Appendix A: Five City Analysis and Results

Appendix Overview

This appendix presents the results of our analysis of the costs and human health benefits of emissions reductions implemented to move towards attainment with the proposed and alternative $PM_{2.5}$ standards in five urban areas. To attempt to achieve these standards we follow a two-part control hierarchy. The first approach analyzes the costs and benefits of urban-area wide controls alone. If that is not sufficient to attain the alternative, we apply the second, which considers the costs and benefits of urban-area controls after incorporation of an assumed level of regional controls in the baseline. We do not analyze the costs and benefits of regional controls in this second control approach. We use air quality-effectiveness and cost-effectiveness data from the Response Surface Model (RSM) and the AirControlNET pollution controls database to identify more cost-optimal controls to analyze. To the extent that we exhaust AirControlNET controls in an urban area, we apply innovative and emerging controls. We analyze control strategies for each of five RSM urban areas (Atlanta, New York/Philadelphia, Chicago, Seattle and San Joaquin valley), providing the estimated costs and benefits of reaching attainment or near-attainment for these areas.[1]

Geographical Scales of PM and Precursor Controls and Impacts

The geographic impact of direct $PM_{2.5}$ and precursor gas controls varies according with the location, pollutants and sources to which they are applied. For the purposes of our analysis we have classified the location and geographic effect of $PM_{2.5}$-related controls into the following two categories:

1. *Urban area controls* are those that apply within an urban area. These controls can have either a *localized* effect on air quality (an effect within the same immediate area as the control) or a broader *regionalized* effect on air quality (that is, an effect within and beyond the location of control). These controls can also have both a regionalized and localized effect. The scale of the urbanized area can be quite large, depending on the character of the particular city and surrounding areas.

2. *Region-wide controls* are those applied to a large state or multi-state area outside of the urban area. These controls can have a *localized* impact as well as a *regionalized* air quality impact.

Thus, the terms "urban area" and "region-wide" refer to the location of the control measure rather than the geographic scope of the resulting air quality change after the implementation of the control.

Figures A-1 and A-2 indicate the spatial distribution of local controls applied entirely within nine RSM urban areas across the US as contrasted with the distribution of $PM_{2.5}$ air quality

[1] The RSM can perform an air quality analysis of emissions controls in nine urban areas. The model indicated that five of these nine areas would violate some level of the $PM_{2.5}$ standard under analysis. For a complete description of the RSM model and air quality methodology, see chapter three.

improvements associated with nationwide reductions in primary emissions (carbonaceous PM) and a secondary PM precursor (SO2).[2]

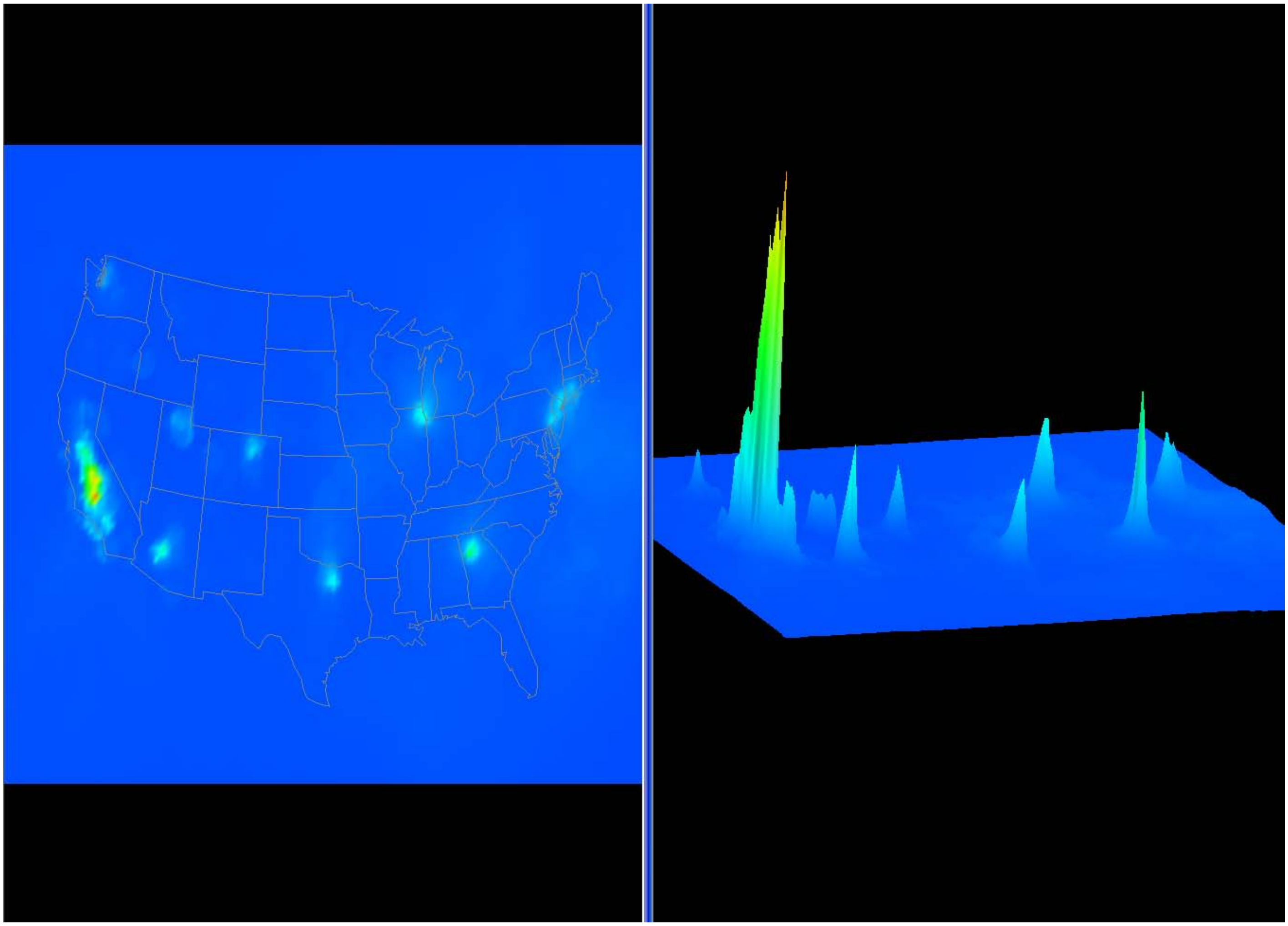


Figure A-1: Depiction of the spatial distribution of PM-related controls applied on a local basis in 9 urban areas. a) Spatial distribution of an 80% reduction in all emissions within each of the 9 urban areas. b) The magnitude of the air quality improvement resulting from the reduction in a), indicated by the height of the peaks. In this example, urban area PM/precursor controls have a highly localized air quality impact.

[2] Ambient $PM_{2.5}$ in each of these urban areas is largely independent of the precursor emissions in all other included urban areas, thus allowing the RSM to analyze air quality changes in these nine urban areas and associated counties independent of one another.

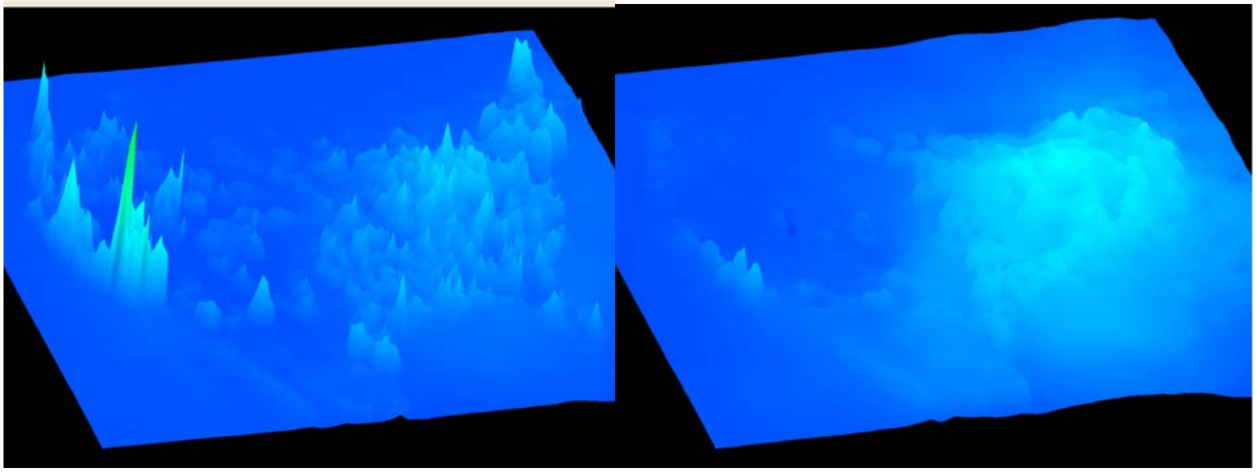


Figure A-2: Spatial distribution of air quality improvements resulting from direct carbonaceous PM controls (left) and Electrical Generating Unit (EGU) SO_2 precursor controls (right) applied on a regional basis for the continental US. The carbonaceous PM controls on the left have a spatially attenuated effect (leading to a spatially "lumpy" air quality impact). The image on the right reflects regional application of EGU SO_2 controls. These controls have a more evenly distributed regional impact, in large part because transported SO_2 continues to form particles in the atmosphere far from the original sources. Primary PM concentrations tend to fall off in concentration more rapidly from the source.

The monitored and modeled air quality data analysis in Chapter 2 suggests that a significant portion of the daily $PM_{2.5}$ problem is local in nature. To the extent that urban areas control "peak" emissions, they may be able to reach attainment for the existing and any more stringent daily standard in a cost-effective manner. Where regional background concentrations are elevated as in much of the eastern US, controls applied on a broader geographical scale can be effective in helping area reach attainment with the annual standard. This was the basis for the recently promulgated Clean Air Interstate Rule (CAIR) to reduce EGU emissions. As noted in Chapter 2, these regional controls can also be effective in reducing daily peaks in some areas. Local controls may also be effective in helping areas reach attainment with the annual standard. The relative effectiveness of local vs. regional controls depends on a number of factors including the nature of transported background, number of areas needing additional reductions, the air quality in relation of the standard, and on which standard, daily or annual, is controlling, (e.g. which standard requires the most reductions to achieve).

Hierarchy of Controls Analysis: Local to Regional

The five-city analysis takes a stepwise approach to applying controls to attain the proposed and alternative NAAQS which we examined. The first step evaluates whether urban areas can attain the current standard and more stringent proposed standards using emissions controls within the greater urbanized area (local Metropolitan Statistical Area) as illustrated in Figure A-1(a). If this urban-only scenario does not result in attaining one or both of the standards, a second scenario is applied. This second approach evaluates the impact of allowing for a specified increment of regional emission controls in the baseline if identified controls within the urban area are insufficient to meet the standards. While costs and benefits are provided for an example regional strategy, we are not analyzing the direct cost and benefit impacts associated with alternative regional emission reduction strategies in this proposal analysis. This is due to a lack of complete information on the specific extent of potential regional strategies and the specific mix of regional controls that might be considered by states or regional planning organizations.

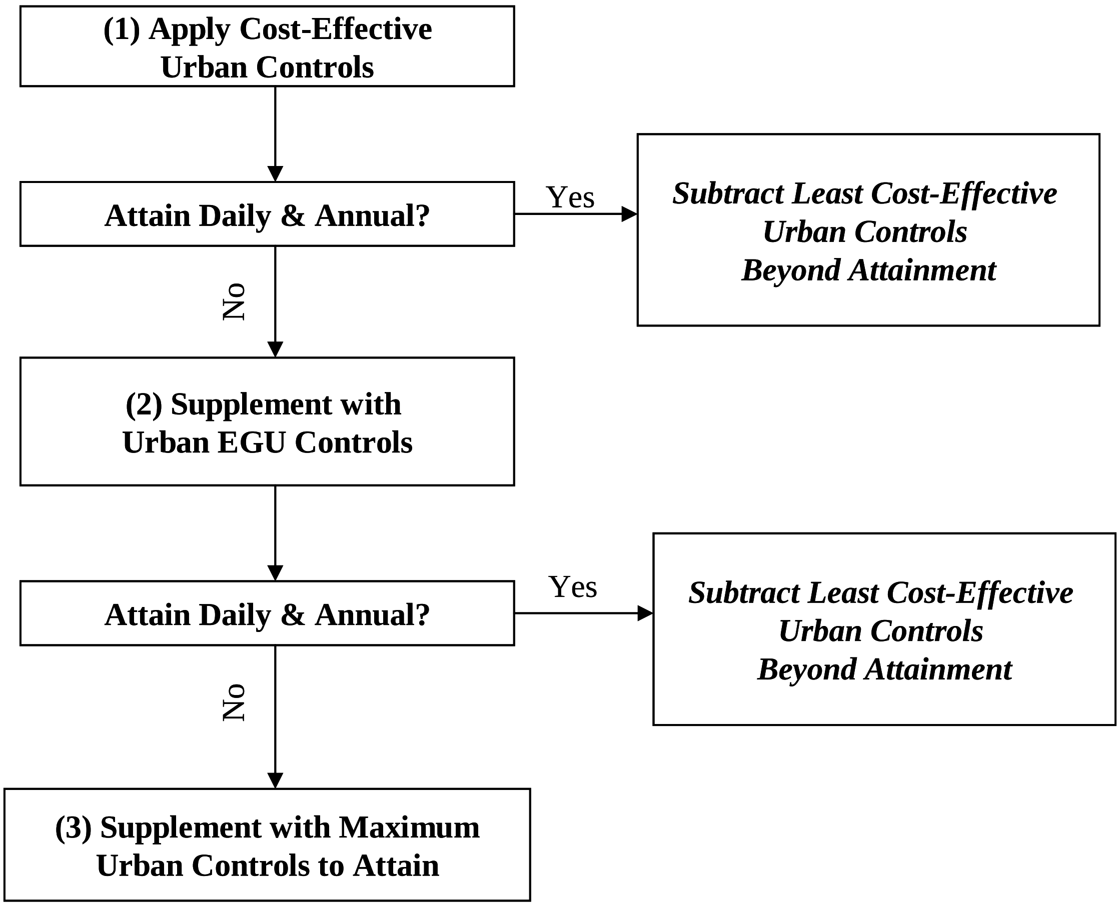
The "Urban-Only" Scenario

We analyzed an "urban-only" scenario for two reasons: First, EPA has promulgated extensive national and regional rules—including mobile source rules (Tier 2 cars, Heavy Duty Diesel Engine rules, and Nonroad Mobile Source rules), the Title IV SO_2 and NOx controls, the NOx SIP Call, the Clean Air Interstate Rules (CAIR) covering the electric power sector, the Clean Air Visibility Rules covering the NOx and SO_2 emissions of the power sector and more than 20 other industries and executed other related actions (New Source Performance Standard, Maximum Achievable Control Technology controls with co-benefits). Given the extent to which these rules reduce regional loadings of fine particles by 2010 to 2015, we assume that States and localities would likely next focus on developing local controls to address the remaining fine particle attainment problems that will exist and look beyond sources covered in the above rules to see what can be done.

Moreover, the available information regarding the scope and magnitude of the $PM_{2.5}$ air quality problem described in Chapter 2 suggests that urbanized area-wide 'local' strategies will generally be effective in reducing 24-hour peak concentrations as is necessary under the proposed and alternative NAAQS. To the extent that the daily standard is the controlling standard (Seattle and the San Joaquin Valley, for example) these local actions would be a logical choice for states to consider in designing attainment strategies.

In following this "urban-only" scenario, we applied controls in three tiers to the five RSM urban areas described in chapter 3 that the model estimated to be out of attainment for some level of the annual or daily standard under consideration; these areas include Seattle and San Joaquin Valley in the West, and New York/Philadelphia, Chicago and Atlanta in the East. These tiers are as follows:

Figure A-3: "Urban-Only" Controls Hierarchy



1. *Apply Cost-Effective Urban Controls.* To determine the cost-effective controls for the first tier, we evaluated the relative effectiveness of potential reductions in emissions from the 12 source/pollutant factors available in the RSM. For each area, we identified the set of potentially effective control factors. Next, we determined the maximum level of control available for each of the factors based on the set of identified control technologies for each urban area in AirControlNet. We did not consider EGU controls in this first tier. We then estimated the impacts of these controls on attainment with the standard options by using the RSM. An important aspect of using the maximum available controls approach is that some very costly controls (on a per ton basis) for particular sources and pollutants are included; these would probably not be selected by rational planners. In cases where costs per-ton are excessively high, rational planners would likely seek more innovative approaches to emissions reductions. In the cost-benefit presentations for each area, we provide additional insights about these highly costly control measures, and demonstrate how sensitive our cost estimates are to inclusion of these controls. Finally, if an area could attain using just local non-EGU controls, we eliminated the least cost-effective controls.

2. *Supplement with Urban EGU Controls*. If the urban area did not reach attainment with the identified controls in AirControlNET, then we considered a second tier of urban area

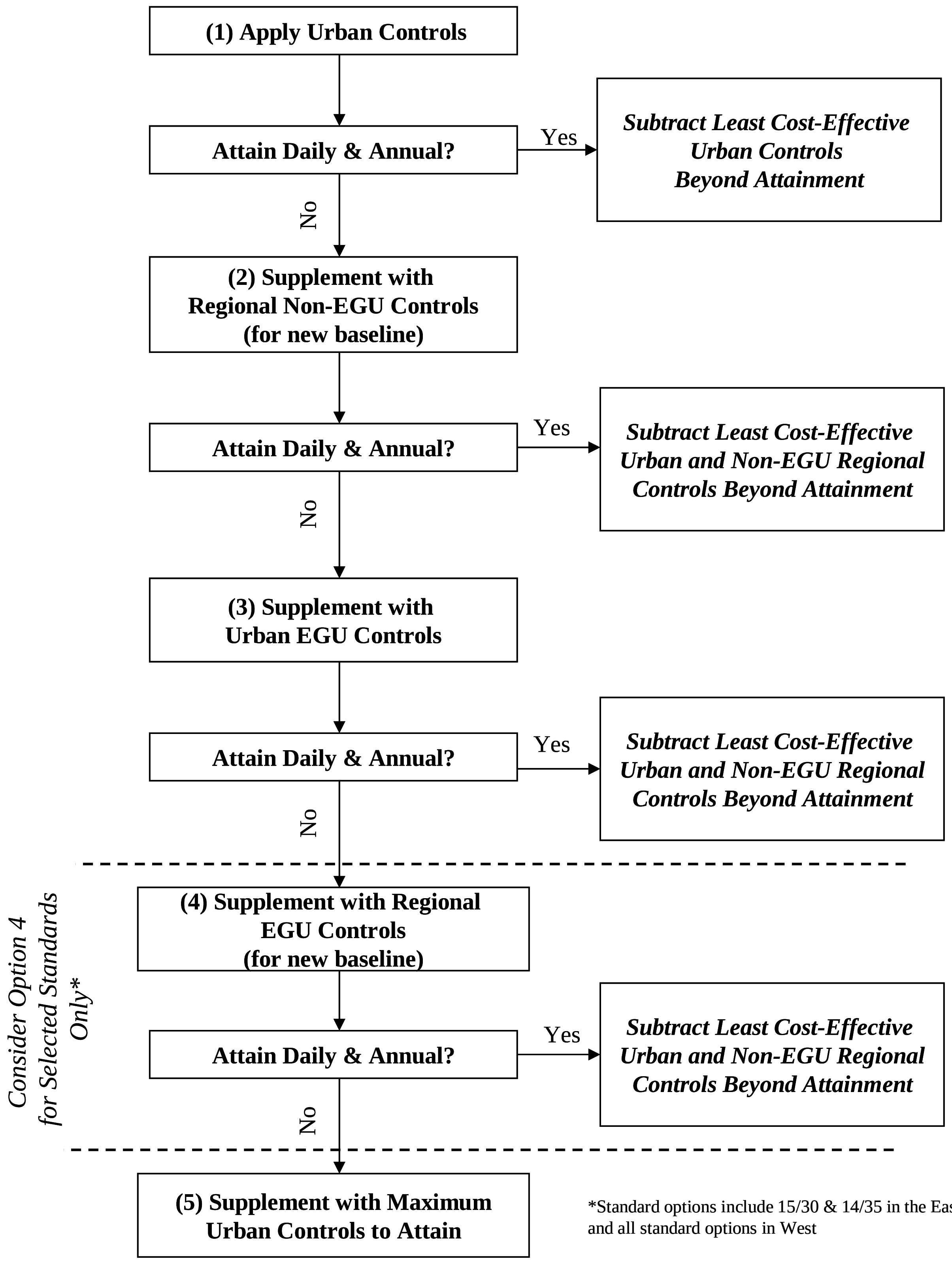
controls. For the second tier, we reduced EGU SO_2 emissions in the urban area by 80 percent of baseline emissions; we performed this reduction for both eastern and western urban areas (although SO_2 emissions are substantially lower in the west). For the East, we assumed that States would work under the existing CAIR program (as they did in several cases in the NOx SIP Call) to rearrange where some of the SO_2 reductions would occur (having more reductions occurring next to nonattainment areas). This would improve the overall cost-effectiveness of the rules without diminishing the overall effectiveness of CAIR in addressing the regional transport problem. We expect that only a limited amount of adjustments would be needed given that CAIR is likely to generate advanced SO_2 controls near the Eastern cities that are projected to be out of attainment. We also reduced EGU NOx emissions by 80 percent for Western urban areas because nitrates play a more important role in nonattainment. Note that for this step of the hierarchy, we did not apply urban area EGU reductions at a proportion lower than 80 percent. Our existing control information indicated that reductions of 80 percent were achievable in these urban areas. However, we had incomplete information regarding the marginal cost of these controls and thus, to the extent that more cost-effective urban area controls were available for a given urban area, we were unable to substitute these controls.

3. *Supplement with Maximum Urban Controls to Attain*. If the urban area did not reach attainment with these first two tiers of controls, we then estimated the emissions reductions for each factor, beyond those available in AirControlNET, which would be necessary to bring the urban area into attainment. We attempted to simulate the most cost-effective combination of urban area emission reductions based on representative cost per-ton estimates for each factor. Because these control strategies are uncertain, we provide a range of cost estimates at the 50^{th} and 90^{th} percentile. These reductions are speculative; uncertainty regarding the costs and the achievability of the level of control could increase or further reduce emissions. In the methodology chapter, we discussed the role that we anticipate innovative and emerging control technologies to have in future attainment. One very important aspect of this technique is that as urban areas near the limit of available emissions reductions to move towards attainment, our algorithm incorporates more and more controls that are relatively ineffective and costly. For areas that only partially attain, this can increase predicted costs of partial attainment substantially, and reflect adoption of controls that are clearly not cost-effective. In the cost-benefit presentations for each area, we provide additional insights for these partial-attainment strategies, and demonstrate how costs are magnified due to the expensive controls applied to obtain the last marginal improvement. Clearly, when costs per microgram of control exceed rational bounds, decision makers will need to consider alternative approaches to developing attainment strategies.

The "Regional/Urban" Strategy

As we demonstrate below, many urban areas are likely to rely upon control measures beyond currently identified technologies to attain progressively tighter standards. For this reason, we examined the effect of moderate regional controls on the ability of urban areas to attain the standard with reductions in urban area emissions through known controls. Similar to above, this approach uses a multi-tiered hierarchy of controls, dependent upon the specific standard being evaluated. These tiers are as follows:

Figure A-4: "Regional/Urban" Controls Hierarchy



*Standard options include 15/30 & 14/35 in the East and all standard options in West

1. *Apply Urban Controls*. As a first step in all cases, we applied the available effective urban area controls we identified within AirControlNet. Note that the same issues of inclusion of relatively high cost-per-ton measures hold in this step as in step 1 of the urban-only approach.

2. *Supplement with Regional Non-EGU Controls.* If the urban area did not reach attainment with 15/30 or 14/35, our second step was to evaluate whether those same urban controls would produce in attainment if a 20 percent reduction in regionally effective emissions for non-EGU source categories was implemented in the baseline. For analysis purposes, we assumed that 20 percent represents a reasonably available level of emission reductions on a regional basis.

3. *Supplement with Urban EGU Controls.* Our third step, if the urban area still did not reach attainment, was to reduce relevant eastern or western urban-area EGU SO_2 emissions by 80 percent. We also reduced EGU NOx emissions for Western urban areas only, where nitrates play a more important role in nonattainment. For Eastern urban areas, if under this tier we found that we could not simulate attainment with either the current standards or with the 15/35 standard option, we applied additional innovative urban area emissions controls. As with the urban-only strategy, we do not apply EGU reductions at a level lower than 80 percent for the reasons we describe above.

4. *Supplement with Regional EGU Controls.* Our fourth step was to evaluate whether the cost-effective urban area controls would be sufficient if an additional 20 percent reduction in regional EGU SO_2 were assumed to be in place. We applied this option to the Western urban area for all standard options and to the Eastern urban areas for the simulation of the 15/30 and 14/35 standard options. The distinction between East and West in the consideration of additional EGU SO_2 controls is meant to reflect the greater extent of existing EGU controls in the East due to CAIR.

5. *Supplement with Maximum Urban Controls to Attain.* Finally, for these standard options, if attainment was still not achieved, additional urban area controls beyond AirControlNET were simulated. Note that the same issues of inclusion of high cost, low effectiveness controls to reach partial attainment hold in this step as in step 3 of the urban-only approach.

In each step above, we consider the impact of the urban controls relative to a baseline that includes all regional controls deemed necessary. Thus, regional controls are always applied first and urban controls second, whether it is necessary to go beyond CAIR or not.

Key Uncertainties and Limitations of this Analysis

We identify several important categories of uncertainties and limitations to this analysis.

Emissions Forecasting and Air Quality Modeling Uncertainties

Chapters 2 and 3 summarize some of the key uncertainties associated with forecasting emissions and modeling air quality for the multiple pollutants that contribute to ambient fine particle concentrations. While EPA's regional scale air quality modeling system has been extensively peer reviewed and represents the state of the science in terms of the formation and fate of $PM_{2.5}$ in the atmosphere, a number of factors affect the conclusions that can be reached about the effectiveness, costs, and benefits of alternative control strategies in the five city analyses:

- Overall, the air quality model performs well in predicting monthly to seasonal concentrations, similar to other recent model applications for $PM_{2.5}$. The model is less well suited to predicting 24-hour values.

- In general, model performance is better for the eastern U.S. than for the West. The air quality model performs well in predicting the formation of sulfates, which are the dominant species in the East. It does not perform as well for nitrates and secondary organic particles from anthropogenic and natural sources.

- A number of uncertainties arise from use of baseline data from EPA's National Emissions Inventory, especially in terms of the overall magnitude of emissions of primary particles from stationary and mobile sources, spatial allocation of area and other source categories, and the relative split of emissions into $PM_{2.5}$ species. Of particular concern is the apparent disparity between estimated contributions of mobile source emissions with receptor modeling results based on ambient air quality data. These comparisons suggest that our base emissions inventory significantly underestimates the emissions of mobile sources. In addition, the RSM system does not allow for evaluation of primary emissions of metals or related inorganic emissions from industrial processes or combustion. This limits control options for primary particles to carbonaceous emissions.

- Additional uncertainty is introduced through our future year projections of emissions due to unrefined growth rates and limited information on the effectiveness of control programs.

- The RSM based air quality modeling likely understates the effectiveness of urban-area controls. The CMAQ photochemical model that provides the basis for the RSM uses a coarse 36 kilometer receptor grid, which spreads point and mobile source emissions that may be concentrated in particular locations across the entire area of each grid. This serves to obscure local-scale air quality improvements that result from urban-area controls. To the extent that this occurs, our estimates may underestimate the effectiveness of local or urban-area controls as compared to broad scale regional controls.

Cost and Emissions Uncertainties

The limitations in our control strategy technology and cost data noted above also affect the five city analyses. As discussed more fully in the RIA and appendix, a number of approximations and assumptions were required to complete the analysis for all of the standards alternatives analyzed. The more important of these include:

- Progress attainable through known controls is underestimated. The analysis does not consider all known control measures, and as a result understates the emissions reductions and progress toward attainment that can be achieved through known measures.

- Attainment cost estimates are highly dependent on costs of unknown measures. In part due to the database limitations discussed above, the analysis of the costs of meeting the current standards and more stringent alternatives rely on innovative and emerging controls with derived costs. Many controls employed to meet the more stringent standards include some unknown measures with assumed costs. Therefore the incremental attainment cost estimates for more stringent standards, and any cost-benefit comparisons, are subject to an unusually high degree of uncertainty.

- Analysis assumes attainment of new standards within 5 years. Although subpart 1 of Part D of the Clean Air Act allows nonattainment areas to qualify for an extension giving up to 10 years from designation for an area to attain, the analysis for simplicity assumes that all areas must attain within 5 years (i.e., in 2015). This assumption tends to overestimate costs associated with attainment for areas qualifying for an extension (to 2020) because federal programs (e.g., on-road and non-road vehicle and engine standards and the Clean Air Interstate Rule) achieve greater emissions reductions over time, so that most areas become cleaner in the base case beyond 2015. Based on current information, it does not appear possible to attain the proposed NAAQS in the San Joaquin area by 2015.

<u>Benefits Uncertainty</u>

The benefits estimates generated for this proposal RIA are subject to a number of assumptions and uncertainties, which are discussed throughout the document. For example, key assumptions underlying the primary estimate for the mortality category include the following:

1. Inhalation of fine particles is causally associated with premature death at concentrations experienced by many Americans on a daily basis. Although biological mechanisms for this effect have not yet been completely established, the weight of the available epidemiological and experimental evidence supports an assumption of causality

2. The analysis also assumes that all components of fine particles have equal toxicity. While it is reasonable to expect that the potency of components may vary across the numerous effect categories associated with particulate matter, EPA's interpretation of current scientific information is that such information does not yet provide a basis for quantification beyond using fine particle mass. While EPA has not performed formal sensitivity analysis of this assumption in its analysis for the proposed PM NAAQS RIA, the Agency is exploring ways to present the importance of this assumption in estimating benefits and its implications for control strategy development and assessment as a part of the analysis for the final RIA.

3. One source of uncertainty that has received recent attention from several scientific review panels is the shape of the concentration-response function for PM-related mortality, and specifically whether there exists a threshold below which there would be no benefit to further reductions in $PM_{2.5}$. That is, the hypothesized relationship includes the possibility that there exists a PM concentration level below which further reductions no longer yield premature mortality reduction benefits. We include a Sensitivity Analysis that examines alternative assumed 'cutpoints' for the concentration-response function below.

In addition to these assumptions, the RIA is also subject to a number of sources of uncertainty that are also discussed at length in the final CAIR RIA. Some of these include: (a) projections of emissions levels for future simulation years; (b) projections of emissions reduction strategies including their source composition and the efficacy of specific strategies at achieving $PM_{2.5}$ reductions; and (c) projections of demographic changes for future simulation years.

An important source of uncertainty resulting in an under-prediction of benefits is the exclusion of a range of potential health endpoints and welfare effects in this benefits analysis due either to limitations in modeling methods or available data, or schedule constraints. The list of excluded endpoints is presented below and is discussed in greater detail in the CAIR RIA. (Note that although ozone-related benefits were modeled for the final CAIR Rule, due to schedule constraints, we did not include any ozone modeling for this RIA.)

Unless specifically noted, our premature mortality benefits estimates are based on an assumed cutpoint in the long-term mortality concentration-response function at 7.5 $\mu g/m^{3}$, and an assumed cutpoint in the short-term morbidity concentration-response functions at 10 $\mu g/m^3$. To consider the impact of a threshold in the response function for the chronic mortality endpoint on the primary benefits estimates, we also constructed a sensitivity analysis by assigning different cutpoints below which changes in $PM_{2.5}$ are assumed to have no impact on premature mortality. In applying the cutpoints, we adjusted the mortality function slopes accordingly.[3] This sensitivity analysis allows us to determine the change (reduction) in avoided mortality cases and associated monetary benefits associated with alternative cutpoints. Four cutpoints were included in this sensitivity analysis: (a) 15 $\mu g/m^3$ (assumes the current NAAQS is in effect nation-wide), (b) 10 $\mu g/m^3$ (reflects comments from CASAC - 2005), (c) 7.5 $\mu g/m^3$ (reflects recommendations from SAB-HES to consider estimating mortality benefits down to the lowest exposure levels considered in the Pope 2002 study used as the basis for modeling chronic mortality) and (d) background or 3 $\mu g/m^3$ (reflects SAB-HES recommendation to consider effects all the way to background). The analysis for each city shows the benefits estimates using long-term mortality at the long-term mortality 7.5 $\mu g/m^3$ cutpoint. We also show the results of our sensitivity analysis, with the 4 various cutpoints, for each city to illustrate the impact of the different assumptions.

[3] Note, that the adjustment to the mortality slopes was only done for the 10 $\mu g/m^3$ and 15 $\mu g/m^3$ cutpoints since the 7.5 $\mu g/m^3$ and background cutpoints are at or below the lowest measured exposure levels reported in the Pope 2002, for the combined exposure dataset.

Identifying Effective Source Control Strategies

The RSM provides a wealth of information that can inform the selection of controls. Within the recognized limitations and uncertainties, the model can provide some insights into the relative effectiveness of alternative source/pollutant specific controls in each RSM urban area and across the U.S. To apply this technique, we begin with forecast emissions of fine particles and relevant precursors forecast for 2015 under the regulatory base case defined elsewhere[4]. We reduced emissions from each RSM source category grouping (e.g. point source SO_2, area source carbonaceous, etc.) by a hypothetical and arbitrary 30 percent, which represents what we believe to be a generally achievable percent reduction for most factors according to the model. This illustrative 30% amount does not, of course, reflect how states may actually design their control strategies; nor is it a control option for which we estimate costs or benefits. For each monitored county in the U.S., the RSM then provides information regarding the relative efficacy of each control factor in terms of impact on the annual mean and daily 98th percentile $PM_{2.5}$ design values as a result of this 30% reduction in emissions.

We used this RSM data to prepare a stacked bar chart showing the individual impact of each of the 24 emissions control factors (12 urban area and 12 region wide factors) and the summed impact of all 12 urban area factors and all 12 region wide factors for every monitored county in the U.S.[5] These charts allow us to quickly identify those factors the model indicates will have a large air quality impact (either because of a high relative effectiveness per-ton in forming $PM_{2.5}$, or due to a large contributing inventory) and those factors that have very little contribution to $PM_{2.5}$.

The stacked bar charts for both the annual mean and daily 98th percentile design values for each county are contained in the Response Surface Modeling Technical Support Document (TSD). For discussion purposes and to highlight the differences in impacts between urban area and region wide reductions in emissions, we present stacked bar charts for a monitored county in each of the 5 RSM urban areas. These charts are presented in Figures A-5 through A-16 below.

In these bar charts, the height of the bar is equal to the total reduction in ambient $PM_{2.5}$ concentration for this illustrative 30% reduction in emissions. The segments within the bar show the amount of the total reduction the model ascribes to each control factor. As is clear from examining the charts for these five cities, the absolute effectiveness of control approaches – individually and collectively - can vary significantly among different areas. Thus, the vertical scale on each chart is scaled to total $PM_{2.5}$ reduction for each area; readers should note this if they choose to compare reductions across cities. Any decrements below zero in a chart indicate a disbenefit; that is, controlling that source/pollutant is projected to increase $PM_{2.5}$ at Federal Reference Method (FRM) monitor locations. Model predicted $PM_{2.5}$ disbenefits shown in these analyses depend on meteorological conditions, seasonal variations, emissions, and atmospheric chemistry that vary for different geographic locations (urban areas). In particular, predicted disbenefits for annual $PM_{2.5}$ concentrations associated with NOx emissions reductions from mobile, non-EGU and area sources mostly occur within urban areas where high NOx emissions

[4] The *regulatory base case* assumes all relevant national and regional rules, including on and non-road mobile source controls, the NOx SIP call and CAIR/CAMR/CAVR controls on the power sector and some other sources, and State rule that were adopted in time to be included in the model emissions baseline developed in 2005.
[5] Note that the summation of the factor level impacts will not be exactly equal to the impact of a 30 percent reduction in all factors simultaneously, due the interactions between emissions in the atmosphere. However, the interactions are relatively small in most cases, so the sum of the factor level impacts gives a reasonable assessment of the expected cumulative impacts across factors.

titrate ozone. This may occur in only limited areas within the urban area, e.g., a single grid-cell, rather than being widespread across the entire urban area. In such areas, these reductions of NOx lead to the increase of ozone and other oxidants and thus increase sulfate formation and the corresponding total $PM_{2.5}$ concentrations

In Figure A-5 below, the model estimates that as of 2015 a 30% reduction in all effective urban factors in Fulton County, Ga beyond the assumed baseline of CAIR/CAMR/CAVR/mobile and current state rules would result in close to a 1.7 ug/m3 reduction in $PM_{2.5}$. Area, point and mobile direct carbonaceous particles are responsible for the largest amount of the total reduction. Non-EGU and Area SO_2 produce a small reduction in $PM_{2.5}$, while mobile NOx and non-EGU and area NOx actually increase $PM_{2.5}$ by a small amount.

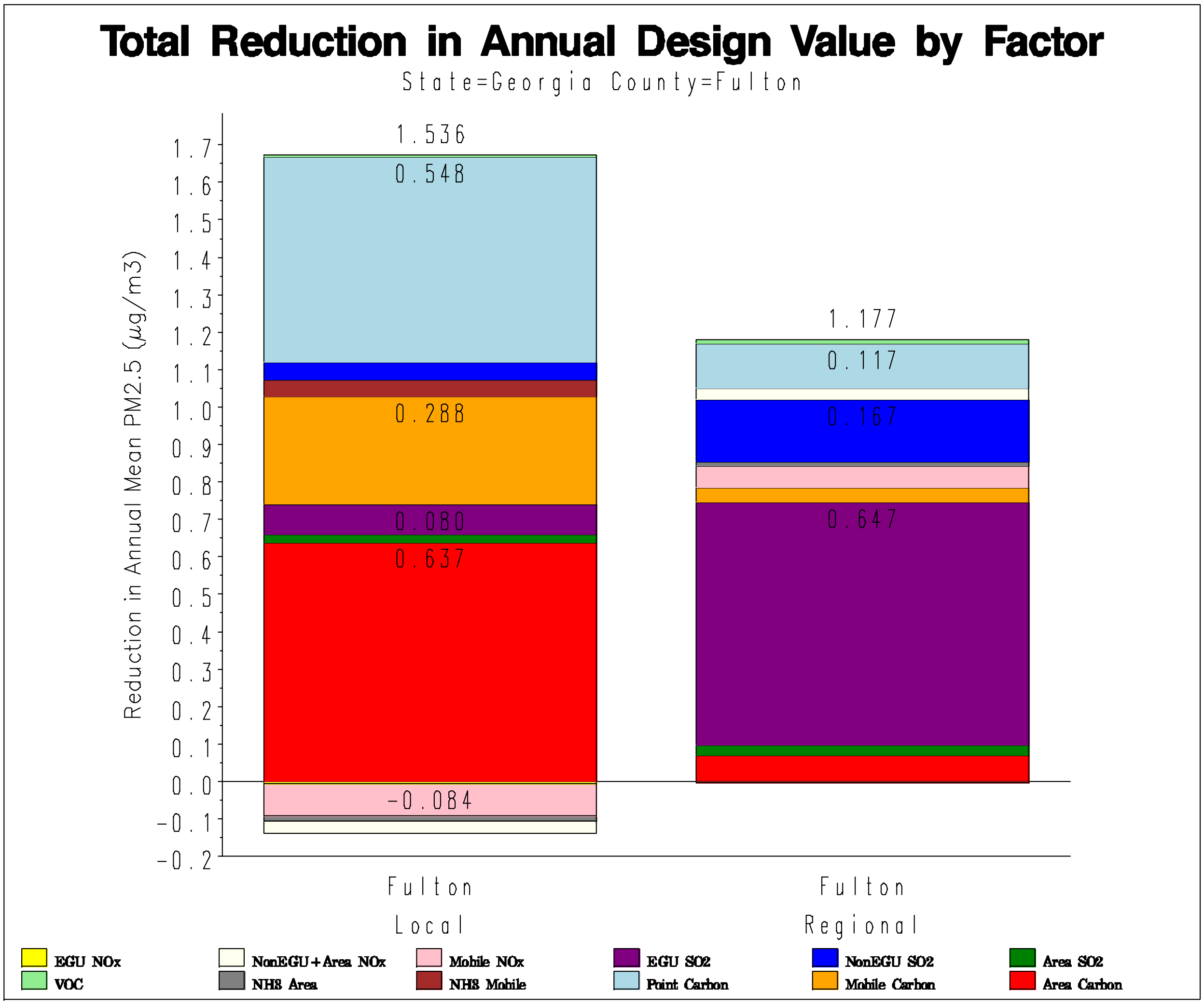


Figure A-5. Estimated Impacts of Urban Area and Region Wide Factors on Annual Mean $PM_{2.5}$ Design Value in the Atlanta MSA for 2015, from a projected emissions baseline which includes CAIR/CAMR/CAVR/National mobile and current state and local rules.[6]

The model results suggest the following observations on control strategy effectiveness for the annual peak monitor in Fulton County:

- Local controls: area, point, and mobile carbonaceous particle controls provide the greatest benefit. Local NOx controls appear ineffective and can produce a small increase in $PM_{2.5}$ concentrations within this urban area.

- Regional controls: EGU SO_2 is the most effective control, followed by point source carbonaceous particles and non-EGU SO_2; the remaining controls provide a smaller air quality benefit.

[6] The predicted increases shown here in annual $PM_{2.5}$ concentrations associated with area NH_3 controls may be an artifact of the analysis and is being fully investigated by EPA.

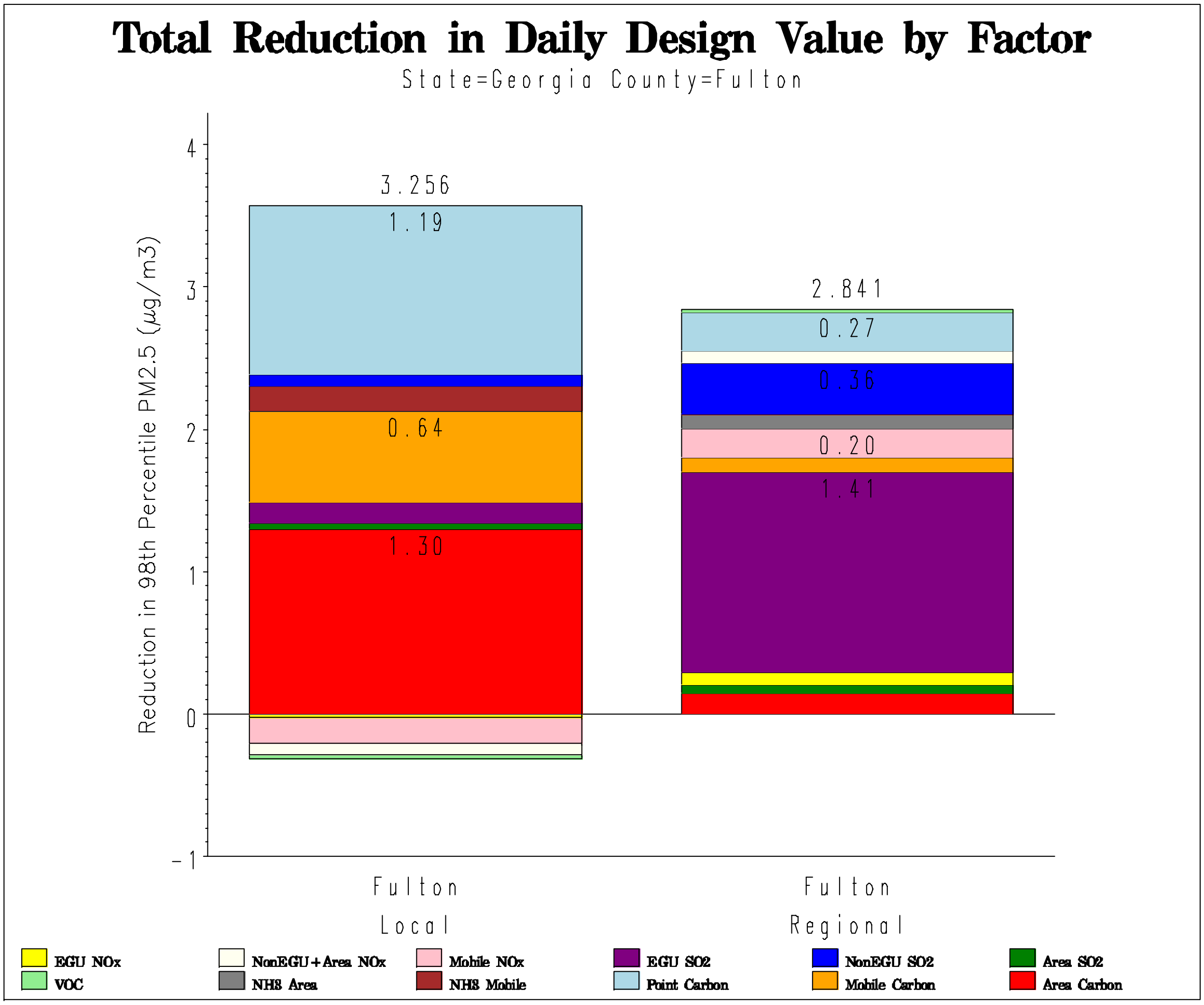


Figure A-6. Estimated Impacts of Urban Area and Region Wide Factors on Daily 98th Percentile $PM_{2.5}$ Design Value in the Atlanta MSA for 2015, from a projected emissions baseline, which includes CAIR/CAMR/CAVR/National mobile and current state and local rules.

The model results suggest the following observations on control strategy effectiveness for the 24-hour peak monitor in Fulton County:

- Local controls: the area, mobile and point source carbonaceous particle controls provide the greatest air quality improvement. The remaining controls provide a smaller air quality benefit. Local VOC and NOx controls are ineffective[7].
- Regional controls: EGU and Non-EGU SO_2 and point source carbonaceous particle controls provide the greatest air quality benefit. The remaining controls provide a smaller air quality benefit.

Thus, comparing the annual and daily charts, we see that several types of controls are effective in helping the Atlanta area in meeting both the daily and annual standards. Point source carbonaceous particle controls show an air quality benefit for both standards. Likewise, both

[7] The predicted increases shown here for the daily $PM_{2.5}$ concentrations associated with local VOC and low-level NOx controls may be an artifact of our analysis and is being fully investigated by EPA.

non-EGU and EGU SOx reductions are potentially helpful to attaining a daily or annual standard.

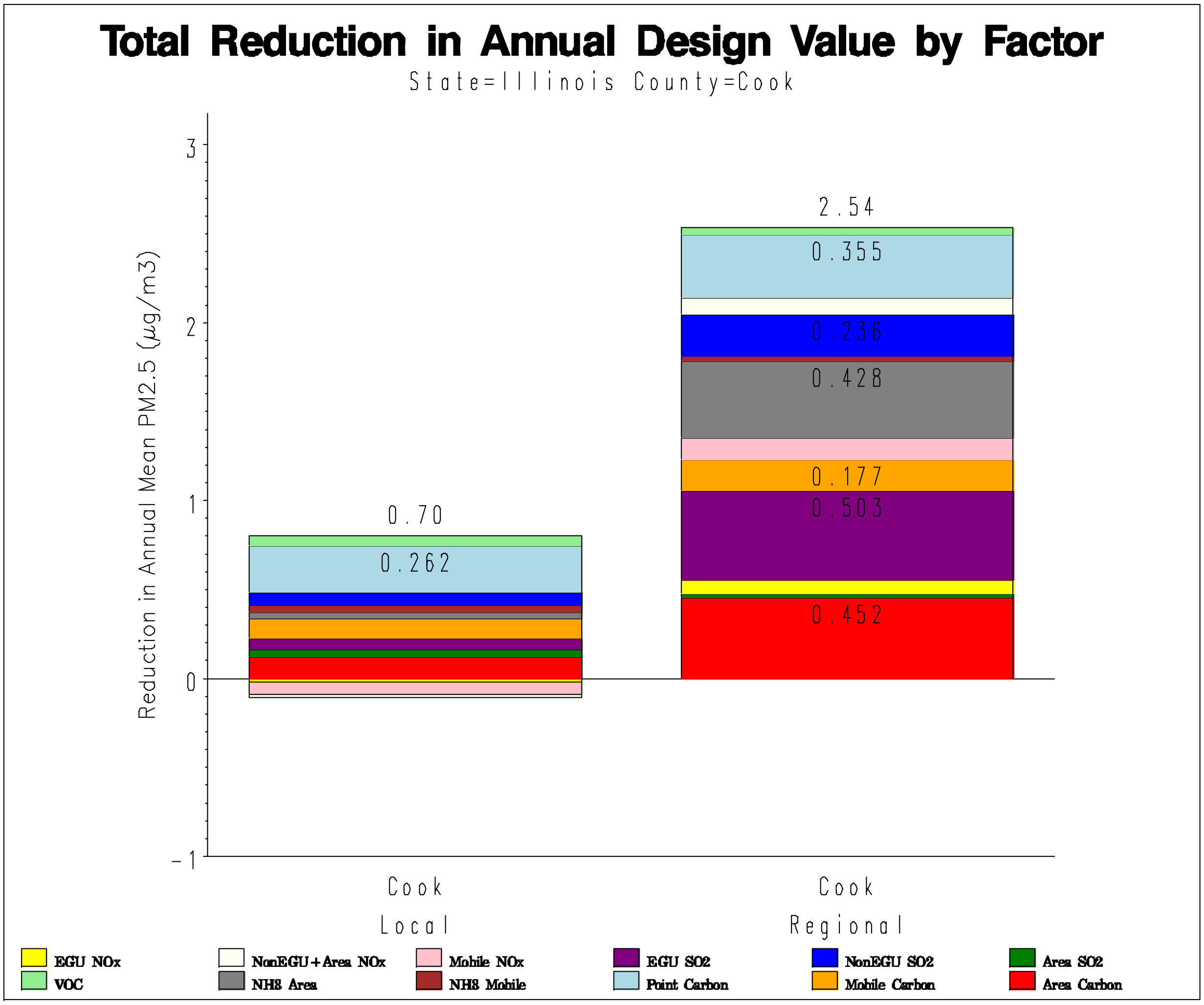


Figure A-7. Estimated Impacts of Urban Area and Region Wide Factors on Annual Mean $PM_{2.5}$ Design Value in the Chicago MSA for 2015, from a projected emissions baseline, which includes CAIR/CAMR/CAVR/National mobile and current state and local rules.

The model results suggest the following observations on control strategy effectiveness for the annual peak monitor in Cook County:

- Local controls: point source carbonaceous particle controls provide the greatest air quality benefit. NOx controls appear ineffective. The remaining available controls provide a smaller benefit.

- Regional controls: Non-EGU SO_2, EGU SO_2, area NH_3, area and point carbonaceous particle controls are the most effective. The remaining controls are less effective.

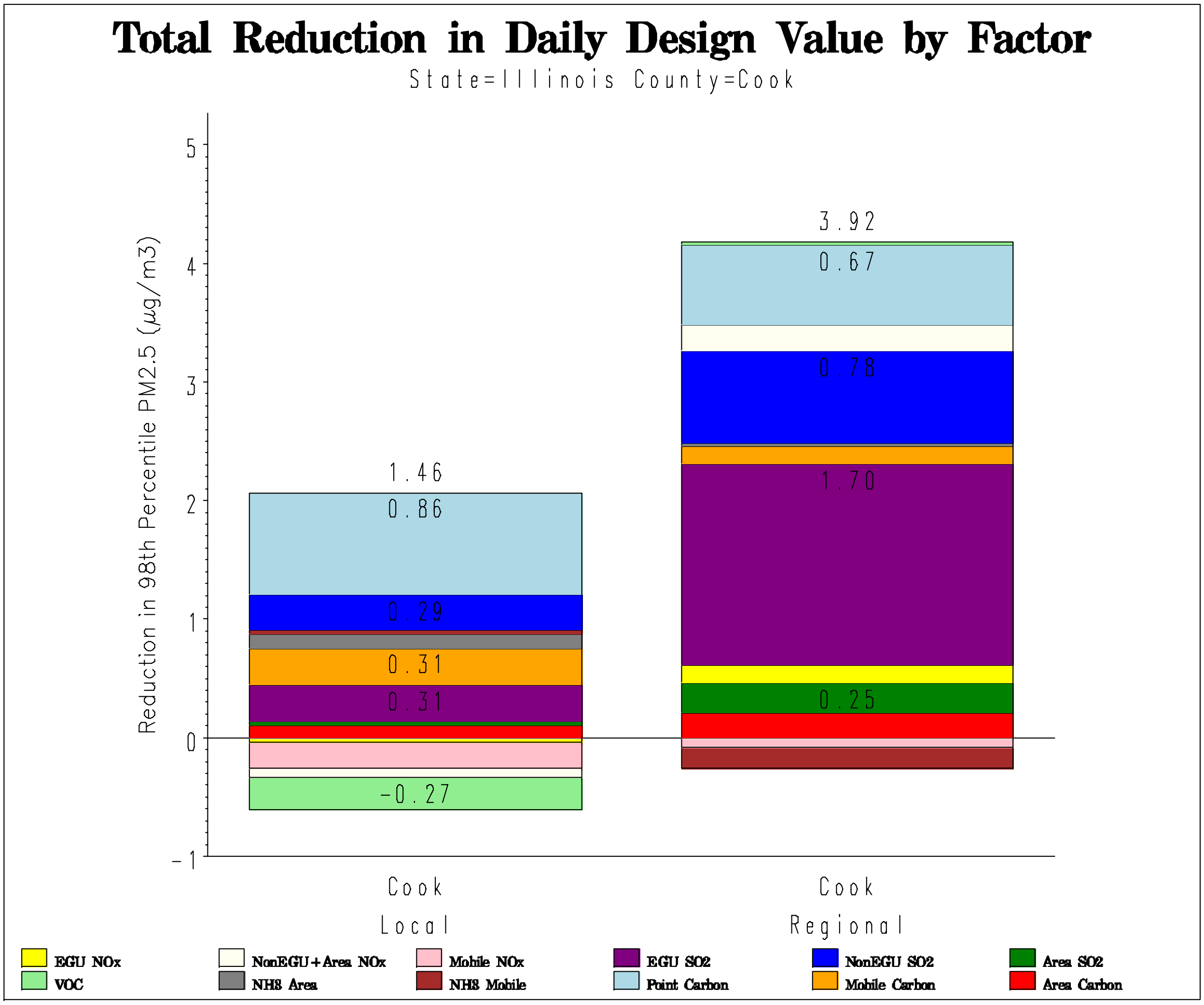


Figure A-8. Estimated Impacts of Urban Area and Region Wide Factors on Daily 98th Percentile $PM_{2.5}$ Design Value in the Chicago MSA for 2015, from a projected emissions baseline, which includes CAIR/CAMR/CAVR/National mobile and current state and local rules.

The model results suggest the following observations on control strategy effectiveness for the 24-hour peak monitor in Cook County:

- Local controls: point and mobile source carbonaceous particle, non-EGU SO_2 and EGU SO_2 controls provide the greatest air quality benefit. VOC and NOx controls are ineffective.[8] The remaining controls provide a smaller benefit.

- Regional controls: EGU and Non-EGU SO_2 and point source carbonaceous particle controls are the most effective in reducing $PM_{2.5}$ on peak days. Mobile NOx and mobile NH_3 are ineffective in reducing $PM_{2.5}$. The remaining controls provide a smaller air quality benefit.

The model results suggest that several types of controls are effective in helping the Chicago area in meeting both the daily and annual standards. Point source carbonaceous particle controls show

[8] The predicted increases shown here for the daily $PM_{2.5}$ concentrations associated with local VOC and low-level NOx controls may be an artifact of our analysis and is being fully investigated by EPA

an air quality benefit for both standards. Likewise, both non-EGU and EGU SOx reductions are potentially helpful to attaining a daily or annual standard.

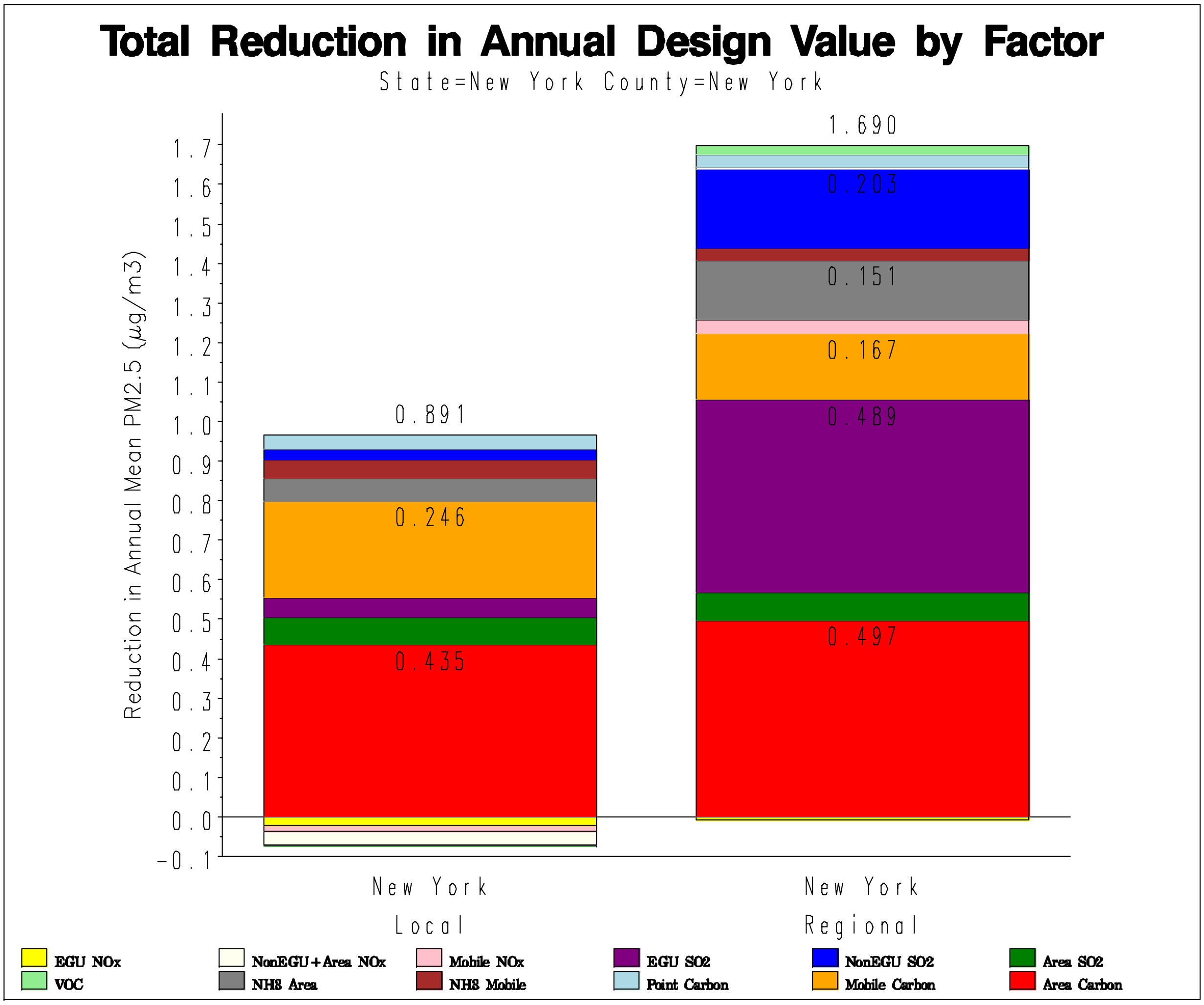


Figure A-9. Estimated Impacts of Urban Area and Region Wide Factors on Annual Mean $PM_{2.5}$ Design Value in the New York MSA for 2015, from a projected emissions baseline, which includes CAIR/CAMR/CAVR/National mobile and current state and local rules.

The model results suggest the following observations on control strategy effectiveness for the annual peak monitor in New York County:

- Local controls: carbonaceous particle controls provide the greatest air quality benefit. NOx controls are ineffective. The remaining available controls provide a smaller air quality benefit.

Regional controls: EGU SO_2, mobile carbonaceous particle, area NH_3 and regional non-EGU SO_2 controls are the most effective. The remaining controls provide a smaller air quality benefit.

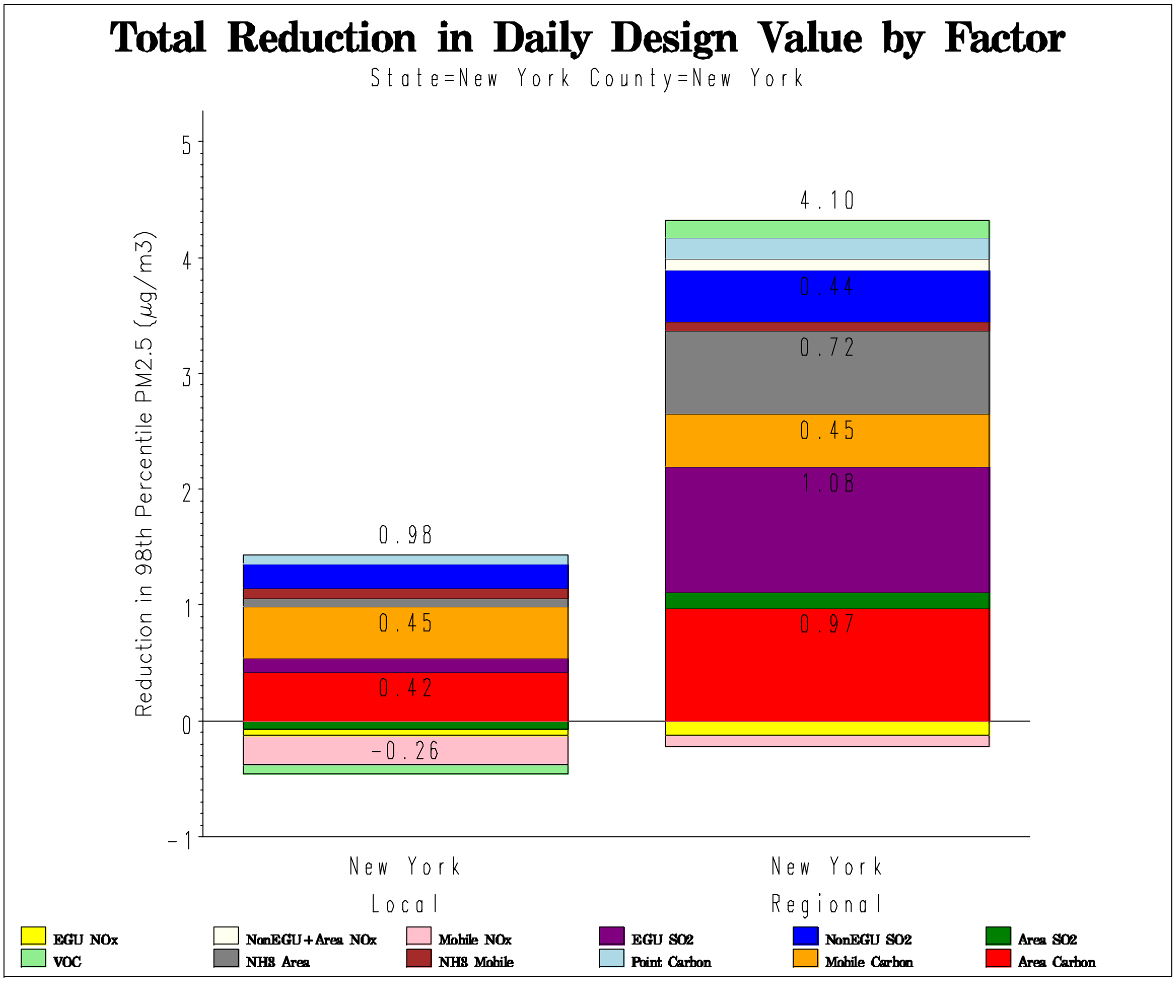


Figure A-10. Estimated Impacts of Urban Area and Region Wide Factors on Daily 98th Percentile $PM_{2.5}$ Design Value in the New York MSA for 2015, from a projected emissions baseline, which includes CAIR/CAMR/CAVR/National mobile and current state and local rules.

The model results suggest the following observations on control strategy effectiveness for the 24-hour peak monitor in New York County:

- Local controls: mobile and area source carbonaceous particle controls provide the greatest air quality benefit. NOx and VOC controls are ineffective.[9] The remaining available controls provide a smaller air quality benefit.

- Regional controls: area and mobile source carbonaceous particle, EGU SO_2, mobile NH_3 and nonEGU SO_2 controls are the most effective. NOx controls are ineffective.[10] The remaining controls provide a smaller benefit.

Several types of controls are effective in helping the New York/Philadelphia area in meeting both the daily and annual standards. Carbonaceous particle controls show an air quality benefit for both standards. Likewise, both non-EGU and EGU SOx reductions are potentially helpful to

[9] The predicted increases shown here for the daily $PM_{2.5}$ concentrations associated with controls on specific source/pollutants may be an artifact of our analysis and is being fully investigated by EPA.

[10] The predicted increases shown here for the daily $PM_{2.5}$ concentrations associated with controls on specific source/pollutants may be an artifact of our analysis and is being fully investigated by EPA.

attaining a daily or annual standard. Area NH_3 controls are also effective for both the annual and daily standard.

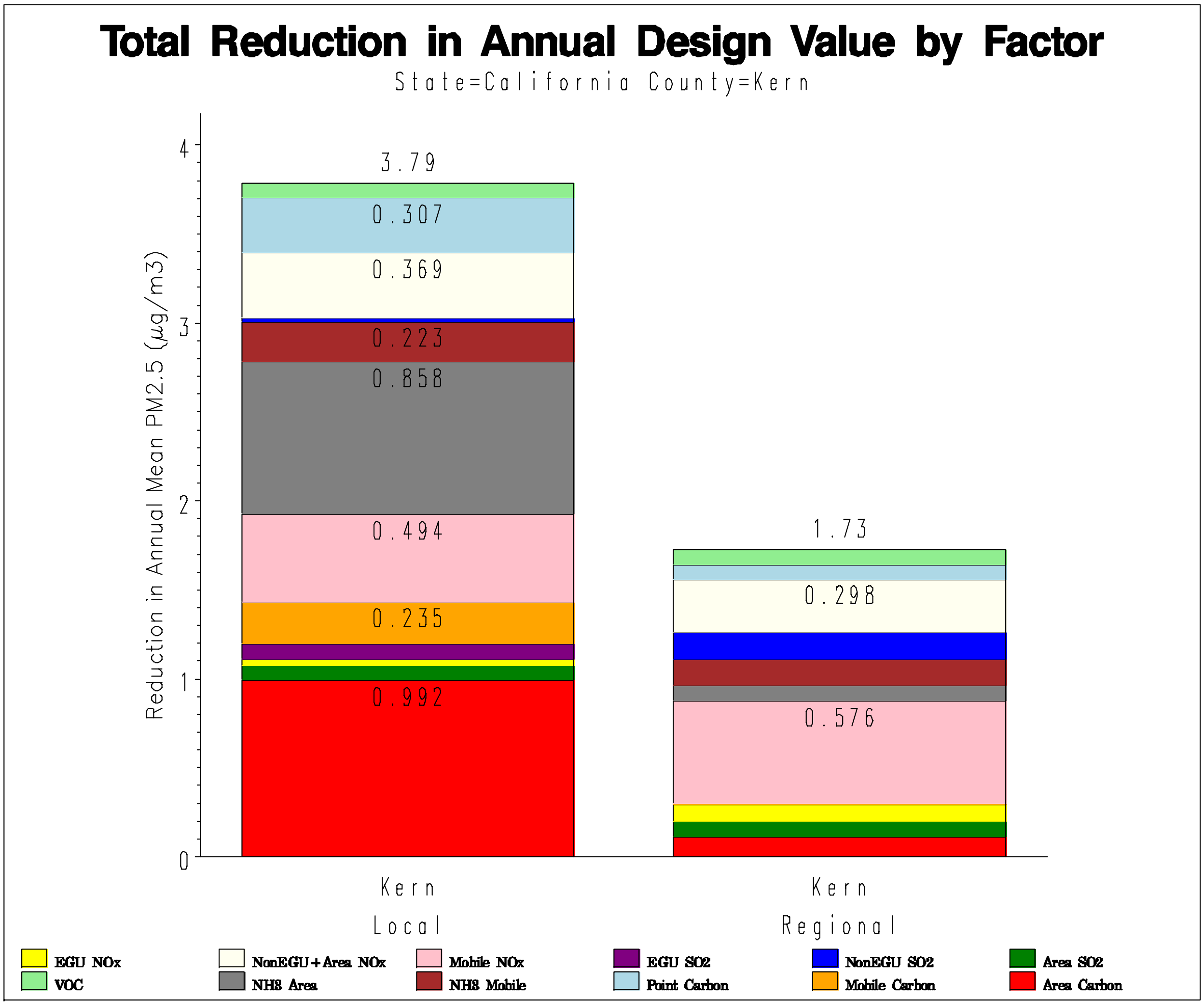


Figure A-11. Estimated Impacts of Urban Area and Region Wide Factors on Annual Mean $PM_{2.5}$ Design Value in the San Joaquin MSA for 2015, from a projected emissions baseline, which includes CAIR/CAMR/CAVR/National mobile and current state and local rules.

The model results suggest the following observations on control strategy effectiveness for the annual peak monitor in Kern County:

- Local controls: area, mobile, and point source carbonaceous particle, mobile NOx, area NH_3, mobile NH_3, non-EGU and area NOx controls provide the greatest air quality benefit. The remaining available controls provide less benefit.

- Regional controls: mobile and non-EGU and area NOx controls are most effective. The remaining controls provide less air quality benefit.

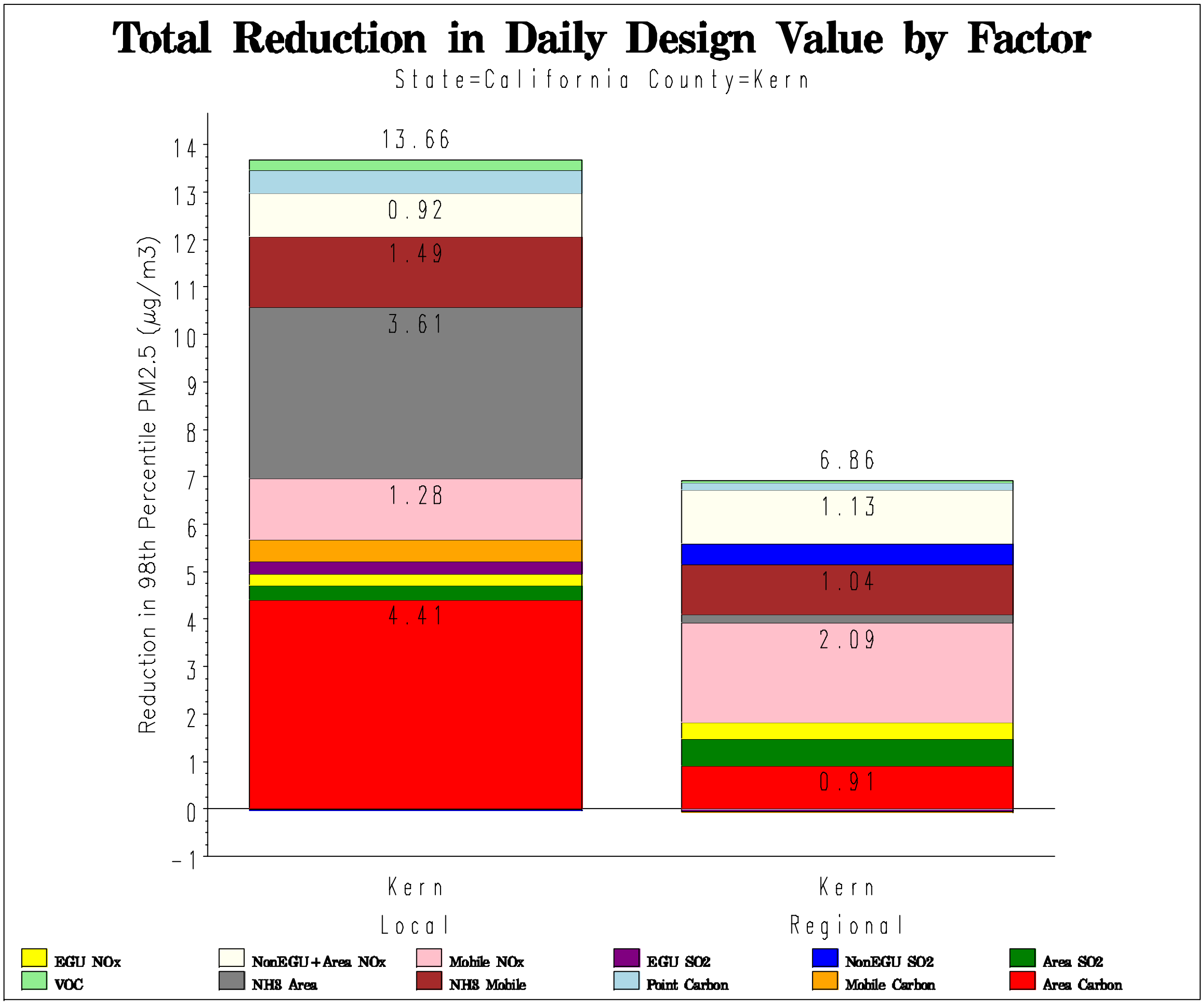


Figure A-12. Estimated Impacts of Urban Area and Region Wide Factors on Daily 98th Percentile $PM_{2.5}$ Design Value in the San Joaquin MSA for 2015, from a projected emissions baseline, which includes CAIR/CAMR/CAVR/National mobile and current state and local rules.

The model results suggest the following observations on control strategy effectiveness for the 24-hour peak monitor in Kern County:

- Local controls: area source carbonaceous particle, mobile NOx, area NH_3, mobile NH_3, non-EGU and area NOx are the most effective controls. The remaining available controls provide a smaller air quality benefit.

- Regional controls: area source carbonaceous particles, mobile NOx, mobile NH_3 and non-EGU and area NOx controls are most effective. The remaining controls are less effective.

Several types of controls are effective in helping the San Joaquin area in meeting both the daily and annual standards. Area source carbonaceous particle controls show an air quality benefit for both standards. Likewise, NOx and NH_3 reductions are potentially helpful to attaining a daily or annual standard.

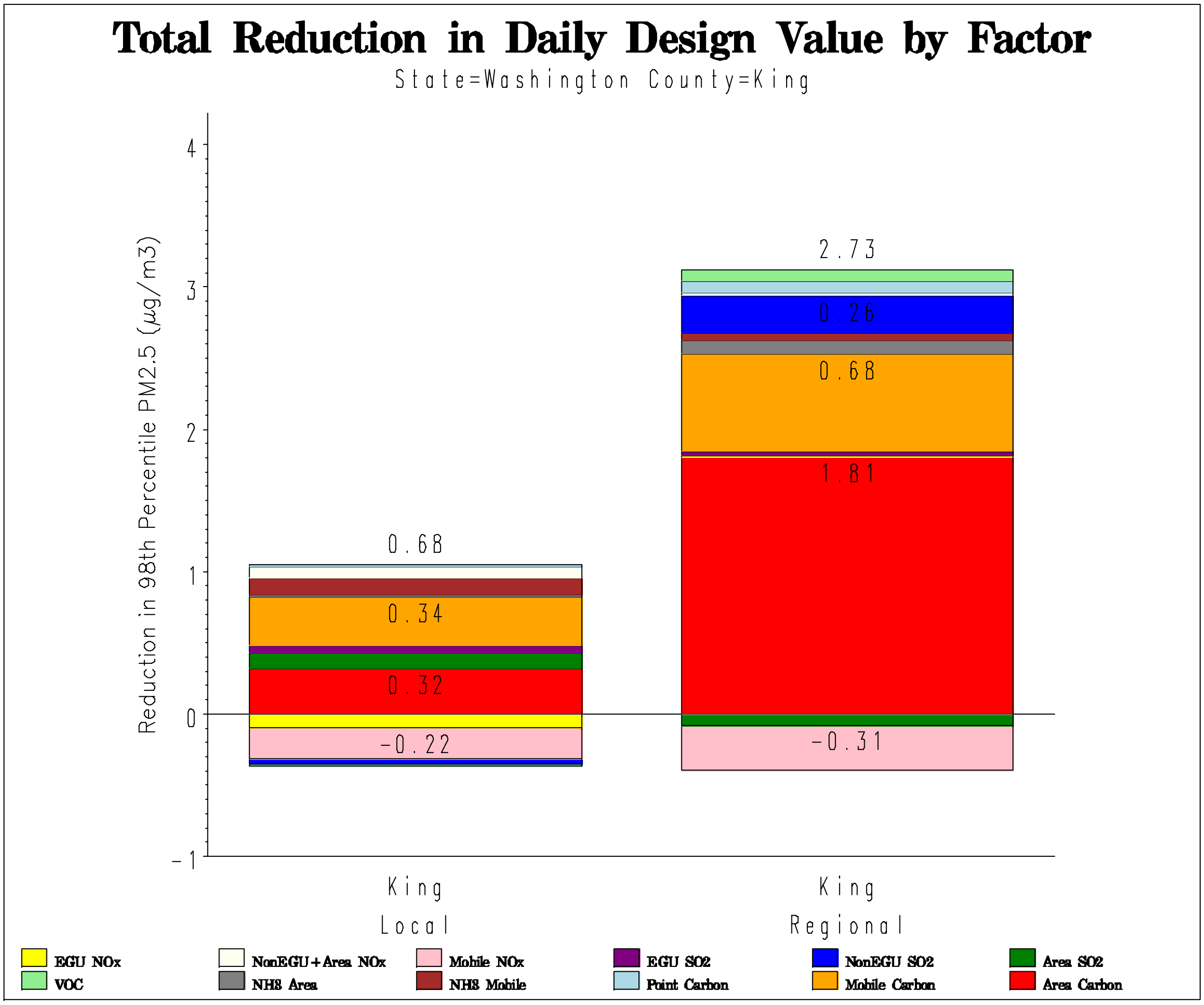


Figure A-13. Estimated Impacts of Urban Area and Region Wide Factors on Daily 98th Percentile $PM_{2.5}$ Design Value in the Seattle MSA for 2015, from a projected emissions baseline, which includes CAIR/CAMR/CAVR/National mobile and current state and local rules.
Note: The predicted increases shown here for the daily PM2.5 concentrations associated with controls on specific source/pollutants may be an artifact of our future projection technique and at this point are not explainable in terms of our current modeling science and therefore are being fully investigated by EPA

The model results suggest the following observations on control strategy effectiveness for the 24-hour peak monitor in King County:

- Local controls: mobile and area source carbonaceous particle controls are highly effective. NOx and some SO_2 controls are ineffective.[11] The remaining available controls provide a smaller air quality benefit.
- Regional controls: area and mobile source carbonaceous particle, and non-EGU SO_2 controls are most effective, while the remaining controls are less effective. Mobile NOx and area SO_2 controls appear to be ineffective.[12]

[11] The predicted increases shown here for the daily $PM_{2.5}$ concentrations associated with controls on specific source/pollutants may be an artifact of the analysis and is being fully investigated by EPA.
[12] The predicted increases shown here for the daily $PM_{2.5}$ concentrations associated with controls on specific source/pollutants may be an artifact of the analysis and is being fully investigated by EPA.

Summary Conclusions Drawn from the RSM Source Control Runs

Our analysis summarized in the stacked bar charts above offer a number of important insights into the nature of the air quality problem in each of the RSM urban areas. These insights include the fact that due to heterogeneity in emissions and atmospheric conditions, different strategies are necessary in each urban area to reduce $PM_{2.5}$. While $PM_{2.5}$ strategies that are effective for meeting annual standards generally are effective at reducing 24 hour values differences exist within cities. The variability in the effectiveness of specific urban-area control measures and specifically the diminished effectiveness of local emission reductions is likely to be due in part to the limitations in the emissions and modeling for local controls. As noted above, the kinds of primary metal and related inorganic emissions that might be expected to be of significance in the industrialized portions of some urban areas are not included in the RSM system. Further, the 36 km grid reduces the effectiveness of local center city mobile controls on peak monitors by spreading all emissions across the entire modeling grid. Finally, it appears that mobile PM emissions may be significantly understated, reducing the modeled effectiveness of national rules or supplemental mobile emissions reductions programs. The greater effectiveness of regional reductions in certain urban areas may reflect differences in the density of regional sources affecting those areas as well as differing meteorological patterns.

Other specific insights include:

- *Carbonaceous particle controls are consistently effective on the urban scale and SO_2 controls are effective in some urban areas.* Overall, carbonaceous particle emissions are the most consistent of the urban area sources in contributing to reductions in both the annual and daily design values. In some locations, urban area emissions of EGU and non-EGU SO_2 are also significant contributors, especially in Eastern urban areas.

- *Some controls can produce benefits or disbenefits that vary with location and scale.* In some locations, incremental reductions in certain factors, primarily from sources within the urban areas, may lead to small *increases* in $PM_{2.5}$ concentrations. For example, urban NOx controls on non-EGU sources (or low-level sources) can produce slight increases in concentrations for some urban areas in the eastern US, but significant decreases in western areas. Note that some of the predicted 'disbenefits' shown in the figures, especially for the daily concentrations, are being further investigated by EPA because they may be an artifact of our future projection technique and at this point may or may not be explainable in terms of our current modeling science.

- *In the East, region-wide SO_2 emissions are important.* Regional EGU and non-EGU point source SO_2 emissions are the most consistently significant sources in the East. Regional reductions in area source NH_3 also contribute to significant reductions in the Northeast and Midwest, although they have little impact in the Southeast.

- *In the West, a wide variety of region-wide sources are important*. NOx reductions are more effective in California, while carbonaceous particle control is most significant in Seattle. In San Joaquin, urban area NOx and NH_3 emissions also provide an important contribution to $PM_{2.5}$. NH_3 controls are also important in the West.

Identifying Cost-Effective Controls

The second step of our analysis was to identify which of the emissions control factors above were also cost-effective for each of the five RSM urban areas on a per-microgram basis.[13] That is, we estimated how much it would cost to reduce $PM_{2.5}$ concentrations by a single microgram if we were to achieve that reduction entirely through a single control. This estimate is very useful to developing cost-effective control strategies because it enables us to prioritize our selection of pollutant controls to identify those controls that achieve the greatest reduction in $PM_{2.5}$ at each violating monitor for the lowest control cost.

To calculate cost per microgram, we first reduced each control factor by 30% within the RSM. The RSM then estimated the total reduction of the daily and annual $PM_{2.5}$ concentration at the highest RSM county monitor as a result of this 30% reduction. Next, we divide the microgram change by the total tons reduced to calculate microgram per-ton. Finally, we divided the cost per-ton estimates (see subsection above) by the micrograms per-ton estimate to obtain an estimate of the cost per microgram at each RSM monitor.

Figures A-14 and A-15 below provide a summary of the cost per microgram by control factor for each of the five RSM urban areas for the daily and annual standard. This chart shows the cost per-microgram of NOx, SO_2, VOC and NH3 and carbonaceous particle controls. The bars reflect cost per-microgram calculations using the 50^{th} percentile cost per-ton; the whiskers extending from the bars reflect costs estimated at the 90^{th} percentile cost per-ton.

[13] In this context we define cost-effective controls to be those that maximize the improvement in the daily and annual value at the least cost. We do not use a specific cost-per-microgram threshold.

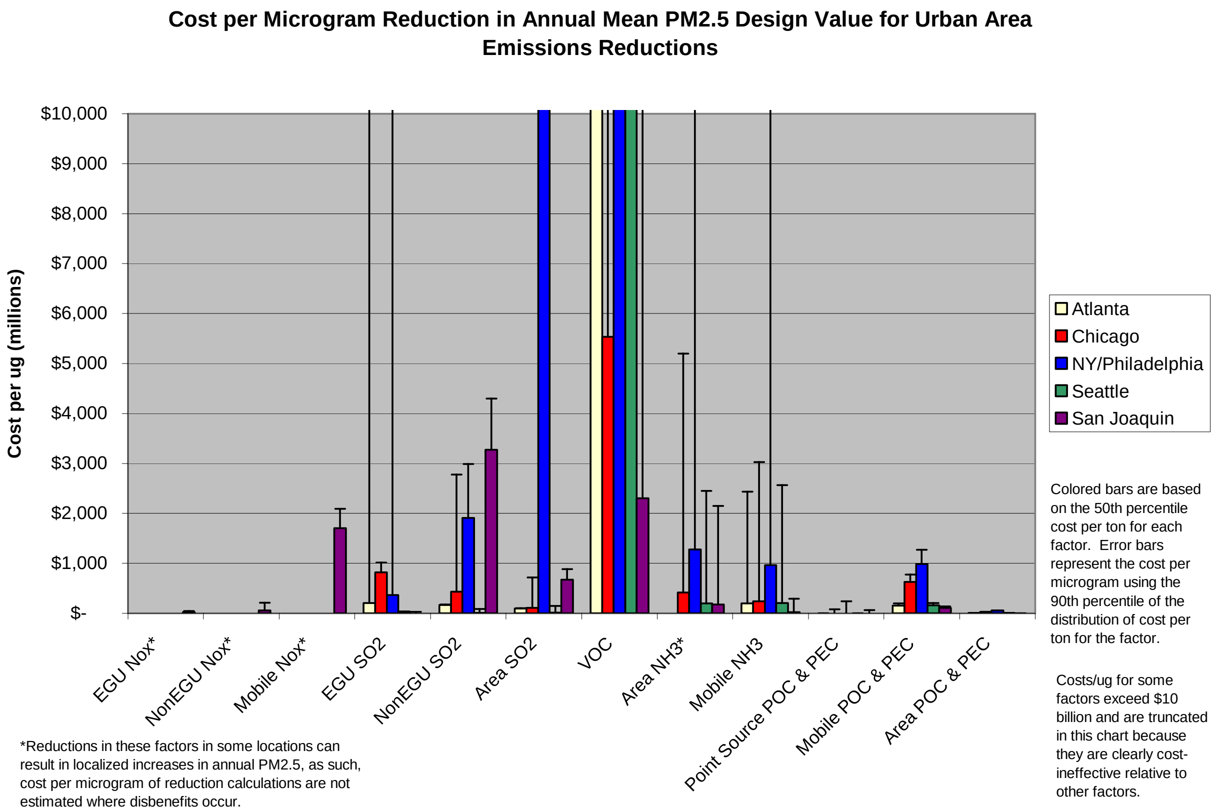


Figure A-14: Cost Per-Microgram of a 30% Reduction in Each of the 12 Response Surface Model Emissions Control Factors: Annual Standard

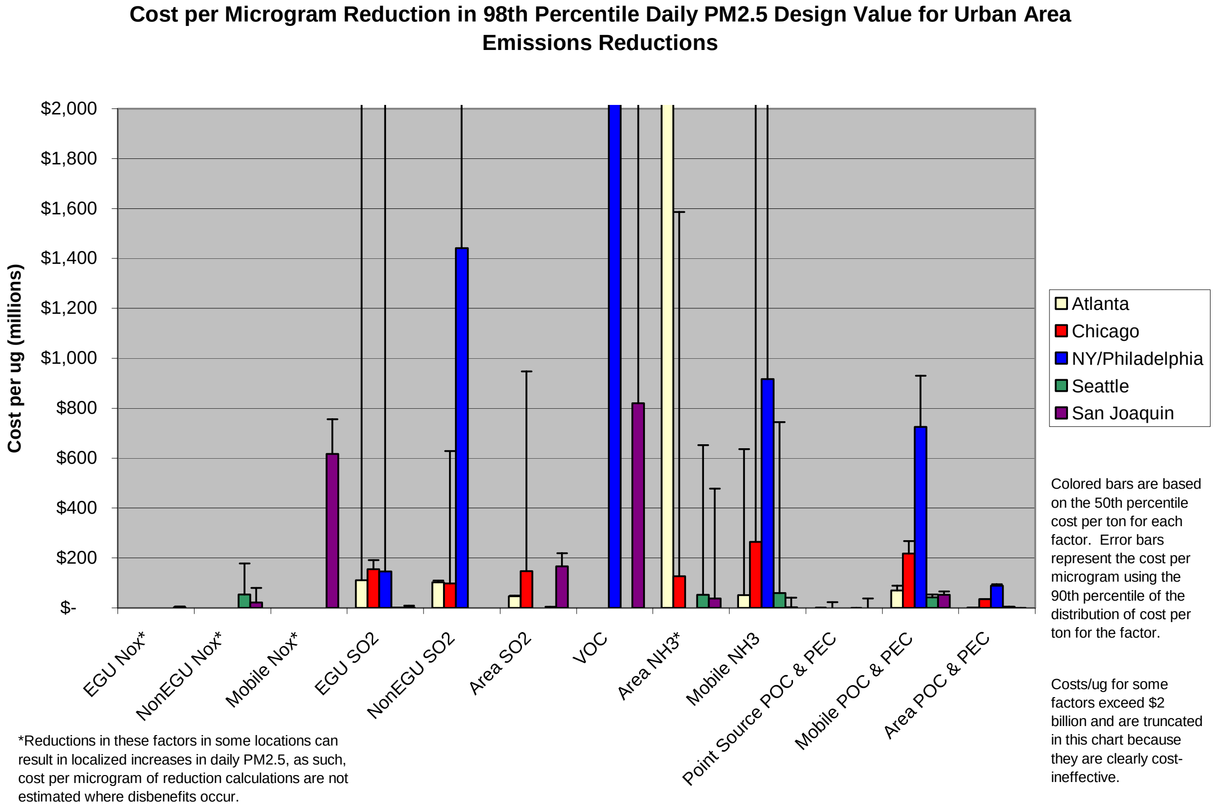


Figure A-15: Cost Per-Microgram of a 30% Reduction in Each of the 12 Response Surface Model Control Factors: Daily Standard

<u>Insights from Cost-Effectiveness Estimates</u>

The preceding cost-per-microgram figures yield several important conclusions, which appear to be robust, considering the uncertainties in the analysis, including:

- *Carbonaceous particle controls are cost-effective across urban areas*. While relatively expensive on a per-ton basis, when compared to other controls on a per-microgram basis, carbonaceous particle controls are cost-effective.

- *Undifferentiated VOC controls are cost-ineffective across urban areas*. VOC controls are relatively inexpensive on a per-ton basis, but highly cost-ineffective on a per-microgram basis.

- *The cost-effectiveness of controls varies by urban area and control.* While area SO_2 controls are generally cost-effective in most areas, they appear to be cost-ineffective in New York/Philadelphia for annual mean values. Similarly, EGU SO_2 controls appear to be very cost-ineffective in Atlanta and New York/Philadelphia for both the annual and daily standard at the 90th percentile of the cost estimate.

There are several important uncertainties and limitations to these data, including:

- *Per-microgram estimates are highly dependent upon the validity of the cost estimates*. Any underlying uncertainty in the control cost estimates will extend into the cost per-microgram estimates.

- *Benefits accrue across the urban area.* The per-microgram calculations above are for a single violating monitor. However, reductions in each of these pollutants will generate air quality benefits at surrounding monitors as well.

- *It is inappropriate to extrapolate the above results to urban areas that were not modeled*. The estimates above are the result of a hypothetical 30% reduction in each urban area control factor; the result of this reduction depends entirely upon the urban area emission inventory, which varies by urban area.

The cost per-microgram estimates for each control factor above tends to vary significantly by urban area. There are two key reasons for this divergence:

1. *The amount of controllable emissions varies by urban area.* To the extent that a pollutant is already well controlled in a particular urban area, successive reductions will become increasingly expensive.

2. *The types of sources to be controlled vary by urban area*. In New York/Philadelphia, EGU and non-EGU carbonaceous reductions are relatively inexpensive at the 50th percentile. However, they become relatively expensive at the 90th percentile. This significant increase in price suggests that the number of sources remaining to be controlled is diminishing and thus further controls become increasingly expensive on a per-ton basis.

Tables A-1, A-2 and A-3 below illustrate these two points. The first table provides the tons of baseline emissions in each RSM urban area by source grouping that have yet to be controlled with AirCotnrolNET controls. As the table indicates, the amount of uncontrolled emissions varies significantly by area. For example, the amount of area source carbonaceous particles remaining to be controlled in New York/Philadelphia is approximately four times as much as is available in Chicago and almost twelve times as much as is available in Seattle. The second table indicates the amount of emissions available to be controlled with the AirControlNET controls. As the second table indicates, AirControlNET does not contain mobile NH_3 or area source SO_2 controls in any urban area. Thus, when viewed together, these two tables illustrate how emissions—and the availability of AirControlNET controls to reduce these emissions—vary by urban area. Finally, Table A-3 lists the maximum percent reduction possible with AirControlNET controls.

Table A-1: Tons of Regulatory Baseline Emissions by RSM Urban Area and Source Grouping

	RSM Source Grouping											
Urban Area	NOx EGU	NOx Non-EGU + Area	NOx Mobile	SOx EGU	SOx Non-EGU Point	SOx Area	VOC	NH_3 Area	NH_3 Mobile	Point Source Carbon	Mobile Source Carbon	Area Source Carbon
Atlanta	20,124	29,885	77,956	72,258	13,819	3,657	155,723	17,823	8,182	7,631	2,964	4,428
Chicago	35,022	122,743	124,096	116,070	147,706	22,497	309,182	15,064	9,173	11,062	5,225	6,427
NY/Philadelphia	41,465	171,819	403,305	51,905	92,570	196,400	673,724	43,525	24,084	5,248	14,007	24,006
San Joaquin	5,388	87,782	67,890	2,354	7,579	5,893	111,589	150,485	5,283	1,808	2,200	5,067
Seattle	621	19,642	54,273	1,117	5,026	1,278	90,788	6,340	4,156	278	2,074	2,466

Table A-2: Tons of Emissions Available for Reduction Using Available AirControlNET Controls

	RSM Source Grouping											
Urban Area	NOx EGU*	NOx Non-EGU + Area	NOx Mobile	SOx EGU*	SOx Non-EGU Point	SOx Area	VOC	NH_3 Area**	NH_3 Mobile	Point Source Carbon	Mobile Source Carbon	Area Source Carbon
Atlanta	---	8,667	38,198	---	1,520	0	48,274	---	0	2,289	326	930
Chicago	---	45,415	57,084	---	47,266	0	136,040	---	0	3,982	470	3,278
NY/Philadelphia	---	30,927	181,487	---	14,811	0	269,490	---	0	262	1,261	12,243
San Joaquin	---	17,556	33,945	---	1,288	0	21,202	---	0	163	308	355
Seattle	---	7,660	25,508	---	402	0	33,592	---	0	92	187	1,381

*Note that because that according to controls hierarchy above we consider EGU reductions in urban area SO_2 and NOx EGU emissions outside of AirControlNET, we do not provide estimated reductions here.
**AirControlNET identifies only a negligible amount of NH_3 control possible in these urban areas. This may be due to the limited number of NH3 controls available in the AirControlNET database, or uncertainty in the inventory regarding uncontrolled NH3 emissions in these 5 urban areas.

Table A-3: Maximum Reductions in RSM Control Factors Possible with AirControlNET Controls

	RSM Source Grouping											
Urban Area	NOx EGU*	NOx Non-EGU + Area	NOx Mobile	SOx EGU*	SOx Non-EGU Point	SOx Area	VOC	NH_3 Area**	NH_3 Mobile	Point Source Carbon	Mobile Source Carbon	Area Source Carbon
Atlanta	---	29%	49%	---	11%	0%	31%	---	0%	30%	11%	21%
Chicago	---	37%	46%	---	32%	0%	44%	---	0%	36%	9%	51%
NY/Philadelphia	---	18%	45%	---	16%	0%	40%	---	0%	5%	9%	51%
San Joaquin	---	20%	50%	---	17%	0%	19%	---	0%	9%	14%	7%
Seattle	---	39%	47%	---	8%	0%	37%	---	0%	33%	9%	56%

*Note that because that according to controls hierarchy above we consider EGU reductions in urban area SO_2 and NOx EGU emissions outside of AirControlNET, we do not provide estimated reductions here.

**AirControlNET identifies only a negligible amount of NH_3 control possible in these urban areas. This may be due to the limited number of NH3 controls available in the AirControlNET database, or uncertainty in the inventory regarding uncontrolled NH3 emissions in these 5 urban areas.

Air Quality, Control Cost and Human Health Benefits Analysis for Five RSM Urban Areas

Applying the cost-effectiveness information above, we developed control strategies for each of the five urban areas according to the hierarchy we describe at the beginning of this section. The subsections below describe: (1) the level of emission control in the RSM that was both cost-optimal and followed the controls hierarchy; (2) the costs commensurate with these control strategies; and, (3) the monetized human health benefits that result from each strategy.

In reviewing the results that follow, there are seven facets of this analysis that readers should note:

1. These analyses consider the costs and benefits of achieving the standard options at the urban-scale only.[14] While we apply regional controls, we do so to illustrate the relative influence that regional reductions have on urban-area air quality. For this reason, we consider multiple regional strategies as adjustments to the baseline for each urban area rather than applying any single strategy that might affect several RSM areas. This strategy makes it difficult, if not impossible, to calculate a regional control cost for each area, and so we provide estimates for the cost of controls applied within the urban area only.

2. To the extent that we can identify a suite of controls that produces attainment, we subtract out any excess controls that are least cost-effective. This is an iterative process that involves the evaluation of multiple control strategies for each urban area. Reproducing this process in this document would require an extensive step-by-step explanation and so we exclude it. Readers interested in understanding more about this aspect of the analysis can consult the technical support document where we have placed these data.

3. For alternatives that require consideration of urban and regional control strategies, in some cases the results show an apparently counter intuitive result of the benefits increasing as regional controls replace urban area only controls even though we are only counting the urban area benefits. This occurs when highly beneficial urban controls (e.g. reducing direct $PM_{2.5}$) replace less beneficial urban controls (e.g. reducing urban area NOx).

4. In many of the scenarios below, we exhaust the existing controls and must rely upon innovative and emerging controls; chapter three provides a brief overview of these controls. Because we have not identified a method to estimate the control cost and control efficiency of these controls, we assume that if such controls were applied they would cost between the 50th and 90th percentile of the cost per-ton for the given RSM control factor. The cost-effectiveness of these innovative controls varies according to whether we calculated their cost at the 50th percentile or the 90th percentile.[15] Thus, below we provide

[14] However, we do estimate the benefits that accrue outside of the RSM urban area from the application of urban-area controls.
[15] The reason for this variability is that each control cost has a differently shaped marginal cost curve. Controls cost-effective at the 50th percentile may become highly cost-ineffective at the 90th percentile because their costs increase

two different control factor tables—those derived assuming innovative cost at the 50^{th} percentile, and those derived assuming innovative cost at the 90^{th} percentile. Chapter 3, page 12 provides a description of how we calculated these cost percentiles.

5. We assume that there is a "control ceiling" which prevents us from reducing emissions from each control factor entirely. For analytical simplicity, we assume that this ceiling is equal to 80% control. We believe this would be a challenge for many source/pollutant combinations and extremely difficult or perhaps infeasible for some of these source/pollutant combinations to achieve by 2015. We deliberately used a high figure to test the effectiveness of relatively extensive controls on any category. Any strategy actually considered by a State in their attainment plans would not use this level of control unless it was identified during their assessment as being available and effective for their area.

6. As noted earlier, when maximum levels of identified AirControlNet controls are included, a few high cost, low ton control measures can greatly magnify the estimated costs of controls. In these cases, we provide an alternative set of cost estimates based on substituting "innovative" controls at the 50^{th} and 90^{th} percentile cost estimate for the these highly costly, ineffective control measures, assuming that rational planners would not adopt cost ineffective controls without first considering technological innovation.

7. As noted earlier, when urban areas cannot reach full attainment, or can only reach attainment at maximum levels of emissions reductions, additional cost uncertainties are introduced. We assume urban areas to adopt all available controls, even those to obtain emission reductions that are not particularly effective in reducing ambient $PM_{2.5}$ concentrations. To help characterize this uncertainty, we provide estimates of costs and benefits with these highly costly and ineffective controls excluded.

Limitations to the Cost Analysis

It should be noted that AirControlNet, while providing a broad set of data on emission reductions and costs associated with control measures, does not provide rules for deciding when a control measure is too costly. In this first round of analysis for the proposal, we did not set specific cost per-ton or cost per microgram limits in determining the maximum amount of emissions reductions that could be obtained from control measures identified within AirControlNet.

During our review of the analytical results, we discovered that some control measures contained in AirControlNet provide very little incremental emissions reductions and have a relatively high cost. These control measures are primarily for mobile sources of carbonaceous particles. As such, these measures will have extremely high costs per-ton of emission reduction (generally orders of magnitude higher than other, more effective controls). As such, rational decision-makers would be very unlikely to recommend adoption of these highly cost-ineffective controls.

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at a rapidly increasing rate. Conversely, controls cost-ineffective at the 50^{th} percentile may become cost-effective at the 90^{th} percentile because their costs increase at a rate slower than costs at the 50^{th} percentile.

For the sake of transparency, we maintained our original assumptions that all potentially effective controls (even those that have relatively small impacts per ton) would be used to reach attainment. However, because some of the emissions reductions are extremely expensive on a per-microgram basis, we are likely to dramatically overstate likely costs for partial attainment scenarios. To demonstrate the impact of removing these costly controls, we provide an illustrative calculation in the discussion for each urban area, based on removing the costly controls and determining the resultant increase in the residual nonattainment increment of PM2.5, and resulting decrease in the cost of the scenario.

In addition, we also did not set specific limits on the cost per microgram of reduction that urban areas might expend to reach attainment or partial attainment. As noted earlier, when urban areas reach the limits of controllable emissions, the marginal cost per microgram increases substantially, such that total costs of partial attainment are dominated by the costs of achieving the last small increment of improvement in the design values. These cost increments are clearly highly uncertain, as rational planners would likely not proceed with controls that are clearly so costly and ineffective. Because there are no clear bounds on what is an acceptable cost per microgram, we include these clearly upper bound estimates for the partial attainment scenarios, but we also provide estimates of what costs and benefits would be without these last, highly expensive, increments of control.

Urban Area Attainment Strategies for Current PM NAAQS

As a first step in our attainment analysis for a tighter NAAQS, we develop an attainment strategy for the existing annual and daily standard of 15/65. We present the results of an urban-only attainment strategy that relies entirely upon cost-effective urban controls. As we describe in the preceding subsection, this analysis calculates the costs of innovative controls at the 50th and 90th percentiles of the distributions of cost per-ton. Because these varying calculations affect our selection of cost-effective controls in some urban areas, we present our RSM air quality modeling and cost estimates using numbers produced with each method.

Tables A-4 and A-5 below summarize the RSM emission reductions necessary to bring each of the five RSM urban areas into attainment for the current PM NAAQS using an urban-only strategy.

Table A-4: RSM Emission Reductions for 15/65 Attainment Scenario—Assumes Innovative Controls Selected Using 50th Percentile Cost per-Ton

	RSM Control Factor and Percentage of Control											
RSM Urban Area	NOx EGU**	NOx Non-EGU + Area	NOx Mobile	SOx EGU**	SOx Non-EGU Point	SOx Area	VOC	NH_3 Area	NH_3 Mobile	Point Source Carbon	Mobile Source Carbon	Area Source Carbon
Atlanta												
Urban Controls	---	---	---	80%	11%	---	---	---	---	30%	11%	21%
Chicago												
Urban Controls	---	---	---	80%	80%	80%	---	80%	80%	80%	10%	80%
NY/Philadelphia*												
Urban Controls	---	---	---	---	---	---	---	---	---	---	---	---
Seattle*												
Urban Controls	---	---	---	---	---	---	---	---	---	---	---	---
San Joaquin												
Urban Controls	80%	80%	---	80%	17%	---	---	---	80%	80%	57%	80%

*These urban areas attain the 15/65 standard and so require no additional controls
** Note that when we apply urban-area EGU controls, we assume an 80 percent reduction for the reasons describe in the controls hierarchy section above.

Table A-5: RSM Emission Reductions for 15/65 Attainment Scenario—Assumes Innovative Controls Selected Using 90th Percentile Cost per-Ton

	RSM Control Factor and Percentage of Control											
RSM Urban Area	NOx EGU**	NOx Non-EGU + Area	NOx Mobile	SOx EGU**	SOx Non-EGU Point	SOx Area	VOC	NH_3 Area	NH_3 Mobile	Point Source Carbon	Mobile Source Carbon	Area Source Carbon
Atlanta												
Urban Controls	---	---	---	80%	11%	---	---	---	---	31%	11%	21%
Chicago												
Urban Controls	---	---	---	80%	58%	80%	---	---	---	80%	80%	80%
NY/Philadelphia*												
Urban Controls	---	---	---	---	---	---	---	---	---	---	---	---
Seattle*												
Urban Controls	---	---	---	---	---	---	---	---	---	---	---	---
San Joaquin												
Urban Controls	80%	80%	---	80%	17%	---	---	---	55%	80%	80%	80%

*These urban areas attain the 15/65 standard and so require no additional controls
** Note that when we apply urban-area EGU controls, we assume an 80 percent reduction for the reasons describe in the controls hierarchy section above.

The percentages in the tables above represent the emissions reductions necessary for each RSM control factor in each urban area to reach attainment with the current standard in the most cost-effective manner (based on assumptions about the costs of innovative controls). Table A-5 reflects an urban-only strategy, in which we must rely solely upon emission reductions within each urban area. NY/Philadelphia and Seattle attain the current standard under baseline conditions. In our analysis three urban areas need significant emission reductions to attain with this strategy:

- *Atlanta may need EGU SO_2 reductions within the urban area to reach attainment*. Atlanta requires SO_2 reductions to reach attainment, and a more moderate amount of carbonaceous particle controls.

- *Chicago may need deep SO_2 reductions within the urban area to reach attainment*. This urban area must increase SO_2 controls significantly to reach attainment. Using the 90th percentile method of calculating control cost, it also cost-effective for Chicago to reduce carbonaceous particle emissions.

- *The San Joaquin Valley may need deep NOx, NH_3 and carbonaceous particle reductions within the urban area to reach attainment* . San Joaquin must reduce urban Non-EGU and EGU NOx to reach attainment.

San Joaquin faces unique attainment challenges with the current standard. As we demonstrate below, simulating attainment with a tighter daily standard is also very difficult. Given the magnitude of the non-attainment problem in this area, the state has performed detailed air quality modeling. EPA has partnered with the San Joaquin Valley in this effort to perform this modeling and consider control strategies that would enable this area to reach attainment.

The next step in our analysis was to estimate the control costs and monetized human health benefits associated with these strategies for attaining the current standard. Table A-6 summarizes these data. For some urban areas we provide a range of benefits estimates. As we discuss above, the specific urban area control factors that we apply vary according to whether we calculate control costs at the 50th or 90th percentile. Hence, the magnitude of the monetized human benefits that result from a $PM_{2.5}$ control strategy will vary, in part, according to the specific pollutant emissions abated. Finally, note that we estimate costs using 1999$ to remain consistent with the recent CAIR analysis.

Table A-6: Control Cost and Monetized Human Health Estimates for 15/65 Attainment Strategy (Million 1999$)

		Costs of Urban Area Controls (3%)		*Costs of Urban Area Controls (7%)*			
Urban Area	*2015 Base case*	50th Percentile Cost	90th Percentile Cost	50th Percentile Cost	90th Percentile Cost	*Benefits of Urban Area Controls (3%)*	*Benefits of Urban Area Controls (7%)*
Atlanta	Regulatory Baseline	$1,940	$1,940	$2,070	$2,070	$2,520	$2,150
Chicago	Regulatory Baseline	$1,940	$2,300	$2,060	$2,410	$7,900—$8,770**	$6,770—$7,510**
NY/Philadelphia*	Regulatory Baseline	---	---	---	---	---	---
San Joaquin	Regulatory Baseline	$1,360	$1,700	$1,430	$1,810	$8,010—$8,310**	$6,850 – $7,110**
Seattle*	Regulatory Baseline	---	---	---	---	---	---

* Urban area attains 15/65 in the CAIR/CAMR/CAVR basecase.

**Different combinations of factor levels were cost-minimizing using the 50th and 90th percentile cost/ton estimates. The low end of the range of benefits is associated with the mix of controls using the 90th percentile cost/ton and the upper end of the range of benefits is associated with the mix of controls using the 50th percentile cost.

These preliminary cost and benefit estimates for the five cities are significantly affected by initial steps of the analysis that we believe can be improved for the final RIA, and these estimates are very likely to change in the final version. While all estimates in RIAs are uncertain, we believe the results of this 5-city analysis are particularly uncertain, and accordingly we have not included them in the Executive Summary. We do believe that making the preliminary analysis available will allow for public comment. The estimates are based on an incomplete menu of known control strategies that needs to be supplemented. Some controls involve costs of more than $1 million a ton; we do not believe that states will adopt control measures requiring control costs of this magnitude. Incremental costs of meeting more stringent standards are highly dependent on assumptions about the costs of additional control measures that have not been identified. The fact that the benefits and costs in this analysis are of the same magnitude is inconsistent with findings in recent RIAs for national rules that reduce $PM_{2.5}$ or precursors. Those RIAs found that benefits of pollutant reductions substantially exceeded costs (see table A-60 for a further illustration of this point). In cases where we assume additional regional controls for the 5-city analysis, we do not include the costs and benefits of these controls because it is not clear what fraction of the costs and benefits of regional controls should be apportioned to an individual city. In the next stage of analysis we will address these and other issues, and produce an improved estimate of costs and benefits for the final RIA.

The benefits estimates for the attainment strategies assessed in this appendix are subject to a number of assumptions and uncertainties, which are discussed throughout this document:

1. The first source of uncertainty that has received recent attention from several scientific review panels is the shape of the concentration-response function for PM-related mortality, and specifically whether there exists a threshold below which there would be no benefit to further reductions in $PM_{2.5}$. Although the consistent advice from EPA's Science Advisory Board (SAB) that provides advice on benefits analysis methods[16] has been to model premature mortality associated with PM exposure as a non-threshold effect, that is, with harmful effects to exposed populations regardless of the absolute level of ambient PM concentrations, EPA's most recent $PM_{2.5}$ Criteria Document concludes that "the available evidence does not either support or refute the existence of thresholds for the effects of PM on mortality across the range of concentrations in the studies" (U.S. EPA, 2004, p. 9-44). Some researchers have hypothesized the presence of a threshold relationship. The nature of the hypothesized relationship is the possibility that there exists a PM concentration level below which further reductions no longer yield premature mortality reduction benefits.

2. To consider the impact of a threshold in the response function for the chronic mortality endpoint on the primary benefits estimates, we constructed a sensitivity analysis by assigning different cutpoints below which changes in $PM_{2.5}$ are assumed to have no

[16] The advice from the 2004 SAB-HES (EPA-SAB-COUNCIL-ADV-04-002) is characterized by the following: "For the studies of long-term exposure, the HES notes that Krewski et al. (2000) have conducted the most careful work on this issue. They report that the associations between $PM_{2.5}$ and both all-cause and cardiopulmonary mortality were near linear within the relevant ranges, with no apparent threshold. Graphical analyses of these studies (Dockery et al., 1993, Figure 3, and Krewski et al., 2000, page 162) also suggest a continuum of effects down to lower levels. Therefore, it is reasonable for EPA to assume a no threshold model down to, at least, the low end of the concentrations reported in the studies."

impact on premature mortality. In applying the cutpoints, we adjusted the mortality function slopes accordingly.[17] This sensitivity analysis allows us to determine the change in avoided mortality cases and associated monetary benefits associated with alternative cutpoints. Four cutpoints were included in this sensitivity analysis: (a) 15 $\mu g/m^3$ (based on the current NAAQS); (b) 10 $\mu g/m^3$ (reflects comments from CASAC, 2005); (c) 7.5 $\mu g/m^3$ (reflects recommendations from SAB-HES, 2004 to consider estimating mortality benefits down to the lowest exposure levels considered in the Pope 2002 study used as the basis for modeling chronic mortality); and (d) background or 3 $\mu g/m^3$ (reflects NAS, 2002 recommendation to consider effects all the way to background).

3. Another source of uncertainty is the relative potency of $PM_{2.5}$ components. All fine particles, regardless of their chemical composition, are assumed to be equally potent in causing premature mortality. This is an important assumption, because there may be significant differences between PM produced via transported precursors, direct PM released from automotive engines, and direct PM from other industrial sources. The analysis also assumes that all components of fine particles have equal toxicity. While it is reasonable to expect that the potency of components may vary across the numerous effect categories associated with particulate matter, EPA's interpretation of scientific information considered to date is that such information does not yet provide a basis for quantification beyond using fine particle mass.

   This issue is an active area of research for EPA. The Agency is exploring ways to estimate the importance of this assumption on the certainty of human health benefits and its implications for control strategy development and assessment. While EPA has not performed formal sensitivity analysis of this assumption for the proposed PM NAAQS RIA, we can, nonetheless, provide several insights:

   - Strategies that reduce a wide array of types of PM and precursor emissions will have more certain health benefits than strategies that are more narrowly focused. EPA's national rules follow this risk management insight by requiring reductions in a number of sources. CAIR reduces SO2 and NOx, precursors to sulfates and nitrates, non-road and on-road reduce directly emitted PM from diesels, and MACT standards reduce PM and its precursors from a wide variety of source categories. Similarly, all strategies analyzed in this RIA are for reductions in a wide array of control factors. Until a more robust scientific basis exists for making reliable judgments about the relative toxicity of PM, it will not be possible to determine whether the strategy of reducing a wide array of PM types is sub-optimal or not.

   - Many of the national rules designed to reduce PM have estimated benefit-cost ratios significantly larger than one, suggesting that the conclusion that benefits exceed costs for these rules is robust to modest deviations from the assumption that all particles are equally potent.

[17] Note, that the adjustment to the mortality slopes was only done for the 10 $\mu g/m^3$ and 15 $\mu g/m^3$ cutpoints since the 7.5 $\mu g/m^3$ and background cutpoints are at or below the lowest measured exposure levels reported in the Pope 2002, for the combined exposure dataset.

- As states explore interventions that have smaller benefit-cost ratios, the importance of this issue will increase.

Note Regarding Analysis of the 15/40 Standard Option

As noted above, this RIA has focused on the existing $PM_{2.5}$ NAAQS, the proposed revised standards and two more stringent alternatives. We also provide an interpolated estimate of costs and benefits for maintaining the annual standard and revising the 24 hour standard to 40 $\mu g/m^3$. San Joaquin was the only urban area projected to be out of attainment for this standard option in 2015 under the regulatory base case. We provide the results of this screening-level analysis in the section on San Joaquin below.

Atlanta Air Quality, Control Cost and Human Health Benefits Results

Following the controls hierarchy, we consider two strategies for Atlanta, one that applies urban controls to a baseline including moderate regional emissions controls, and one that applies urban area controls alone. Below we present the results in this sequence, starting first with urban area controls.

Attainment Analysis Using Only Urban Area Controls

Table A-7 below presents the emission reductions we modeled in the RSM to attempt to reach attainment with each level of the standard under consideration.

Table A-7: RSM Emission Reductions for Atlanta Urban-Only Scenario: Assumes Innovative Controls at 50th and 90th Percentile Cost

	RSM Control Factor and Percentage of Control											
Attainment Target ($\mu g/m^3$)	NOx EGU*	NOx Non-EGU + Area	NOx Mobile	SOx EGU*	SOx Non-EGU Point	SOx Area	VOC	NH_3 Area	NH_3 Mobile	Point Source Carbon	Mobile Source Carbon	Area Source Carbon
15/35												
Urban Controls	---	---	---	80%	11%	---	---	---	---	31%	11%	21%
15/30												
Urban Controls	---	---	---	80%	80%	---	80%	---	80%	80%	80%	80%
14/35												
Urban Controls	---	---	---	80%	11%	---	---	---	---	80%	11%	24%

* Note that when we apply urban-area EGU controls, we assume an 80 percent reduction for the reasons describe in the controls hierarchy section above.

We developed these urban-only control factors for Atlanta by applying our estimates of cost-effectiveness found in the previous section. Three key aspects of these Atlanta urban area controls reflect our use of these data:

- *Maximum urban area EGU SO_2 controls (80%) appears necessary under all options.*

- *We rely upon a modest to maximal control mix of non-EGU SO_2, carbonaceous particle, and mobile NH_3 controls* We apply these controls with increasing strigency to meet the more stringent annual and daily standards.

- *Low cost-effectiveness controls appear necessary*. Because we exhaust all other cost-effective controls, we move to less cost-effective controls that still generate some air quality benefits, including controls on VOC and mobile NH_3, to meet the more stringent annual and daily standards.

Table A-8 indicates that Atlanta is able to attain the 15/35 standard option by applying urban-controls alone. However, it would remain out of attainment for the both the 14/35 and 15/30 alternatives under an urban-only strategy

Table A-8: Atlanta Air Quality Results: Urban-Only Analysis

Standard ($\mu g/m^3$)	*Attain?*	*Notes*	*Controlling Standard*	*Remaining Air Quality Increment ($\mu g/m^3$)*
15/35	Yes	No additional innovative urban measures beyond those used to reach attainment with the 15/65 standard are necessary.	Annual	---
15/30	No	Cannot attain with all available local emissions reductions.	Daily	2.92
14/35	No	Cannot attain with all available local emissions reductions.	Annual	0.56

<u>Urban and Regional Controls Analysis</u>

Table A-9 presents the urban emission reductions we modeled in the RSM to attempt to reach attainment in Atlanta with each level of the standard under consideration, as well as the regional emissions reductions considered as elements of the baseline for urban reductions.

Table A-9: RSM Emission Reductions for Atlanta Urban and Regional Control Scenario: Assumes Innovative Controls at 50th and 90th Percentile Cost

	RSM Control Factor and Percentage of Control											
Attainment Target ($\mu g/m^3$)	NOx EGU*	NOx Non-EGU + Area	NOx Mobile	SOx EGU*	SOx Non-EGU Point	SOx Area	VOC	NH_3 Area	NH_3 Mobile	Point Source Carbon	Mobile Source Carbon	Area Source Carbon
15/30												
Urban Controls	---	---	---	80%	11%	---	---	---	---	48%	11%	21%
Regional Controls**	---	20%	---	20%	20%	20%	---	20%	---	20%	20%	20%
14/35												
Urban Controls	---	---	---	80%	11%	---	---	---	---	45%	11%	21%
Regional Controls**	---	20%	---	20%	20%	20%	---	20%	---	20%	20%	20%

* Note that when we apply urban-area EGU controls, we assume an 80 percent reduction for the reasons describe in the controls hierarchy section above.
**Note that these regional controls form a new baseline from which we evaluate the costs and benefits of reaching attainment with urban controls

The urban and regional controls applied in the table above reflect our use of the air quality-effectiveness and cost-effectiveness data in the previous sections above. There are three key aspects that guide the strategies for Atlanta:

- *Carbonaceous controls are cost-effective*. In meeting attainment for successively tighter annual and daily standards, we apply additional local carbonaceous particle controls because these are most cost-effective. As we aim to meet the tighter standard options, we supplement with additional local carbonaceous particle controls.

- *Regional Non-EGU and area NOx controls can be effective*. We apply region-wide NOx controls, but do not apply such controls on the urban scale because they are not cost-effective. Moreover, we do not apply regional or local mobile NOx controls because these are cost-ineffective.

- *Local and regional SO_2 controls are cost-effective*. We increasingly apply these controls to meet successively tighter annual and daily standards. To meet the more stringent standard options, we rely upon local SO_2 EGU controls. In the 15/30 and 14/35 cases, we also add moderate regional EGU SO_2 emissions reductions to the baseline.

Table A-10 below indicates that Atlanta is able to attain all levels of the daily and annual standard options under consideration by using a combination of local and regional controls.

Table A-10: Atlanta Air Quality Results: Urban/Regional Analysis

Standard ($\mu g/m^3$)	*Attain?*	*Notes*	*Controlling Standard*	*Remaining Air Quality Increment ($\mu g/m^3$)*
15/30	Yes	Innovative urban controls are necessary for attainment.	Daily	---
14/35	Yes	Innovative urban controls necessary for attainment.	Annual	---

<u>Comparison of Control Costs and Monetized Human Health Benefits for Atlanta</u>

Tables A-11 provides the estimated control costs and benefits at a 3% and 7% discount rate for both the regional-urban and urban-only control hierarchies. Because Atlanta is projected to attain the proposed standard of 15/35 with no controls beyond those necessary to attain the current standard, the incremental costs and benefits of attainment are zero. Atlanta is not able to attain the 15/30 standard with local controls alone, but the benefits of the local controls are still substantial, ranging from $2.4 to $2.8 billion. The costs of partial attainment may also be substantial, ranging from $0.8 to $6.0 billion at the 50^{th} and 90^{th} percentile of cost. Note that the relatively high costs of partial attainment are driven largely by the costs of VOC controls, which account for $600 million of the total costs using the 50^{th} percentile cost/ton, and $5 billion of the total costs using the 90^{th} percentile cost/ton. These expensive controls result in less than 0.1 $\mu g/m^3$ reduction in the daily design value, and almost no impact on benefits. Partial attainment costs without these measures would range from $200 to $1,000 million at the 50^{th} and 90^{th} percentile of cost. As a result, the partial attainment strategy may have positive or negative net benefits. Clearly, if actual costs are closer to the 90^{th} percentile cost estimates, then more cost-effective technologies, potentially from regional strategies, should be considered. In fact, with a 20 percent control on regional emissions, Atlanta is able to attain the 15/30 standard, with urban area control costs of only $0.5 million, obtained largely through carbonaceous particle controls, which are highly effective at reducing urban $PM_{2.5}$ concentrations. Atlanta is able to attain the 14/35 alternative standard using urban area controls alone, if innovative and emerging $PM_{2.5}$ controls beyond those in AirControlNet are included. Attainment using this urban-only approach has benefits of $1.4 to $1.7 billion and costs of between $0.5 and $3.0 million. Clearly, if costs are within the range of our estimates, attainment of this alternative standard will have high net benefits. Addition of moderate regional controls to the baseline reduces the projected costs and benefits of urban controls by a small amount, by reducing the amount of urban point source carbonaceous particle reduction needed.

Table A-11: Benefits and Costs of Attaining Alternative Standards in Atlanta Urban Area Incremental to Attainment of the Current 15/65 Standard (Million 1999$)

		Costs of Urban Area Controls (3%)		*Costs of Urban Area Controls (7%)*			
Strategy	*2015 Base case*	50th Percentile Cost	90th Percentile Cost	50th Percentile Cost	90th Percentile Cost	Benefits of Urban Area Controls (3%)	Benefits of Urban Area Controls (7%)
Urban-Only Path ($\mu g/m^3$)							
15/35*	Regulatory Baseline	---	---	---	---	---	---
15/30**	Regulatory Baseline	$800	$6,020	$800	$6,020	$2,770	$2,360
14/35	Regulatory Baseline	$0.50	$3	$0.75	$3.50	$990	$850
Urban/Regional Path ($\mu g/m^3$)***							
15/30	Regulatory Baseline +20% Reduction in Regional NonEGU and EGU Emissions	$471	$472	$595	$596	$1,730	$1,470
14/35	Regulatory Baseline +20% Reduction in Regional NonEGU and EGU Emissions	$471	$472	$595	$596	$1,670	$1,420

* Atlanta attains 15/35 with no incremental controls beyond those necessary to attain 15/65.
** Atlanta unable to attain 15/30 with local emission reductions alone. Costs and benefits are for partial attainment. Note that the relatively high costs of partial attainment are driven largely by the costs of VOC controls, which account for $600 million of the total costs using the 50th percentile cost/ton, and $5 billion of the total costs using the 90th percentile cost/ton. These expensive controls result in less than 0.1 µg/m3 reduction in the daily design value. Partial attainment costs without these measures would range from $200 to $1,000 million.
***Note that while this strategy assumes the presence of certain regional controls in the baseline, the costs and benefit estimates reflect air quality improvements from the urban controls alone.

Tables A-12 to A-17 provide detailed estimates of the health impacts and monetized benefits associated with the various attainment strategies and alternative standards.[18] It is worth repeating that these benefits estimates do not reflect the overall benefits of national attainment with the standards, as regional strategies and strategies in other urban areas will likely result in additional air quality improvements and thus additional health benefits beyond those achieved with local emissions reductions alone.

In addition to the tables of primary estimates, we also provide analyses of the sensitivity of mortality impacts to alternative assumptions about possible thresholds in the mortality concentration-response function, for both incidence and monetized value. These sensitivity analyses can be difficult to interpret, because when a threshold above the lowest observed level of $PM_{2.5}$ in the underlying epidemiology study (Pope et al 2002) is assumed, the slope of the concentration-response function above that level must be adjusted upwards to account for the assumed threshold (see NAS, 2002, EPA, 2005 for discussions of this issue). Depending on the amount of slope adjustment and the proportion of the population exposed above the assumed threshold, the estimated mortality impact can either be lower (if most of the exposures occur below the threshold) or higher (if most of the exposures occur above the threshold). In the case of Atlanta, where annual mean levels are generally lower, the level of the mortality impact (and thus the benefits of mortality reductions) is generally decreasing with higher assumed thresholds. As would be expected, no impacts occur above a threshold of 15, because all of the alternative standards are evaluated incremental to attaining the 15/65 current standard. Assumption of a 10 $\mu g/m^3$ threshold has relatively little impact, suggesting that most exposures in Atlanta and the surrounding area are in the range from 10 to15 $\mu g/m^3$.

We also provide a sensitivity analysis showing the impacts of using alternative concentration-response functions for premature mortality based on the results of a pilot expert elicitation project (see U.S. EPA, 2004 for complete details on this project). In this sensitivity analysis, we provide both point estimates of the mean impact for comparison with our primary estimate, and 5th and 95th percentiles of the distribution of mortality impacts to show the range of uncertainty provided by each expert, and the range of estimates across experts. We also provide uncertainty estimates for the value of mortality associated with each expert's distribution of mortality impacts, which incorporates additional uncertainty in the value of mortality. For details on this approach, see the CAIR RIA, Appendix B.

[18] Note that due to a technical problem, we are unable to estimate impacts on chronic bronchitis for this analysis. In previous RIAs, chronic bronchitis has accounted for around 3 percent of total monetized health benefits. Thus, while important, the omission of these impacts will not substantially alter conclusions regarding net benefits of attainment strategies. We intend to address the technical problem before the final RIA and include chronic bronchitis impacts in the estimates for the final rule.

Table A-12. Estimated Reductions in Incidence of $PM_{2.5}$ Related Health Effects Due to Emissions Reductions in the Atlanta Urban Area for Attainment of Alternative $PM_{2.5}$ NAAQS

	Urban Area Emissions Reductions Only				*Urban Area Emissions Reductions with Alternative Regional Emissions Reduction Baselines*	
	Reductions due to Urban Area Emissions Reductions to Attain the Current 15/65 Standards	Reductions due to Urban Area Emissions Reductions to Attain Alternative Standards Incremental to Attainment of Current 15/65 Standards			Reductions due to Urban Area Emissions Reductions to Attain Alternative Standards Incremental to Attainment of Current 15/65 Standards	
Endpoint	15/65	15/35**	15/30	14/35	15/30	14/35
Premature mortality						
Long-term exposure (adults, 30 and over)	430	0	480	180	300	290
Long-term exposure (infant, <1 yr)	1	0	2	1	0	0
Chronic bronchitis (adults, 26 and over)	NA	0	NA	NA	NA	NA
Non-fatal myocardial infarctions (adults, 18 and older)	730	0	770	270	390	380
Hospital admissions—Respiratory (all ages)c	100	0	110	50	54	51
Hospital admissions—Cardiovascular (adults, >18)d	220	0	230	90	117	117
Emergency Room Visits for Asthma (18 and younger)	500	0	600	260	280	260
Acute bronchitis (children, 8-12)	840	0	1,060	360	560	530
Lower respiratory symptoms (children, 7-14)	8,300	0	9,700	3,700	4,500	4,300
Upper respiratory symptoms (asthmatic children, 9-18)	6,100	0	6,900	3,100	3,300	3,100
Asthma Exacerbations (asthmatic children, 6-18)	7,500	0	8,500	3,500	4,100	3,900
Work loss days (adults, 18-65)	55,000	0	65,000	27,000	29,000	28,000
Minor restricted activity days (adults, age 18-65)	320,000	0	390,000	170,000	180,000	170,000

* Shading indicates that Atlanta unable to attain 15/30 with urban controls.
****** Atlanta attains 15/35 with no incremental controls beyond the regulatory basecase and those necessary to attain 15/65; as such no incremental benefits accrue.

Table A-13. Estimated Monetized Health Benefits of Emissions Reductions in the Atlanta Urban Area for Attainment of Alternative $PM_{2.5}$ NAAQS

		Urban Area Emissions Reductions Only				*Urban Area Emissions Reductions with Alternative Regional Emissions Reduction Baselines*	
		Benefits of Urban Area Emissions Reductions to Attain the Current 15/65 Standards	Benefits of Urban Area Emissions Reductions to Attain Alternative Standards Incremental to Attainment of Current 15/65 Standards			Benefits of Urban Area Emissions Reductions to Attain Alternative Standards Incremental to Attainment of Current 15/65 Standards	
Endpoint		15/65	15/35*	15/30**	14/35	15/30	14/35
Premature mortality							
Long-term exposure, (adults, >30yrs)							
3% discount rate		$2,417.8	$0.0	$2,657.6	$948.4	$1,677.0	$1,620.5
7% discount rate		$2,034.3	$0.0	$2,236.1	$798.0	$1,411.0	$1,363.5
Long-term exposure (child <1yr)		$7.9	$0.0	$9.9	$3.7	$5.3	$5.1
Chronic bronchitis (adults, 26 and over)		NA		NA	NA	NA	NA
Non-fatal myocardial infarctions							
3% discount rate		$60.8	$0.0	$64.5	$27.0	$32.8	$31.3
7% discount rate		$75.5	$0.0	$79.1	$32.9	$40.8	$38.9
Hospital Admissions from Respiratory Causes		$0.6	$0.0	$0.6	$0.3	$0.3	$0.3
Hospital Admissions from Cardiovascular Causes		$4.4	$0.0	$4.7	$2.0	$2.4	$2.3
Emergency Room Visits for Asthma		$0.1	$0.0	$0.2	$0.1	$0.1	$0.1
Acute bronchitis (children, 8-12)		$0.3	$0.0	$0.4	$0.1	$0.2	$0.2
Lower respiratory symptoms (children, 7-14)		$0.3	$0.0	$0.3	$0.1	$0.1	$0.1
Upper respiratory symptoms (asthmatic children, 9-11)		$0.2	$0.0	$0.2	$0.1	$0.1	$0.1
Asthma exacerbations		$0.3	$0.0	$0.4	$0.2	$0.2	$0.2
Work loss days (adults, 18-65)		$6.7	$0.0	$7.9	$3.3	$3.6	$3.4
Minor restricted activity days (adults, age 18-65)		$16.7	$0.0	$19.6	$8.3	$9.0	$8.5
Totals	3%	$2,516.0	$0.0	$2,766.3	$993.5	$1,731.2	$1,672.0
	7%	$2,147.2	$0.0	$2,359.4	$849.0	$1,473.1	$1,422.6

* Atlanta attains 15/35 with no incremental controls beyond the regulatory base case and those necessary to attain 15/65; as such no incremental benefits accrue.
**Shading indicates Atlanta unable to attain 15/30 with urban controls. Benefits to partial attainment with the standards.

Table A-14. Mortality Threshold Senstivity Analysis for Atlanta Urban Area Attainment Scenarios

Certainty Regarding Benefits Above Assumed Threshold	*Level of Assumed Threshold**	*Reductions in Mortality Incidence* Urban Area Emissions Reductions Only			Urban Area Emissions Reductions with Alternative Regional Emissions Reduction Baselines	
		15/35**	15/30	14/35	15/30	14/35
More Certain	15 μg/m^3 [a]	0	0	0	0	0
	10 μg/m^3 [b]	0	444	183	230	219
	7.5 μg/m^3 [c]	0	478	170	301	291
Less Certain	3 μg/m^3 [d]	0	493	172	334	323

[a] Current NAAQS
[b] CASAC (2005)
[c] SAB-HES (2004)
[d] NAS (2002)
*****Note that the threshold is the cutpoint below which no benefits acrue
** Atlanta attains the 15/35 standard alternative under the regulatory base case plus the same controls necessary to meet the 15/65 standard; as such, no incremental benefits accrue.

Table A-15. Mortality Threshold Sensitivity Analysis for Atlanta Urban Area Attainment Scenarios

			Value of Reductions in Mortality Risk				
			Urban Area Emissions Reductions Only			*Urban Area Emissions Reductions with Alternative Regional Emissions Reduction Baselines*	
Certainty Regarding Benefits Above Assumed Threshold	*Level of Assumed Threshold**	*Discount Rate*	15/35**	15/30	14/35	15/30	14/35
More Certain	15 µg/m^{3} [a]	3%	$0	$0	$0	$0	$0
		7%	$0	$0	$0	$0	$0
	10 µg/m^{3} [b]	3%	$0	$2,468	$1,016	$1,278	$1,220
		7%	$0	$2,077	$855	$1,076	$1,026
	7.5 µg/m^{3} [c]	3%	$0	$2,658	$948	$1,677	$1,621
		7%	$0	$2,236	$798	$1,411	$1,364
	3 µg/m^{3} [d]	3%	$0	$2,744	$959	$1,856	$1,799
Less Certain		7%	$0	$2,309	$807	$1,562	$1,514

[a] Current NAAQS
[b] CASAC (2005)
[c] SAB-HES (2004)
[d] NAS (2002)
*****Note that the threshold is the cutpoint below which no benefits acrue
** No incremental benefits accrue to the 15/35 scenario

Table A-16. Reduction in Mortality Incidence for Atlanta Urban Attainment Scenarios Incremental to Attainment of Current 15/65 Standards Using Expert Judgments Regarding the Distribution of the $PM_{2.5}$ Mortality Concentration Response Function

	Mean	*5th %ile*	*50th %ile*	*95th %ile*
15/65 Urban Area Emissions Reductions Only				
Pope et al (2002)	435	170	435	699
Expert A	372	0	384	699
Expert B	158	0	23	701
Expert C	70	0	14	243
Expert D	298	0	242	776
Expert E	598	0	552	1237
15/35 Urban Area Emissions Reductions Only*				
Pope et al (2002)	0	0	0	0
Expert A	0	0	0	0
Expert B	0	0	0	0
Expert C	0	0	0	0
Expert D	0	0	0	0
Expert E	0	0	0	0
15/30 Urban Area Emissions Reductions Only				
Pope et al (2002)	478	188	478	766
Expert A	403	0	417	756
Expert B	195	0	29	862
Expert C	79	0	15	277
Expert D	323	0	263	839
Expert E	646	0	598	1328
14/35 Urban Area Emissions Reductions Only				
Pope et al (2002)	170	67	171	273
Expert A	141	0	146	264
Expert B	75	0	11	331
Expert C	28	0	5	101
Expert D	113	0	92	293
Expert E	226	0	209	464
15/30 Urban Area Emissions Reductions Only with Regional Emissions Reductions in Baseline				
Pope et al (2002)	301	118	301	485
Expert A	273	0	281	513
Expert B	80	0	12	353
Expert C	47	0	10	157
Expert D	218	0	177	569
Expert E	438	0	405	906
14/35 Urban Area Emissions Reductions Only with Regional Emissions Reductions in Baseline				
Pope et al (2002)	291	114	291	468
Expert A	264	0	273	497
Expert B	76	0	11	335
Expert C	45	0	10	151
Expert D	212	0	172	552
Expert E	425	0	392	879

* Atlanta attains 15/35 with no incremental controls beyond those necessary to attain 15/65. As such, no incremental benefits accrue

Table A-17. Value of Mortality Risk Reduction Benefits Incremental to Attainment of Current 15/65 Standards Using Expert Judgments Regarding the Distribution of the $PM_{2.5}$ Mortality Concentration Response Function for Atlanta

	Mean	*5th %ile*	*50th %ile*	*95th %ile*
15/65 Urban Area Emissions Reductions Only				
Pope et al (2002)	$2,418	$572	$2,240	$4,929
Expert A	$2,067	$0	$1,858	$4,957
Expert B	$878	$0	$6	$4,186
Expert C	$389	$0	$4	$1,578
Expert D	$1,655	$0	$1,158	$5,025
Expert E	$3,328	$0	$2,780	$8,564
15/35 Urban Area Emissions Reductions Only*				
Pope et al (2002)	$0	$0	$0	$0
Expert A	$0	$0	$0	$0
Expert B	$0	$0	$0	$0
Expert C	$0	$0	$0	$0
Expert D	$0	$0	$0	$0
Expert E	$0	$0	$0	$0
15/30 Urban Area Emissions Reductions Only				
Pope et al (2002)	$2,658	$631	$2,465	$5,414
Expert A	$2,241	$0	$2,017	$5,367
Expert B	$1,083	$0	$8	$5,157
Expert C	$438	$0	$4	$1,793
Expert D	$1,794	$0	$1,259	$5,435
Expert E	$3,593	$0	$3,009	$9,215
14/35 Urban Area Emissions Reductions Only				
Pope et al (2002)	$948	$225	$879	$1,932
Expert A	$783	$0	$705	$1,875
Expert B	$415	$0	$3	$1,977
Expert C	$158	$0	$1	$653
Expert D	$627	$0	$440	$1,899
Expert E	$1,256	$0	$1,051	$3,223
15/30 Urban Area Emissions Reductions Only with Regional Emissions Reductions in Baseline				
Pope et al (2002)	$1,677	$397	$1,554	$3,418
Expert A	$1,516	$0	$1,363	$3,634
Expert B	$442	$0	$3	$2,108
Expert C	$260	$0	$3	$1,031
Expert D	$1,214	$0	$849	$3,684
Expert E	$2,439	$0	$2,038	$6,276
14/35 Urban Area Emissions Reductions Only with Regional Emissions Reductions in Baseline				
Pope et al (2002)	$1,621	$384	$1,501	$3,303
Expert A	$1,469	$0	$1,321	$3,523
Expert B	$420	$0	$3	$2,002
Expert C	$250	$0	$3	$993
Expert D	$1,176	$0	$823	$3,571
Expert E	$2,364	$0	$1,976	$6,083

* Atlanta attains 15/35 with no incremental controls beyond those necessary to attain 15/65. As such, no incremental benefits accrue

Chicago Air Quality, Control Cost and Human Health Benefits Results

Following the controls hierarchy, we consider two strategies for Chicago, one that applies urban controls to a baseline including moderate regional emissions controls, and one that applies urban area controls alone. Below we present the results in this sequence, starting first with urban area controls.

Attainment Analysis Using Only Urban Area Controls

Tables A-18 and A-19 present the emission reductions we modeled in the RSM to attempt to reach attainment with each level of the standard under consideration for the urban-only analysis.

Table A-18: RSM Emission Reductions for Chicago Urban Control Scenario: Assumes Innovative Controls at 50th Percentile Cost

	RSM Control Factor and Percentage of Control											
Attainment Target ($\mu g/m^3$)	NOx EGU*	NOx Non-EGU + Area	NOx Mobile	SOx EGU*	SOx Non-EGU Point	SOx Area	VOC	NH_3 Area	NH_3 Mobile	Point Source Carbon	Mobile Source Carbon	Area Source Carbon
15/35												
Urban Controls	---	---	---	80%	80%	80%	---	80%	80%	80%	10%	80%
15/30												
Urban Controls	---	---	---	80%	80%	80%	---	80%	80%	80%	80%	80%
14/35												
Urban Controls	---	---	---	80%	80%	80%	---	80%	80%	80%	80%	80%

Table A-19: RSM Emission Reductions for Chicago Urban Control Scenario: Assumes Innovative Controls at 90th Percentile Cost

	RSM Control Factor and Percentage of Control											
Attainment Target ($\mu g/m^3$)	NOx EGU*	NOx Non-EGU + Area	NOx Mobile	SOx EGU*	SOx Non-EGU Point	SOx Area	VOC	NH3 Area	NH3 Mobile	Point Source Carbon	Mobile Source Carbon	Area Source Carbon
15/35												
Urban Controls	---	---	---	80%	58%	80%	---	---	---	80%	80%	80%
15/30												
Urban Controls	---	---	---	80%	80%	80%	---	80%	80%	80%	80%	80%
14/35												
Urban Controls	---	---	---	80%	80%	80%	---	80%	80%	80%	80%	80%

* Note that when we apply urban-area EGU controls, we assume an 80 percent reduction for the reasons describe in the controls hierarchy section above.

Following our controls hierarchy, we consider Chicago urban area controls alone in this analysis. Our selection of the controls in the preceding table reflects our application of the air quality-effectiveness and cost-effectiveness information—even if, in this instance, we must apply maximum controls for certain RSM emission control factors, the cost-effectiveness information above illuminates which factors to leave uncontrolled. There are two key aspects that guide the strategies for Chicago:

- *Even with maximum local emissions reductions, attainment with tighter standards is not possible without moderate regional reductions in the baseline*. In the absence of regional controls in the baseline, it was necessary to apply the maximum level of urban-scale carbonaceous particle controls available from both AirControlNET and the innovative set in order to get as close to attainment as possible for the 15/30 and 14/35 alternative standards. For all policy options we applied maximum available SO_2, NH_3 and point source carbonaceous particle controls.

- *The 50th and 90th percentile control sets differ for the 15/35 attainment strategy*. The 50th percentile control set applies more SO_2 controls, while the 90th percentile control set applies more carbonaceous particle controls. As discussed above, our method of calculating 50th and 90th percentile control costs affects the cost-effectiveness determination, which in turn affects our selection of controls for each policy option.

Table A-20 indicates that Chicago cannot reach attainment for the 15/30 or 14/35 standard by using local controls alone. Chicago is within about 3 ug/m3 of the daily standard for 15/30 and within about 0.5 ug/m3 of the annual standard.

Table A-20: Chicago Air Quality Results: Urban-Only Analysis

Standard ($\mu g/m^3$)	*Attain?*	*Notes*	*Controlling Standard*	*Remaining Air Quality Increment ($\mu g/m^3$)*
15/35	Yes	No additional measures beyond those necessary to reach attainment with the 15/65 standard are necessary.	Annual	---
15/30	No	Cannot attain with all available local emissions reductions	Daily	2.92
14/35	No	Cannot attain with all available local emissions reductions	Annual	0.73

Attainment Analysis for Urban Area Controls With Regional Controls in the Baseline

Tables A-21 and A-22 present the emission reductions we modeled in the RSM to attempt to reach attainment with each level of the standard under consideration.

Table A-21: RSM Emission Reductions for Chicago Urban and Regional Control Scenario: Assumes Innovative Controls at 50th Percentile Cost

	RSM Control Factor and Percentage of Control											
Attainment Target ($\mu g/m^3$)	NOx EGU*	NOx Non-EGU + Area	NOx Mobile	SOx EGU*	SOx Non-EGU Point	SOx Area	VOC	NH_3 Area	NH_3 Mobile	Point Source Carbon	Mobile Source Carbon	Area Source Carbon
15/30												
Urban Controls	---	---	---	80%	80%	80%	---	80%	76%	80%	80%	80%
Regional Controls**	---	20%	---	20%	20%	20%	---	20%	---	20%	20%	20%
14/35												
Urban Controls	---	---	---	80%	32%	---	---			80%	9%	66%
Regional Controls**	---	20%	---	20%	20%	20%	---	20%	---	20%	20%	20%

*Note that when we apply urban-area EGU controls, we assume an 80 percent reduction for the reasons describe in the controls hierarchy section above.
**Note that these regional controls form a new baseline from which we evaluate the costs and benefits of reaching attainment with urban controls.

Table A-22: RSM Emission Reductions for Chicago Urban and Regional Control Scenario: Assumes Innovative Controls at 90th Percentile Cost

	RSM Control Factor and Percentage of Control											
Attainment Target (μg/m³)	NOx EGU*	NOx Non-EGU + Area	NOx Mobile	SOx EGU*	SOx Non-EGU Point	SOx Area	VOC	NH_3 Area	NH_3 Mobile	Point Source Carbon	Mobile Source Carbon	Area Source Carbon
15/30												
Urban Controls	---	---	---	80%	80%	80%	---	80%	76%	80%	80%	80%
Regional Controls**	---	20%	---	20%	20%	20%	---	20%	---	20%	20%	20%
14/35												
Urban Controls	---	---	---	80%	32%	---	---	---	---	74%	9%	80%
Regional Controls**	---	20%	---	20%	20%	20%	---	20%	---	20%	20%	20%

* Note that when we apply urban-area EGU controls, we assume an 80 percent reduction for the reasons describe in the controls hierarchy section above.
**Note that these regional controls form a new baseline from which we evaluate the costs and benefits of reaching attainment with urban controls.

More stringent policy options require additional urban controls. After moderate reductions in regional emissions, including regional EGU SO_2, it is possible for Chicago to attain both the 15/30 and 14/35 standards, however, attaining 15/30 requires maximum or close to maximum emission reductions in almost all effective factors. Attainment of 14/35 benefits from reductions in urban area EGU SO_2, also requires deep reductions in point and area source carbonaceous particles within the urban area. Controlling urban area NH_3, NOx, or VOCs is not an effective strategy for Chicago.

Table A-23 indicates that Chicago can reach attainment for different levels of the annual and daily standard under consideration if it applies a cost-effective combination of urban and regional controls.

Table A-23: Chicago Air Quality Results: Urban/Regional Analysis

Standard ($\mu g/m^3$)	*Attain?*	*Notes*	*Controlling Standard*	*Remaining Air Quality Increment ($\mu g/m^3$)*
15/30	Yes	Additional urban innovative controls are necessary for attainment.	Daily	---
14/35	Yes	Additional urban innovative controls are necessary for attainment.	Annual	---

Comparison of Control Costs and Monetized Human Health Benefits for Chicago

Table A-24 provides the estimated control costs and benefits at a 3% and 7% discount rate for both the regional-urban and urban-only control hierarchies. Because Chicago is projected to attain the proposed standard of 15/35 with no controls beyond those necessary to attain the current standard, the incremental costs and benefits of attainment are zero. Chicago is not able to attain the 15/30 or 14/35 standards with local controls alone. The benefits of the local controls range from $290 to $340 million. The costs of partial attainment may be substantial, ranging from $200 to $1,000 million. As a result, the partial attainment strategy may have positive or negative net benefits. Clearly, if actual costs are closer to the 90th percentile cost estimates, then more cost-effective technologies, potentially from regional strategies, should be considered. With a 20 percent control on regional emissions, Chicago is able to attain the 15/30 standard, with urban area control costs of $0.5 to $1.6 billion, compared with benefits of $4.8 to $5.6 billion. With regional reductions in the baseline, Chicago is also able to attain the 14/35 standard, at a cost of $0.14 billion to $0.17 billion compared with benefits of $3.8 to $4.6 billion, obtained largely through carbonaceous particle controls, which are highly effective at reducing urban $PM_{2.5}$ concentrations. These strategies depend on the availability of as yet to be identified or developed technologies that can substantially reduce urban emissions of carbonaceous particles, NH3, and SO_2, and the costs depend on these innovative technologies being available at costs within the range of most currently available control technologies.

Table A-24: Benefits and Costs of Attaining Alternative Standards in Chicago Urban Area Incremental to Attainment of the Current 15/65 Standard (Million 1999$)

		Costs of Urban Area Controls (3%)		*Costs of Urban Area Controls (7%)*			
Strategy	*2015 Basecase*	50th Percentile Cost (in millions of 1999$)	90th Percentile Cost (in millions of 1999$)	50th Percentile Cost (in millions of 1999$)	90th Percentile Cost (in millions of 1999$)	Benefits of Urban Area Controls (3%)	Benefits of Urban Area Controls (7%)
Urban-Only Path							
15/35*	Regulatory Baseline	---	---	---	---	---	---
15/30**	Regulatory Baseline	$170	$1,040	$170	$1,040	$290	$340
14/35**	Regulatory Baseline	$170	$1,040	$170	$1,040	$290	$340
Urban/Regional Path****							
15/30	Regulatory Baseline +20% Reduction in Regional NonEGU and EGU Emissions	$450	$1,660	$520	$1,700	$5,620	$4,810
14/35	Regulatory Baseline +20% Reduction in Regional NonEGU and EGU Emissions	$140	$170	$200	$230	$4,470 - $4,580***	$3,820 - $3,920***

* Chicago attains 15/35 with no incremental controls beyond those necessary to attain 15/65.
** Chicago unable to attain 15/30 or 14/35 with local emission reductions alone. Costs and benefits are for partial attainment.
*** Different combinations of factor levels were cost-minimizing using the 50th and 90th percentile cost/ton estimates. The low end of the range of benefits is associated with the mix of controls using the 50th percentile cost/ton and the upper end of the range of benefits is associated with the mix of controls using the 90th percentile cost/ton.
****Note that while this strategy assumes the presence of certain regional controls in the baseline, the costs and benefit estimates reflect air quality improvements from the urban controls alone.

The tables A-25 to A-28 provide detailed estimates of the health impacts and monetized benefits associated with the various attainment strategies and alternative standards for Chicago.[19] It is also worth repeating that these benefits estimates do not reflect the overall benefits of national attainment with the standards, as regional strategies and strategies in other urban areas will likely result in additional air quality improvements and thus additional health benefits beyond those achieved with local emissions reductions alone.

In addition to the tables of primary estimates, we also provide analyses of the sensitivity of mortality impacts to alternative assumptions about possible thresholds in the mortality concentration-response function, for both incidence and monetized value. These sensitivity analyses can be difficult to interpret, because when a threshold above the lowest observed level of $PM_{2.5}$ in the underlying epidemiology study (Pope et al 2002) is assumed, the slope of the concentration-response function above that level must be adjusted upwards to account for the assumed threshold (see NAS, 2002, EPA, 2005 for discussions of this issue). Depending on the amount of slope adjustment and the proportion of the population exposed above the assumed threshold, the estimated mortality impact can either be lower (if most of the exposures occur below the threshold) or higher (if most of the exposures occur above the threshold). In the case of Chicago, annual mean levels are generally higher, and there is a two part pattern to the relationship between assumed threshold and mortality impacts. As the threshold increases from background to 7.5 $\mu g/m^3$, the mortality impact falls (because there is no slope adjustment). However, at an assumed threshold of 10 $\mu g/m^3$, estimated mortality impacts actually increase, because the populations exposed above 10 $\mu g/m^3$ are now assumed to have a larger response to particulate matter reductions (due to the increased slope above the assumed threshold). And finally, mortality impacts again fall to zero if a 15 $\mu g/m^3$ threshold is assumed, because these impacts are being measured incremental to attainment of the current standard.

[19] Note that due to a technical problem, we are unable to estimate impacts on chronic bronchitis for this analysis. In previous RIAs, chronic bronchitis has accounted for around 3 percent of total monetized health benefits. Thus, while important, the omission of these impacts will not substantially alter conclusions regarding net benefits of attainment strategies. We intend to address the technical problem before the final RIA and include chronic bronchitis impacts in the estimates for the final rule.

Table A-25. Estimated Reductions in Incidence of $PM_{2.5}$ Related Health Effects Due to Emissions Reductions in the Chicago Urban Area for Attainment of Alternative $PM_{2.5}$ NAAQS

	Urban Area Emissions Reductions Only					*Urban Area Emissions Reductions with Alternative Regional Emissions Reduction Baselines*		
	Benefits of Urban Area Emissions Reductions to Attain the Current 15/65 Standards		Benefits of Urban Area Emissions Reductions to Attain Alternative Standards Incremental to Attainment of Current 15/65 Standards			Benefits of Urban Area Emissions Reductions to Attain Alternative Standards Incremental to Attainment of Current 15/65 Standards		
Endpoint	15/65		15/35*	15/30	14/35	15/30	14/35	
	50th %ile cost/ton	90th %ile cost/ton					50th %ile cost/ton	90th %ile cost/ton
Premature mortality								
Long-term exposure (adults, 30 and over)	1,400	1,500	0	57	57	990	790	790
Long-term exposure (infant, <1 yr)	4	4	0	0	0	3	2	2
Chronic bronchitis (adults, 26 and over)	NA	NA	0	0	0	NA	NA	NA
Non-fatal myocardial infarctions (adults, 18 and older)	2,900	3,200	0	176	176	1,720	1,420	1,420
Hospital admissions—Respiratory (all ages)	360	400	0	25	25	220	170	180
Hospital admissions—Cardiovascular (adults, >18)	730	790	0	46	46	440	340	350
Emergency Room Visits for Asthma (18 and younger)	1,900	2,100	0	141	141	1,210	910	910
Acute bronchitis (children, 8-12)	2,500	2,800	0	136	136	1,780	1,380	1,480
Lower respiratory symptoms (children, 7-14)	26,000	29,000	0	1,934	1,934	15,800	12,800	12,800
Upper respiratory symptoms (asthmatic children, 9-18)	19,000	21,000	0	1,492	1,492	12,000	9,000	9,000
Asthma Exacerbations (asthmatic children, 6-18)	24,000	26,000	0	1,814	1,814	14,600	11,600	11,600
Work loss days (adults, 18-65)	170,000	180,000	0	12,253	12,253	108,000	78,000	78,000
Minor restricted activity days (adults, age 18-65)	1,000,000	1,100,000	0	71,811	71,811	610,000	470,000	480,000

Note: Shading indicates that Chicago is not able to attain 15/30, or 14/35 with local emissions reductions alone. Benefits are for partial attainment with the standards.
Note: Due to technical difficulties, chronic bronchitis has been omitted from this analysis. This important health endpoint will be evaluated for the final RIA.
* Chicago attains the 15/35 with no incremental controls beyond the regulatory base case and those necessary to attain 15/65; as such no incremental benefits accrue.

Table A-26. Estimated Monetized Health Benefits of Emissions Reductions in the Chicago Urban Area for Attainment of Alternative $PM_{2.5}$ NAAQS

	Urban Area Emissions Reductions Only					*Urban Area Emissions Reductions with Alternative Regional Emissions Reduction Baselines*		
	Benefits of Urban Area Emissions Reductions to Attain the Current 15/65 Standards		Benefits of Urban Area Emissions Reductions to Attain Alternative Standards Incremental to Attainment of Current 15/65 Standards			Benefits of Urban Area Emissions Reductions to Attain Alternative Standards Incremental to Attainment of Current 15/65 Standards		
Endpoint	15/65		15/35*	15/30	14/35	15/30	14/35	
	50th %ile cost/ton	90th %ile cost/ton					50th %ile cost/ton	90th %ile cost/ton
Premature mortality								
Long-term exposure, (adults, >30yrs)								
3% discount rate	$7,537.0	$8,377.2	$0.0	$318.5	$318.5	$5,402.3	$4,295.3	$4,406.2
7% discount rate	$6,341.7	$7,048.6	$0.0	$268.0	$268.0	$4,545.5	$3,614.1	$3,707.4
Long-term exposure (child <1yr)	$24.1	$26.7	$0.0	$1.5	$1.5	$17.5	$13.0	$13.3
Chronic bronchitis (adults, 26 and over)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Non-fatal myocardial infarctions	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
3% discount rate	$245.2	$266.0	$0.0	$14.9	$14.9	$147.0	$116.3	$119.0
7% discount rate	$311.2	$337.6	$0.0	$18.7	$18.7	$186.5	$147.8	$151.3
Hospital Admissions from Respiratory Causes	$2.3	$2.5	$0.0	$0.1	$0.1	$1.4	$1.1	$1.1
Hospital Admissions from Cardiovascular Causes	$14.4	$15.6	$0.0	$0.9	$0.9	$8.7	$6.9	$7.0
Emergency Room Visits for Asthma	$0.5	$0.6	$0.0	$0.0	$0.0	$0.3	$0.2	$0.2
Acute bronchitis (children, 8-12)	$0.9	$1.0	$0.0	$0.0	$0.0	$0.7	$0.5	$0.5
Lower respiratory symptoms (children, 7-14)	$0.8	$0.9	$0.0	$0.1	$0.1	$0.5	$0.4	$0.4
Upper respiratory symptoms (asthmatic children, 9-11)	$0.5	$0.6	$0.0	$0.0	$0.0	$0.3	$0.2	$0.2
Asthma exacerbations	$1.1	$1.1	$0.0	$0.1	$0.1	$0.7	$0.5	$0.5
Work loss days (adults, 18-65)	$20.7	$22.5	$0.0	$1.5	$1.5	$12.7	$9.7	$9.9
Minor restricted activity days (adults, age 18-65)	$51.9	$56.4	$0.0	$3.7	$3.7	$31.8	$24.4	$24.9
Totals 3%	$7,899.5	$8,771.0	$0.0	$341.4	$341.4	$5,623.8	$4,468.5	$4,583.4
7%	$6,770.2	$7,514.0	$0.0	$294.7	$294.7	$4,806.6	$3,818.8	$3,916.9

Note: Shading indicates Chicago is not able to attain 15/30, or 14/35 with local emissions reductions alone. Benefits are for partial attainment with the standards.
* Chicago attains the 15/35 with no incremental controls beyond the regulatory base case and those necessary to attain 15/65; as such no incremental benefits accrue.

Table A-27. Mortality Threshold Sensitivity Analysis for Chicago Urban Area Attainment Scenarios

Certainty Regarding Benefits Above Assumed Threshold	*Level of Assumed Threshold**	**Reductions in Mortality Incidence (incremental to attainment of the 15/65 standard)** *Urban Area Emissions Reductions Only*			*Urban Area Emissions Reductions with Alternative Regional Emissions Reduction Baselines*	
		15/35**	15/30	14/35	15/30	14/35
More Certain						
	15 ug/m3 [a]	0	0	0	0	0
	10 ug/m3 [b]	0	84	84	863	684
	7.5 ug/m3 [c]	0	57	57	971	772
Less Certain	3 ug/m3 [d]	0	56	56	994	802

[a] Current NAAQS
[b] CASAC (2005)
[c] SAB-HES (2004)
[d] NAS (2002)
* Assumed threshold is the cutpoint below which no benefits accrue
** Chicago attains the 15/35 with no incremental controls beyond the regulatory base case and those necessary to attain 15/65; as such no incremental benefits accrue.

Table A-28. Value of Mortality Risk Reductions Threshold Sensitivity Analysis for Chicago Urban Area Attainment Scenarios

Certainty Regarding Benefits Above Assumed Threshold	*Level of Assumed Threshold**	*Discount Rate*	**Value of Reductions in Mortality Risk (incremental to attainment of the 15/65 standards)** *Urban Area Emissions Reductions Only* 15/35**	15/30	14/35	*Urban Area Emissions Reductions with Alternative Regional Emissions Reduction Baselines* 15/30	14/35
More certain	15 $\mu g/m^3$ [a]	3%	$0	$0	$0	$0	$0
		7%	$0	$466	$466	$4,802	$3,805
	10 $\mu g/m^3$ [b]	3%	$0	$392	$392	$4,041	$3,201
		7%	$0	$318	$318	$5,402	$4,295
	7.5 $\mu g/m^3$ [c]	3%	$0	$268	$268	$4,546	$3,614
		7%	$0	$310	$310	$5,530	$4,463
	3 $\mu g/m^3$ [d]	3%	$0	$261	$261	$4,653	$3,755
Less Certain		7%	$0	$0	$0	$0	$0

[a] Current NAAQS
[b] CASAC (2005)
[c] SAB-HES (2004)
[d] NAS (2002)
*****Note that the threshold is the cutpoint below which no benefits acrue
** Chicago attains the 15/35 with no incremental controls beyond the regulatory base case and those necessary to attain 15/65; as such no incremental benefits accrue.

New York/Philadelphia Air Quality, Control Cost and Human Health Benefits Results

Following the controls hierarchy, we consider two strategies for New York/Philadelphia, one that applies urban controls to a baseline including moderate regional emissions controls, and one that applies urban area controls alone. Below we present the results in this sequence, starting first with urban area controls.

Attainment Analysis Using Only Urban Area Controls

Table A-29 below presents the emission reductions we modeled in the RSM to attempt to reach attainment in New York/Philadelphia with each level of the standard under consideration for the urban-only analysis.

Table A-29: RSM Emission Reductions for New York/Philadelphia Urban Control Scenario: Assumes Innovative Controls at 50th and 90th Percentile Cost

	RSM Control Factor and Percentage of Control											
Attainment Target ($\mu g/m^3$)	NOx EGU*	NOx Non-EGU + Area	NOx Mobile	SOx EGU*	SOx Non-EGU Point	SOx Area	VOC	NH_3 Area	NH_3 Mobile	Point Source Carbon	Mobile Source Carbon	Area Source Carbon
15/35												
Urban Controls	---	---	---	---	16%	---	---	---	---	5%	9%	51%
15/30												
Urban Controls	---	---	---	80%	80%	---	80%	---	80%	5%	80%	80%
14/35												
Urban Controls	---	---	---	---	16%	---	---	---	---	5%	9%	51%

* Note that when we apply urban-area EGU controls, we assume an 80 percent reduction for the reasons describe in the controls hierarchy section above.

Two key aspects of these local controls for New York/Philadelphia controls reflect our use of the cost-effectiveness and air-quality effectiveness data:

- *Attainment with the proposed 15/35 standard or the alternative 14/35 standard is possible with a combination of local non-EGU SO2 and carbonaceous particle emission reductions.* These controls include only those identified within AirControlNet and do not use any emission reductions associated with unidentified controls.

- *Even with maximum local emissions reductions, attainment with the 15/30 alternative standard is not possible without regional reductions in the baseline*. In the absence of regional controls in the baseline, it was necessary to apply the maximum level of urban-scale controls available from both AirControlNET and the innovative set in order to get as close to attainment as possible to the 15/30 alternative standards

Table A-302 indicates that New York/Philadelphia can meet each level of the standard with urban-only controls, except for 15/30. This urban area is out of attainment by about 3 ug/m3 with the daily standard for the 15/30 option.

Table A-30: New York/Philadelphia Air Quality Results: Urban-Only Analysis

Standard ($\mu g/m^3$)	*Attain?*	*Notes*	*Controlling Standard*	*Remaining Air Quality Increment ($\mu g/m^3$)*
15/35	Yes	Attains the standard with local AirControlNet measures alone.	Daily	---
15/30	No	Cannot attain with all available local emissions reductions	Daily	3.07
14/35	Yes	Attains the standard with local AirControlNet measures alone.	Annual	---

Attainment Analysis for Urban Area Controls With Regional Controls in the Baseline

Tables A-31 and A-32 present the emission reductions we modeled in the RSM to attempt to reach attainment with each level of the standard under consideration.

Table A-31: RSM Emission Reductions for New York/Philadelphia Urban and Regional Control Scenario: Assumes Innovative Controls at 50th Percentile Cost

	RSM Control Factor and Percentage of Control											
Attainment Target ($\mu g/m^3$)	NOx EGU*	NOx Non-EGU + Area	NOx Mobile	SOx EGU*	SOx Non-EGU Point	SOx Area	VOC	NH_3 Area	NH_3 Mobile	Point Source Carbon	Mobile Source Carbon	Area Source Carbon
15/30												
Urban Controls	---	---	---	80%	80%	---	---	---	---	80%	11%	80%
Regional Controls**	---	---	---	20%	20%	20%	---	20%	---	20%	20%	20%
14/35												
Urban Controls	---	---	---	---	16%	---	---	---	---	5%	9%	51%
Regional Controls	---	---	---	---	---	---	---	---	---	---	---	---

* Note that when we apply urban-area EGU controls, we assume an 80 percent reduction for the reasons describe in the controls hierarchy section above.
**Note that these regional controls form a new baseline from which we evaluate the costs and benefits of reaching attainment with urban controls.

Table A-32: RSM Emission Reductions for New York/Philadelphia Urban and Regional Control Scenario: Assumes Innovative Controls at 90th Percentile Cost

	RSM Control Factor and Percentage of Control											
Attainment Target (µg/m³)	NOx EGU*	NOx Non-EGU + Area	NOx Mobile	SOx EGU*	SOx Non-EGU Point	SOx Area	VOC	NH_3 Area	NH_3 Mobile	Point Source Carbon	Mobile Source Carbon	Area Source Carbon
15/30												
Urban Controls	---	---	---	80%	11%	---	---	---	---	48%	11%	21%
Regional Controls**	---	---	---	20%	20%	20%	---	20%	---	20%	20%	20%
14/35												
Urban Controls	---	---	---	---	16%	---	---	---	---	5%	9%	51%
Regional Controls	---	---	---	---	---	---	---	---	---	---	---	---

* Note that when we apply urban-area EGU controls, we assume an 80 percent reduction for the reasons describe in the controls hierarchy section above.
** Note that these regional controls form a new baseline from which we evaluate the costs and benefits of reaching attainment with urban controls.

As with the previous urban analyses, we applied control factors on the basis of both the controls hierarchy and the cost-effectiveness information. Because New York can reach attainment with local controls only for 15/35 and 14/35, no regional control alternative baselines were analyzed for those standards. For the 15/30 alternative standard, two key aspects are important in our strategy design:

- *Local carbonaceous particle controls are effective for most levels of the standard*. Carbonaceous particle controls in particular are highly cost-effective for New York/Philadelphia. Thus after adding regional controls to the baseline, we still added additional carbonaceous particle controls to reach attainment in a cost-effective manner.

- *Local EGU and non-EGU SO_2 reductions are also beneficial*. These controls, in combination with carbonaceous particle controls, effectively attain even the 15/30 standards.

Table A-33 indicates that New York/Philadelphia can meet each standard option with a combination of cost-effective urban and regional controls.

Table A-33: New York/Philadelphia Air Quality Results: Regional-Urban Analysis

Standard ($\mu g/m^3$)	*Attain?*	*Notes*	*Controlling Standard*	*Remaining Air Quality Increment ($\mu g/m^3$)*
15/30	Yes	Additional urban reductions are necessary for attainment.	Daily	---
14/35	Yes	Attains the standard with local AirControlNet measures alone.	Annual	---

Comparison of Control Costs and Monetized Human Health Benefits for New York/Philadelphia

Table A-34 below provides the estimated control costs and benefits at a 3% and 7% discount rate for both the regional-urban and urban-only control hierarchies. The New York/Philadelphia urban area is not able to attain the 15/30 standards with local controls alone, but the benefits of the local controls are still substantial, ranging from \$9.8 to \$11.6 billion. The costs of partial attainment may also be substantial, ranging from \$7.7 to \$27.8 billion, although these costs are dominated by the high costs of VOC controls which are applied to obtain the last increment of air quality reduction. These VOC controls account for \$2 billion of the costs using the 50^{th} percentile cost/ton estimate and \$21 billion of the costs using the 90^{th} percentile cost estimate.

Removing these controls would only increase the nonattainment increment by 0.2 $\mu g/m^3$, which would have a relatively small impact on total benefits. Rational implementation policies may choose to limit the acceptable cost per-ton or per microgram of improvement. As such it would be likely that partial attainment strategies would be less costly than we have predicted. As a result, the partial attainment strategy may have positive or negative net benefits. Clearly, if actual costs are closer to the 90th percentile cost estimates, then more cost-effective technologies, potentially from regional strategies, should be considered. With a 20 percent control on regional emissions, New York is able to attain the 15/30 standard, with urban area control costs of approximately \$5 billion, compared with benefits of \$8 to \$10 billion. The New York/Philadelphia urban area is able to attain 15/35 and 14/35 with only currently identified local controls on nonEGU SO_2 and carbonaceous particles, at an estimated cost approximately \$4.2 billion, compared with benefits of \$2.5 to \$2.9 billion. In the analysis for the final rule, we will be able to more carefully select controls using available cost information, and we plan to develop more optimized attainment strategies that exclude those controls that are clearly not cost-effective.

Table A-34 Benefits and Costs of Attaining Alternative Standards in New York/Philadelphia Urban Area Incremental to Attainment of the Current 15/65 Standard (Million 1999$)

		Costs of Urban Area Controls (3%)		*Costs of Urban Area Controls (7%)*			
Strategy	*2015 Basecase*	50th Percentile Cost (in millions of 1999$)	90th Percentile Cost (in millions of 1999$)	50th Percentile Cost (in millions of 1999$)	90th Percentile Cost (in millions of 1999$)	*Benefits of Urban Area Controls (3%)*	*Benefits of Urban Area Controls (7%)*
<u>Urban-Only Path</u>							
15/35	Regulatory Baseline	$4,230	$4,230	$4,290	$4,290	$2,950	$2,520
15/30*	Regulatory Baseline	$7,730	$27,800	$7,970	$28,300	$11,570	$9,830
14/35	Regulatory Baseline	$4,230	$4,230	$4,290	$4,290	$2,950	$2,520
<u>Urban/Regional Path</u>**							
15/30	Regulatory Baseline + 20% Reduction in Regional NonEGU and EGU Emissions	$5,160	$5,340	$5,400	$5,860	$9,620	$8,130
14/35	Regulatory Baseline + 20% Reduction in Regional NonEGU and EGU Emissions	$4,230	$4,230	$4,290	$4,290	$2,950	$2,520

* New York/Philadelphia unable to attain 15/30 with local emission reductions alone. Costs and benefits are for partial attainment.

**Note that while this strategy assumes the presence of certain regional controls in the baseline, the costs and benefit estimates reflect air quality improvements from the urban controls alone.

The next set of tables provides detailed estimates of the health impacts and monetized benefits associated with the various attainment strategies and alternative standards for Chicago.[20] It is also worth repeating that these benefits estimates do not reflect the overall benefits of national attainment with the standards, as regional strategies and strategies in other urban areas will likely result in additional air quality improvements and thus additional health benefits beyond those achieved with local emissions reductions alone.

In addition to the tables of primary estimates, we also provide analyses of the sensitivity of mortality impacts to alternative assumptions about possible thresholds in the mortality concentration-response function, for both incidence and monetized value. These sensitivity analyses can be difficult to interpret, because when a threshold above the lowest observed level of $PM_{2.5}$ in the underlying epidemiology study (Pope et al 2002) is assumed, the slope of the concentration-response function above that level must be adjusted upwards to account for the assumed threshold (see NAS, 2002, EPA, 2005 for discussions of this issue). Depending on the amount of slope adjustment and the proportion of the population exposed above the assumed threshold, the estimated mortality impact can either be lower (if most of the exposures occur below the threshold) or higher (if most of the exposures occur above the threshold). In the case of New York/Philadelphia, annual mean levels are generally higher, and there is a two part pattern to the relationship between assumed threshold and mortality impacts. As the threshold increases from background to 7.5 $\mu g/m^3$, the mortality impact falls (because there is no slope adjustment). However, at an assumed threshold of 10 $\mu g/m^3$, estimated mortality impacts actually increase, because the populations exposed above 10 $\mu g/m^3$ are now assumed to have a larger response to particulate matter reductions (due to the increased slope above the assumed threshold). And finally, mortality impacts again fall dramatically if a 15 $\mu g/m^3$ threshold is assumed, because these impacts are being measured incremental to attainment of the current standard. There is a small residual impact in the 14/35 and 15/30 cases because the deep reductions in local emission reductions provides reductions in downwind areas that still exceed the 15 $\mu g/m^3$ standard (if all areas were assumed to be in attainment with15 $\mu g/m^3$ then the benefits would be zero above a 15 $\mu g/m^3$ threshold be definition).

[20] Note that due to a technical problem, we are unable to estimate impacts on chronic bronchitis for this analysis. In previous RIAs, chronic bronchitis has accounted for around 3 percent of total monetized health benefits. Thus, while important, the omission of these impacts will not substantially alter conclusions regarding net benefits of attainment strategies. We intend to address the technical problem before the final RIA and include chronic bronchitis impacts in the estimates for the final rule.

Table A-35. Estimated Reductions in Incidence of $PM_{2.5}$ Related Health Effects Due to Emissions Reductions in the New York/Philadelphia Urban Area for Attainment of Alternative $PM_{2.5}$ NAAQS

	Urban Area Emissions Reductions Only				*Urban Area Emissions Reductions with Alternative Regional Emissions Reduction Baselines*	
	Reductions due to Urban Area Emissions Reductions to Attain the Current 15/65 Standards	Reductions due to Urban Area Emissions Reductions to Attain Alternative Standards Incremental to Attainment of Current 15/65 Standards			Reductions due to Urban Area Emissions Reductions to Attain Alternative Standards Incremental to Attainment of Current 15/65 Standards	
Endpoint	15/65*	15/35	15/30	14/35	15/30	14/35
Premature mortality						
Long-term exposure (adults, 30 and over)	0	510	2,000	510	1,700	NA
Long-term exposure (infant, <1 yr)	0	1	4	1	3	NA
Chronic bronchitis (adults, 26 and over)	0	0	0	0	0	NA
Non-fatal myocardial infarctions (adults, 18 and older)	0	920	2,400	920	730	NA
Hospital admissions—Respiratory (all ages)	0	110	290	110	86	NA
Hospital admissions—Cardiovascular (adults, >18)	0	220	590	220	180	NA
Emergency Room Visits for Asthma (18 and younger)	0	250	710	250	210	NA
Acute bronchitis (children, 8-12)	0	890	3,400	890	2,800	NA
Lower respiratory symptoms (children, 7-14)	0	6,500	17,000	6,500	4,900	NA
Upper respiratory symptoms (asthmatic children, 9-18)	0	4,700	12,000	4,700	3,600	NA
Asthma Exacerbations (asthmatic children, 6-18)	0	5,900	15,000	5,900	4,500	NA
Work loss days (adults, 18-65)	0	44,000	110,000	44,000	34,000	NA
Minor restricted activity days (adults, age 18-65)	0	260,000	690,000	260,000	200,000	NA

* New York/Philadelphia attains the current 15/65 under the regulatory base case.
Note: New York/Philadelphia attains 14/35 with identified local emission reduction strategies. Thus, no analysis of attainment with alternative regional reductions in the baseline was conducted for 14/35.
Note: Shading indicates New York/Philadelphia unable to attain 15/30 with local emissions only. Health impacts are for partial attainment with the 15/30 standard.
Note: Due to technical difficulties, chronic bronchitis has been omitted from this analysis. This important health endpoint will be evaluated for the final RIA.

Table A-36. Estimated Monetized Health Benefits of Emissions Reductions in the New York/Philadelphia Urban Area for Attainment of Alternative $PM_{2.5}$ NAAQS

		Urban Area Emissions Reductions Only				*Urban Area Emissions Reductions with Alternative Regional Emissions Reduction Baselines*	
		Benefits of Urban Area Emissions Reductions to Attain the Current 15/65 Standards	Benefits of Urban Area Emissions Reductions to Attain Alternative Standards Incremental to Attainment of Current 15/65 Standards			Benefits of Urban Area Emissions Reductions to Attain Alternative Standards Incremental to Attainment of Current 15/65 Standards	
Endpoint		15/65*	15/35	15/30	14/35	15/30	14/35
Premature mortality							
Long-term exposure, (adults, >30yrs)							
3% discount rate		$0	$2,840	$11,281	$2,840	$9,520	NA
7% discount rate		$0	$2,390	$9,492	$2,390	$8,010	NA
Long-term exposure (child <1yr)		$0	$6	$23	$6	$19	NA
Chronic bronchitis (adults, 26 and over)		$0	$0	$0	$0	$0	NA
Non-fatal myocardial infarctions		$0	$0	$0	$0	$0	NA
3% discount rate		$0	$76	$196	$76	$60	NA
7% discount rate		$0	$97	$251	$97	$77	NA
Hospital Admissions from Respiratory Causes		$0	$1	$2	$1	$1	NA
Hospital Admissions from Cardiovascular Causes		$0	$4	$12	$4	$4	NA
Emergency Room Visits for Asthma		$0	$0	$0	$0	$0	NA
Acute bronchitis (children, 8-12)		$0	$0	$1	$0	$1	NA
Lower respiratory symptoms (children, 7-14)		$0	$0	$1	$0	$0	NA
Upper respiratory symptoms (asthmatic children, 9-11)		$0	$0	$0	$0	$0	NA
Asthma exacerbations		$0	$0	$1	$0	$0	NA
Work loss days (adults, 18-65)		$0	$5	$14	$5	$4	NA
Minor restricted activity days (adults, age 18-65)		$0	$13	$35	$13	$10	NA
Totals	3%	$0	$2,947	$11,566	$2,947	$9,619	NA
	7%	$0	$2,517	$9,831	$2,517	$8,127	NA

* New York/Philadelphia attains the current 15/65 under the regulatory base case..

Note: New York/Philadelphia attains 15/35 and 14/35 with identified local emission reduction strategies. Thus, no analysis of attainment with alternative regional reductions in the baseline was conducted for 15/35 or 14/35.

Note: Shading indicates New York/Philadelphia unable to attain 15/30 with local emissions only. Health impacts are for partial attainment with the 15/30 standard.

Note: Due to technical difficulties, chronic bronchitis has been omitted from this analysis. This important health endpoint will be evaluated for the final RIA.

Table A-37. Mortality Threshold Sensitivity Analysis for New York/Philadelphia Urban Area Attainment Scenarios

Certainty Regarding Benefits Above Assumed Threshold	*Level of Assumed Cutpoint**	*Reductions in Mortality Incidence (incremental to attainment of the 15/65 standard)*				
		Urban Area Emissions Reductions Only			Urban Area Emissions Reductions with Alternative Regional Emissions Reduction Baselines	
		15/35	15/30	14/35	15/30	14/35
More Certain	15 µg/m³ [a]	0	0	0	0	NA
	10 µg/m³ [b]	394	1092	394	352	NA
	7.5 µg/m³ [c]	510	2028	510	1,711	NA
Less Certain	3 µg/m³ [d]	511	2032	511	1,735	MA

[a] Current NAAQS
[b] CASAC (2005)
[c] SAB-HES (2004)
[d] NAS (2002)
*****The threshold is the cutpoint below which no benefits acrue

Table A-38. Value of Mortality Risk Reductions Threshold Sensitivity Analysis for New York/Philadelphia Urban Area Attainment Scenarios

Certainty Regarding Benefits Above Assumed Threshold	*Level of Assumed Threshold**	*Discount Rate*	*Value of Reductions in Mortality Risk (incremental to attainment of the 15/65 standards)* Urban Area Emissions Reductions Only 15/35	15/30	14/35	Urban Area Emissions Reductions with Alternative Regional Emissions Reduction Baselines 15/30	14/35
More Certain	15 µg/m³ [a]	3%	$0	$0	$0	$0	NA
		7%	$0	$0	$0	$0	NA
	10 µg/m³ [b]	3%	$2,192	$6,076	$2,192	$1,960	NA
		7%	$1,844	$5,112	$1,844	$1,649	NA
	7.5 µg/m³ [c]	3%	$2,840	$11,281	$2,840	$9,520	NA
		7%	$2,390	$9,492	$2,390	$8,010	NA
	3 µg/m³ [d]	3%	$2,841	$11,306	$2,841	$9,655	NA
Less Certain		7%	$2,390	$9,513	$2,390	$8,124	NA

Note: In cases where benefits are estimated using both the 50th percentile cost/ton scenario and 90th percentile cost/ton scenario, the sensitivity analysis is performed on the 50th percentile cost/ton scenario.

*****The threshold is the cutpoint below which no benefits acrue

[a] Current NAAQS

[b] CASAC (2005)

[c] SAB-HES (2004)

[d] NAS (2002)

Seattle Air Quality, Control Cost and Human Health Benefits Results

Following the controls hierarchy, we consider two strategies for Seattle, one that applies urban controls to a baseline including moderate regional emissions controls, and one that applies urban area controls alone. Below we present the results in this sequence, starting first with urban area controls.

Attainment Analysis Using Only Urban Area Controls

Table A-39 below presents the emission reductions we modeled in the RSM to attempt to reach attainment in Seattle with each level of the standard under consideration for the urban-only analysis.

Table A-39: RSM Emission Reductions for Seattle Urban Control Scenario: Assumes Innovative Controls at 50th and 90th Percentile Cost

Attainment Target ($\mu g/m^3$)	*RSM Control Factor and Percentage of Control*											
	NOx EGU*	NOx Non-EGU + Area	NOx Mobile	SOx EGU*	SOx Non-EGU Point	SOx Area	VOC	NH_3 Area	NH_3 Mobile	Point Source Carbon	Mobile Source Carbon	Area Source Carbon
15/35												
Urban Controls	---	39%	---	80%	---	80%	---	---	---	80%	46%	80%
15/30												
Urban Controls	---	80%	---	80%	---	80%	---	80%	80%	80%	80%	80%
14/35												
Urban Controls	---	39%	---	80%	---	80%	---	---	---	80%	46%	80%

* Note that when we apply urban-area EGU controls, we assume an 80 percent reduction for the reasons described in the controls hierarchy section above.

We selected the control factors above based on the information in the previous subsections regarding the cost-effectiveness of various controls. Two key aspects of these local controls for Seattle controls reflect our use of the cost-effectiveness and air-quality effectiveness data:

- *Seattle is dominated by the daily standard, and may need significant emission reductions to meet the 15/30 standards*.

- *Even with maximum local emissions reductions, attainment with the 15/30 alternative standard is not possible without moderate regional reductions in the baseline*. In the absence of regional controls in the baseline, it was necessary to apply the maximum level of urban-scale controls available from both AirControlNET and the innovative set in order to get as close to attainment as possible for the 15/30 alternative standards.

- *Carbonaceous particle controls are cost-effective*. All of our strategies utilize carbonaceous particle controls.

Table A-40 below indicates that with an urban-only strategy, Seattle is able to reach attainment for all levels of the daily and annual standard except 15/30. Seattle is able to attain a 14 µg/m3 under baseline conditions, so the daily standard is controlling. Thus, there is no incremental difference between the control strategy for the 15/35 and 14/35 standards.

Table A-40: Seattle Air Quality Results: Urban-Only Analysis

Standard ($\mu g/m^3$)	*Attain?*	*Notes*	*Controlling Standard*	*Remaining Air Quality Increment ($\mu g/m^3$)*
15/35	Yes	Additional innovative urban controls are necessary for attainment. Factor levels are identical using either the 50th percentile cost/ton or the 90th percentile cost/ton.	Daily	---
15/30	No	Cannot attain with all available local emissions reductions	Daily	3.51
14/35	Yes	Attains with same additional local controls as necessary for 15/35	Daily	---

Attainment Analysis for Urban Area Controls With Regional Controls in the Baseline

Table A-41 presents the emission reductions we modeled in the RSM to attempt to reach attainment with each level of the standard under consideration.

Table A-41: RSM Emission Reductions for Seattle Urban and Regional Control Scenario: Assumes Innovative Controls at 50th and 90th Percentile Cost

	RSM Control Factor and Percentage of Control											
Attainment Target (μg/m³)	NOx EGU*	NOx Non-EGU + Area	NOx Mobile	SOx EGU*	SOx Non-EGU Point	SOx Area	VOC	NH_3 Area	NH_3 Mobile	Point Source Carbon	Mobile Source Carbon	Area Source Carbon
15/35												
Urban Controls	---	39%	---	---	---	---	---	---	---	33%	9%	56%
Regional Controls**	---	20%	---	---	20%	---	---	20%	20%	20%	20%	20%
15/30												
Urban Controls	---	80%	---	80%	---	80%	---	80%	80%	80%	80%	80%
Regional Controls**	20%	20%	20%	20%	20%	---	---	20%	20%	20%	20%	20%
14/35												
Urban Controls	---	39%	---	---	---	---	---	---	---	33%	9%	56%
Regional Controls**	---	20%	---	---	20%	---	---	20%	20%	20%	20%	20%

* Note that when we apply urban-area EGU controls, we assume an 80 percent reduction for the reasons describe in the controls hierarchy section above.
** Note that these regional controls form a new baseline from which we evaluate the costs and benefits of reaching attainment with urban controls.

As with the previous urban-scale analyses, we selected controls on the basis of their cost-effectiveness and air quality-effectiveness. A few key aspects of these local and regional Seattle controls reflect our use of these data:

- *When moderate regional emissions reductions are included in the baseline, AirControlNet identified controls are sufficient to reach attainment with 15/35 and 14/35.* Only non-EGU NOx and directly emitted carbonaceous particles are controlled to reach attainment with the largest reduction in area source emissions of carbonaceous particles.

- *Even with maximum local emissions reductions, attainment with the 15/30 alternative standard is not possible*. However, we have likely understated the contribution of mobile source carbonaceous emissions to peak $PM_{2.5}$ concentrations, and thus understated the ability of mobile source controls to reduce peak concentrations. In addition, our RSM modeling excluded controls on directly emitted non-carbonaceous particles, which may contribute to nonattainment on peak days (see the AERMOD local-scale modeling appendix for details).

- *In areas like Seattle, the portion of regional reductions likely to impact air quality is limited*. Because of Seattle's topography, "regional" contribution is likely to come from emissions within or very near to the borders of the State of Washington. This is in contrast to cities in the Eastern U.S., where emissions from hundreds of kilometers upwind can have impacts on local air quality.

Table A-42 below indicates that the Seattle analysis is able to simulate attainment for all standard options except 15/30 through urban controls with regional emission reductions included in the baseline. For the 15/30 standard option, these controls would leave the area about 2 $\mu g/m^3$ above the daily standard

Table A-42: Seattle Air Quality Results: Regional-Urban Analysis

Standard ($\mu g/m^3$)	*Attain?*	*Notes*	*Controlling Standard*	*Remaining Air Quality Increment ($\mu g/m^3$)*
15/35	Yes	Requires regional nonEGU emissions reduction and existing AirControlNET measures to reach attainment. No local EGU or additional innovative urban reductions are necessary.	Daily	---
15/30	No	Cannot attain with all available urban emissions reductions and regional controls in the baseline	Daily	1.72
14/35	Yes	Attains with same additional urban controls as necessary for 15/35	Daily	---

Comparison of Control Costs and Monetized Human Health Benefits for Seattle

Tables A-43 through A-47 below provide the estimated control costs and benefits at a 3% and 7% discount rate for both the regional-urban and urban-only control hierarchies. We were able to demonstrate attainment of the 15/35 and 14/35 standards with urban area emissions reductions alone. Estimated costs range from $750 to $760 million, compared with benefits of $450 to $540 million. The relatively low benefits are due to the smaller population affected by air pollution in the Seattle area, and the relatively low annual average concentrations in Washington. As with other urban areas, the relatively high costs are dominated by the high costs of mobile source carbonaceous particles included in the set of identified controls within AirControlNet. To the extent that these costs are overestimated, costs of control will be much closer to benefits. Adding moderate regional controls to the baseline offsets the need for local controls beyond those identified with AirControlNet, but total costs fall only by $40 to $50 million, because of the large portion of total costs accounted for by the most expensive mobile source controls.

The Seattle urban area is not able to attain the 15/30 standards with urban are controls, even with moderate regional reductions in the baseline. Benefits of partial attainment range from $660 to $780 million, while costs range from $820 to $1,210 million. Again, these costs are dominated by the high costs of a few mobile source carbonaceous particle controls. Rational implementation policies may choose to limit the acceptable cost per-ton or per microgram of improvement. As such it would be likely that partial attainment strategies would be less costly than we have predicted. As a result, the partial attainment strategy may have positive or negative net benefits. Clearly, if actual costs are closer to the 90th percentile cost estimates, then more cost-effective technologies, potentially from regional strategies, should be considered. In the analysis for the final rule, we will be able to more carefully select controls using available cost information, and we plan to develop more optimized attainment strategies that exclude those controls that are clearly not cost-effective.

Table A-43: Benefits and Costs of Attaining Alternative Standards in the Seattle Urban Area Incremental to Attainment of the Current 15/65 Standard (Million 1999$)

		Costs of Urban Area Controls (3%)		*Costs of Urban Area Controls (7%)*			
Strategy	*2015 Basecase*	50th Percentile Cost (in millions of 1999$)	90th Percentile Cost (in millions of 1999$)	50th Percentile Cost (in millions of 1999$)	90th Percentile Cost (in millions of 1999$)	Benefits of Urban Area Controls (3%)	Benefits of Urban Area Controls (7%)
Urban-Only Path							
15/35	Regulatory Baseline	$750	$760	$760	$770	$540	$450
15/30*	Regulatory Baseline	$820	$1,210	$830	$1,230	$780	$660
14/35	Regulatory Baseline	$750	$760	$760	$770	$540	$450
Urban/Regional Path**							
15/35	Regulatory Baseline + 20% Reduction in Regional NonEGU Emissions	$710	$710	$720	$720	$230	$190
15/30*	Regulatory Baseline + 20% Reduction in Regional NonEGU Emissions	$820	$1,210	$830	$1,230	$720	$610
14/35	Regulatory Baseline + 20% Reduction in Regional NonEGU Emissions	$710	$710	$720	$720	$230	$190

* Seattle unable to attain 15/30 with local emission reductions alone, either with or without a 20 percent reduction in regional emissions in the basecase. Costs and benefits are for partial attainment.

**Note that while this strategy assumes the presence of certain regional controls in the baseline, the costs and benefit estimates reflect air quality improvements from the urban controls alone.

Table A-44. Estimated Reductions in Incidence of $PM_{2.5}$ Related Health Effects Due to Emissions Reductions in the Seattle Urban Area for Attainment of Alternative $PM_{2.5}$ NAAQS

	Urban Area Emissions Reductions Only				*Urban Area Emissions Reductions with Alternative Regional Emissions Reduction Baselines*			
	Reductions due to Urban Area Emissions Reductions to Attain the Current 15/65 Standards	Reductions due to Urban Area Emissions Reductions to Attain Alternative Standards Incremental to Attainment of Current 15/65 Standards			Reductions due to Urban Area Emissions Reductions to Attain the Current 15/65 Standards	Reductions due to Urban Area Emissions Reductions to Attain Alternative Standards Incremental to Attainment of Current 15/65 Standards		
Endpoint	15/65*	15/35	15/30	14/35	15/65*	15/35	15/30	14/35
Premature mortality								
Long-term exposure (adults, 30 and over)	0	97	140	97	0	41	130	41
Long-term exposure (infant, <1 yr)	0	0	0	0	0	0	0	0
Chronic bronchitis (adults, 26 and over)	0	NA	NA	NA	0	NA	NA	NA
Non-fatal myocardial infarctions (adults, 18 and older)	0	1	1	1	0	0	0	0
Hospital admissions—Respiratory (all ages)c	0	0	0	0	0	0	0	0
Hospital admissions—Cardiovascular (adults, >18)	0	0	0	0	0	0	0	0
Emergency Room Visits for Asthma (18 and younger)	0	0	0	0	0	0	0	0
Acute bronchitis (children, 8-12)	0	190	280	190	0	81	250	81
Lower respiratory symptoms (children, 7-14)	0	13	15	13	0	-1	1	-1
Upper respiratory symptoms (asthmatic children, 9-18)	0	9	11	9	0	-1	1	-1
Asthma Exacerbations (asthmatic children, 6-18)	0	11	14	11	0	-1	1	-1
Work loss days (adults, 18-65)	0	64	81	64	0	-6	5	-6
Minor restricted activity days (adults, age 18-65)	0	380	480	380	0	-40	32	-40

* Seattle attains the current 15/65 under baseline conditions.
Note: Shading indicates that Seattle is unable to attain 15/30 with local emission reductions, with or without regional emissions reductions in the baseline. Health impacts are for partial attainment with the 15/30 standard.
Note: Due to technical difficulties, chronic bronchitis has been omitted from this analysis. This important health endpoint will be evaluated for the final RIA.

Table A-45. Estimated Monetized Health Benefits of Emissions Reductions in the Seattle Urban Area for Attainment of Alternative $PM_{2.5}$ NAAQS

		Urban Area Emissions Reductions Only				*Urban Area Emissions Reductions with Alternative Regional Emissions Reduction Baselines*			
		Benefits of Urban Area Emissions Reductions to Attain the Current 15/65 Standards	Benefits of Urban Area Emissions Reductions to Attain Alternative Standards Incremental to Attainment of Current 15/65 Standards			Benefits of Urban Area Emissions Reductions to Attain the Current 15/65 Standards	Benefits of Urban Area Emissions Reductions to Attain Alternative Standards Incremental to Attainment of Current 15/65 Standards		
Endpoint		15/65*	15/35	15/30	14/35	15/65*	15/35	15/30	14/35
Premature mortality									
Long-term exposure, (adults, >30yrs)									
3% discount rate		$0	$537	$777	$537	$0	$228	$720	$228
7% discount rate		$0	$452	$654	$452	$0	$192	$606	$192
Long-term exposure (child <1yr)		$0	$1	$2	$1	$0	$1	$2	$1
Chronic bronchitis (adults, 26 and over)		$0	$0	$0	$0	$0	$0	$0	$0
Non-fatal myocardial infarctions		$0	$0	$0	$0	$0	$0	$0	$0
3% discount rate		$0	$0	$0	$0	$0	$0	$0	$0
7% discount rate		$0	$0	$0	$0	$0	$0	$0	$0
Hospital Admissions from Respiratory Causes		$0	$0	$0	$0	$0	$0	$0	$0
Hospital Admissions from Cardiovascular Causes		$0	$0	$0	$0	$0	$0	$0	$0
Emergency Room Visits for Asthma		$0	$0	$0	$0	$0	$0	$0	$0
Acute bronchitis (children, 8-12)		$0	$0	$0	$0	$0	$0	$0	$0
Lower respiratory symptoms (children, 7-14)		$0	$0	$0	$0	$0	$0	$0	$0
Upper respiratory symptoms (asthmatic children, 9-11)		$0	$0	$0	$0	$0	$0	$0	$0
Asthma exacerbations		$0	$0	$0	$0	$0	$0	$0	$0
Work loss days (adults, 18-65)		$0	$0	$0	$0	$0	$0	$0	$0
Minor restricted activity days (adults, age 18-65)		$0	$0	$0	$0	$0	$0	$0	$0
Totals	3%	$0	$539	$779	$539	$0	$228	$722	$228
	7%	$0	$454	$656	$454	$0	$192	$608	$192

* Seattle attains the current 15/65 under baseline conditions.

Note: Shading indicates Seattle unable to attain 15/30 with local emissions reductions, with or without regional emissions reductions in the baseline. Health impacts are for partial attainment with the 15/30 standard.

Note: Due to technical difficulties, chronic bronchitis has been omitted from this analysis. This important health endpoint will be evaluated for the final RIA.

Note: The non-mortality endpoints above appear to receive a zero valuation because we have rounded the numbers to one significant figure.

Table A-46. Mortality Threshold Senstivity Analysis for Seattle Urban Area Attainment Scenarios

Certainty Regarding Benefits Above Assumed Threshold	*Level of Assumed Threshold**	*Reductions in Mortality Incidence (incremental to attainment of the 15/65 standard)*					
		Urban Area Emissions Reductions Only			Urban Area Emissions Reductions with Alternative Regional Emissions Reduction Baselines		
		15/35	15/30	14/35	15/35	15/30	14/35
More Certain	15 μg/m^3 [a]	0	0	0	0	0	0
↓	10 μg/m^3 [b]	1	1	1	0	0	0
	7.5 μg/m^3 [c]	97	140	97	41	129	41
Less Certain	3 μg/m^3 [d]	105	155	105	46	156	46

*****Note that the threshold is the cutpoint below which no benefits acrue
[a] Current NAAQS
[b] CASAC (2005)
[c] SAB-HES (2004)
[d] NAS (2002)

Table A-47. Value of Mortality Risk Reductions Threshold Sensitivity Analysis for Seattle Urban Area Attainment Scenarios

Certainty Regarding Benefits Above Assumed Threshold	*Level of Assumed Threshold**	*Discount Rate*	*Value of Reductions in Mortality Risk (incremental to attainment of the 15/65 standards)* Urban Area Emissions Reductions Only			Urban Area Emissions Reductions with Alternative Regional Emissions Reduction Baselines		
			15/35	15/30	14/35	15/35	15/30	14/35
More Certain	15 µg/m^3 [a]	3%	$0	$0	$0	$0	$0	$0
		7%	$0	$0	$0	$0	$0	$0
	10 µg/m^3 [b]	3%	$3	$4	$3	$0	$0	$0
		7%	$2	$3	$2	$0	$0	$0
	7.5 µg/m^3 [c]	3%	$537	$777	$537	$228	$720	$228
		7%	$452	$654	$452	$192	$606	$192
	3 µg/m^3 [d]	3%	$584	$862	$584	$256	$866	$256
Less Certain		7%	$491	$725	$491	$215	$728	$215

***Note that the threshold is the cutpoint below which no benefits acrue

Note: In cases where benefits are estimated using both the 50th percentile cost/ton scenario and 90th percentile cost/ton scenario, the sensitivity analysis is performed on the 50th percentile cost/ton scenario.

[a] Current NAAQS

[b] CASAC (2005)

[c] SAB-HES (2004)

[d] NAS (2002)

San Joaquin Air Quality, Control Cost and Human Health Benefits Results

Following the controls hierarchy, we consider two strategies for the San Joaquin urban area, one that applies urban controls to a baseline including moderate regional emissions controls, and one that applies urban area controls alone. Below we present the results in this sequence, starting first with urban area controls.

Attainment Analysis Using Only Urban Area Controls

Table A-48 below present the emission reductions we modeled in the RSM to attempt to reach attainment in Seattle with each level of the standard under consideration for the urban-only analysis.

Table A-48: RSM Emission Reductions for San Joaquin Urban Control Scenario: Assumes Innovative Controls at 50th and 90th Percentile Cost

Attainment Target ($\mu g/m^3$)	*RSM Control Factor and Percentage of Control*											
	NOx EGU*	NOx Non-EGU + Area	NOx Mobile	SOx EGU*	SOx Non-EGU Point	SOx Area	VOC	NH_3 Area	NH_3 Mobile	Point Source Carbon	Mobile Source Carbon	Area Source Carbon
15/35												
Urban Controls	80%	80%	80%	80%	17%	80%	80%	80%	80%	80%	80%	80%
15/30												
Urban Controls	80%	80%	80%	80%	17%	80%	80%	80%	80%	80%	80%	80%
14/35												
Urban Controls	80%	80%	80%	80%	17%	80%	80%	80%	80%	80%	80%	80%

* Note that when we apply urban-area EGU controls, we assume an 80 percent reduction for the reasons describe in the controls hierarchy section above.

The San Joaquin urban area faces a unique challenge in meeting the current and more stringent annual and daily standards. Attainment of the current standards with local controls alone requires steep reductions in almost every emissions category. As such, the availability of local controls to meet more stringent standards is limited. We are unable to show attainment with the proposed or either alternative standard using all available local emissions reductions. As with other urban areas, carbonaceous particle emissions are a large contributor to overall nonattainment. As such, to the extent that we are understating the extent to which controls on local sources of carbonaceous particles can reduce daily peak $PM_{2.5}$ levels, we are understating the ability of San Joaquin to attain, especially for the 35 $\mu g/m^3$, which San Joaquin misses by only 3.4 $\mu g/m^3$. Note that because it is the daily standard that is controlling, San Joaquin would be able to attain the 14 $\mu g/m^3$ annual standard with local controls alone.

Table A-49 below indicates that San Joaquin cannot attain a daily or annual standard tighter than the current NAAQS following the urban-only strategy.

Table A-49: San Joaquin Air Quality Results: Urban-Only Analysis

Standard ($\mu g/m^3$)	*Attain?*	*Notes*	*Controlling Standard*	*Remaining Air Quality Increment ($\mu g/m^3$)*
15/35	No	Cannot attain with all available local emissions reductions	Daily	3.38
15/30	No	Cannot attain with all available local emissions reductions	Daily	8.38
14/35	No	Cannot attain with all available local emissions reductions	Daily	3.38

Attainment Analysis for Urban Area Controls With Regional Controls in the Baseline

Table A-52 below present the emission reductions we modeled in the RSM to attempt to reach attainment with each level of the standard under consideration.

Table A-50: RSM Emission Reductions for San Joaquin Urban and Regional Control Scenario: Assumes Innovative Controls at 50th and 90th Percentile Cost

	RSM Control Factor and Percentage of Control											
Attainment Target ($\mu g/m^3$)	NOx EGU*	NOx Non-EGU + Area	NOx Mobile	SOx EGU*	SOx Non-EGU Point	SOx Area	VOC	NH_3 Area	NH_3 Mobile	Point Source Carbon	Mobile Source Carbon	Area Source Carbon
15/35												
Urban Controls	80%	80%	80%	80%	17%	80%	52%	80%	80%	80%	80%	80%
Regional Controls	20%	20%	20%	20%	20%	---	---	20%	20%	20%	20%	20%
15/30												
Urban Controls	80%	80%	80%	80%	17%	80%	80%	80%	80%	80%	80%	80%
Regional Controls	20%	20%	20%	20%	20%	---	---	20%	20%	20%	20%	20%
14/35												
Urban Controls	80%	80%	80%	80%	17%	80%	52%	80%	80%	80%	80%	80%
Regional Controls	20%	20%	20%	20%	20%	---	---	20%	20%	20%	20%	20%

* Note that when we apply urban-area EGU controls, we assume an 80 percent reduction for the reasons describe in the controls hierarchy section above.

We selected the control factors above based on the information in the previous subsections regarding the cost-effectiveness of various controls. A few key observations are important to make regarding our controls selection:

- *Even with moderate regional reductions in the baseline, steep reductions in local emissions will be necessary to reach 15/35 and 14/35*. Because San Joaquin is so far out of attainment for all levels of the standard as stringent or more stringent that the proposed standard, we needed to maximize most of the air-quality effective controls.

- *Carbonaceous particle and NH_3 controls appear cost-effective*. All of our strategies maximized carbonaceous particle controls.

- *NOx controls appear effective*. In contrast to most eastern urban areas, all of the strategies selected for San Joaquin include NOx controls, because nitrates are a more significant contributor to nonattainment in the West.

- *Based on current information, it does not appear possible to attain the proposed NAAQS in the San Joaquin area by 2015.* Even with moderate regional reductions in the baseline, San Joaquin cannot attain the most stringent alternative with local emissions reductions alone.

Table A-51 below summarizes the attainment information for San Joaquin, and indicates that, with the assumed controls, it could meet the proposed and 14/35 alternative NAAQS. For the 15/30 standard, San Joaquin would remain about 5 $\mu g/m^3$ above the level of the daily standard. Even for the least stringent alternatives, maximal level of assumed controls (80%) appear needed on most source categories of interest, including mobile source NOx. Such levels of additional controls are not likely to be feasible in the date projected in this analyses (2015).

Table A-51: San Joaquin Air Quality Results: Regional/Urban Analysis

Standard ($\mu g/m^3$)	*Attain?*	*Notes*	*Controlling Standard*	*Remaining Air Quality Increment ($\mu g/m^3$)*
15/35	Yes	Unknown controls are necessary for attainment	Daily	---
15/30	No	Cannot attain with all available urban emissions reductions	Daily	4.76
14/35	Yes	Attains with same additional urban controls as necessary for 15/35	Daily	---

Comparison of Control Costs and Monetized Human Health Benefits for San Joaquin

Table A-52 provides the estimated control costs and benefits at a 3% and 7% discount rate for both the regional-urban and urban-only control hierarchies. We were not able to demonstrate attainment with the proposed standard or more stringent alternatives with urban emission reductions alone. Benefits of partial attainment range from $2.6 to $3.0 billion, while costs range from $3.7 to $13.4 billion.

When moderate regional emissions reductions are included in the baseline, we were able to model attainment of the 15/35 and 14/35 standards with additional urban area emissions reductions if each of the source/pollutant factors are assumed to be reduced by 80 percent. Such a scenario does not appear possible by 2015. Estimated costs range from $3.6 to $12.1 billion, compared with benefits of $3.6 to $4.3 billion. Note that because the daily standard is controlling in San Joaquin, the incremental costs and benefits of attaining 15/35 and 14/35 are the same (which implies that the incremental costs and benefits of tightening the annual standard on top of the tighter daily standard are zero).

Table A-52: Estimated Control Costs and Monetized Human Health Benefits for San Joaquin

		Costs of Urban Area Controls (3%)		*Costs of Urban Area Controls (7%)*			
Strategy	*2015 Basecase*	50th Percentile Cost/ton (in millions of 1999$)	90th Percentile Cost/ton (in millions of 1999$)	50th Percentile Cost/ton (in millions of 1999$)	90th Percentile Cost/ton (in millions of 1999$)	Benefits of Urban Area Controls (3%)	Benefits of Urban Area Controls (7%)
Urban-Only Path							
15/35*	Regulatory Baseline	$3,720	$13,440	$3,730	$13,600	$3,020	$2,580
15/30*	Regulatory Baseline	$3,720	$13,440	$3,730	$13,600	$3,020	$2,580
14/35*	Regulatory Baseline	$3,720	$13,440	$3,730	$13,600	$3,020	$2,580
Urban/Regional Path***							
15/35	Regulatory Baseline + 20% Reduction in Regional NonEGU Emissions	$3,600	$12,100	$3,600	$12,200	$4,250	$3,640
15/30 **	Regulatory Baseline + 20% Reduction in Regional NonEGU Emissions	$3,790	$13,670	$3,800	$13,800	$4,290	$3,670
14/35	Regulatory Baseline + 20% Reduction in Regional NonEGU Emissions	$3,600	$12,100	$3,600	$12,200	$4,250	$3,640

* San Joaquin unable to attain 15/35, 15/30, or 14/35 with local emission reductions alone. Costs and benefits are for partial attainment.
** San Joaquin unable to attain 15/30 with local controls incremental to baseline with 20 percent regional emissions reductions. Costs and benefits are for partial attainment.
***Note that while this strategy assumes the presence of certain regional controls in the baseline, the costs and benefit estimates reflect air quality improvements from the urban controls alone.

Table A-53. Estimated Reductions in Incidence of $PM_{2.5}$ Related Health Effects Due to Emissions Reductions in the San Joaquin Urban Area for Attainment of Alternative $PM_{2.5}$ NAAQS

	Urban Area Emissions Reductions Only					*Urban Area Emissions Reductions with Alternative Regional Emissions Reduction Baselines*				
	Benefits of Urban Area Emissions Reductions to Attain the Current 15/65 Standards		Benefits of Urban Area Emissions Reductions to Attain Alternative Standards Incremental to Attainment of Current 15/65 Standards			Benefits of Urban Area Emissions Reductions to Attain the Current 15/65 Standards		Benefits of Urban Area Emissions Reductions to Attain Alternative Standards Incremental to Attainment of Current 15/65 Standards		
Endpoint	15/65		15/35	15/30	14/35	15/65		15/35	15/30	14/35
	50th %ile cost/ton	90th %ile cost/ton				50th %ile cost/ton	90th %ile cost/ton			
Premature mortality										
Long-term exposure (adults, 30 and over)	1,400	1,400	500	500	500	1,000	990	810	810	810
Long-term exposure (infant, <1 yr)	5	4	2	2	2	3	3	3	3	3
Chronic bronchitis (adults, 26 and over)	0	0	0	0	0	0	0	0	0	0
Non-fatal myocardial infarctions (adults, 18 and older)	2,800	2,700	1,000	1,000	1,000	2,000	1,900	1,500	1,500	1,500
Hospital admissions—Respiratory (all ages)	310	300	120	120	120	230	210	180	180	180
Hospital admissions—Cardiovascular (adults, >18)d	610	590	240	240	240	440	410	340	350	340
Emergency Room Visits for Asthma (18 and younger)	710	680	260	260	260	520	490	380	380	380
Acute bronchitis (children, 8-12)	3,500	3,400	1,300	1,300	1,300	2,600	2,500	1,800	1,800	1,800
Lower respiratory symptoms (children, 7-14)	38,000	37,000	14,000	14,000	14,000	28,000	27,000	20,000	20,000	20,000
Upper respiratory symptoms (asthmatic children, 9-18)	29,000	28,000	10,000	10,000	10,000	21,000	20,000	15,000	15,000	15,000
Asthma Exacerbations (asthmatic children, 6-18)	35,000	34,000	13,000	13,000	13,000	26,000	24,000	19,000	19,000	19,000
Work loss days (adults, 18-65)	230,000	220,000	90,000	90,000	90,000	170,000	160,000	120,000	130,000	120,000
Minor restricted activity days (adults, age 18-65)	1,400,000	1,300,000	500,000	500,000	500,000	990,000	930,000	770,000	770,000	770,000

Note: Shading indicates San Joaquin is not able to attain 15/35, 15/30, or 14/35 with local emissions reductions alone. Health impacts are for partial attainment with the 15/35 standard.
Note: Shading indicates San Joaquin is not able to attain 15/30 alternative standard with local emissions reductions and regional emissions reductions in the alternative basecase. Health impacts are for partial attainment with the 15/30 standard.

Table A-54. Estimated Monetized Health Benefits of Emissions Reductions in the San Joaquin Urban Area for Attainment of Alternative $PM_{2.5}$ NAAQS

	Urban Area Emissions Reductions Only					*Urban Area Emissions Reductions with Alternative Regional Emissions Reduction Baselines*				
	Benefits of Urban Area Emissions Reductions to Attain the Current 15/65 Standards		Benefits of Urban Area Emissions Reductions to Attain Alternative Standards Incremental to Attainment of Current 15/65 Standards			Benefits of Urban Area Emissions Reductions to Attain the Current 15/65 Standards		Benefits of Urban Area Emissions Reductions to Attain Alternative Standards Incremental to Attainment of Current 15/65 Standards		
	15/65		15/35	15/30	14/35	15/65		15/35	15/30	14/35
Endpoint	50th %ile cost/ton	90th %ile cost/ton				50th %ile cost/ton	90th %ile cost/ton			
Premature mortality										
Long-term exposure, (adults, >30yrs)										
3% discount rate	$7,926.4	$7,640.3	$2,889.7	$2,889.7	$2,889.7	$5,816.4	$5,489.0	$4,066.1	$4,100.4	$4,066.1
7% discount rate	$6,669.3	$6,428.6	$2,431.4	$2,431.4	$2,431.4	$4,893.9	$4,618.5	$3,421.2	$3,450.1	$3,421.2
Long-term exposure (child <1yr)	$27.8	$26.8	$9.9	$9.9	$9.9	$20.7	$19.6	$14.0	$14.0	$14.0
Chronic bronchitis (adults, 26 and over)	NA	$0.0	NA	NA	NA	NA	$0.0	NA	NA	NA
Non-fatal myocardial infarctions		$0.0	$0.0				$0.0	$0.0	$0.0	$0.0
3% discount rate	$237.3	$228.2	$79.4	$79.4	$79.4	$173.2	$162.0	$115.4	$115.7	$115.4
7% discount rate	$296.5	$285.2	$99.7	$99.7	$99.7	$216.4	$202.4	$144.6	$145.1	$144.6
Hospital Admissions from Respiratory Causes	$1.6	$1.6	$0.6	$0.6	$0.6	$1.2	$1.1	$0.8	$0.8	$0.8
Hospital Admissions from Cardiovascular Causes	$12.3	$11.8	$4.4	$4.4	$4.4	$8.9	$8.3	$6.3	$6.3	$6.3
Emergency Room Visits for Asthma	$0.2	$0.2	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1
Acute bronchitis (children, 8-12)	$1.3	$1.2	$0.4	$0.4	$0.4	$1.0	$0.9	$0.6	$0.6	$0.6
Lower respiratory symptoms (children, 7-14)	$1.2	$1.2	$0.4	$0.4	$0.4	$0.9	$0.8	$0.6	$0.6	$0.6
Upper respiratory symptoms (asthmatic children, 9-11)	$0.8	$0.7	$0.3	$0.3	$0.3	$0.6	$0.5	$0.4	$0.4	$0.4
Asthma exacerbations	$1.5	$1.5	$0.5	$0.5	$0.5	$1.1	$1.1	$0.8	$0.8	$0.8
Work loss days (adults, 18-65)	$28.0	$26.9	$9.9	$9.9	$9.9	$20.4	$19.1	$14.2	$14.2	$14.2
Minor restricted activity days (adults, age 18-65)	$69.8	$67.1	$24.4	$24.4	$24.4	$50.9	$47.6	$35.1	$35.2	$35.1
Totals 3%	$8,308.1	$8,007.5	$3,020.0	$3,020.0	$3,020.0	$6,095.4	$5,750.3	$4,254.3	$4,289.1	$4,254.3
7%	$7,110.3	$6,852.8	$2,582.0	$2,582.0	$2,582.0	$5,216.1	$4,920.2	$3,638.6	$3,638.6	$3,638.6

Note: Shading indicates San Joaquin is not able to attain 15/35, 15/30, or 14/35 with local emissions reductions alone. Benefits are for partial attainment with the 15/35 standard.
Note: Due to technical difficulties, chronic bronchitis has been omitted from this analysis. This important health endpoint will be evaluated for the final RIA.

Table A-55. Mortality Threshold Sensitivity Analysis for San Joaquin Urban Area Attainment Scenarios

Certainty Regarding Benefits Above Assumed Threshold	*Level of Assumed Threshold**	*Reductions in Mortality Incidence (incremental to attainment of the 15/65 standard)* Urban Area Emissions Reductions Only			Urban Area Emissions Reductions with Alternative Regional Emissions Reduction Baselines		
		15/35	15/30	14/35	15/35	15/30	14/35
More Certain	15 µg/m^3 [a]	275	275	275	455	442	455
	10 µg/m^3 [b]	559	559	559	785	790	785
	7.5 µg/m^3 [c]	519	519	519	731	737	731
Less Certain	3 µg/m^3 [d]	523	523	523	737	743	737

***Note that the threshold is the cutpoint below which no benefits acrue

[a] Current NAAQS

[b] CASAC (2005)

[c] SAB-HES (2004)

[d] NAS (2002)

Table A-56. Value of Mortality Risk Reductions Threshold Sensitivity Analysis for San Joaquin Urban Area Attainment Scenarios

Certainty Regarding Benefits Above Assumed Threshold	*Level of Assumed Threshold**	*Discount Rate*	*Value of Reductions in Mortality Risk (incremental to attainment of the 15/65 standards)* Urban Area Emissions Reductions Only			Urban Area Emissions Reductions with Alternative Regional Emissions Reduction Baselines		
			15/35	15/30	14/35	15/35	15/30	14/35
More Certain								
	15 µg/m^3 [a]	3%	$1,529	$1,529	$1,529	$2,532	$2,460	$2,532
		7%	$1,286	$1,286	$1,286	$2,130	$2,070	$2,130
	10 µg/m^3 [b]	3%	$3,109	$3,109	$3,109	$4,369	$4,394	$4,369
		7%	$2,616	$2,616	$2,616	$3,676	$3,697	$3,676
	7.5 µg/m^3 [c]	3%	$2,890	$2,890	$2,890	$4,066	$4,100	$4,066
		7%	$2,431	$2,431	$2,431	$3,421	$3,450	$3,421
	3 µg/m^3 [d]	3%	$2,913	$2,913	$2,913	$4,102	$4,137	$4,102
Less Certain		7%	$2,451	$2,451	$2,451	$3,452	$3,481	$3,452

***Note that the threshold is the cutpoint below which no benefits acrue

[a] Current NAAQS

[b] CASAC (2005)

[c] SAB-HES (2004)

[d] NAS (2002)

Table A-57. Reduction in Mortality Incidence for San Joaquin Urban Attainment Scenarios Incremental to Attainment of Current 15/65 Standards Using Expert Judgments Regarding the Distribution of the $PM_{2.5}$ Mortality Concentration Response Function

	Mean	*5th %ile*	*50th %ile*	*95th %ile*
15/65 Urban Area Emissions Reductions Only				
Pope et al (2002)	1,425	560	1,426	2,285
Expert A	1,169	0	1,208	2,194
Expert B	775	15	115	3,426
Expert C	996	15	985	1,874
Expert D	936	0	763	2,433
Expert E	1,874	0	1,736	3,856
15/35 Urban Area Emissions Reductions Only (incremental to attainment of 15/65)				
Pope et al (2002)	519	206	520	827
Expert A	428	0	444	798
Expert B	277	4	42	1,211
Expert C	308	4	295	599
Expert D	343	0	281	884
Expert E	679	0	634	1,382
15/30 Urban Area Emissions Reductions Only (incremental to attainment of 15/65)				
Pope et al (2002)	519	206	520	827
Expert A	428	0	444	798
Expert B	277	4	42	1,211
Expert C	308	4	295	599
Expert D	343	0	281	884
Expert E	679	0	634	1,382
14/35 Urban Area Emissions Reductions Only (incremental to attainment of 15/65)				
Pope et al (2002)	519	206	520	827
Expert A	428	0	444	798
Expert B	277	4	42	1,211
Expert C	308	4	295	599
Expert D	343	0	281	884
Expert E	679	0	634	1,382
15/65 Urban Area Emissions Reductions with Regional Emissions Reductions in Baseline				
Pope et al (2002)	1,045	411	1,046	1,677
Expert A	858	0	887	1,611
Expert B	557	10	83	2,465
Expert C	686	10	661	1,327
Expert D	687	0	560	1,788
Expert E	1,377	0	1,275	2,836
15/35 Urban Area Emissions Reductions Only with Regional Emissions Reductions in Baseline (incremental to attainment of 15/65)				
Pope et al (2002)	731	289	732	1,167
Expert A	602	0	624	1,126
Expert B	381	6	58	1,673
Expert C	433	6	406	862
Expert D	483	0	395	1,248

Expert E	960	0	894	1,960
15/30 Urban Area Emissions Reductions Only with Regional Emissions Reductions in Baseline (incremental to attainment of 15/65)				
Pope et al (2002)	737	291	738	1,177
Expert A	608	0	629	1,136
Expert B	382	6	58	1,677
Expert C	430	6	402	860
Expert D	487	0	398	1,258
Expert E	968	0	901	1,977
14/35 Urban Area Emissions Reductions Only with Regional Emissions Reductions in Baseline (incremental to attainment of 15/65)				
Pope et al (2002)	731	289	732	1,167
Expert A	602	0	624	1,126
Expert B	381	6	58	1,673
Expert C	433	6	406	862
Expert D	483	0	395	1,248
Expert E	960	0	894	1,960

Table A-58. Value of Mortality Risk Reduction Benefits for San Joaquin Attainment Scenarios Incremental to Attainment of Current 15/65 Standards Using Expert Judgements Regarding the Distribution of the $PM_{2.5}$ Mortality Concentration Response Function

	Mean	*5th %ile*	*50th %ile*	*95th %ile*
15/65 Urban Area Emissions Reductions Only				
Pope et al (2002)	$7,926	$1,880	$7,350	$16,149
Expert A	$6,502	$0	$5,851	$15,570
Expert B	$4,303	$0	$30	$20,496
Expert C	$5,540	$76	$5,007	$13,118
Expert D	$5,204	$0	$3,649	$15,766
Expert E	$10,426	$0	$8,735	$26,739
15/35 Urban Area Emissions Reductions Only (incremental to attainment of 15/65)				
Pope et al (2002)	$2,890	$687	$2,684	$5,879
Expert A	$2,380	$0	$2,145	$5,678
Expert B	$1,536	$0	$11	$7,289
Expert C	$1,712	$22	$1,509	$4,174
Expert D	$1,904	$0	$1,341	$5,738
Expert E	$3,780	$0	$3,199	$9,620
15/30 Urban Area Emissions Reductions Only (incremental to attainment of 15/65)				
Pope et al (2002)	$2,890	$687	$2,684	$5,879
Expert A	$2,380	$0	$2,145	$5,678
Expert B	$1,536	$0	$11	$7,289
Expert C	$1,712	$22	$1,509	$4,174
Expert D	$1,904	$0	$1,341	$5,738
Expert E	$3,780	$0	$3,199	$9,620

14/35 Urban Area Emissions Reductions Only (incremental to attainment of 15/65)				
Pope et al (2002)	$2,890	$687	$2,684	$5,879
Expert A	$2,380	$0	$2,145	$5,678
Expert B	$1,536	$0	$11	$7,289
Expert C	$1,712	$22	$1,509	$4,174
Expert D	$1,904	$0	$1,341	$5,738
Expert E	$3,780	$0	$3,199	$9,620
15/65 Urban Area Emissions Reductions with Regional Emissions Reductions in Baseline				
Pope et al (2002)	$5,816	$1,379	$5,393	$11,851
Expert A	$4,773	$0	$4,295	$11,434
Expert B	$3,093	$0	$22	$14,736
Expert C	$3,815	$52	$3,380	$9,254
Expert D	$3,821	$0	$2,678	$11,581
Expert E	$7,661	$0	$6,413	$19,662
15/35 Urban Area Emissions Reductions Only with Regional Emissions Reductions in Baseline (incremental to attainment of 15/65)				
Pope et al (2002)	$4,066	$967	$3,775	$8,277
Expert A	$3,351	$0	$3,020	$8,007
Expert B	$2,116	$0	$15	$10,050
Expert C	$2,410	$31	$2,107	$5,959
Expert D	$2,681	$0	$1,886	$8,096
Expert E	$5,340	$0	$4,504	$13,624
15/30 Urban Area Emissions Reductions Only with Regional Emissions Reductions in Baseline (incremental to attainment of 15/65)				
Pope et al (2002)	$4,100	$975	$3,807	$8,346
Expert A	$3,380	$0	$3,045	$8,075
Expert B	$2,121	$0	$15	$10,073
Expert C	$2,394	$30	$2,086	$5,934
Expert D	$2,704	$0	$1,902	$8,164
Expert E	$5,385	$0	$4,542	$13,739
14/35 Urban Area Emissions Reductions Only with Regional Emissions Reductions in Baseline (incremental to attainment of 15/65)				
Pope et al (2002)	$4,066	$967	$3,775	$8,277
Expert A	$3,351	$0	$3,020	$8,007
Expert B	$2,116	$0	$15	$10,050
Expert C	$2,410	$31	$2,107	$5,959
Expert D	$2,681	$0	$1,886	$8,096
Expert E	$5,340	$0	$4,504	$13,624

15/40 Standard Option Analysis

We performed a screening-level cost analysis to estimate the control costs associated with meeting a 15/40 $PM_{2.5}$ air quality standard. We calculated these costs by using simple linear interpolation:

1. First, we determined both the total cost associated with meeting the recommended standard (15/35) and the total change in the daily design value necessary to meet this standard (about 48 $\mu g/m^3$).

2. Second, we divided the cost for each of the 50^{th} and 90^{th} percentile cost estimates at both the 3% and 7% discount rate by the change in the daily design value necessary to meet the recommended option.

3. Finally, we multiplied the proportion in step 2 by the change in the design value necessary to meet a 15/40 standard to produce an estimate of total cost; to produce an estimate of incremental cost we subtracted the cost of meeting the current standard.

This interpolated estimate is subject to even greater uncertainties than the other options because the costs and benefits may not scale in a linear way with the 24-hour design value. The summary results of this calculation are below in table A-59:

Table A-59: Screening-Level Estimate of Costs to Attaining 15/40Standard Option in the San Joaquin Area Incremental to Attainment of the Current 15/65 Standard (Million 1999$)

		Costs of Urban Area Controls (3%)		*Costs of Urban Area Controls (7%)*			
Strategy	*2015 Basecase*	50th Percentile Cost (in millions of 1999$)	90th Percentile Cost (in millions of 1999$)	50th Percentile Cost (in millions of 1999$)	90th Percentile Cost (in millions of 1999$)	Benefits of Urban Area Controls (3%)	Benefits of Urban Area Controls (7%)
Urban/Regional Path**							
15/40	Regulatory Baseline + 20% Reduction in Regional NonEGU Emissions	$3,000	$10,000	$3,000	$10,000	$10,000	$9,000

Note: Numbers rounded to one significant figure to reflect greater uncertainty in estimates of costs and benefits.

Assessment of Regional Strategies

For the more stringent 15/30 and 14/35 standards, the urban-area analyses above assume a example of regional control strategy as part of the baseline if they were not able to reach attainment with urban-area controls alone. Illustrative strategies analyzed in this RIA assume a flat 20% reduction in each relevant RSM source grouping. We made no attempt to develop a cost-optimal regional strategy for the standard alternatives and therefore did not attempt to estimate costs and benefits.

However, in recent analyses, EPA has generated estimates of the costs and benefits of additional reductions in regional SO_2 under assumed alternative caps on SO_2 emissions from EGUs. One scenario examined SO_2 emission reductions approximately equivalent to those included in the baseline for the regional/urban strategies evaluated above. Thus it is possible to use the results of the previous analysis to help estimate the costs and benefits of the regional EGU SO_2 reduction that we included in the baseline for the regional/urban analysis above.

Incremental to the base case of CAIR/CAMR/CAVR, the incremental benefits of the illustrative additional SO2 reductions are estimated to be \$26 to \$31 billion assuming a threshold of 7.5$\mu g/m^3$, while the incremental costs are estimated to be \$2.1 billion. Although we did not perform analysis of thresholds for this scenario due to time limitations, we did perform such an analysis for CAIR. In that analysis we found that mortality benefits would be reduced by 16 percent with a threshold of 10 $\mu g/m^3$ and would be reduced by 96 percent with a threshold of 15 $\mu g/m^3$.[21] We would expect similar or somewhat larger percent reductions associated with the same thresholds for illustrative additional SO_2 reductions beyond CAIR/CAMR/CAVR. This suggests that additional reductions in SO_2 can provide large benefits and are relatively cost-effective for all assumed thresholds less than 15 $\mu g/m^3$. Our analysis indicates that in 2015, the additional reductions in EGU SO_2 may result in additional reductions in annual mean $PM_{2.5}$ concentration of between 0.5 $\mu g/m^3$ and 1.0 $\mu g/m^3$ in a large section of the Eastern U.S.

Comparing the Results of the Urban Area Analysis with those of Previous National Rules

The results of this urban-area analysis suggest that for several of the alternatives, estimated monetized benefits are roughly equivalent (within the same order of magnitude) to the estimated control costs. These estimates are not consistent with the results of previous EPA rulemakings, where benefits tend to be significantly higher than costs. A direct comparison between the urban analysis results and the analysis of the national rules on a benefits per-ton basis is not possible due to the fact that the benefits of the urban analysis are not expressed in this form. However, it is possible to compare the difference between the costs and benefits of this urban area assessment with the difference between the costs and benefits of the national rules.

EPA has compiled dollar per-ton estimates of the monetary value of improvements in human health as a result of reduced $PM_{2.5}$ levels for some sectors. Table A-62 below provides a list of the monetized human health benefit/ton of reducing $PM_{2.5}$ or its precursors for various national rules. This table is based on values derived from several recent RIAs developed to support EPA

[21] See http://www.epa.gov/cair/pdfs/finaltech08.pdf page C-7.

rulemakings over the past few years. Each of these estimates has been subject to review and public comment during the rulemaking for the individual rules.

As an example, EPA recently looked at the cost of retrofitting diesel school buses at a cost of $12,000 to $50,000 per ton. These reductions could be beneficial since the value of a ton of $PM_{2.5}$ reduced from on road heavy duty engines ranges between $150,000 and $200,000 (depending on the year of the reduction). Within the final RIA, EPA is exploring ways to develop a much broader list of $ benefit/ton estimates covering more source types.

Table A-60: Summary of Available PM Benefit per-ton Estimates:

		Ambient $PM_{2.5}$ Precursor Emissions		
Source Category	*Year*	NOx	SO2	Direct PM
Utilities				
Eastern US (CAIR)				
	2010	$2,200	$18,000	
	2015	$5,400	$22,000	
Western US (BART)				
	2015	$1,100	$22,000	
Industrial Boilers				
	2005		$20,000	$88,000
Onroad Heavy Duty Engines				
	2005	$10,700	$17,000	$150,000
	2010	$11,500	$18,000	$160,000
	2015	$13,300	$21,000	$190,000
	2020	$14,200	$23,000	$200,000
Nonroad Diesel Engines				
	2005	$5,000	$16,000	$230,000
	2010	$6,000	$19,000	$260,000
	2015	$8,000	$23,000	$300,000
	2020	$10,000	$29,000	$340,000

Fine Particle Control Strategy Insights

The 5 urban-area analysis above provides a number of provisional insights regarding the air quality effects of local and regional emission reductions and the benefits and costs of various control strategies.

- Urban areas are very heterogeneous with respect to both the composition of air pollution and the urban-scale emissions profiles. This makes it difficult to draw broad conclusions about the design of urban-scale emissions control strategies. For example, Chicago is projected to benefit from reductions in area source NH_3 emissions, while Atlanta is not; and urban NOx controls are far more effective in western areas than in the east. However:

  – Despite substantial variability across the nation, there are still some commonalities which can be exploited on a broad scale:

    - Preliminary modeling shows that carbonaceous particle reductions from any source are likely to result in positive air quality impacts and are likely to be cost-effective.

- There are broad differences between nonattaining urban areas in the eastern U.S. and those in the West. Specifically:

  – Nitrates are a more substantial contributor to nonattainment in the West than the East, suggesting that NOx controls may be an important component of strategies in the West.

  – Organic aerosols are a large fraction of the overall remaining $PM_{2.5}$ mass in New York and Salt Lake City. Sulfate is a considerable part of the total $PM_{2.5}$ mass in both cities and is the largest contributor to $PM_{2.5}$ mass in New York City. Nitrate is a relatively small contributor to $PM_{2.5}$ for New York City but nitrate is the second largest contributor to the remaining $PM_{2.5}$ problem in Salt Lake City. The relatively large contribution of sulfate to $PM_{2.5}$ mass in New York City is characteristic of the urban air pollution mixture in the East, while the nitrate contribution to $PM_{2.5}$ mass in Salt Lake City is characteristic of that found in the West.

  – Even in the West, there are substantial differences between California and the rest of the West in the nature and extent of the air quality problem. Parts of California have consistently higher levels of $PM_{2.5}$ and are dominated by NOx and NH_3.

- These areas can reach or make considerable progress towards attainment of different standards using local emissions controls alone.

  – These local strategies are complementary to EPA's current suite of regional and national emissions reductions strategies for utilities and mobile sources.

- Local strategies are more heavily focused on reductions in carbonaceous particle emissions.

- Due to limits in current knowledge about the availability and effectiveness of local controls, there is a large amount of uncertainty about the cost and achievability of these local reductions in emissions.

- It is also important to recognize that predicting what control strategies will be used 10 years into the future is not an exact science; technological progress, innovation and changes in energy use, population growth and other factors will significantly influence these choices.

- In particular, these limitations have not permitted identification of the least-cost attainment strategies; thus, costs are likely to be overstated by a significant amount in EPA's analysis.

- While local strategies may be effective in making progress towards attainment with the proposed $PM_{2.5}$ standards, they should be evaluated against broader regional strategies (of differing geographic scales) to determine the most cost-effective strategies for reaching attainment across urban areas.

Conclusions and Implications for Further Analysis

- EPA identified several limitations to the cost and benefit information that indicate, while useful as a guide on the ability of an area to attain the various standard levels, these data are of limited value. Thus, care should be taken in drawing any conclusions about the relative merit of different strategies for attaining proposed standards and alternatives without further analysis.

- In addition, while our modeling is suggestive of the types of controls that may be effective in reducing urban $PM_{2.5}$, the models we used reflect a relatively large scale (36km) and are likely to understate the localized impacts of emissions reductions from point sources and some mobile emissions within a finely resolved urban area.

- Our current understanding of available control strategies for industrial point and process sources is very limited in many urban areas. Therefore, our ability to estimate the extent of emissions reductions available in these areas is limited, and it is difficult for us to determine the cost-effectiveness of these potential reductions.

- For the purposes of analysis, we made certain bounding assumptions in the RIA to explore whether urban areas could attain alternative standards with reductions in emissions within the urban area alone. These assumptions do not necessarily represent reasonably achievable reduction levels, because in some cases it was necessary to assume, for exploratory purposes, a level of control of urban sources that exceeds that which can be achieved through known technologies.

- To improve our ability to more accurately reflect the costs and benefits of different attainment strategies, EPA must refine emissions inventories, control strategies, and cost data.
  - For control strategies, this is especially true for non-EGU industrial sources, and for mobile sources of carbonaceous particles and NH_3.
  - For emissions inventories, this is especially important for mobile and area sources of carbonaceous particles.