Section 3: Re-analysis of the Benefits of Attaining Alternative Ozone Standards to Incorporate Current Methods

Synopsis

This chapter presents a benefits analysis of three alternate ozone standards updated to reflect key methodological changes that EPA has implemented since having published the 2008 Ozone NAAQS RIA. In this updated analysis we re-estimate the human health benefits of reduced exposure to ambient ozone and $PM_{2.5}$ co-benefits from simulated attainment with three alternate daily 8hr maximum standards: 0.075 ppm, 0.070 ppm, and 0.065 ppm. For an alternative standard at 0.075 ppm, EPA estimates the monetized benefits to be $6.9 to $18 billion (2006$, 3% discount rate) in 2020.[1] For an alternative standard at 0.070 ppm, EPA estimates the monetized benefits to be $13 to $37 billion (2006$, 3% discount rate) in 2020. For an alternative standard at 0.065 ppm, EPA estimates the monetized benefits to be $22 to $61 billion (2006$, 3% discount rate) in 2020. Higher or lower estimates of benefits are possible using other assumptions. The benefits of attaining an alternate standard of 0.060 ppm and 0.055 ppm may be found in Section 2 of this supplement. These updated estimates reflect three key methodological changes we have implemented since the publication of the 2008 RIA that reflect EPA's most current interpretation of the scientific literature and include: (1) a no-threshold model for $PM_{2.5}$ that calculates incremental benefits down to the lowest modeled air quality levels; (2) removal of the assumption of no causality for the relationship between ozone exposure and premature mortality; (3) a different Value of Statistical Life (VSL). These benefits are incremental to an air quality baseline that reflects attainment with the 1997 ozone and 2006 $PM_{2.5}$ National Ambient Air Quality Standards (NAAQS). Methodological limitations prevented EPA from monetizing the benefits from several important benefit categories, including ecosystem effects.

S3.1 Background

In response to the recent court vacatur of the 2008 Ozone NAAQS, EPA is reconsidering this rulemaking. Consistent with EPA's decision to, in general, use the "existing record" for this reconsideration, we present a benefits analysis based on the same air quality modeling inputs as the 2008 analysis. However, we update this analysis to make the results consistent with an array of methodological updates that EPA has incorporated since the release of Regulatory Impact Analysis (RIA) for the 2008 Ozone NAAQS (U.S. EPA, 2008). Because the rulemaking period for the reconsideration is condensed, we only provide estimates associated with the

[1] Results are shown as a range from Bell et al. (2004) with Pope et al. (2002) to Levy (2005) with Laden et al. (2006). $PM_{2.5}$ co-benefits using a 7% discount rate would be approximately 9% lower.

promulgated standard level of 0.075 ppm and the two more stringent standard levels previously analysis (i.e., 0.070 ppm and 0.065 ppm). A separate analysis of the costs and benefits of simulated attainment with 0.060 ppm and 0.055 ppm may be found in Section 2 of this Supplement. All benefits estimates in this analysis are incremental to the 1997 Ozone NAAQS standard at 0.08 ppm and the 2006 $PM_{2.5}$ NAAQS standard at 15/35 µg/m^3.

S3.2 Key updates to the benefits assessment

In this analysis, we update several aspects of our benefits assessment for the human health benefits of reducing exposure to ozone and $PM_{2.5}$.[2] Both ozone benefits and $PM_{2.5}$ co-benefits incorporate the updated population projections in BenMAP. In addition, both ozone benefits and $PM_{2.5}$ co-benefits reflect EPA's current interpretation of the economic literature on mortality valuation to use the value-of-a statistical life (VSL) based on meta-analysis of 26 studies.[3]

For ozone benefits, these updates are a response to recent recommendations from the National Research Council (NRC, 2008). In this analysis, we have incorporated three of NRC's recommendations:

1) We no longer include estimates of ozone benefits with an assumption of no causal relationship between ozone exposure and premature mortality.
2) We include two additional ozone mortality estimates, one based on the National Morbidity, Mortality and Air Pollution Study (NMMAPS) (Huang, 2005), and one 14-city study (Schwartz, 2005), placing the greatest emphasis on the multi-city studies, such as NMMAPS.
3) We present additional risk metrics, including the change in the percentage of baseline mortality attributable, and the number of life years lost due, to ozone-related premature mortality.

In addition to these recommendations, we modify the health functions used to estimate the number of emergency department visits for asthma avoided by reducing exposure to ozone. Specifically, we removed the Jaffe et al. (2003) function because the age range overlaps partially with Wilson et al. (2005) and Peel et al. (2005) functions. This change results in a

[2] This analysis does not attempt to describe the overall methodology for estimating the benefits of reducing ozone and $PM_{2.5}$. For more information, please consult Chapter 6 of the 2008 Ozone NAAQS RIA (U.S. EPA, 2008).
[3] For more information regarding mortality valuation, please consult section 5.7 of the proposed NO_2 RIA (U.S. EPA, 2009b).

slightly larger estimate of ozone-related emergency department visits as compared to the 2008 analysis.

For $PM_{2.5}$ co-benefits, this analysis is consistent with proposed Portland Cement NESHAP RIA (U.S. EPA, 2009a) and proposed NO_2 NAAQS RIA (U.S. EPA, 2009b). In this analysis, we incorporate four updates:

1) We removed assumed thresholds from the mortality and morbidity concentration-response functions for $PM_{2.5}$.[4] Removing the assumed 10 μg/m^3 threshold is a key difference between the method used in this analysis of $PM_{2.5}$-co benefits and the methods used in RIAs prior to Portland Cement, and we now calculate incremental benefits down to the lowest modeled $PM_{2.5}$ air quality levels. This change results in a larger estimate of PM-related premature mortality as compared to the 2008 analysis.
2) We now present the summary of the $PM_{2.5}$ co-benefits results using concentration-response functions for mortality from two cohort studies (Pope et al. (2002) and Laden et al. (2006)) instead of range between the minimum and maximum results from an expert elicitation of the relationship between exposure to $PM_{2.5}$ and premature mortality (Roman et al., 2008). This change produces a slightly narrower range of PM-related mortality estimates as compared to the 2008 analysis. In addition, we provide the full suite of results based on the expert elicitation in the body of the benefits results chapter.
3) When adjusting the benefits of the modeled PM co-benefits for alternate standard levels, we apply $PM_{2.5}$ benefit per ton estimates calculated using a broader geographic area, which, when compared to the 2008 analysis, produces more reliable and generally larger PM-related benefits estimates.
4) We incorporated an updated methodology for quantifying the health incidences associated with the benefit-per-ton estimates. This change should produce more reliable estimates of PM-related health impacts.

In this analysis we estimate ozone-related premature mortality using risk coefficients drawn from short-term mortality studies. Two recent epidemiologic studies assessed the relationship between long-term exposure to ozone and premature mortality. Jerrett et al. (2009) utilized the ACS cohort with air quality data from 1977 through 2000 (April through September). Jarrett et al. reported a positive and statistically significant association between ambient ozone concentration and respiratory causes of death after controlling for $PM_{2.5}$ using

[4] For more information regarding thresholds in the $PM_{2.5}$ mortality relationship, please consult the proposed Portland Cement NESHAP RIA (U.S. EPA, 2009a).

co-pollutant models. Further examination of the association between ozone exposure and respiratory-related mortality revealed the association was increased by higher temperatures and geographic variation. In single pollutant models, long-term ozone exposure was also associated with cardiopulmonary, cardiovascular, and ischemic heart disease mortality, but the associations were not present in the co-pollutant model. Krewski et al. (2009) also utilized data from the ACS cohort with air quality data from 1980 (April through September) and observed a positive association between ozone exposure and all-cause and cardiopulmonary disease mortality. This association was robust to control for ecologic variables, but no association was observed with ischemic heart disease or lung cancer. In addition, Krewski et al. observed no association with year-round ozone exposure.

EPA anticipates incorporating risk coefficients from one or both of these two long-term cohort studies after consulting with the EPA SAB to resolve key technical questions regarding the specification of the health impact analysis. For example, when estimating long-term $PM_{2.5}$-related mortality we apply an SAB-recommended 20-year distributed cessation lag, over which period we discount monetized benefits. To the extent that there is a lag between the cessation of ozone exposure and the return of population risk to a new steady state risk level, EPA would specify this parameter in the health impact analysis. We also plan to elicit guidance from the SAB regarding the selection of: national versus regional effect coefficients; the use of estimators derived using single versus co-pollutant models; and, the health mortality endpoint to be quantified, among other issues. EPA anticipates consulting with the SAB in late 2009.

S3.3 Presentation of results

Tables S3.1 through S3.6 show the results of this updated analysis. Figures S3.1 and S3.2 show the breakdown of ozone benefits and $PM_{2.5}$ co-benefits by endpoint category using a single mortality study as an example. Figures S3.3 and S3.4 show the ozone benefits and $PM_{2.5}$ co-benefits by mortality study. Figures S3.5 and S3.6 show the breakdown of monetized benefits between ozone, PM, morbidity, mortality, and visibility. Figure S3.7 shows the results of this updated analysis graphically.

Table S3.1: Summary of Total Number of Ozone and $PM_{2.5}$-Related Premature Mortalities and Morbidity Incidences Avoided in 2020 [A, D]

Combined Estimate of Mortality		0.075 ppm			0.070 ppm			0.065 ppm		
Multi-city	Bell et al. (2004)	760	to	1,900	1,500	to	3,500	2,500	to	5,600
	Schwartz	800	to	1,900	1,600	to	3,600	2,700	to	5,800
	Huang	820	to	1,900	1,600	to	3,600	2,800	to	5,900
Meta-analysis	Bell et al. (2005)	930	to	2,000	2,000	to	4,000	3,500	to	6,600
	Ito et al.	1,000	to	2,100	2,300	to	4,300	4,000	to	7,100
	Levy et al.	1,000	to	2,100	2,300	to	4,300	4,100	to	7,200

Combined Estimate of Morbidity	0.075 ppm	0.070 ppm	0.065 ppm
Acute Myocardial Infarction [B]	1,300	2,200	3,500
Upper Respiratory Symptoms [B]	9,900	19,000	31,000
Lower Respiratory Symptoms [B]	13,000	25,000	41,000
Chronic Bronchitis [B]	470	880	1,400
Acute Bronchitis [B]	1,100	2,100	3,400
Asthma Exacerbation [B]	12,000	23,000	38,000
Work Loss Days [B]	88,000	170,000	270,000
School Loss Days [C]	190,000	600,000	1,100,000
Hospital and ER Visits	2,600	6,700	11,000
Minor Restricted Activity Days	1,000,000	2,600,000	4,500,000

[A] Does not reflect estimates for the San Joaquin and South Coast Air Basins

[B] PM-related benefits only

[C] Ozone-related benefits only

[D] All estimates rounded to two significant digits

Table S3.2: Summary of Total Monetized Benefits in 2020 (3% discount rate, in millions of 2006$)[A, B, C]

Combined Estimate of Mortality		0.075 ppm			0.070 ppm			0.065 ppm		
NMMAPS	Bell et al. (2004)	$6,900	to	$15,000	$13,000	to	$29,000	$22,000	to	$47,000
	Schwartz	$7,200	to	$16,000	$15,000	to	$30,000	$24,000	to	$49,000
	Huang	$7,300	to	$16,000	$15,000	to	$30,000	$25,000	to	$50,000
Meta-analysis	Bell et al. (2005)	$8,300	to	$17,000	$18,000	to	$34,000	$31,000	to	$56,000
	Ito et al.	$9,100	to	$18,000	$21,000	to	$37,000	$36,000	to	$61,000
	Levy et al.	$9,200	to	$18,000	$21,000	to	$37,000	$36,000	to	$61,000

[A] Does not reflect estimates for the San Joaquin and South Coast Air Basins

[B] All estimates rounded to two significant digits

[c] Includes Visibility benefits of $160,000

Table S3.3: Summary of Total Monetized Benefits in 2020 (7% discount rate, in millions of 2006$)[A, B, C]

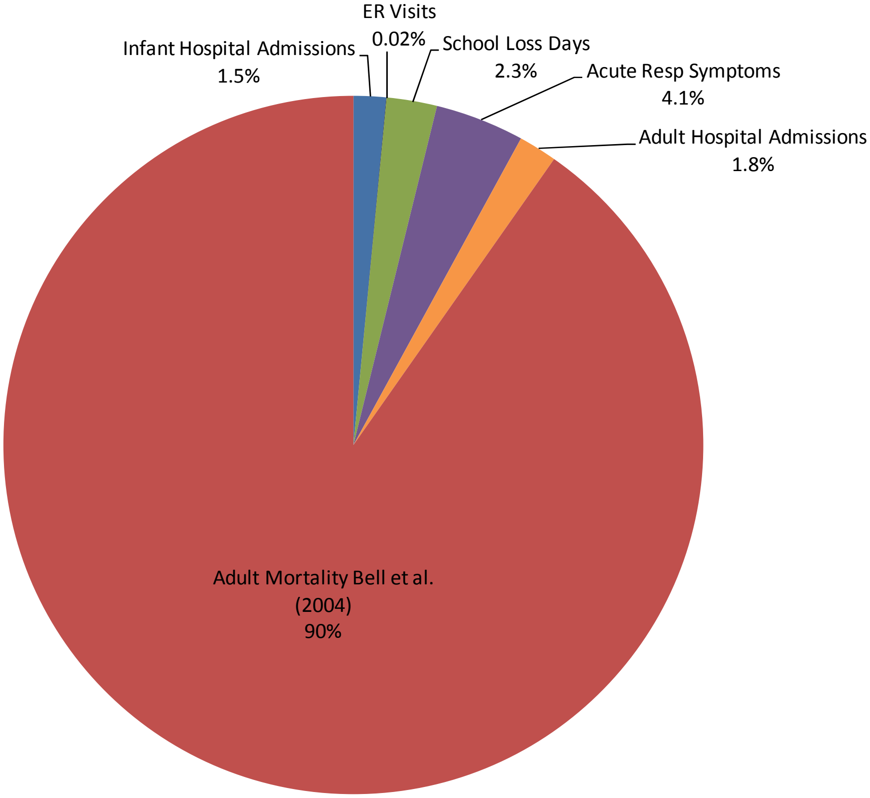
Combined Estimate of Mortality		0.075 ppm			0.070 ppm			0.065 ppm		
NMMAPS	Bell et al. (2004)	$6,400	to	$13,000	$11,000	to	$24,000	$19,000	to	$39,000
	Schwartz	$6,700	to	$13,000	$12,000	to	$25,000	$21,000	to	$41,000
	Huang	$6,800	to	$13,000	$13,000	to	$26,000	$21,000	to	$42,000
Meta-analysis	Bell et al. (2005)	$7,800	to	$14,000	$16,000	to	$29,000	$27,000	to	$48,000
	Ito et al.	$8,600	to	$15,000	$18,000	to	$31,000	$31,000	to	$52,000
	Levy et al.	$8,700	to	$15,000	$18,000	to	$31,000	$32,000	to	$52,000

[A] Does not reflect estimates for the San Joaquin and South Coast Air Basins

[B] All estimates rounded to two significant digits

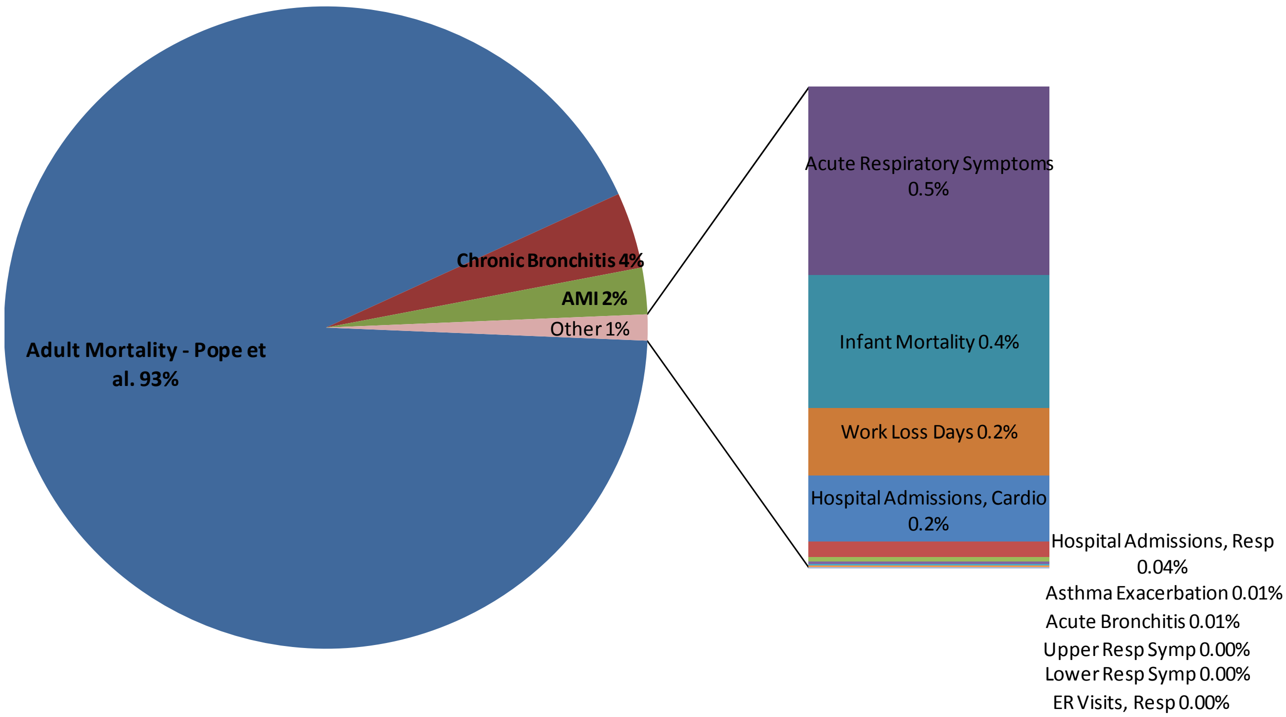
[c] Includes Visibility benefits of $160,000

Figure S3-1: Breakdown of Ozone Health Benefits (using Bell 2004)*



*This pie chart breakdown is illustrative, using the results based on Bell et al. (2004) as an example. Using the Levy et al. (2006) function for premature mortality, the percentage of total monetized benefits due to adult mortality would be 97%.

Figure S3-2: Breakdown of $PM_{2.5}$ Health Benefits (using Pope)*



*This pie chart breakdown is illustrative, using the results based on Pope et al. (2002) as an example. Using the Laden et al. (2006) function for premature mortality, the percentage of total monetized benefits due to adult mortality would be 97%. This chart shows the breakdown using a 3% discount rate, and the results would be similar if a 7% discount rate was used.

Table S3.4: Summary of National Ozone Benefits by Standard Level with 95th percentile confidence intervals (in millions of 2006$)[A, B, C]

Endpoint Group	Author	0.075 ppm Valuation	0.075 ppm Incidence	0.070 ppm Valuation	0.070 ppm Incidence	0.065 ppm Valuation	0.065 ppm Incidence
Infant Hospital Admissions, Respiratory		$11 ($5.7 -- $16)	550 (310 -- 830)	$17 ($8.5 -- $25)	1,700 (960 -- 2,600)	$30 ($15 -- $43)	3,000 (1,700 -- 4,500)
Emergency Room Visits, Respiratory		$0.11 (-$.21 -- $.35)	290 (-310 -- 930)	$0.36 (-$.71 -- $1.2)	990 (-890 -- 3,200)	$0.66 (-$1.3 -- $2.2)	1,800 (-1,600 -- 5,800)
School Loss Days		$17 ($7.5 -- $24)	190,000 (93,000 -- 280,000)	$53 ($23 -- $76)	600,000 (300,000 -- 880,000)	$96 ($42 -- $140)	1,100,000 (550,000 -- 1,600,000)
Acute Respiratory Symptoms		$30 ($12 -- $56)	510,000 (280,000 -- 790,000)	$96 ($37 -- $180)	1,600,000 (910,000 -- 2,500,000)	$170 ($68 -- $320)	2,900,000 (1,700,000 -- 4,500,000)
Hospital Admissions, Respiratory		$13 ($1.7 -- $22)	550 (130 -- 980)	$45 ($5.6 -- $77)	1,900 (550 -- 3,400)	$81 ($11 -- $140)	3,400 (1,000 -- 6,100)
Mortality	Bell et al. 2004	$660 ($54 -- $2,000)	74 (36 -- 120)	$2,200 ($180 -- $6,600)	250 (130 -- 410)	$4,000 ($330 -- $12,000)	450 (240 -- 730)
Mortality	Schwartz	$1,000 ($82 -- $3,000)	110 (54 -- 190)	$3,400 ($270 -- $10,000)	380 (190 -- 630)	$6,200 ($500 -- $19,000)	700 (350 -- 1,100)
Mortality	Huang	$1,100 ($95 -- $3,300)	130 (66 -- 200)	$3,800 ($320 -- $11,000)	420 (230 -- 670)	$6,800 ($580 -- $20,000)	770 (420 -- 1,200)
Mortality	Bell et al. 2005	$2,000 ($190 -- $6,100)	240 (140 -- 350)	$7,000 ($630 -- $21,000)	800 (490 -- 1,200)	$10,000 ($1,100 -- $37,000)	1,500 (910 -- 2,200)
Mortality	Ito et al.	$2,900 ($280 -- $8,200)	330 (230 -- 450)	$9,900 ($930 -- $28,000)	1,100 (790 -- 1,500)	$18,000 ($1,700 -- $50,000)	2,000 (1,400 -- 2,800)
Mortality	Levy et al.	$3,000 ($280 -- $8,200)	340 (260 -- 430)	$10,000 ($930 -- $28,000)	1,100 (870 -- 1,500)	$18,000 ($1,700 -- $50,000)	2,100 (1,600 -- 2,600)

[A] Does not reflect estimates for the San Joaquin and South Coast Air Basins

[B] Confidence intervals are not available for PM co-benefits because of methodological limitations when using benefit-per-ton estimates.

[C] All estimates rounded to two significant digits

Table S3.5: Summary of National Ozone Benefits and $PM_{2.5}$ Co-Benefits by Standard Level (in millions of 2006$ at a 3% discount rate)[A, B, C]

	Endpoint Group	Author	0.075 ppm Valuation	0.075 ppm Incidence	0.070 ppm Valuation	0.070 ppm Incidence	0.065 ppm Valuation	0.065 ppm Incidence
Ozone	Infant Hospital Admissions, Respiratory		$11	550	$17	1,700	$30	3,000
Ozone	Emergency Room Visits, Respiratory		$0.11	290	$0.36	990	$0.66	1,800
Ozone	School Loss Days		$17	190,000	$53	600,000	$96	1,100,000
Ozone	Acute Respiratory Symptoms		$30	510,000	$96	1,600,000	$170	2,900,000
Ozone	Hospital Admissions, Respiratory		$13	550	$45	1,900	$81	3,400
Ozone	Mortality	Bell et al. (2004)	$660	74	$2,200	250	$4,000	450
Ozone	Mortality	Schwartz	$1,000	110	$3,400	380	$6,200	700
Ozone	Mortality	Huang	$1,100	130	$3,800	420	$6,800	770
Ozone	Mortality	Bell et al. (2005)	$2,100	240	$7,100	800	$13,000	1,500
Ozone	Mortality	Ito et al.	$2,900	330	$9,900	1,100	$18,000	2,000
Ozone	Mortality	Levy et al.	$3,000	340	$10,000	1,100	$18,000	2,100
$PM_{2.5}$	Chronic Bronchitis		$230	470	$430	880	$700	1,400
$PM_{2.5}$	Acute Myocardial Infarction		$140	1,300	$240	2,200	$380	3,500
$PM_{2.5}$	Hospital Admissions, Respiratory		$2.5	180	$4.3	310	$6.8	490
$PM_{2.5}$	Hospital Admissions, Cardiovascular		$11	390	$18	670	$29	1,000
$PM_{2.5}$	Emergency Room Visits, Respiratory		$0.22	590	$0.39	1,100	$0.63	1,700
$PM_{2.5}$	Acute Bronchitis		$0.08	1,100	$0.15	2,100	$0.25	3,400
$PM_{2.5}$	Work Loss Days		$11	88,000	$20	170,000	$34	270,000
$PM_{2.5}$	Asthma Exacerbation		$0.64	12,000	$1.2	23,000	$2.0	38,000
$PM_{2.5}$	Acute Respiratory Symptoms		$31	520,000	$58	980,000	$95	1,600,000
$PM_{2.5}$	Lower Respiratory Symptoms		$0.24	13,000	$0.45	25,000	$0.75	41,000
$PM_{2.5}$	Upper Respiratory Symptoms		$0.29	9,900	$0.54	19,000	$0.89	31,000
$PM_{2.5}$	Infant Mortality		$22	3	$44	5	$73	8
$PM_{2.5}$	Mortality	Pope et al	$5,500	690	$10,000	1,200	$16,000	2,000
$PM_{2.5}$	Mortality	Laden et al	$14,000	1,800	$26,000	3,200	$41,000	5,100
$PM_{2.5}$	Mortality	Expert K	$1,900	230	$3,500	430	$5,700	700
$PM_{2.5}$	Mortality	Expert E	$19,000	2,300	$34,000	4,200	$55,000	6,800

[A] Does not reflect estimates for the San Joaquin and South Coast Air Basins

[B] Does not include confidence intervals

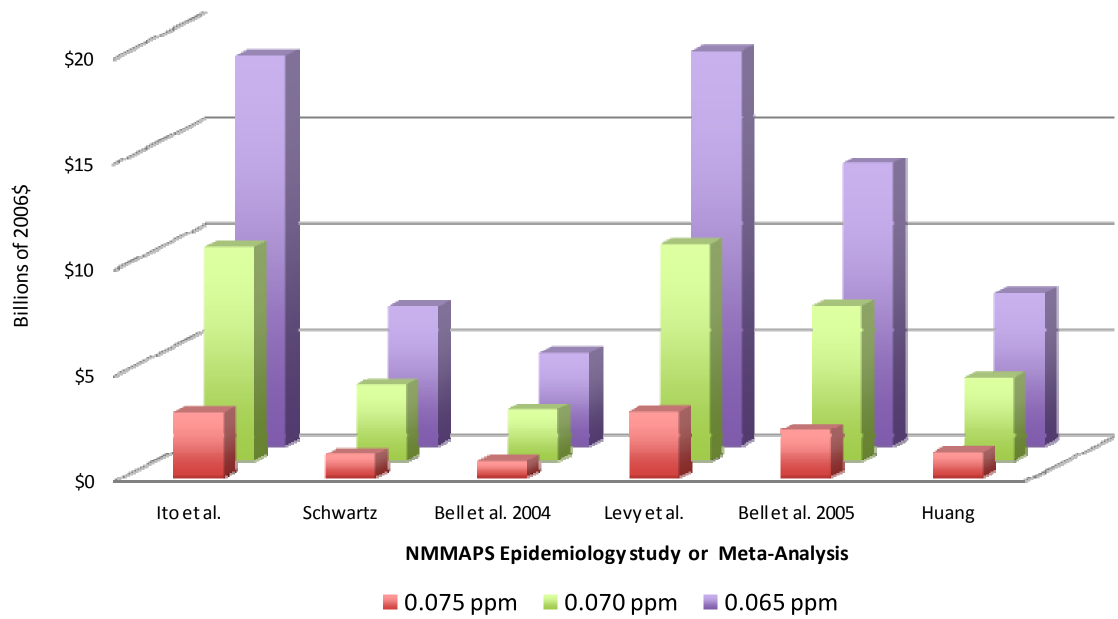
[C] All estimates rounded to two significant digits

Table S3.6: Summary of National Ozone Benefits and $PM_{2.5}$ Co-Benefits by Standard Level (in millions of 2006$ at a 7% discount rate)[A, B, C]

	Endpoint Group	Author	0.075 ppm Valuation	0.075 ppm Incidence	0.070 ppm Valuation	0.070 ppm Incidence	0.065 ppm Valuation	0.065 ppm Incidence
Ozone	Infant Hospital Admissions, Respiratory		$11	550	$17	1,700	$30	3,000
	Emergency Room Visits, Respiratory		$0.11	290	$0.36	990	$0.66	1,800
	School Loss Days		$17	190,000	$53	600,000	$96	1,100,000
	Acute Respiratory Symptoms		$30	510,000	$96	1,600,000	$170	2,900,000
	Hospital Admissions, Respiratory		$13	550	$45	1,900	$81	3,400
	Mortality	Bell et al. (2004)	$660	74	$2,200	250	$4,000	450
	Mortality	Schwartz	$1,000	110	$3,400	380	$6,200	700
	Mortality	Huang	$1,100	130	$3,800	420	$6,800	770
	Mortality	Bell et al. (2005)	$2,100	240	$7,100	800	$13,000	1,500
	Mortality	Ito et al.	$2,900	330	$9,900	1,100	$18,000	2,000
	Mortality	Levy et al.	$3,000	340	$10,000	1,100	$18,000	2,100
$PM_{2.5}$	Chronic Bronchitis		$230	470	$430	880	$700	1,400
	Acute Myocardial Infarction		$140	1,300	$240	2,200	$380	3,500
	Hospital Admissions, Respiratory		$2.5	180	$4.3	310	$6.8	490
	Hospital Admissions, Cardiovascular		$11	390	$18	670	$29	1,000
	Emergency Room Visits, Respiratory		$0.22	590	$0.39	1,100	$0.63	1,700
	Acute Bronchitis		$0.08	1,100	$0.15	2,100	$0.25	3,400
	Work Loss Days		$11	88,000	$20	170,000	$34	270,000
	Asthma Exacerbation		$0.64	12,000	$1.2	23,000	$2.0	38,000
	Acute Respiratory Symptoms		$31	520,000	$58	980,000	$95	1,600,000
	Lower Respiratory Symptoms		$0.24	13,000	$0.45	25,000	$0.75	41,000
	Upper Respiratory Symptoms		$0.29	9,900	$0.54	19,000	$0.89	31,000
	Infant Mortality		$22	3	$44	5	$73	8
	Mortality	Pope et al	$5,000	690	$9,000	1,200	$14,000	2,000
	Mortality	Laden et al	$13,000	1,800	$23,000	3,200	$37,000	5,100
	Mortality	Expert K	$1,700	230	$3,100	430	$5,100	700
	Mortality	Expert E	$17,000	2,300	$31,000	4,200	$49,000	6,800

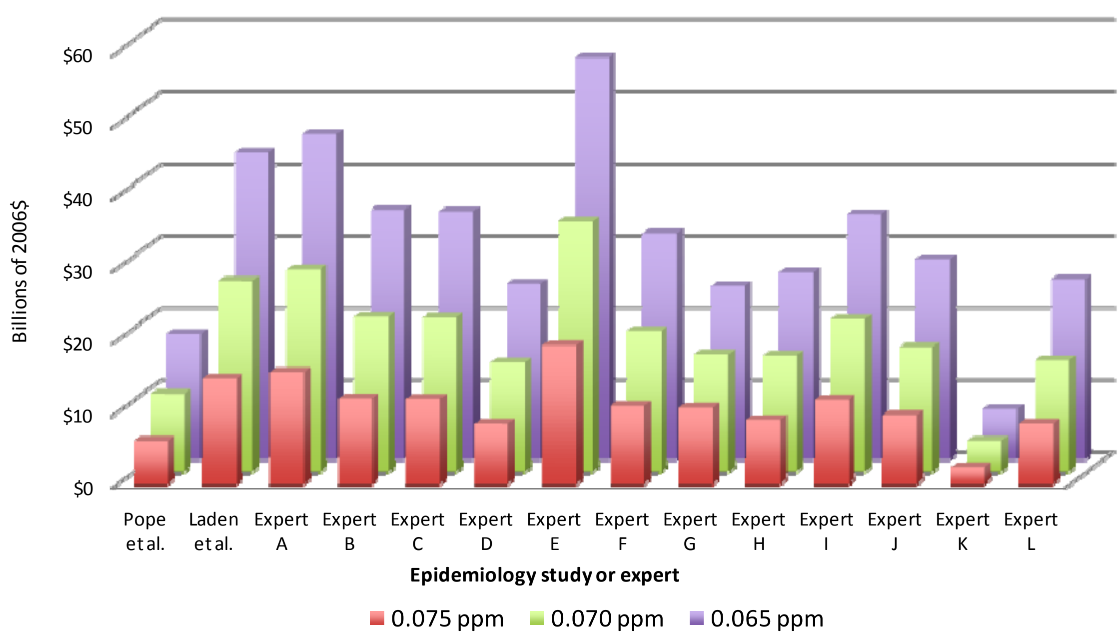
[A] Does not reflect estimates for the San Joaquin and South Coast Air Basins
[B] Does not include confidence intervals
[C] All estimates rounded to two significant digits

Figure S3.3: Ozone benefits for Alternate Standard Levels*



*This graph shows the estimated ozone benefits in 2020 using three NMMAPS-based epidemiology studies and three meta-analyses. The results shown are not the direct results from the studies; rather, the estimates are based in part on the concentration-response function provided in those studies. Because all ozone-related health effects are short-term, the discount rate does not affect the results.

Figure S3.4: $PM_{2.5}$ co-benefits for Alternate Standard Levels*



*This graph shows the estimated $PM_{2.5}$ co-benefits in 2020 using the no-threshold model at discount rates of 3% using effect coefficients using the Pope et al. study and the Laden et al study, as well as 12 effect coefficients derived from EPA's expert elicitation on PM mortality. The results shown are not the direct results from the studies or expert elicitation; rather, the estimates are based in part on the concentration-response function provided in those studies. Results using a 7% discount rate would be similar, but approximately 9% lower.

Figure S3.5: Breakdown of total monetized benefits for Alternate Standard Levels (Low)

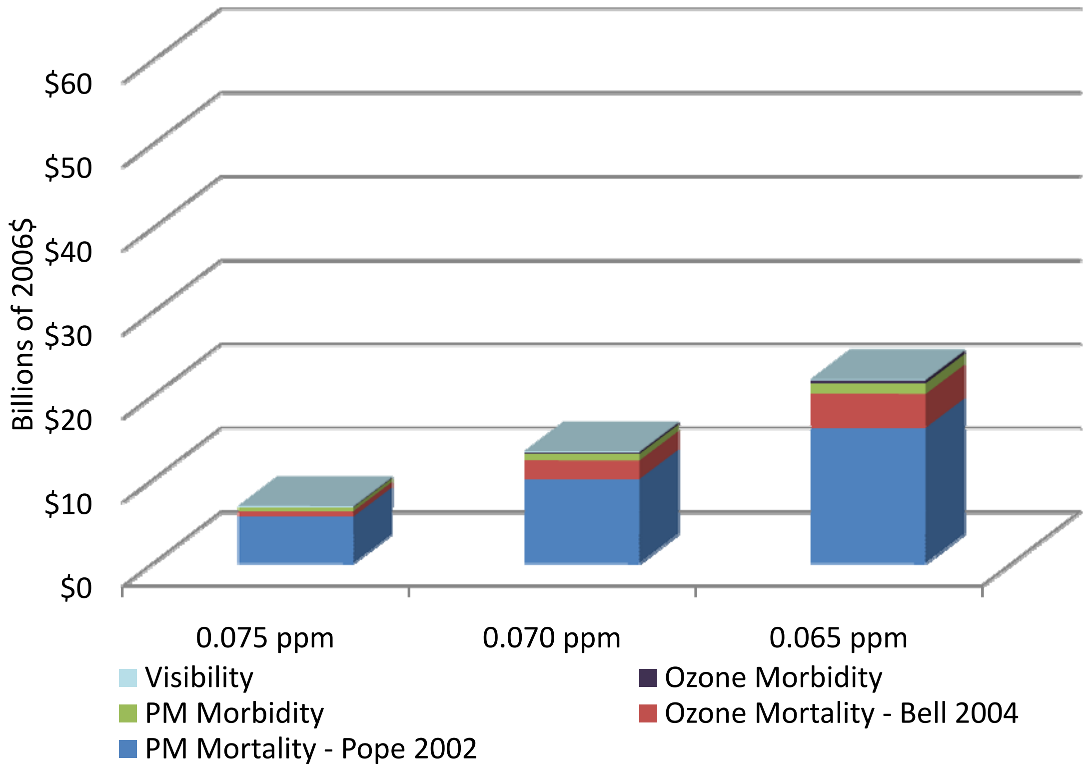


Figure S3.6: Breakdown of total monetized benefits for Alternate Standard Levels (High)

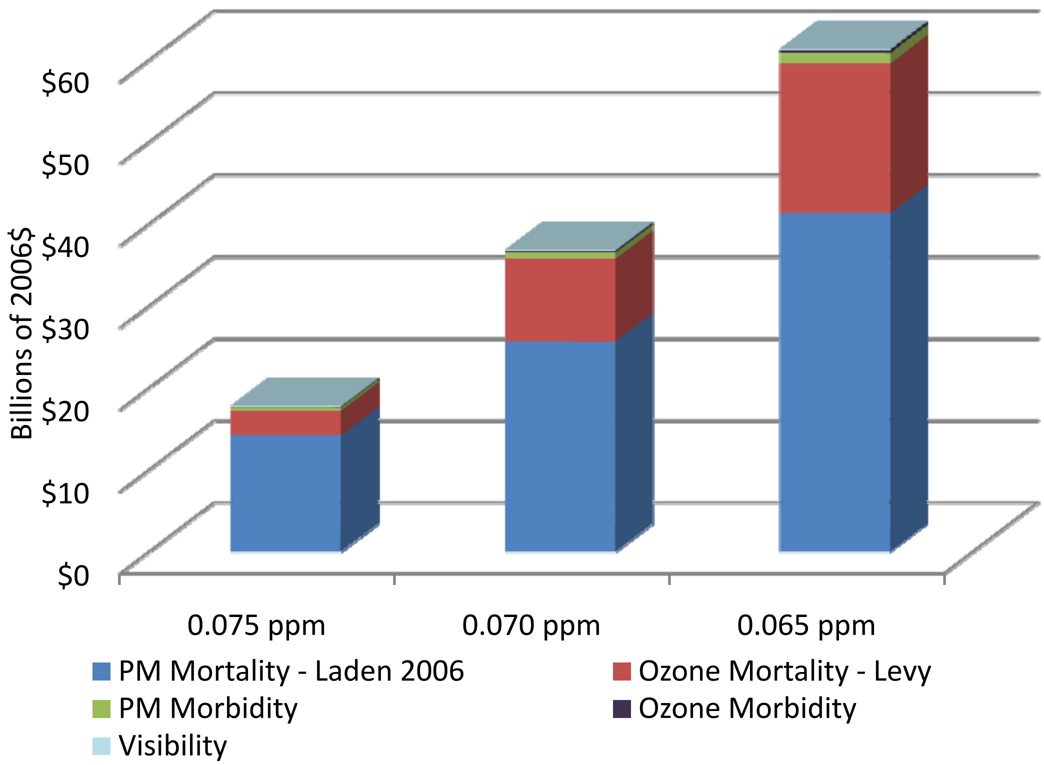
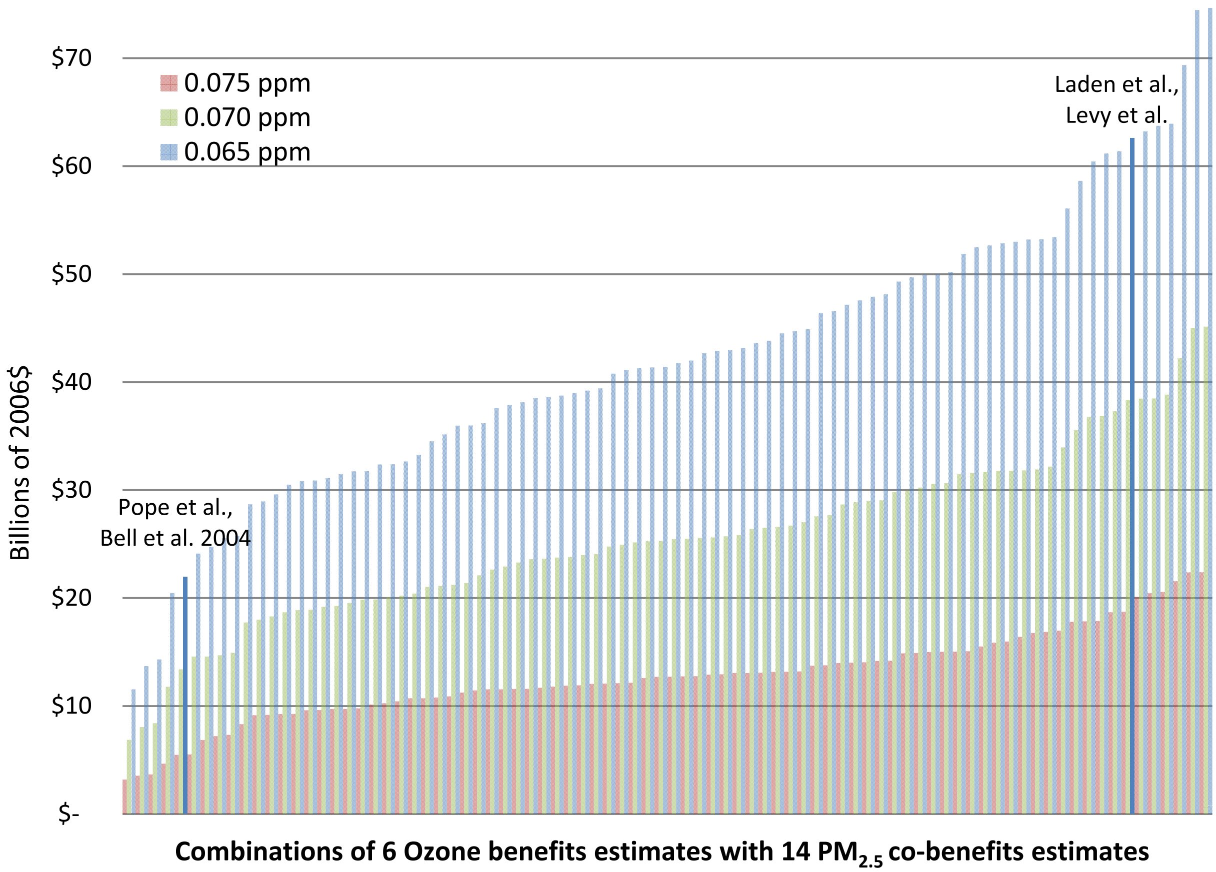


Figure S3.7: Total Monetized Benefits for Alternate Standard Levels*



*This graph shows the estimated total monetized benefits in 2020 using the no-threshold model at discount rates of 3% using effect coefficients derived from the 6 ozone mortality studies and PM co-benefits estimates using the Pope et al. study and the Laden et al study, as well as 12 effect coefficients derived from EPA's expert elicitation on PM mortality. The highlighted results represent the combined estimates from Bell et al. (2004) with Pope et al. (2002) and Levy (2005) with Laden et al. (2006). The results shown are not the direct results from the studies or expert elicitation; rather, the estimates are based in part on the concentration-response function provided in those studies. PM co-benefit results using a 7% discount rate would be similar, but approximately 9% lower.

In 2008, the National Research Council (NRC) evaluated the EPA's approach to estimating ozone-related mortality benefits. Among other recommendation, in its report the NRC indicated that "EPA should consider placing greater emphasis on reporting decrease in age-specific death rates and increases in life expectancy…" (NRC, 2008). As a first step in implementing this recommendation, below for two of the three scenarios, we present changes in the percentage of total cause-specific mortality attributable to ozone and the change in the number of life years.[5] Table 7 summarizes the estimated number of life years gained resulting from simulated attainment with the 0.065 ppm and 0.070 ppm standard alternatives. To

[5] Here we omit the results for the 0.075 ppm alternative. We estimated the benefits of attaining this alternative through an interpolation approach that made subsequent estimation of life years and changes in death rates technically challenging.

simplify this presentation we include results based on the estimates of ozone mortality reported in Levy et al. (2005) and Bell et al. (2004), which provide upper and lower-bound estimates, respectively.

Table S3.7: Estimated Reduction in Ozone-Related Premature Mortality in Terms of Life Years Gained from Increases in Life Expectancy

	Bell et al. (2004) mortality estimate		*Levy et al. (2005) mortality estimate*	
Age Range	0.070 ppm	0.065 ppm	0.070 ppm	0.065 ppm
25-29	75 (32—120)	130 (58—210)	660 (780—830)	1,200 (850—1,500)
30-34	66 (28—100)	120 (51—180)	580 (420—740)	1,000 (750—1,300)
35-44	260 (110—410)	460 (200—730)	1,600 (1,200—2,000)	2,800 (2,000—3,500)
45-54	520 (220—830)	930 (400—1,500)	2,600 (1,900—3,300)	4,500 (3,300—5,700)
55-64	1,000 (440—1,600)	1,800 (780—2,800)	4,600 (3,400—5,900)	8,100 (5,900—10,000)
65-74	1,200 (500—1,900)	2,100 (900—3,300)	5,200 (3,800—6,600)	9,100 (6,700—12,000)
75-84	810 (340—1,300)	1,400 (620—2,200)	3,500 (2,600—4,500)	6,200 (4,600—7,900)
85-99	400 (170—630)	720 (310—1,100)	1,800 (1,300—2,200)	3,100 (2,300—4,000)

Table S3.8 summarizes the percentage of total mortality attributable to ozone. As above, we include estimates based on the Bell et al. (2004) and Levy et al. (2005) risk coefficients.

Table S3.8: Percentage of Total Mortality Attributable to Ozone

	Bell et al. (2004) mortality estimate		*Levy et al. (2005) mortality estimate*	
Age Range	0.070 ppm	0.065 ppm	0.070 ppm	0.065 ppm
25-29	0.030%	0.054%	0.126%	0.224%
30-34	0.029%	0.052%	0.123%	0.217%
35-44	0.029%	0.051%	0.123%	0.217%
45-54	0.030%	0.052%	0.127%	0.224%
55-64	0.028%	0.050%	0.122%	0.212%
65-74	0.027%	0.047%	0.114%	0.200%
75-84	0.026%	0.046%	0.112%	0.197%
85-99	0.027%	0.048%	0.115%	0.206%

S3.4 Comparison of results to previous results in 2008 Ozone NAAQS RIA

The overall effect of incorporating the array of methodological changes was to increase the estimated benefits of attaining alternate ozone standards estimates presented in the 2008 Ozone NAAQS RIA. In general, the key update that had the largest effect on the valuation and the incidence results is removing the threshold from the PM concentration-response functions. Tables 9 and 10 show the total monetized benefits, costs, and net benefits for the 2008 Ozone RIA analysis and this updated analysis, respectively. Figure 6 shows a comparison of the range of net benefits estimates in this updated analysis compared to the net benefits presented in the 2008 Ozone NAAQS RIA.[6]

Table S3.9: Total Monetized Costs with Ozone Benefits and $PM_{2.5}$ Co-Benefits in 2020 (in Billions of 2006$) * 2008 RIA

	Ozone Mortality Function	Reference	Total Benefits **		Total Costs ***	Net Benefits	
			3%	7%	7%	3%	7%
0.075 ppm	NMMAPS and Multi-city	Bell et al. 2004	$4.4 to $8.5	$4.1 to $7.7	$7.6 to $8.8	$-4.4 to $0.9	$-4.7 to $0.1
		Schwartz 2005	N/A	N/A	N/A	N/A	N/A
		Huang 2005	N/A	N/A	N/A	N/A	N/A
	Meta-analysis	Bell et al. 2005	$5.6 to $9.7	$5.3 to $9.0	$7.6 to $8.8	$-3.2 to $2.1	$-3.5 to $1.4
		Ito et al. 2005	$6.3 to $10	$5.9 to $9.6	$7.6 to $8.8	$-2.5 to $2.7	$-2.9 to $2.0
		Levy et al. 2005	$6.3 to $10	$6.0 to $9.7	$7.6 to $8.8	$-2.5 to $2.8	$-2.8 to $2.1
0.070 ppm	NMMAPS and multi-city	Bell et al. 2004	$8.8 to $16	$8.2 to $15	$19 to $25	$-16 to $-2.8	$-17 to $4.1
		Schwartz 2005	N/A	N/A	N/A	N/A	N/A
		Huang 2005	N/A	N/A	N/A	N/A	N/A
	Meta-analysis	Bell et al. 2005	$13 to $21	$13 to $19	$19 to $25	$-12 to $1.5	$-12 to $0.2
		Ito et al. 2005	$15 to $23	$15 to $21	$19 to $25	$-9.6 to $3.8	$-10 to $2.5
		Levy et al. 2005	$16 to $23	$15 to $22	$19 to $25	$-9.3 to 4.1	$9.9 to $2.7
0.065 ppm	NMMAPS and multi-city	Bell et al. 2004	$15 to $27	$14 to $24	$32 to $44	$-29 to $-5.4	$-30 to $-7.5
		Schwartz 2005	N/A	N/A	N/A	N/A	N/A
		Huang 2005	N/A	N/A	N/A	N/A	N/A
	Meta-analysis	Bell et al. 2005	$22 to $34	$21 to $32	$32 to $44	$-22 to $2.4	$-23 to $0.3
		Ito et al. 2005	$27 to $39	$26 to $36	$32 to $44	$-17 to $6.6	$-18 to $4.4
		Levy et al. 2005	$27 to $39	$26 to $37	$32 to $44	$-17 to $7.0	$-18 to $4.9

*All estimates rounded to two significant figures. As such, they may not sum across columns. Only includes areas required to meet the current standard by 2020, does not include San Joaquin and South Coast areas in California.
**Includes ozone benefits, and $PM_{2.5}$ co-benefits. Range was developed by adding the estimate from the ozone premature mortality function to estimates from the $PM_{2.5}$ premature mortality functions from Pope et al. and Laden et al. Tables exclude unquantified and nonmonetized benefits.
***Range reflects lower and upper bound cost estimates. Data for calculating costs at a 3% discount rate was not available for all sectors, and therefore total annualized costs at 3% are not presented here. Additionally, these estimates assume a particular trajectory of aggressive technological change. An alternative storyline might hypothesize a much less optimistic technological trajectory, with increased costs, or with decreased benefits in 2020 due to a later attainment date.

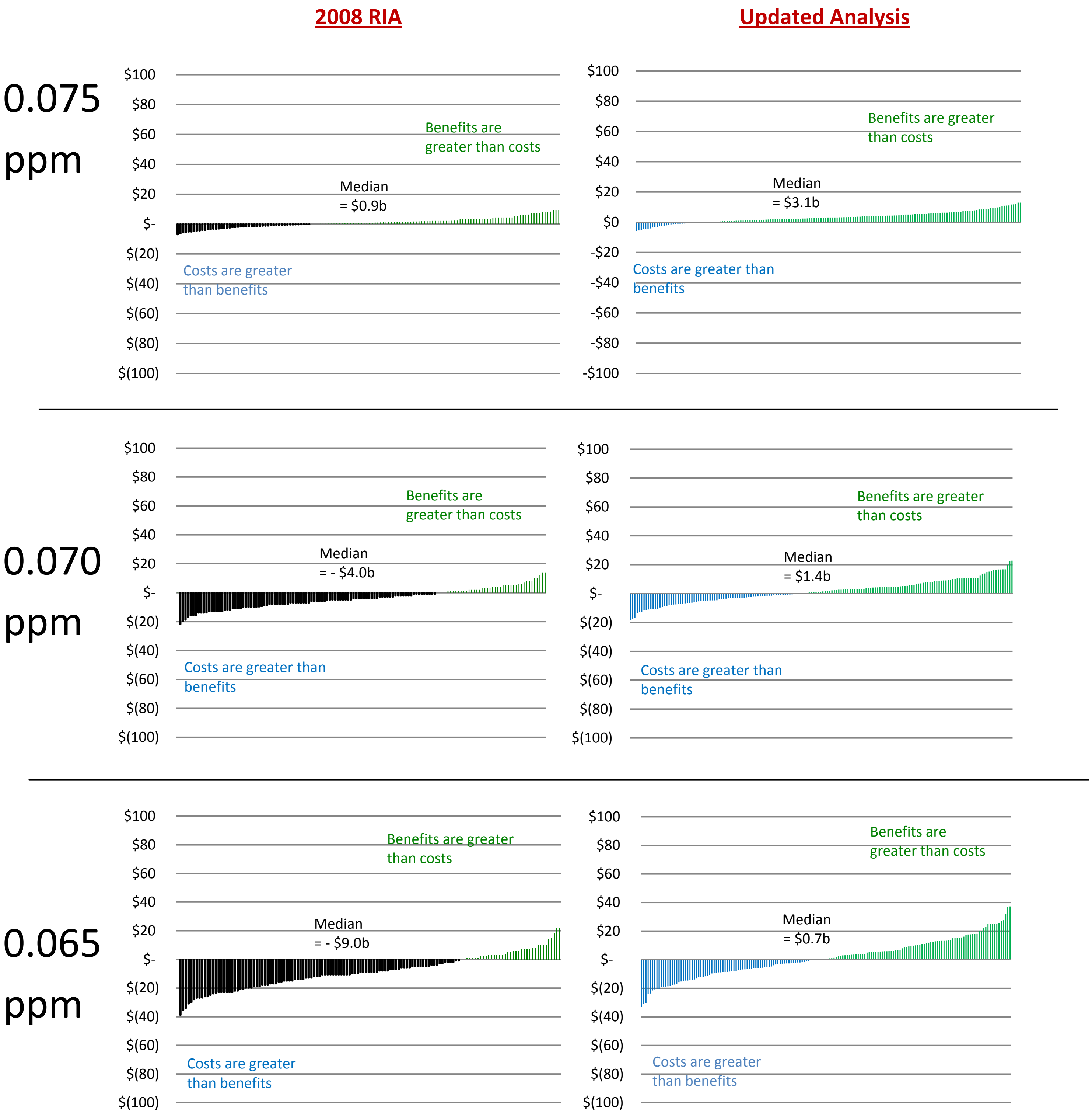
[6] Net benefits are total monetized benefits minus total monetized costs. Total monetized benefits include ozone health benefits, $PM_{2.5}$ health co-benefits, visibility benefits, but not other unquantified benefit categories.

Table S3.10: Total Monetized Costs with Ozone Benefits and $PM_{2.5}$ Co-Benefits in 2020 (in Billions of 2006$) * Updated Analysis

	Ozone Mortality Function	Reference	Total Benefits **		Total Costs ***	Net Benefits	
			3%	7%	7%	3%	7%
0.075 ppm	NMMAPS and multi-city	Bell et al. 2004	\$6.9 to \$15	\$6.4 to \$13	\$7.6 to \$8.8	\$-1.9 to \$7.4	\$-2.4 to \$5.4
		Schwartz 2005	\$7.2 to \$16	\$6.8 to \$13	\$7.6 to \$8.8	\$-1.6 to \$8.4	\$-2.1 to \$5.4
		Huang 2005	\$7.3 to \$16	\$6.9 to \$13	\$7.6 to \$8.8	\$-1.5 to \$8.4	\$-2.0 to \$5.4
	Meta-analysis	Bell et al. 2005	\$8.3 to \$17	\$7.9 to \$14	\$7.6 to \$8.8	\$-0.50 to \$9.4	\$-1.0 to \$6.4
		Ito et al. 2005	\$9.1 to \$18	\$8.7 to \$15	\$7.6 to \$8.8	\$0.30 to \$10	\$-0.20 to \$7.4
		Levy et al. 2005	\$9.2 to \$18	\$8.8 to \$15	\$7.6 to \$8.8	\$0.40 to \$10	\$-0.10 to \$7.4
0.070 ppm	NMMAPS and multi-city	Bell et al. 2004	\$13 to \$29	\$11 to \$24	\$19 to \$25	\$-12 to \$10	\$-14 to \$5.0
		Schwartz 2005	\$15 to \$30	\$12 to \$25	\$19 to \$25	\$-10 to \$11	\$-13 to \$6.0
		Huang 2005	\$15 to \$30	\$13 to \$26	\$19 to \$25	\$-10 to \$11	\$-12 to \$7.0
	Meta-analysis	Bell et al. 2005	\$18 to \$34	\$16 to \$29	\$19 to \$25	\$-7.0 to \$15	\$-9.0 to \$10
		Ito et al. 2005	\$21 to \$37	\$18 to \$31	\$19 to \$25	\$-4.0 to \$18	\$-6.0 to \$12
		Levy et al. 2005	\$21 to \$37	\$18 to \$31	\$19 to \$25	\$-4.0 to \$18	\$-6.0 to \$12
0.065 ppm	NMMAPS and multi-city	Bell et al. 2004	\$22 to \$47	\$19 to \$40	\$32 to \$44	\$-22 to \$15	\$-25 to \$7.0
		Schwartz 2005	\$24 to \$49	\$21 to \$42	\$32 to \$44	\$-20 to \$17	\$-23 to \$9.0
		Huang 2005	\$25 to \$50	\$22 to \$42	\$32 to \$44	\$-19 to \$18	\$-23 to \$10
	Meta-analysis	Bell et al. 2005	\$31 to \$56	\$27 to \$48	\$32 to \$44	\$-13 to \$24	\$-17 to \$16
		Ito et al. 2005	\$36 to \$61	\$32 to \$53	\$32 to \$44	\$-8.0 to \$29	\$-13 to \$20
		Levy et al. 2005	\$36 to \$61	\$32 to \$53	\$32 to \$44	\$-7.0 to \$29	\$-12 to \$20

*All estimates rounded to two significant figures. As such, they may not sum across columns. Only includes areas required to meet the current standard by 2020, does not include San Joaquin and South Coast areas in California.
**Includes ozone benefits, and $PM_{2.5}$ co-benefits. Range was developed by adding the estimate from the ozone premature mortality function to estimates from the $PM_{2.5}$ premature mortality functions from Pope et al. and Laden et al. Tables exclude unquantified and nonmonetized benefits.
***Range reflects lower and upper bound cost estimates. Data for calculating costs at a 3% discount rate was not available for all sectors, and therefore total annualized costs at 3% are not presented here. Additionally, these estimates assume a particular trajectory of aggressive technological change. An alternative storyline might hypothesize a much less optimistic technological trajectory, with increased costs, or with decreased benefits in 2020 due to a later attainment date.

Figure S3.6: Comparison of Net Benefits in Updated Analysis to 2008 Ozone NAAQS RIA*



These graphs shows all combinations of the 6 different ozone mortality functions and assumptions, the 14 different PM mortality functions, and the 2 cost methods. These combinations do not represent a distribution.

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