South Coast Air Quality Management District

Estimation of Health Benefits of South Coast Air Basin 2007 AQMP/SIP Oceangoing Marine Vessel Control Measures

October 18, 2007

Background

The purpose of this analysis is to estimate the health benefits in the South Coast Air Basin of controlling emissions from oceangoing marine vessels. Marine vessels create a substantial amount of particulate and nitrogen oxides emissions in the Basin, and cause the majority of all sulfur oxides emissions.

Control measures in the 2007 South Coast Air Quality Management Plan (AQMP) — which has been approved for submittal as part of the State Implementation Plan to attain the federal "annual" PM2.5 ambient air quality standard — will reduce particulate and precursor emissions and result in lower regional PM2.5 concentrations and reduced cases of regional mortality and morbidity. In addition, the Low Sulfur Fuel Auxiliary Engine Rule (LSAER) adopted by the California Air Resources Board is a key component of the AQMP year 2014 emissions baseline. Without this measure, baseline PM2.5 concentrations — the starting point from which the AQMP control measures reduce emissions — would be significantly higher.

The analysis described in this memorandum calculates the air quality, health and monetary benefits of LSAER and the benefit of the collective oceangoing marine vessel control measures (grouped as "ARBOFF-1") in the 2007 AQMP. **The analysis concludes that the oceangoing marine vessel control measures in the AQMP will result in over 700 premature deaths avoided in the year 2015, as well as other significant health benefits. This accounts for over one third of the health benefits of the entire PM2.5 plan.** It should be noted that a major portion of these benefits are due to reductions of sulfur oxides which react in the atmosphere to form particulate sulfates. While there is uncertainty associated with the extent of the risk, the analysis shows that the benefits of controlling marine vessel emissions are substantial and essential for attainment of federal health-based ambient air quality standards.

Study Structure

To estimate the benefits of the AQMP, regional PM2.5 annual air quality simulations were conducted to determine future year (2015) PM2.5 air quality assuming full implementation of the AQMP. (See SCAQMD *2007 Air Quality Management Plan* http://www.aqmd.gov/aqmp/07aqmp/index.html.) State-of-the-science annual PM2.5 simulations using CAMx with the "one atmosphere" aerosol chemistry were conducted for the 2005 base and 2014 attainment years. (Note: projected emissions inventories for 2014 were used to assess the impact in 2015 since all control measures are required to be implemented prior to the attainment deadline year, 2015.) MM5 meteorological simulations, the 2007 AQMP emissions inventory and boundary conditions extracted from WRAP regional haze analyses provided the key input parameters to the CAMx simulations. These simulations were the primary components of the 2007 AQMP PM2.5 attainment demonstration that has been adopted by AQMD and CARB Governing Boards for inclusion in the State Implementation Plan.

To assess the benefits of marine vessel controls, model simulations were conducted to determine the (1) 2014 air quality for the baseline emissions inventory, (2) the baseline inventory with the LSAER emissions added back (increasing the baseline) and (3) for the AQMP control strategy with control measure ARBOFF-1 removed (less overall emissions reductions). The PM2.5 air quality benefits from ARBOFF-1 strategy were calculated by subtracting air quality predicted using the full AQMP strategy from the ARBOFF-1 simulation (columns A-B in the attached Table 1). Similarly the benefits of LSAER were determined by subtracting the 2014 baseline simulation PM2.5 concentrations from the LSAER simulated concentration (columns D-E in the attached table).

Domain

The CAMx simulations were conducted using a 2,600 five km square grid domain that extended more than 100 km offshore from the ports of Los Angeles and Long Beach, north to Point Conception and south to the Mexican border. The model simulations incorporated emissions from vessels moving in the north-south shipping lanes paralleling the coast and the west bound shipping lane used by Asian transport. Two methods were used to calculate a representative regional PM2.5 for each simulation: (1) an area average concentration incorporating PM2.5 concentrations for all grids having population; and (2) a population weighted version of the area average. The two methods provide bounds for the exposure estimate and rely solely on areas where impacts are affecting people. Figure 1 depicts the modeling domain where grid cells with population greater than zero are used to calculate the area and population weighted average concentrations (shaded in gray).

Mortality and Morbidity

In the 2007 AQMP Socioeconomic Analysis, the benefits of reduced mortality and morbidity associated with attaining the PM2.5 standard were calculated using U.S. EPA's BENMAP program. BENMAP uses the annual PM2.5 simulations and a series of health/cost functions derived from epidemiological analyses focusing on PM2.5 exposure. The annual PM2.5 simulations were conducted for all hours in 2005 (8,760).

The AQMP analysis determined that approximately 1,500 premature deaths would be avoided if the annual PM 2.5 standard is met in 2015 (the federal attainment deadline). The 1,500 avoided premature deaths were based on a pooled estimate of three adult (age 30 and above) concentration response functions, Pope et al. (50%), Jerrett et al. (25%), and Laden et al. (25%), along with an infant all-cause mortality function from Woodruff et al. The population exposure was performed at the 5 km grid level. It is important to note that the health functions derived from epidemiological studies represent the impact of breathing PM2.5 as a total particulate sample, not individual specific component species.

Monetized Benefits

Analysis conducted for the AQMP placed the year 2015 annual savings due to AQMP PM2.5 reductions at $9.1 billion per year based on a single death avoided valued at approximately $6 million. The monetary valuation was in year 2000 dollars with adjustments made to reflect real income growth and a social discount rate of three percent.

Benefits of LSAER and ARBOFF-1

Estimates of the avoided deaths from the implementation of LSAER and ARBOFF-1, individually and together, were calculated as a two-step process. First, the air quality benefits obtained from implementation of the specific measures were divided by the total benefit gain projected for the year 2015 implementation of the AQMP (columns C/H for ARBOFF-1, F/H for LSAER and G/H for the combined benefit). The benefit specific ratios were then multiplied by the AQMP estimate of 1,500 avoided premature deaths. LSAER accounts for approximately 313 - 406 avoided premature deaths annually (dependent upon the weighting assumption to determine regional average concentration) and ARBOFF-1 accounts for between 406 - 502 avoided deaths. The difference in the weighting assumption to calculate a regional air quality impact created a spread of approximately 20 percent (between low and high value measured from the high value). Overall, avoided premature deaths from the combined marine vessel measures range from 719 to 908. Table 2 provides the annual monetary benefit from 2008 to 2030, with the total value ranging between $96 and $126 billion dollars.

Uncertainties

All ambient data monitoring and analysis, regional modeling, and PM2.5 benefits assignment from health/cost functions have associated uncertainty. The health/cost analysis is based upon the concentration of PM2.5 mass as a comprehensive sample, not individual particulate components. Estimates of risk have been determined for diesel particulate by Cal-EPA. CARB, as part of the Goods Movement Strategy evaluation, has estimated mortality associated with directly emitted particulate and secondary nitrates, as well as elemental carbon and diesel soot. Sulfate is a key component species of the PM2.5 mass in South Coast. To date, however, CARB has not included sulfur oxides and resulting secondary sulfates as part of quantitative assessments, but CARB staff acknowledges that sulfates are significant contributors to health effects. There remains a need to further quantify the extent of formation of particulate sulfate from SOx emissions. CARB is currently conducting analyses regarding this issue. The analyses are focusing on further identifying mechanisms that are natural and biogenic sources and sinks of SOx and sulfate, transport and transformation of SOx, as well as deposition. The analysis described in this memorandum will be updated if more information becomes available. The present analysis is based on the best available information and uses the same methodology which forms the basis of the State Implementation Plan, which was approved by the AQMD and CARB boards.

Conclusion

Implementation of LSAER and ARBOFF-1 will result in a large number of avoided premature deaths, as well as other health benefits. As this analysis and the 2007 AQMP demonstrate, the benefits of controlling marine vessel emissions are both substantial and essential for attainment of federal health-based ambient air quality standards.

Table 1. Avoided Premature Death Analysis (2015)

Variable	AQMP Without ARBOFF-1 Modeled (ug/m3)	AQMP Modeled (ug/m3)	Delta Modeled Shipping (ug/m3)	AQMP 2015 Baseline (ug/m3)	Adjustment Low Sulfur Auxiliary Engines (ug/m3)	Delta Baseline Adjustment (ug/m3)	Total Shipping Delta (ug/m3)	AQMP Improvement (ug/m3)	Ratio Percent Change (ug/m3)	Avoided Deaths LSAER	Avoided Deaths ARBOFF-1	Total Avoided Deaths
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)			
Area Weight	10.39	10	0.39	11.44	11.74	0.3	0.69	1.44	0.48	406	313	719
Pop Weight	13.09	12.37	0.72	14.52	15.15	0.63	1.35	2.15	0.63	502	440	942
Area Weighted Component Analysis												
Area NH4	1.06	0.98	0.08	1.17	1.22	0.05	0.13	0.19	0.68			
Area NO3	2.15	2.15	0	2.76	2.66	-0.1	-0.1	0.61	-0.16			
Area SO4	2.37	2.06	0.31	2.47	2.76	0.29	0.6	0.41	1.46			
Area OC	1.27	1.3	-0.03	1.41	1.42	0.01	-0.02	0.11	-0.18			
Area EC	1.07	1.06	0.01	1.15	1.17	0.02	0.03	0.09	0.33			
Area Otr	1.45	1.44	0.01	1.48	1.5	0.02	0.03	0.04	0.75			
Population Weighted Component Analysis												
Pop NH4	1.34	1.24	0.1	1.51	1.57	0.06	0.16	0.27	0.59			
Pop NO3	3.36	3.26	0.1	3.94	3.86	-0.08	0.02	0.68	0.03			
Pop SO4	3.18	2.64	0.54	3.38	3.92	0.54	1.08	0.74	1.46			
Pop OC	1.55	1.58	-0.03	1.79	1.81	0.02	-0.01	0.21	-0.05			
Pop EC	1.31	1.3	0.01	1.47	1.5	0.03	0.04	0.17	0.24			
Pop Otr	1.86	1.86	0	1.93	1.98	0.05	0.05	0.07	0.71			

Table 2. Combined Benefits of LSAER and ARBOFF-1: 2008-2030

Year	Area Weighted Billions $	Population Weighted Billions $
2008	1.700	2.228
2009	2.880	3.775
2010	3.608	4.728
2011	3.791	4.967
2012	3.958	5.186
2013	4.155	5.445
2015	4.340	5.687
2015	4.364	5.719
2016	4.386	5.748
2017	4.407	5.775
2018	4.458	5.842
2019	4.505	5.903
2020	4.548	5.96
2021	4.495	5.89
2022	4.447	5.827
2023	4.404	5.771
2024	4.442	5.821
2025	4.476	5.866
2026	4.507	5.906
2027	4.535	5.943
2028	4.561	5.977
2029	4.585	6.008
2030	4.606	6.036
Total Billions Dollars	96.158	126.007

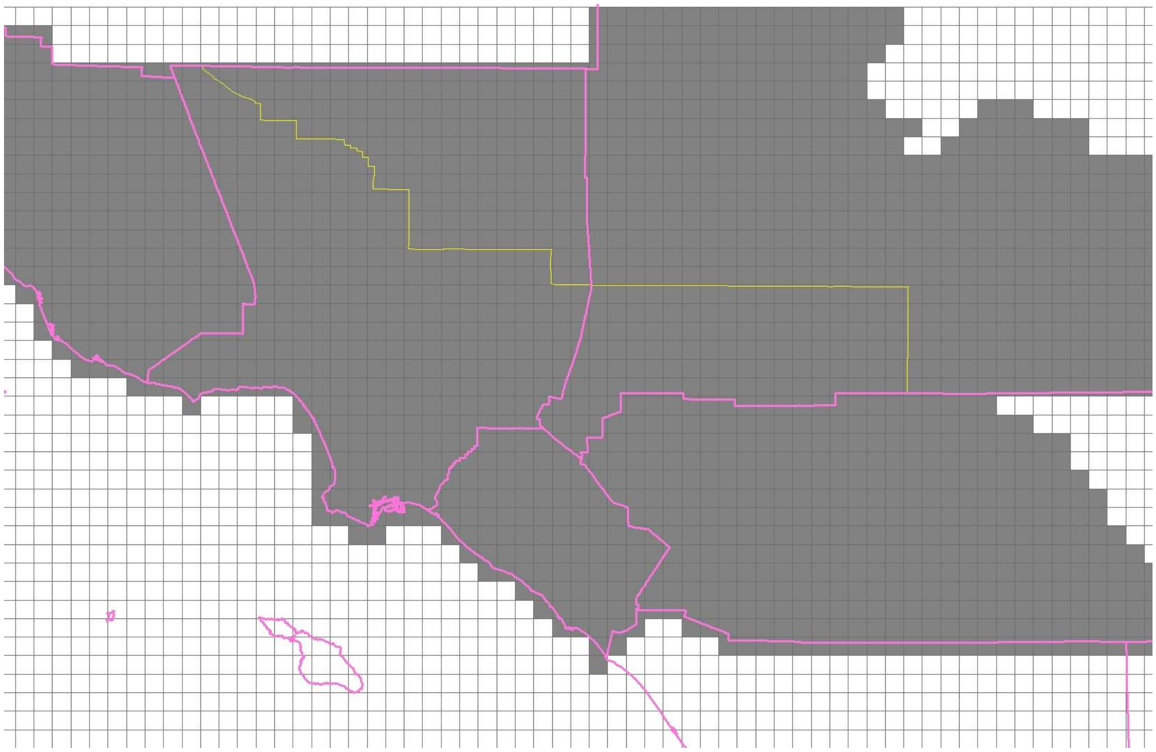

Figure 1. South Coast Air Basin Modeling Domain
(Grid cells with population used in domain concentration averaging are shaded).