as vegetation in national parks and recreation areas; and
- reduced forest growth and crop yields,[1] potentially impacting species diversity in ecosystems.

Acid Deposition and Acidification

Acidification can occur when nitric acid and sulfuric acid are deposited into aquatic or terrestrial ecosystems. When SO2 and NOx are emitted from power plants, motor vehicles, and other sources, they can be transported long distances by prevailing winds, reacting in the atmosphere with water, oxygen, and other chemicals, and eventually falling to earth in the form of dust, acid rain or snow.

[1] Ozone damage to orchards in the Santa Clara Valley was a major factor in the creation of the Bay Area AQMD in 1955, when agriculture was still the backbone of the economy in the South Bay.

When nitric and sulfuric acids are deposited into waterways, such as rivers, streams, lakes or marshes, the impact of the increased acid on the ecosystem depends on the sensitivity of the water body. Generally, this sensitivity is highest when the soil in the watershed has a limited capacity to neutralize acidic compounds (referred to as "buffering capacity"). In areas where buffering capacity is low, acid rain releases aluminum from soils into lakes and streams. Aluminum is highly toxic to many species of aquatic organisms. [2] Increased concentrations of CO_2 in the atmosphere, the primary cause of climate change, also causes acidification of ocean waters, because the CO_2 absorbed by oceans dissolves to create carbonic acid. This increased acid content impedes the ability of some marine life to develop shells and skeletal structures.

On land, acid deposition can damage trees, especially at higher elevations, where exposure to acid-heavy clouds and mist is greater. The ability of a forest to cope with acid deposition depends on the buffering capacity of its soil. Acid dissolves and removes the nutrients in forest soils before trees and other plants can use them to grow. At the same time, acid rain causes the release of substances that are toxic to trees and plants, such as aluminum, into the soil. Acid rain is not a problem for water bodies in the Bay Area. However, because SO_2 and NO_x can travel great distances in the atmosphere before their deposition, pollution emitted in the Bay Area may impact ecosystems in downwind areas, including the Sierra Nevada. According to a National Parks Service report,[3] acid rain and snow is not as serious a problem in the Sierra Nevada as in the eastern U.S. or the Colorado Rockies. However, many high-elevation Sierra lakes have low buffering capacity, so it is important to minimize any future acid deposition.

Nitrogen Deposition on Land

Deposition of reactive nitrogen on land acts as an unintended fertilizer which can have impacts on terrestrial flora and fauna. Of the 225 plant species in California listed as threatened or endangered by the state or federal government, 101 are exposed to levels of nitrogen suspected of causing ecological disruption (CEC 2006). In areas where Nr is deposited on nutrient-poor soil, this can fuel the expansion of invasive, non-native species that choke out native plants. As the flora changes, animal species that depend on the native vegetation may be adversely impacted.

The case of the Bay Checkerspot Butterfly, which has been on the federal endangered species list since 1987, provides an example of the impact of reactive nitrogen on diversity of native flora and fauna. The Checkerspot depends on native grasses, such as plantain, that grow on nutrient-poor serpentine soils. The serpentine ecosystem provides food for both the larval and adult stages of the butterfly. Edgewood Natural Preserve in San Mateo County historically supported a healthy population of

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[2] "Acid Deposition Impacts on Aquatic and Terrestrial Ecosystems", http://www.epa.gov/acidrain/effects/surface_water.html

[3] See http://www.nature.nps.gov/air/Pubs/pdf/techInfoEpaDeposition.pdf

Checkerspots. However, nitrogen deposition from vehicles on Interstate 280, which is adjacent and upwind to the Preserve, has allowed the aggressive, non-native grasses, such as Italian rye grass, to crowd out native grass species in recent years.[4] As a result of habitat reduction, the Checkerspot population at Edgewood is in jeopardy.

Nitrogen Deposition in Water Bodies

When excessive nutrients are introduced to a water body, through fertilizer run-off, atmospheric deposition of nitrogen compounds, or wastewater discharge, this can stimulate excessive plant growth (often referred to as algal blooms), which can in turn degrade water quality. Algal blooms can reduce oxygen content of water, damaging other water-based organisms. This process is called eutrophication. NOx emissions from power plants and motor vehicle exhaust contribute to eutrophication. San Francisco Bay is somewhat protected from the impacts of eutrophication due to the high sediment content of the Bay, which filters out sunlight and impedes phytoplankton growth. However, periodic elevated levels of algal growth (such as "red tides") do occur in the Bay and could become a more serious problem if deposition of excess nutrients is not kept in check. In addition, more than half the nitrogen that fuels algae growth in Lake Tahoe is a result of atmospheric deposition.[5] Thus, emissions of nitrogen compounds in the Bay Area may also contribute to the loss of clarity in Lake Tahoe, a prime aesthetic, recreational, and tourism asset for both California and Nevada.

Other Impacts on Water Systems

According to the San Francisco Estuary Institute's Regional Monitoring Program, although some contaminants are reduced from peak levels seen in earlier decades, the level of contamination in the Bay today is high enough to impair the health of the ecosystem. Pollutants found in waterways increase, or bioaccumulate, through the food chain. Beginning with their ingestion in the water by filter feeders such as clams and oysters, these pollutants eventually make their way up through fish to marine mammals and humans.

Tidal marshes and vegetated areas on the shoreline help prevent the degradation of water quality from non-point source pollution by filtering out contaminants, intercepting run-off, dampening wave action, and reducing bank erosion. However, the ability of marshlands to perform these critical services decline if the health of marsh habitats is compromised.

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[4] Weiss, Stuart, *Final Report on NFWF Grant for Habitat Restoration at Edgewood Natural Preserve, San Mateo County*, CA; October, 2002.

[5] See Suzanne Bohan, "Nitrogen Overdose: Element quietly rivaling CO2 as a global climate threat." *Oakland Tribune,* August 12, 2007.
www.creeksidescience.com/files/oaklandtribune_nitrogen_12aug07.pdf

Deposition of particulate matter, including heavy metals, may also have negative impacts on the Bay and other water bodies. Tire wear is a significant source of zinc, and brake pad wear is a significant source of copper (Stolzenbach 2006). Copper from brake pad wear is washed into streams, rivers and coastal waters where it is toxic to aquatic organisms such as phytoplankton, that serve as the foundation of the food chain, thus affecting the health of entire ecosystems. Elevated copper levels may also be one of the factors contributing to the decline of salmon populations.[6]

Climate Change

In addition to ecosystem impacts from air pollution, climate change due to increasing levels of greenhouse gases in the atmosphere is expected to cause a wide range of detrimental impacts to Bay Area ecology. These impacts will be most damaging to sensitive ecosystems that do not have the ability to rapidly adapt to a changing environment.

When the earth's average temperature changes, even only to a slight degree, it can cause major changes to weather patterns and ecosystems. The Bay Area is already experiencing the impacts of climate change. Examples of ecosystem impacts of climate change include the following.

- Sea levels have risen by as much as seven inches along the California coast over the last century. Rising sea levels may alter, or even submerge, existing wetlands.
- Less winter precipitation is falling as snow, and snow is melting earlier in the year, causing water shortages.
- Spring is arriving earlier, which alters the timing of natural cycles.
- Wildfires are becoming more frequent and intense due to dry seasons that start earlier and end later. This can cause a wide range of direct and indirect ecosystems impacts.
- Higher summer temperatures are causing an increase in ground-level ozone (smog) formation. Higher ozone levels mean more damage to vegetation and crops.

A changing climate will mean warmer temperatures and less rainfall for most of the Bay Area. Plant species that require cooler, moister environments will either migrate to higher elevations or move north if they are able; if they are unable to migrate, they will simply disappear. This may cause assemblages of species that depend on each other for survival, such as broadleaf forests, to break up as stronger species are able to migrate. It is estimated that statewide, up to 1,300 species (two-thirds of California's endemic

[6] For discussion regarding the impact of copper from brake pads on water bodies, see http://www.suscon.org/bpp/#

flora) will either disappear or be greatly reduced from their current ranges.[7] When native plants die out, they are often replaced by weedier replacements that can evolve and adapt quickly.

The Bay Conservation and Development Commission expects sea level in the Bay Area to rise by approximately 4.6 feet by the end of the 21^{st} century. This will inundate most of the Bay's coastal wetlands, leaving very little buffer zone between rising tides and storm waters and the built environment. A wide range of both migratory and resident species, such as the California Tiger Salamander, depend upon San Francisco Bay wetlands for nesting, breeding, and feeding. Loss of these wetlands would be a major blow, particularly to the more specialized, or exotic native species. Generalist species which are more capable of adapting to rapid environmental change, such as crows, raccoons, skunks and coyotes, are likely to increase in numbers.

Recent research has linked increased wildfires in the west to warmer springs and earlier melting of the sierra snowpack, both symptoms of climate change. In recent years, California is experiencing longer, more intense fire seasons, with more destructive fires. Most of the native plants in the California wild lands depend upon intermittent drought and seasonal burning. These species drop seeds which lay dormant in the soil until a wildfire uncovers them and allows them to germinate. With more frequent forest fires, native plants may not have enough time to grow and set seed. A loss of native plant life due to increase occurrence of wildfires could lead to an invasion of more generalist, weedier species.

How the 2010 CAP Helps to Protect Ecosystems

The Bay Area 2010 CAP provides a multi-pollutant control strategy to reduce emissions and ambient concentrations of ozone precursors (ROG and NOx); directly-emitted PM, as well as PM precursors (ROG, NOx, SO2, and NH3); key air toxics; and key greenhouse gases (CO2, methane, N2O). The primary focus of the CAP is to reduce air pollution in order to protect public health. However, ecosystem protection is another important co-benefit of the CAP.

It is beyond the scope of this analysis to directly measure how the anticipated emission reductions from CAP control measures will prevent or mitigate the ecosystem impacts described in this appendix. However, by reducing emissions of ROG, NOx, NH3, SO2, PM, and CO2, the CAP will help to protect the health of terrestrial and aquatic ecosystems and native flora and fauna in the Bay Area, as well as in downwind areas, such as the Central Valley and the Sierra Nevada. It is likely that the emission reductions

[7] See: *Taking the Heat* in Bay Nature: Exploring Nature in the San Francisco Bay Area, Jan-March 2009. http://baynature.org/articles/jan-mar-2009/taking-the-heat/taking-the-heat

from the 2010 CAP control strategy will play only a modest role in directly reducing ecosystem impacts. However, for the reasons described in this appendix, the issue of how to reduce the ecosystem impacts of air pollution merits additional attention in future air quality planning efforts.

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Appendix E – Photochemical Modeling

Although no air quality modeling was required to be performed for the 2010 CAP, results of the Air District's recent air quality modeling helped to inform the development of the CAP. A brief overview of the Air District's modeling and key findings were summarized in CAP Chapter 2. This appendix provides a more detailed description of the Air District's recent modeling work.

BAAQMD Modeling History and Scope

From 1989 to 2006, the Air District's photochemical modeling effort mostly focused on the preparation of the State Implementation Plans for national ozone standards. Because the Bay Area is currently classified as a marginal non-attainment area for national 8-hour ozone standard, the Air District is not required to use photochemical models for attainment demonstration. However, the Air District is committed to continue working with neighboring districts and CARB to study regional ozone transport through the use of photochemical models.

The Bay Area also does not attain the national 24-hour PM2.5 standard. Since a significant percentage of PM2.5 is formed via chemical processes of precursor pollutants affected by sunlight, U.S. EPA is expected to require the use of photochemical models for attainment demonstration in the preparation of the State Implementation Plan for this pollutant. Photochemical modeling is not currently required for demonstrating attainment for State standards.

There are no federal or State requirements to perform photochemical air toxics modeling. The Air District added photochemical air toxics modeling capabilities to its program in 2005 to investigate the nature of toxic concentrations over the entire Bay Area and in sub-regions. Air toxics simulations prior to this date were limited to permit evaluation.

Other applications of photochemical modeling at the Air District include:

- better understanding of ozone and particulate matter formation in the Bay Area;
- assessing the benefit of various proposed and adopted emission control measures;
- weighing alternative emissions control strategies for future planning;
- estimating human exposure to pollutants and associated health impacts;
- analyzing potential impacts of land use development; and
- providing modeling support to District programs and functions such as permit evaluation, rule development, grants and incentives, climate protection, and the CARE Program.

Through the use of photochemical models, the Air District participates in collaborative regional air quality study efforts such as the Central California Ozone Study (CCOS) and the California Regional Particulate Air Quality Study (CRPAQS). Collaborators include U.S. EPA, CARB, the National Oceanic and Atmospheric Administration (NOAA), universities, and neighboring districts, especially the San Joaquin Valley Air Pollution Control District and the Sacramento Metropolitan Air Quality Management District.

Modeling Methodology

An air quality model estimates pollutant concentrations by accounting for pollutant transport, mixing and chemical transformation in the atmosphere, and removal through deposition to the ground. There are two state-of-the-science air quality models that are publicly available and are used by the Air District: U.S. EPA's Community Multiscale Air Quality (CMAQ) model and Environ International Corporation's Comprehensive Air Quality Model with extensions (CAMx). Both of these models are capable of handling multiple pollutants, including ozone, toxics and PM.

Currently, the Air District uses CAMx for simulating ozone and TACs, and CMAQ for simulating PM2.5. In the future, the Air District plans to use CMAQ as the primary model for simulating all three pollutants and CAMx as a back-up model.

Emissions inventory and meteorological inputs to these models are prepared using several specialized computer programs. The anthropogenic emissions input is prepared using U.S. EPA's Sparse Matrix Operator Kernel Emissions (SMOKE) program. The biogenic emissions input is prepared using CARB's Biogenic Emissions Inventory - Geographic Information System (BEIGIS) program. The meteorological input is prepared using the Penn State University/National Center for Atmospheric Research Mesoscale Model version 5 (MM5). These computer programs, along with documentation, are publicly available.

To prepare the anthropogenic emissions inventory input, county-level, source-specific, daily total emissions data are allocated spatially to a predefined grid over the modeling domain. Emissions are then further distributed to each hour of the day and chemically speciated for modeling. Biogenic vegetation emissions are estimated based on leaf area index and ambient temperatures of each grid cell at each hour.

MM5 is applied to simulate hourly wind speed and direction, temperatures, humidity, and solar radiation values needed for the air quality model simulations. Observations are injected in the model to minimize the difference between simulations and observations.

Both meteorological and photochemical models are applied over a relatively large domain to capture the regional impact of meteorology and air quality. For most Bay

Area ozone and PM modeling, the domain covers all of Central California and portions of northern California, extending from Redding in the north to the Mojave Desert in the south and from the Pacific Ocean in the west to the Sierra Nevadas in the east.

The Air District has been applying both the CMAQ and CAMx models following the guidelines of U.S. EPA and CARB. Both air quality models and the meteorological model are routinely evaluated against observations using U.S. EPA's and the CARB's model evaluation criteria. Simulations are repeated using various physics and chemistry options of the models until they meet the model evaluation criteria of both U.S. EPA and CARB. Once model performance is deemed satisfactory, the models can be used to evaluate the effects of potential emission reductions.

Ozone Modeling Simulations

This section summarizes results of the Air District's most recent ozone modeling. The Air District used CAMx to simulate two ozone episodes occurring in 1999 and 2000. The 1999 episode was a two-day episode that occurred on July 11 and 12. The maximum 8-hour observed ozone concentrations reached 116 and 122 ppb, respectively, at Concord on these days. The 2000 episode was a three-day episode that occurred from July 31 through August 2. The maximum 8-hour observed ozone concentrations reached 89, 76 and 84 ppb, respectively, at Livermore on these three days. CARB classified the five days included in these two episodes as transport days from the Bay Area to the Central Valley.[1]

The modeling domain for ozone is the Central California Ozone Study (CCOS) domain shown in Figure E-1. First, CAMx was applied for the base case. Model performance met CARB and US EPA modeling criteria. Daily maximum 8-hr ozone levels were somewhat overestimated for some regions, including the Bay Area, and somewhat underestimated for others. These small discrepancies, however, were within accepted tolerances. Next, combined anthropogenic NOx and VOC emissions reductions of 40% were simulated for the Bay Area, Sacramento, and the San Joaquin Valley separately. This level of emissions reduction was discussed at the CARB Northern California SIP/Transport Meeting as representing the maximum feasible statewide emissions controls between 2000 and 2024. This predicted level of emissions reductions includes projected CARB mobile source regulations in combination with other measures.

[1] See "Ozone Transport: 2001 Review" prepared by CARB staff, April, 2001.

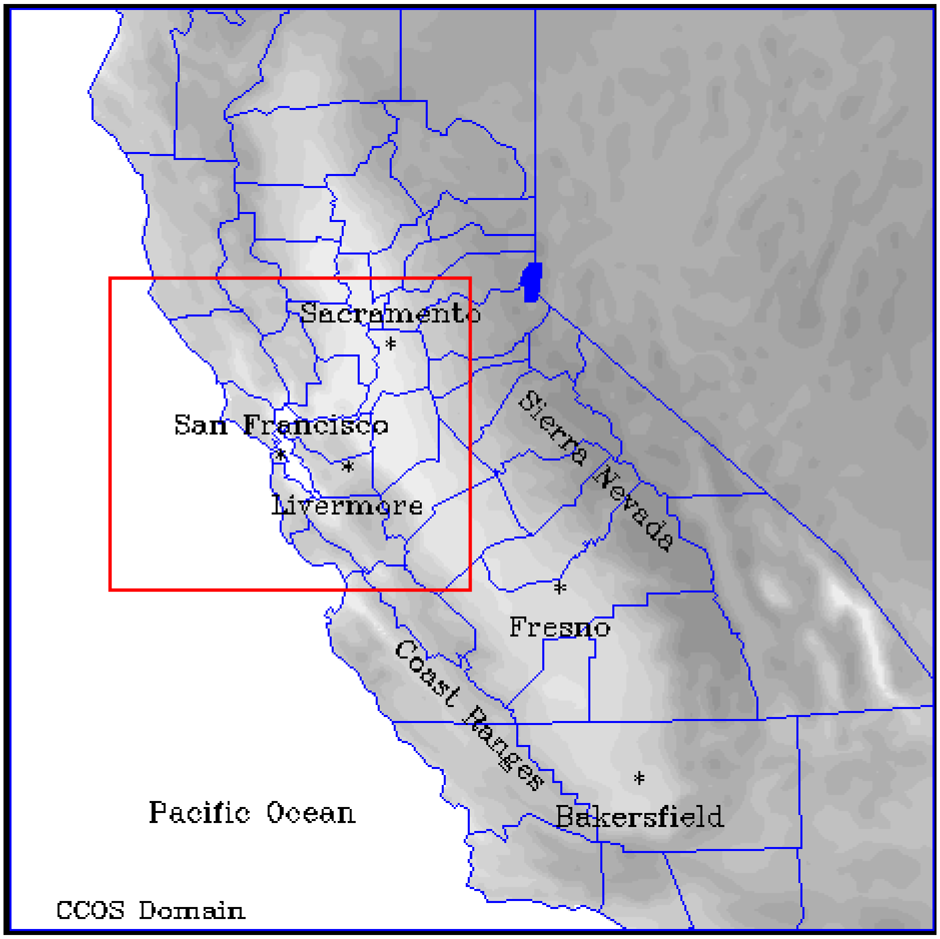

Figure E-1. Ozone and PM2.5 modeling domain (entire figure). Wood smoke modeling domain (inner domain shown in red).

Table E-1 shows the simulated and observed maximum 8-hour average ozone concentrations in the Bay Area, Sacramento, central San Joaquin Valley, and southern San Joaquin Valley. In the simulations with reduced Bay Area anthropogenic emissions, the Bay Area maximum 8-hour ozone levels decreased 13 and 15 ppb for July 11 and 12, and 3, 7 and 5 ppb for July 31 – August 2, 2000, respectively.

Table E-1. Simulated and observed 8-hour maximum ozone concentrations in the Bay Area, Sacramento, and the central and southern San Joaquin Valley. Also shown is the impact of 40% anthropogenic emission reductions on ozone.

July 11, 1999				
	SFB	SAC	C SJV	S SJV
Observation	116	123	123	97
Simulation	126	110	102	83
Simulation with 40% emissions reduction in:				
Bay Area	113	108	101	83
Sacramento	124	100	101	83
San Joaquin Vly	125	109	93	76

July 31, 2000				
	SFB	SAC	C SJV	S SJV
Observation	89	89	103	95
Simulation	105	103	101	100
Simulation with 40% emissions reduction in:				
Bay Area	102	102	99	98
Sacramento	103	97	100	100
San Joaquin Vly	105	103	93	93

July 12, 1999				
	SFB	SAC	C SJV	S SJV
Observation	122	106	109	77
Simulation	135	121	99	84
Simulation with 40% emissions reduction in:				
Bay Area	120	120	99	84
Sacramento	135	109	99	84
San Joaquin Vly	133	120	89	80

August 1, 2000				
	SFB	SAC	C SJV	S SJV
Observation	76	108	109	104
Simulation	107	114	111	96
Simulation with 40% emissions reduction in:				
Bay Area	100	111	109	95
Sacramento	106	105	109	95
San Joaquin Vly	106	114	103	89

August 2, 2000				
	SFB	SAC	C SJV	S SJV
Observation	84	107	106	112
Simulation	93	102	114	98
Simulation with 40% emissions reduction in:				
Bay Area	88	100	112	97
Sacramento	92	96	113	98
San Joaquin Vly	93	102	104	95

Results in Table E-1 give typical mid-summer episodic representations of the relative importance of transport. When Bay Area anthropogenic emissions were reduced, Sacramento and San Joaquin Valley maximum 8-hour ozone levels showed reductions of 1-3 ppb. When anthropogenic emissions were reduced in Sacramento or the San Joaquin Valley, Bay Area maximum 8-hour ozone levels decreased by 1-2 ppb.

In summary, photochemical modeling was used to estimate the impacts of NOx and VOC emissions reductions on ozone concentrations for the Bay Area and its neighboring ozone nonattainment regions. Reducing Bay Area emissions by 40% resulted in significant reductions of up to 15 ppb for Bay Area 8-hour ozone levels. The impacts of reductions in precursor emissions transported from the Bay Area were much smaller than the local impacts of the Bay Area emissions. Reducing the Bay Area emissions by 40% benefited the downwind Sacramento and San Joaquin Valley nonattainment areas by only 1-3 ppb reduced relative to the 8-hour ozone level.

Simulations re: Impacts of Climate Change on Ozone

As discussed in Chapter 1, higher temperatures related to global warming are expected to promote ozone formation through several mechanisms. One major factor is an increase in biogenic emissions of ozone precursors (ROG). The Air District performed simulations to estimate how increased temperatures may affect Bay Area ozone levels. According to the Intergovernmental Panel on Climate Change (IPCC), the current rate of accumulation of greenhouse gases is expected to increase the global average temperature 2 degrees Celsius by 2050.

For the purpose of this modeling, anthropogenic emissions of ozone precursors were held constant, ambient temperature was increased 2 degrees Celsius, biogenic emissions were estimated using the increased temperature, and the simulations described in the Ozone Modeling Simulations section were repeated. The 2 degree increase in temperature increased biogenic emissions by about 20 percent and the maximum 8-hour ozone levels by about 8 ppb in the Bay Area. The uncertainty in these results is large because emissions are constantly changing and the scientific community's understanding of the effect of global changes in emissions and temperatures on regional air quality is still developing. The Bay Area may respond to climate change differently than other parts of the world. Also, changes in temperatures may be accompanied with significantly changing Bay Area wind patterns, which play an important role in ozone formation.

In summary, photochemical modeling was used to estimate the impacts of a 2 degree Celsius increase in Bay Area temperatures on regional ozone levels. The model indicated Bay Area maximum 8-hour ozone levels would increase by about 8 ppb during ozone exceedance days. Assuming the simulated scenario is reasonable, increased ozone levels due to climate change may offset at least 10 years of ozone emissions control efforts in the Bay Area between now and 2050.[2]

[2] See "The effects of climate change on emissions and ozone in Central California" by Su-Tzai Soong, Cuong Tran, David Fairley, Yiqin Jia, and Saffet Tanrikulu. Paper #590 presented in the 101st Annual Meeting, Air and Waste Management Association, June 24-26, 2008 Portland OR.

PM2.5 Modeling Simulations

PM2.5 simulations were performed with the CMAQ model for four months (December-January, 2000-01 and 2006-07). The modeling domain (Figure E-1) included the Bay Area and the entire Central Valley to account for the impact of inter-basin transport. The model was applied on 4-km horizontal grids.

The base case simulation was validated against measurements to ensure that results adequately represented PM2.5 levels in the Bay Area and Delta regions. Simulation results for a typical Bay Area exceedance day, January 4, 2001, are shown in Figure E-2 as an example. This day exhibited light surface-level winds in the Central Valley that entered the Bay Area from the east. The PM2.5 that accumulated around all urban source areas in the modeling domain was composed mainly of primary PM2.5. Most low-lying inland locations were affected by PM2.5 as well, but were usually dominated by secondary PM2.5. Secondary PM2.5 levels were especially high deeper into the San Joaquin Valley, where considerable air mass aging occurred due to lack of ventilation. PM2.5 accumulated in a relatively thin layer near the surface in low-lying valley areas throughout the modeling domain under very stable atmospheric conditions. A plume of PM2.5 downwind of Central California formed over the Pacific Ocean.

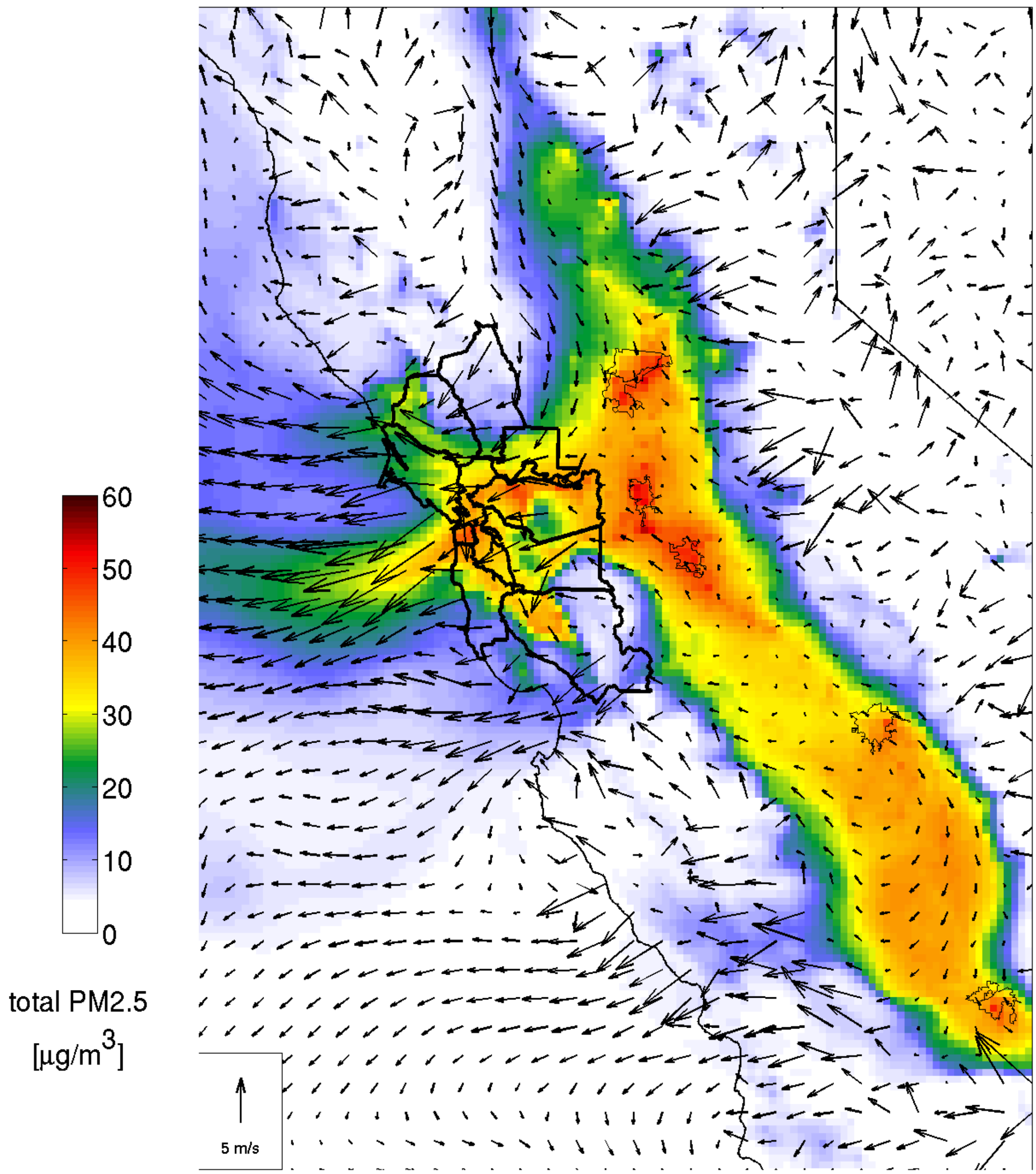

Figure E-2. PM2.5 simulation results for January 4, 2001. Spatial distribution for 24-hour PM2.5 level shown with color scale and 24-hour winds shown with arrow length proportional to speed and pointing along the direction of air flow. Bay Area counties, California boundaries, and city limits for Sacramento, Stockton, Modesto, Fresno, and Bakersfield are shown as black lines.

Figure E-3 shows the spatial distribution of simulated primary and secondary PM2.5 concentrations around the Bay Area. These results were averaged across the 52 simulated days for which measured Bay Area 24-hour PM2.5 levels exceeded 35 μg/m^3. For most of these episodic days, light winds flowed through the Bay Area from the east, and Central Valley conditions were near calm. Primary PM2.5 levels were elevated mainly in and around major Bay Area cities, including Oakland, San Francisco and San Jose; near industrial facilities and highways along the Carquinez Strait; at Travis AFB; and Santa Rosa. Secondary PM2.5, present mostly as ammonium nitrate, was not localized near the sources of its precursor emissions, NO_x and ammonia. Rather, secondary PM2.5 was regionally elevated. A sharp gradient existed, with very high secondary PM2.5 levels in the Central Valley decreasing westward through the Bay Area.

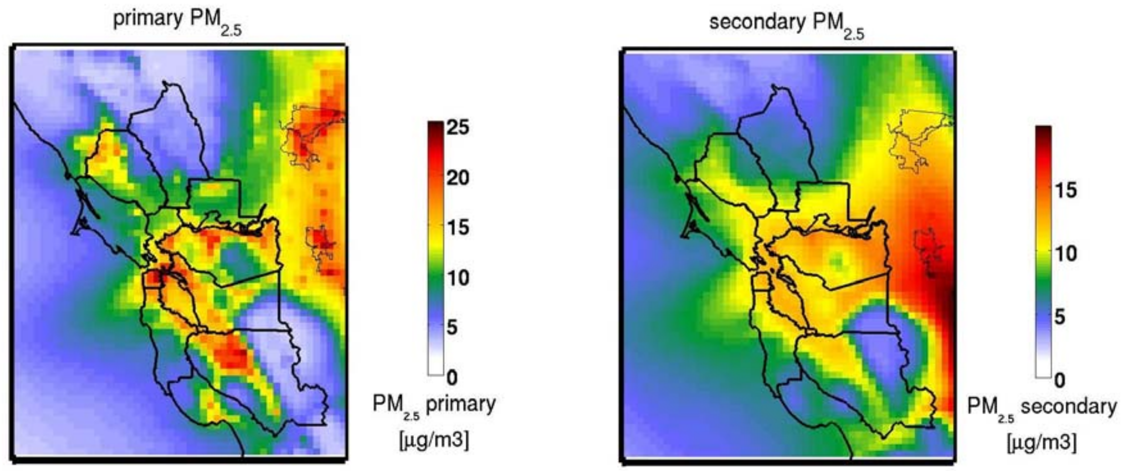

Figure E-3. Spatial distribution of simulated 24-hr primary and secondary PM2.5 levels averaged across the 52 simulated days for which measured Bay Area 24-hr PM2.5 level exceeded 35 µg/m^3. Bay Area counties and the California coastline are drawn using thick black lines. City limits for Sacramento and Stockton are drawn using thin black lines.

Around San Francisco and San Jose, PM2.5 levels were dominated by primary (directly-emitted) PM. For other areas affected by PM episodes, such as the eastern, northern, and southern Bay Area and also the Delta, primary and secondary PM2.5 levels were comparable. Both primary and secondary build-up were required for exceedances to occur in these locations.

PM2.5 sensitivity simulations were performed by reducing emissions at different regions of the modeling domain relative to the base case. First, Bay Area emissions reductions of 20% were simulated for the following five classes of chemical species: NO_x and VOC combined; gaseous sulfur species; ammonia; directly emitted PM; and these four classes combined, comprising all anthropogenic emissions. These reductions were simulated for one episode each from the 2000-01 and 2006-07 winter seasons. Reducing the directly-emitted PM reduced peak PM2.5 levels nearly ten times more effectively than reducing the secondary PM precursors. Reducing primary PM emissions by 20% typically reduced primary PM2.5 levels by 12-20% depending on location, with an average around 16%. Reductions of directly emitted PM were most effective near the PM emissions sources where primary PM2.5 levels were highest. Reducing ammonia emissions by 20% was the most effective of the secondary PM2.5 precursor emissions reductions. Reducing combined NO_x and VOC emissions by 20% was relatively ineffective (0-1%). Reducing sulfur-containing PM precursor emissions by 20% typically had a small impact on Bay Area ambient PM2.5 levels. Under certain conditions, however, reductions of sulfur-containing emissions reduced ambient PM2.5 levels by around 1 $\mu g/m^3$.

Also investigated was the impact of sources outside of the Bay Area on the Bay Area's PM2.5 concentrations by zeroing out the Bay Area's anthropogenic emissions and repeating the above (base case) simulations. Simulated concentrations were averaged across 52 days for which the Bay Area's maximum 24-hour PM2.5 levels were observed to exceed 35 $\mu g/m^3$. Significant amounts of both primary and secondary PM2.5 were found in the Bay Area even when Bay Area anthropogenic emissions were zeroed out. Primary PM2.5 levels were as high as 8 $\mu g/m^3$. Secondary PM2.5 concentrations were as high as 13 $\mu g/m^3$ along the eastern boundary of the Bay Area and about 5-8 $\mu g/m^3$ elsewhere.

In summary, photochemical modeling was used to estimate the impacts of reducing PM and its precursor emissions for the Bay Area and its neighboring PM nonattainment regions. Reducing Bay Area primary (directly emitted) PM2.5 emissions provided far greater reductions in ambient Bay Area PM2.5 levels than reducing Bay Area secondary PM2.5 precursor emissions. Of the precursor emissions reductions simulated, Bay Area ammonia reductions were most effective. The ammonia emissions reductions lowered ammonium nitrate PM2.5 levels only for relatively cold winter days favoring ammonium nitrate buildup. (Ammonium nitrate PM2.5 tends to evaporate faster than it forms at temperatures above around 60 degrees Fahrenheit.) Combined NOx and VOC emissions reductions for the Bay Area were relatively ineffective. NOx emissions reductions were relatively ineffective because ammonium nitrate PM2.5 formation involves the relatively slow and incomplete conversion of NOx to nitric acid. Reducing Bay Area sulfur-containing PM precursor emissions typically had a small impact on Bay Area ambient PM2.5 levels. Under certain conditions, however, reducing Bay Area sulfur-containing emissions did provide around 1 $\mu g/m^3$ reduced Bay Area PM2.5 level. Photochemical simulations were also performed with zero Bay Area anthropogenic emissions to gauge the impacts of transported PM2.5 and precursors. Significant amounts of both primary and secondary PM2.5 were transported into the Bay Area. During Bay Area PM2.5 24-hr exceedance days, transported primary PM2.5 levels averaged as high as 8 $\mu g/m^3$ and transported secondary PM2.5 levels averaged as high as 13 $\mu g/m^3$. The largest transport impacts for both primary and secondary PM2.5 occurred along the eastern boundary of the Bay Area.

Wood Smoke PM2.5 Simulations

Chemical Mass Balance (CMB) analysis has estimated that approximately one-third of Bay Area ambient PM2.5 mass during 24-hour PM2.5 exceedance days is wood smoke from household wood burning.[3] The Air District adopted a wood smoke rule (Regulation 6, Rule 3) in 2008 to reduce wood-burning emissions throughout the region. The wood-smoke rule was first implemented during the 2008-09 winter, during which 11 Spare the Air ("no burn") periods were issued. Simulations using the CAMx model were applied over the Bay Area and surrounding regions (see red box in Figure E-1) to determine the effectiveness of the rule to reduce ambient wood-smoke levels.

The modeling period included 8 of the 11 Spare the Air periods during the winter of 2008-09. Bay Area wood-smoke levels were simulated with and without wood-burning restrictions during these periods. Without burning restrictions during these Spare the Air periods, the simulations indicated that peak wood-smoke levels of up to 10-20 $\mu g/m^3$ would have occurred over the areas that generally have high wood-burning emissions. For many of the remaining populated locations within the Bay Area, wood-smoke levels would have been around 5 $\mu g/m^3$. Peak benefits of the wood-smoke rule were around 10 $\mu g/m^3$ of reduced wood smoke. The 24-hour wood-smoke levels (averaged midnight to midnight) were not reduced to zero for two main reasons. First, the burning restrictions did not begin until noon of the Spare the Air days. Second, carried over wood smoke from previous days still impacted the Bay Area during the Spare the Air periods. Because the burning restrictions reduced carry over, enhanced benefits may be achieved for multiple, consecutive Spare the Air calls. Two consecutive Spare the Air calls during 2008-09 provided the largest simulated reductions of wood-smoke levels.

Maximum simulated benefits of the wood-smoke rule occurred for areas that generally have the highest wood-smoke levels. Often, the areas most heavily impacted by wood smoke are away from the monitoring locations. Simulated wood-smoke levels for the eight simulated Spare the Air days would have averaged around 11, 7, 5, 3, and 3 $\mu g/m^3$ for the Concord, San Jose, San Francisco, Vallejo, and Livermore monitoring locations, respectively, without the burning restrictions. Preliminary wood-smoke simulations suggest that the wood-smoke rule may have been effective at reducing ambient wood smoke levels by 50-75 percent at key PM2.5 monitoring locations. However, this finding is based on an assumption of 100% compliance with the wood-smoke rule, which may not have occurred.

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[3] Chemical mass balance (CMB) analysis is a methodology in which a computer model is used to apportion ambient PM2.5 collected on filters over 24-hour periods at monitoring sites around the Bay Area to a set of source categories. Each filter was analyzed for a range of chemical species. The same species were measured in special studies of emissions from various sources, such as motor vehicles and wood burning. The CMB model finds the mix of these source measurements that best matches the ambient sample, chemical species by chemical species. See report entitled *Sources of Bay Area Fine Particles*. www.baaqmd.gov/~/media/Files/Planning%20and%20Research/Particulate%20Matter/PM_Report.ashx

In summary, locally-emitted wood smoke accounts for approximately one-third of Bay Area PM2.5 levels during 24-hr PM2.5 exceedance days. The largest reductions in wood-smoke PM2.5 levels were simulated for the locations that generally have the highest peak wood-smoke levels. These locations often are not near any monitor. Therefore, reductions of population exposure to wood smoke resulting from the rule may be significantly greater than indicated by the monitoring data. Multiple, consecutive no-burn days may provide the added benefit of reducing both fresh and carried-over wood-smoke levels.

Air Toxics Modeling

Air toxics species are either directly emitted into the atmosphere from their sources (primary toxics) or are formed through chemical transformation of other pollutants (secondary toxics). Atmospheric oxidants play an important role in the chemical transformation, which is closely related to ozone photochemistry. Therefore, photochemical models provide additional information over engineering models that either ignore secondary toxics formation or estimate secondary toxics concentrations with a simplified chemical mechanism.

Six toxics species were simulated for the air toxics modeling. Five of the species were estimated to account for the bulk of total air toxics cancer risk in the Bay Area: acetaldehyde; benzene; 1,3-butadiene; diesel PM; and formaldehyde. The sixth species, acrolein, was believed to be the ambient toxic with the most serious non-cancer health effects. Air toxics risk assessment required estimates of annual average levels for these six species. Simulations were performed on a 1-km horizontal grid over the Bay Area. Air toxics emissions inventories were estimated for the base year 2005. Because secondary toxics chemistry is very computationally-intensive, toxics simulations were performed for one week in summer and one week in winter, with the exception of diesel PM. To estimate annual average toxics concentrations for these species, the Air District averaged the concentrations obtained for these two weeks. Diesel PM concentrations were simulated for one summer month and one winter month; the average of these two months was used to estimate annual average diesel PM concentrations.

The modeled toxics levels compared reasonably well with ambient measurements. Simulated diesel PM levels were compared against elemental carbon levels measured on filters from the District's routine PM monitoring network. The five other simulated air toxics species were compared against VOC canister measurements taken from about 20 locations throughout the Bay Area. Annual average toxics concentrations were then calculated as averages of the July and December model results. The annual average concentrations for each toxics species were multiplied by their respective unit risk factors and overlaid on Bay Area population data to calculate population-adjusted risk.

Cancer risk was used to define six impacted communities [4] within the Bay Area: Concord; eastern San Francisco; western Alameda County; Redwood City and East Palo Alto; Richmond and San Pablo; and San Jose. These six impacted communities accounted for nearly half of the total Bay Area population-weighted lifetime cancer risk for sensitive groups (those under 18 or over 64 years of age).

Future Directions in Air Quality Modeling

The Air District recognizes that synergies and trade-offs exist in regulating ozone, PM, air toxics, and greenhouse gases. This was the primary reason that the Air District chose to pursue a multi-pollutant approach in developing the 2010 CAP. The results of modeling performed separately for ozone, PM2.5, and air toxics, which are described in the respective sections above, provided critical information used in developing the Air District's MPEM. For purposes of future air quality plans, however, the multi-pollutant framework would benefit greatly from the results of integrated, multi-pollutant modeling performed on a full-year basis. Performing simulations that cover an entire year will enable the Air District to enhance the accuracy of the existing MPEM by eliminating the need to extrapolate episodic modeling results to the full year (as was done for the MPEM used in the 2010 CAP).

Integrated modeling will require a unified modeling platform. The crucial elements of such a platform are: unified, full-year, multi-pollutant emission inventories; a single modeling system; and full-year meteorological fields, as described below.

One key input required for multi-pollutant modeling is a single, comprehensive emissions inventory accounting for all pollutants of interest and their precursors. Currently, relatively independent (though non-conflicting) inventories are used for modeling each pollutant type. Using a single, multi-pollutant emissions inventory, the effects of various proposed control strategies could be evaluated using the same input emissions data. One prerequisite to facilitate full-year modeling is to develop year-round inventories that account for all pollutant types in each season of the year. Traditionally, PM2.5 modeling has focused on the winter months, whereas ozone modeling has focused on the summer months. Year-round inventories for ozone and PM2.5 will facilitate direct estimation of their respective cumulative impacts on public health and evaluation of emission reduction strategies.

The Air District is also moving toward using a single, unified modeling system for all pollutant types. As discussed above, the CMAQ model currently is used for photochemical PM2.5 modeling, whereas CAMx is used for ozone and air toxics

[4] See *Applied Method for Developing Polygon Boundaries for CARE Impacted Communities* (December 2009) available at www.baaqmd.gov/Divisions/Planning-and-Research/CARE-Program/CARE-Documents.aspx.

modeling. Previous experience has demonstrated that secondary PM2.5 chemistry is better handled by CMAQ, whereas Bay Area ozone episodes are better represented by CAMx. Both models employ a “one atmosphere" approach in which similar physics and chemistry formulations are used to relate changes in emissions to changes in ambient pollutant levels. However, comparison of results from these two modeling systems may not always be directly achievable. Discrepancies may arise because of differences in their numerical algorithms. Use of a single modeling system will help avoid the potential for mathematical artifacts to bias the evaluation of a control strategy across multiple pollutants. The Air District is currently investigating the optimization of CMAQ for all modeling applications.

A final aspect of multi-pollutant modeling is developing meteorological fields that are necessary to drive year-round air quality simulations. Current modeling practices evaluate the effectiveness of emissions controls on PM2.5 and ozone only when elevated levels occur. This approach may place greater weight on acute health impacts over chronic health impacts. A year-round multi-pollutant approach, on the other hand, will ensure that acute and chronic health impacts are weighted appropriately when analyzing potential control measures. The Air District is developing meteorological simulations to match all periods that will be represented in the multi-pollutant, year-round emissions inventories described above.

Appendix F – Evaluation of Potential CAP Control Measures

This appendix summarizes the review of potential control measures for the Bay Area 2010 Clean Air Plan (CAP) performed by Air District staff. Tables providing details about staff review of specific control measures are posted on the web page for the 2010 CAP at: www.baaqmd.gov/Divisions/Planning-and-Research/Plans/Clean-Air-Plans.aspx.

Background

Pursuant to California Health & Safety Code Section 40914, the Bay Area 2010 Clean Air Plan is required to include all feasible control measures to reduce region-wide emissions for each nonattainment pollutant (e.g., ozone precursors). To identify feasible measures for the 2010 CAP, Air District staff reviewed and evaluated 844 potential control measures compiled from a variety of sources.[1] Air District staff sought ideas for new control measures, as well as ways to strengthen existing rules and programs. Sources of potential measures included ideas submitted by the public and Air District staff, other California air district control measures contained in recently-adopted air quality plans, as well as air quality plans from metropolitan areas outside of California. In addition, staff reviewed measures that had previously been considered and rejected during preparation of the Bay Area 2005 Ozone Strategy, to see if the rationale for rejecting a measure at that time is still valid for purposes of the 2010 CAP. The 844 measures reviewed included:

- 368 measures from recently-adopted air quality attainment plans.
- 390 measures from the 2005 Ozone Strategy control measure review process.
- 39 measures suggested by the public.
- 47 measures suggested by Air District staff.

Staff reviewed stationary source, area source, mobile source, and transportation control measures from the following plans:

California Air Quality Attainment Plans
- 2007 Air Quality Management Plan (May 2007, South Coast AQMD)
- Sacramento Regional 8-Hour Ozone Attainment And Reasonable Further Progress Plan (Draft January 2009, Sacramento Metropolitan AQMD)
- 2007 Ozone Plan (April 30, 2007, San Joaquin Valley Unified APCD)
- 2008 Air Quality Management Plan (August 2008, Monterey Bay Unified APCD)
- 2007 Clean Air Plan (August 2007, Santa Barbara APCD)

[1] Air District staff and staff of the Metropolitan Transportation Commission (MTC) collaborated in evaluating transportation control measures for the 2010 CAP.

- Eight-Hour Ozone Attainment Plan For San Diego County (May 2007, San Diego APCD)
- Ventura County 2007 Air Quality Management Plan (May 13, 2008, Ventura APCD)

Out of State Air Quality Attainment Plans

- Houston-Galveston-Brazoria regional SIP (April 2010)
- New York SIP for Ozone (8-Hour NAAQS) Attainment Demonstration for NY Metro Area (August 9, 2007)
- Proposed Maintenance Plan for Southeast Michigan (February 2009)
- Draft Chicago 8-Hour Ozone Attainment Demonstration and Maintenance Plan (December 2008)
- Proposed Georgia's State Implementation Plan for the Atlanta 8-Hour Ozone Nonattainment Area (March 29, 2009)

Control Measure Framework and Evaluation Criteria

Potential control measures were reviewed and evaluated as described below and as summarized in Table F-1. Potential measures were initially screened to identify and eliminate measures that have been either implemented and completed by the Air District, or implemented within the Air District's jurisdiction by the Air Resources Board, US EPA, or another agency.

Remaining measures were evaluated according to the criteria specified in California Health & Safety Code Section 40922, namely:

- Cost-effectiveness
- Technological feasibility
- Total emission reduction potential
- Rate of reduction
- Public acceptability
- Enforceability

In addition to the criteria specified in the California Health & Safety Code, control measures were also evaluated based upon their potential to reduce:

- Emissions of PM, air toxics, greenhouse gases (in addition to ozone precursors), and
- Population exposure to pollutants in one or more of the "impacted communities" identified in the District's CARE program

In reviewing measures based on the evaluation criteria described above, some measures were eliminated for the reasons shown in Table F-1 below.

Measures that are recommended for inclusion in the 2010 CAP fall into three categories:

- Measures incorporated in one of the five control measure categories:
  - Stationary Source Measures
  - Mobile Source Measures
  - Transportation Control Measures
  - Land Use & Local Impact Measures
  - Energy & Climate Measures
- Further Study Measures: This category includes measures which appear to have merit but require more research and information to determine if they are viable for implementation. These measures will be further evaluated, but are not proposed as formal control measures at this time.
- Measures incorporated in draft CAP Leadership Platform: Staff is proposing to include a Leadership Platform in the 2010 CAP to encourage actions by other agencies and/or potential legislation that would be beneficial for air quality. Some potential measures have been included in the draft Leadership Platform.

Please note that Table F-1 indicates that 347 of the potential measures reviewed have been incorporated in the 55 proposed CAP control measures. The reason that these numbers do not match is due to (1) duplication or overlap among the potential measures reviewed, (2) the fact that many of the proposed CAP control measures incorporate multiple actions that have been combined within a single measure. For the same reason, 39 of the potential measures reviewed have been incorporated into the 17 proposed Further Study Measures.

Table F-1. Outcome of all feasible measures review.

Category	Category Definition	# of Measures
Already Implemented by the Air District		219
Already Implemented by Another Agency	Measures that have already been implemented through State, Federal, or regional programs.	116
Measures Deemed Not Feasible	De minimus or no sources exist in the Bay Area. Not cost-effective. Not publicly acceptable. Not applicable to this plan. Not technologically feasible. Not enforceable. Other. Subtotal: Measures deemed not feasible:	62 11 10 13 3 3 9 111
Total # Potential Measures Not Incorporated into Draft Control Strategy		**446**
Incorporated into Draft Control Strategy: Stationary Source Measures	Measures implemented through District rule-making: industrial /commercial processes, stationary combustion, petroleum products processing and distribution, and area sources.	45
Incorporated into Draft Control Strategy: Mobile Source Measures	Measures to reduce emissions from on-road and off-road mobile sources by means of cleaner engines or fuels.	76

Table F-1 (continued). Outcome of all feasible measures review.

Category	Category Definition	# of Measures
Incorporated into Draft Control Strategy: Transportation Control Measures	Measures to reduce motor vehicle emissions by reducing vehicle use or traffic congestion.	171
Incorporated into Draft Control Strategy: Land Use and Local Impact Measures	Land use measures to reduce motor vehicle travel and decrease human exposure to air pollutants.	41
Incorporated into Draft Control Strategy: Energy and Climate Measures	Measures to reduce energy use, promote renewable energy sources, and reduce urban heat island effects.	14
Total # Potential Measures Recommended to be Incorporated into Draft Control Strategy		**347**
Included as Further Study Measures	Measures which meet some evaluation criteria but require further analysis to determine if they are potentially viable.	39
Included in Draft Leadership Platform	Measures which will be pursued through advocacy and partnerships as part of the Leadership Platform.	12
Total # Potential Measures Included as Further Study Measures or in Leadership Platform		**51**

Appendix G – Progress Towards 2010 CAP Performance Objectives

Overview

In addition to striving to attain applicable standards for criteria air pollutants, the 2010 Clean Air Plan defines numerical performance objectives related to the plan's goals of protecting public health and protecting our climate. The performance objectives focus on three pollutants: particulate matter less than 2.5 microns (PM2.5), diesel particulate matter (DPM), and greenhouse gases (GHGs). The performance objectives are as follows:

- Reduce PM2.5 exposure by 10% by 2015
- Reduce diesel PM exposure by 85% by 2020
- Reduce GHG emissions to 1990 levels by 2020 and 40% below 1990 by 2035

This appendix analyzes the extent to which the CAP control strategy and related efforts will achieve these objectives. For purposes of this analysis, estimates of anticipated emissions reductions were based on the following:

- implementation of control measures described in the 2010 CAP;
- estimated benefit of rules and measures adopted by the Air District between 2006 and 2009, which are not reflected in the base year 2005 emission inventory;
- expected benefits from recent State actions and current proposed regulations, including air toxics control measures (ATCMs) to reduce emissions from diesel engines, and greenhouse gas measures included in the CARB AB 32 Scoping Plan.

This analysis does not include potential emissions reductions from efforts such as climate action plans that have been developed by many Bay Area cities and counties, or the Sustainable Communities Strategy that will be developed for the Bay Area in response to SB 375 by 2013, or other voluntary, independent actions by Bay Area governments, residents and businesses. These efforts will be vitally important in reducing the region's GHG emissions, but accurately quantifying their effects is not practicable at this time.

Methodology

This analysis relies on the Air District's 2005 baseline emission inventory for PM2.5 and the base year 2007 inventory for greenhouse gases. The baseline and projected inventories for PM and for GHGs are provided in Table 2-9 and 2-12, respectively, in Chapter 2. The baseline emission levels were projected into the future to establish a trend line for future emissions in the absence of additional regulations. Air District staff developed expected benefits from recent state actions and current proposed regulations, as well as the estimated benefits of the proposed control measures in the 2010 CAP. Estimates of benefits from Air District actions since 2005 (or 2007 in the case of GHG emissions) were also developed. The sum of these actions represents the progress towards the performance objectives.

The analysis accounts for emission reductions projected to occur with the implementation of control measures either already adopted or proposed for adoption by the Air District or CARB. Air District measures included herein are the proposed 2010 CAP measures; Regulations 6, Rules 2 and 3; and GHG strategies implemented through local grant programs. CARB measures include the air toxics control measures (ATCMs) adopted as part of the statewide Diesel Risk Reduction Program and the GHG reduction measures included in the AB 32 Scoping Plan, as adopted in December 2008. Estimates of emission reductions for these measures are taken from published staff reports, or in the case of the proposed 2010 CAP measures, from the Air District staff analysis provided in control measure write-ups in Volume II and summarized in Table 4-8 in Chapter 4.

The performance objectives for PM2.5 and diesel PM are expressed in terms of reductions in population exposure to these pollutants; this is the clearest metric for estimating the benefits of reduced pollution. The Air District does not yet have available methodologies to reliably perform an analysis of reduction in regional population exposure. Therefore, this analysis uses expected reductions in emissions as a surrogate for reduction in population exposure. That is, it is assumed that a given reduction in emissions of PM2.5 or diesel PM will yield a corresponding reduction in population exposure to these pollutants. For diesel PM, the assumption of a one-to-one correspondence between reductions in emissions and exposures is consistent with the approach taken by CARB in the risk reduction plan for diesel emissions.

The Air District has inventory and modeling efforts underway to better evaluate future reductions in ambient concentrations and population exposure of Bay Area residents to PM2.5 and diesel PM. The results of these studies will be made available in the years ahead.

PM2.5

The CAP performance objective is to reduce PM2.5 exposure by 10% by 2015. Direct emissions of PM2.5 are estimated to increase from 86 tons per day in 2005 from all sources to 90.2 tons per day in 2015. A ten percent reduction, equivalent to 9.0 tons per day, is needed to meet the performance objective. As shown in Table G-1, a combination of control measures adopted by the Air District between 2006 and 2009, adopted and proposed State regulations, and the proposed 2010 CAP control measures are expected to achieve reductions in direct emissions of PM2.5 of 9.2 tons per day. Figure G-1 plots this data on a graph. Additional reductions in PM2.5 are expected to occur as secondary sources of PM2.5, such as oxides of nitrogen and sulfur, are further controlled; however, estimates of these benefits have not been included in this analysis.

Table G-1. PM2.5 performance objective. (Estimated emissions in tons/day)

Projected 2015 PM2.5 Emissions	90.7
Total Reductions needed 2015	- 9.0
Reductions from Air District Measures 2006-2009	2.2 *
Reductions from State Regulations	5.9
Reductions from 2010 CAP	1.1
Total Reductions	**9.2**

* The emission reduction from Air District measures adopted between the 2006-2009 period is based on adoption of Regulation 6, Rule 2 to reduce emission from charbroilers in restaurants and Regulation 6, Rule 3 to reduce emissions from residential wood-burning.

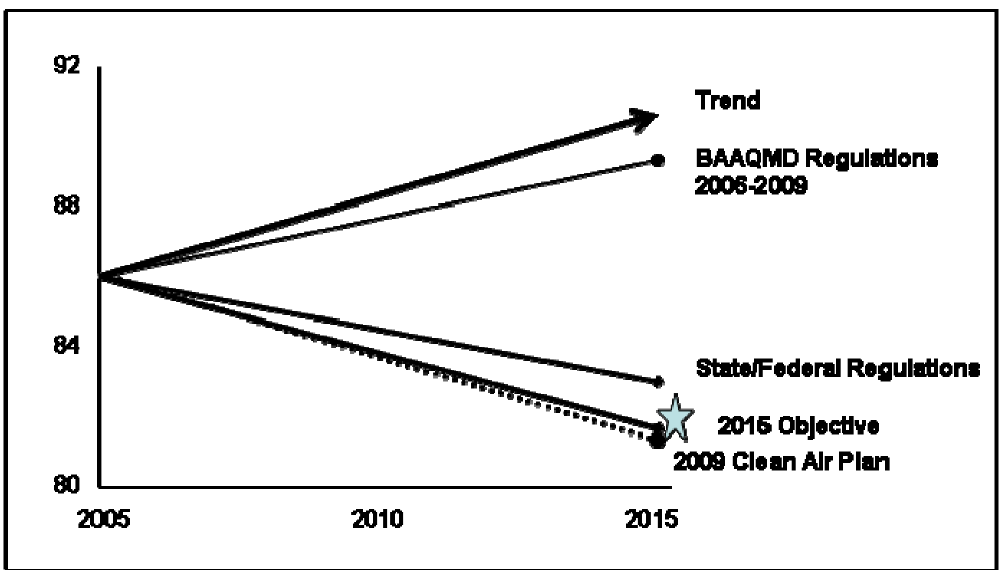

Figure G-1. PM2.5 Performance objective. (Estimated emissions in tons/day)

Diesel PM

The CAP performance objective is by 2020 to reduce diesel PM exposure by 85% from levels experienced in the year 2000.. For the purposes of this analysis, District staff have assumed a one-to-one relationship between reductions in emissions and exposure. Emissions of diesel PM are estimated to have been 14.8 tons per day in 2000 from all sources. An 85 percent reduction of 12.6 tons per day is needed to meet the performance objective. As shown in Table G-2, Air District staff estimates that a combination of control measures adopted between 2006 and 2009, adopted and proposed State regulations and the proposed 2010 CAP control measures will achieve 7 tons per day. Figure G-2 plots this data on a graph.

Table G-2. Diesel PM performance objective. (Estimated emissions in tons/day)

BASELINE DPM Emissions	14.8
Total Reductions needed 2020	- 12.6
Reductions from Air District Measures 2006-2009	<0.1
Reductions from State Regulations	6.4
Reductions from 2010 CAP	0.6
Total Reductions	**7.0**

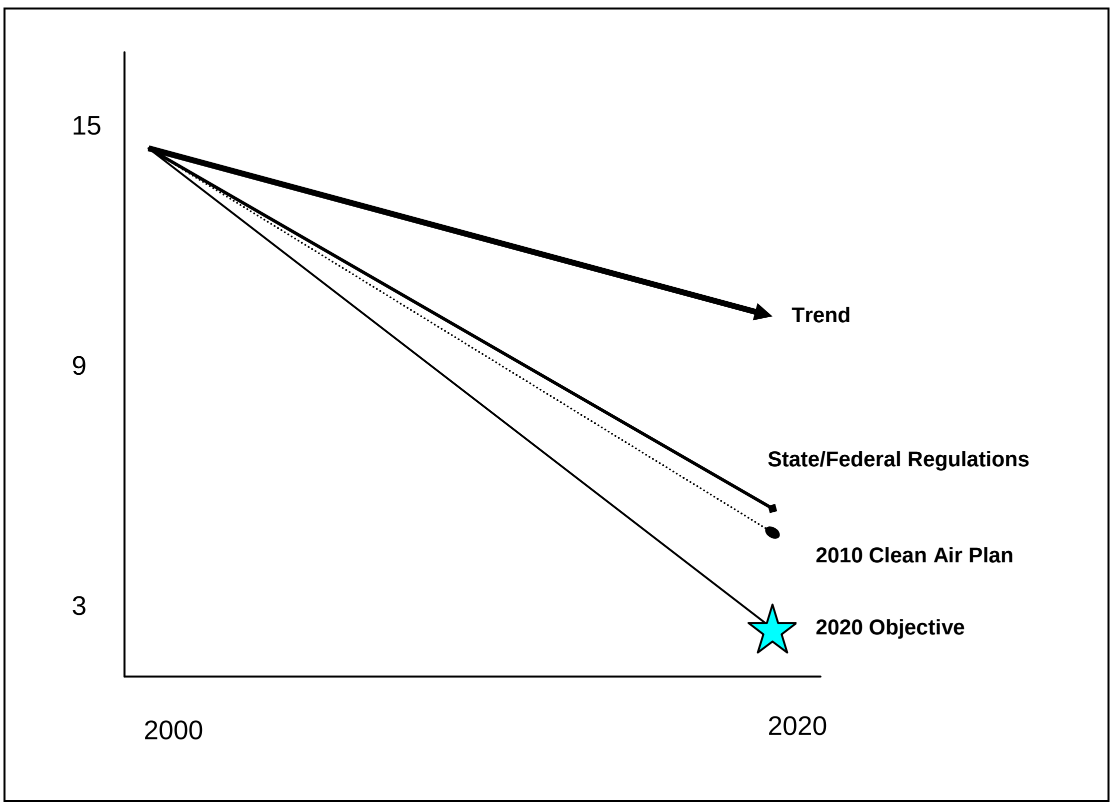

Figure G-2. Diesel PM Performance Objective. (Estimated emissions in tons/day)

Greenhouse Gases

The CAP performance objective is to reduce GHG emissions to 1990 levels by 2020 and 40% below 1990 by 2035. This corresponds with GHG reduction goals established by the State of California. Emissions of GHG in 1990 have been estimated at 273,910 tons per day, and have been projected to increase to 385,650 tons per day in 2020.[1] To meet the performance objectives there will need to be reductions of 111,740 tons by 2020 and 221,306 tons by 2035. As shown in Table G-3, Air District staff estimates that a combination of control measures adopted between 2006 and 2009, adopted and proposed State regulations and the proposed 2010 CAP control measures will achieve 87,980 tons per day in reductions by 2020. It is not possible at this time to predict GHG reductions in the 2020-2035 period. However, if the GHG reductions during the 2010-2020 period continue on the same trajectory through 2035, then GHG reductions would reach 117,000 tons per day by 2035, which is slightly below 1990 levels. Figure G-3 plots this data on a graph.

Table G-3. Greenhouse gases performance objective. (Estimated emissions in tons/day)

Estimated 1990 Levels	273,910
Projected 2020 Levels	385,650
Total reductions needed 2010-2020	111,740
Total reductions needed 2010-2035	221,310
Reductions from Air District Measures 2006-2009	1,230
Reductions from State Regulations through 2020	71,740
Reductions from 2010 CAP through 2020	15,010
Total Reductions through 2020	**87,980**
Additional projected reductions: 2021-2035	29,110
Total Reductions through 2035	**117,000**

[1] For purposes of this analysis, GHG emissions are expressed in terms of short tons (2000 lbs.), not metric tons.

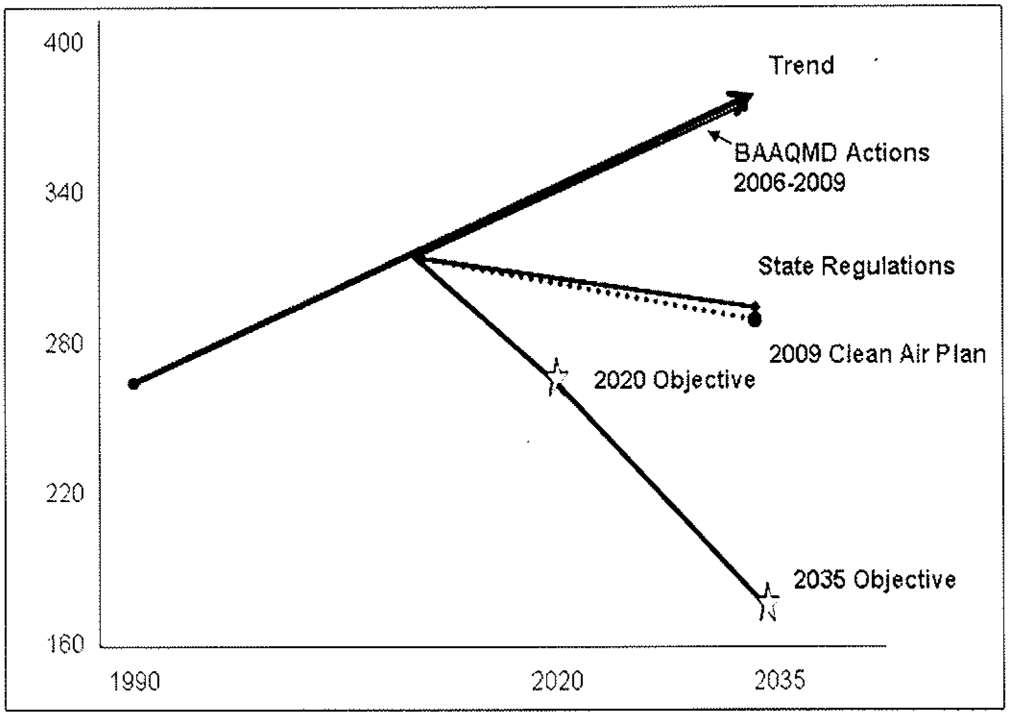

Figure G-3. Greenhouse gases performance objective. (Estimated emissions in 1,000 tons/day)

Discussion of Findings

Our analysis finds that anticipated emissions reductions will enable the Bay Area to reach the performance objective to reduce PM2.5 10% by 2015, but that we will fall short of the diesel PM and the greenhouse gas reduction objectives.

In the case of the diesel PM objective, EPA and CARB set emissions standards for most diesel engines, including trucks, buses, construction equipment, harbor craft, etc. For the past decade, CARB has been adopting and implementing ambitious ATCMs to reduce emissions from all types of diesel engines, both new and existing, with a goal of reducing diesel PM by 85% by 2020. To implement recent changes in State law intended to address the current severe economic recession, CARB has modified compliance timelines for the construction equipment diesel ATCM (i.e., the in-use off-road diesel vehicle regulation). CARB is currently also considering changes to the requirements for in-use on-road trucks and further changes to the in-use off-road diesel vehicle regulation, to account for emission reductions occurring due to the current economic downturn. However, none of the recent or proposed changes to the in-use off-road and in-use on-road regulations would result in fewer reductions of diesel PM by 2020. Combined diesel emissions from all sources should still ultimately be reduced by 85%, although achievement of this objective may not occur by 2020. Nevertheless, the Bay Area should still see a very significant reduction in diesel PM emissions.

In support of the desired 85% reduction of diesel PM emissions by 2020, the Air District will continue to aggressively implement its effort to reduce diesel PM emissions and exposure via enhanced monitoring and analysis of impacted communities, targeted enforcement of CARB regulations in impacted communities, and targeting its grant programs to projects in impacted communities.

The CAP GHG performance objectives goals are based on state goals articulated in AB 32 and Governor's Executive Order S-3-05. This analysis demonstrates that additional measures will be needed to achieve the GHG targets, beyond the measures defined and quantified in the CARB AB 32 Scoping Plan and the 2010 CAP. The additional reductions may be obtained through some combination of State actions that have not yet been fully defined, the Sustainable Communities Strategy that will be developed by Bay Area regional agencies in cooperation with local governments by year 2013, local climate action plans, future Air District actions, and voluntary actions by Bay Area residents and businesses.