EPA White Paper
Preliminary Analyses of Proposed $PM_{2.5}$ NAAQS Alternatives

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Office of Air and Radiation, USEPA
Research Triangle Park, NC 27711
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Purpose of the White Paper

This White Paper summarizes the results of analyses EPA has conducted as part of the process of developing a regulatory impacts analysis (RIA) that will accompany the proposed revision of the National Ambient Air Quality Standards for Particulate Matter. The analyses summarized here provide insights related to implementation of the standards, including forecasts of potential nonattainment and considerations for developing control strategies to attain the revised standards for fine particles ($PM_{2.5}$) and two alternatives that were proposed by EPA on December 20, 2005. Specifically, this document summarizes:

- National forecasts of air quality status with respect to the current standards, the proposed revisions and two alternatives for 2010 and 2015
- Information on the nature of the air quality problem and on the contribution from influential source categories for selected area
- Insights about the design and impacts of strategies which states may adopt to attain the proposed standards and the alternatives.

As further described at the end of this document, as EPA carried out its analysis, we discovered that the available tools and datasets were inadequate to complete a national scale analysis in time for the proposal deadline of December 20, 2005. EPA will release the RIA for the proposal in January 2006; this interim RIA, in addition to containing the full analysis underlying this white paper, will provide an assessment of the costs and benefits of the proposed standards in several selected urban areas. Complete national-scale assessment of costs and benefits will be completed in time for the final RIA (September 2006).

Alternative $PM_{2.5}$ NAAQS analyzed

The December 20, 2005 preamble to the proposed rule provides the rationale for EPA's proposed revisions to the primary $PM_{2.5}$ NAAQS and as well as other alternatives on which the Agency is requesting comment. In our analyses, we have selected a subset of options designed to encompass the range of alternative standards upon which the Agency is requesting comment. This analysis examines the current standards and 3 alternatives in depth. The alternatives analyzed are summarized in following table as combinations of the annual and daily $PM_{2.5}$ standards:

Table 1: Annual and Daily $PM_{2.5}$ NAAQS Considered in This Analysis

Combination of Annual and Daily Values, in µg/m^3	*Notes*
15/65	Current standards
15/35	Proposed Revisions
14/35	Alternative for comment
15/30	Alternative for comment

Future-year Predictions of $PM_{2.5}$ Concentrations and Attainment under Alternatives

Overview of methodology and uncertainties

As part of a recent assessment of multi-pollutant legislative approaches (http://www.epa.gov/airmarkets/mp), EPA analyzed the combination of the all of the major national regional, regional, and state regulatory programs that affect the principle sources of fine particles and ozone. The Clean Air Interstate Rule (CAIR), the Clean Air Mercury Rule (CAMR), and the Clean Air Visibility Rule (CAVR), promulgated in 2005, affect utility emissions. CAVR also applied to industrial boiler emissions. National mobile rules for light and heavy-duty vehicles and non-road mobile sources were also included. Current state programs that address these and other source categories that were on the books as of early 2005 are also modeled for future years. In addition to forecasting emissions, EPA analyzed projected annual $PM_{2.5}$ concentrations using the CMAQ model. The assumptions and specific approaches are described in supporting documentation available at the web address above. EPA further processed these results to estimate the 98 percentile 24-hour values associated with these forecasts.[1] Staff then compared these air quality projections with the current, proposed, and alternative revised $PM_{2.5}$ standards.

The air quality modeling system (i.e., emissions, meteorology, and models) and our projection technique provide estimates of both daily and annual $PM_{2.5}$ concentrations for future year emissions scenarios. It is important to summarize the strengths and limitations of this system:

- EPA's 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.
- Overall, the 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.
- For the proposal RIA, we used an interim projection methodology based on quarterly average species concentrations to calculate the projected daily average $PM_{2.5}$ concentrations. The lack of a more refined peak concentration relative factor to predict changes in daily peaks may introduce additional uncertainty in the daily average projections. We intend to improve the methodology for the final rule RIA.
- Because we project future year concentrations by translating the projected relative change in $PM_{2.5}$ species into projected changes in ambient measurements, the magnitude of future year concentrations is tied to the magnitude of current measurements. This approach is intended to mitigate, to some extent, situations in which the model over/under predicts concentrations compared to ambient measurements.
- In general, model performance is better for the eastern U.S. than for the West. The 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 carbon, which are the dominant species in the West. Therefore, we have greater confidence in our projections in the East.

[1] For a description of the methodology that EPA used to derive these 98^{th} percentile 24-hour values, please see the forthcoming Regulatory Impact Analysis for the proposed $PM_{2.5}$ NAAQS.

- There are known uncertainties in the state of the science regarding the formation of secondary organic carbon, as well as with the techniques for measuring carbon and primary emissions of organic carbon. These uncertainties affect the model's ability to properly predict organic carbon concentrations and the effectiveness of VOC controls for reducing carbon particles.

- A number of factors affect the extent to which the modeling system can properly characterize attainment/nonattainment associated with localized concentrations and the benefits of local control measures.
    - Our current $PM_{2.5}$ modeling system is applied with a geographic resolution of 36 x 36 km. At this scale, it is difficult to resolve local, urban scale gradients in $PM_{2.5}$ due to a lack of resolution of meteorological conditions and emissions.
    - The underlying emissions inventories used in our modeling system are derived from the EPA's National Emissions Inventory, which includes a mix of State-supplied and EPA generated data. The uncertainties in these data, 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, limit our ability to properly determine the relative effectiveness of emissions reductions across different spatial scales and among different source categories.

- 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.

Summary of Attainment Analyses

Table 2 summarizes the results of these analyses in terms of the projected numbers of counties with monitors that would not attain the standards alternatives under the same CAIR/CAMR/CAVR/Mobile base case scenario for two forecast years, 2010 and 2015. This is not a forecast of the air quality EPA would expect to occur in these years, because the baseline analyzed contains only current programs, and not the additional reductions that will be made in response to State Implementation Plans designed to meet the current PM NAAQS. These State Implementation Plans are due in April 2008. The Clean Air Act presumptively requires each area to attain the current $PM_{2.5}$ standards within 5 years of designation, by 2010, with authority for EPA to grant a state an attainment date extension of up to an additional 5 years for specific areas.

This baseline scenario analyses shows that EPA's recently promulgated CAIR/CAVR/CAMR program, mobile source regulations, and current state and local programs would make significant contributions to reducing projected $PM_{2.5}$ nonattainment in the eastern US under any of the standards alternatives analyzed, as compared to current air quality levels. EPA modeling indicates that by 2010, 77 of the 116 areas currently not attaining the existing $PM_{2.5}$ standards will come into attainment just based on regulatory programs already in place, including CAIR/CAMR/CAVR and other federal measures. Seven more $PM_{2.5}$ areas are projected to attain the existing standards by 2015 based on the implementation of these programs. All areas in the eastern United States will have lower $PM_{2.5}$ concentration in 2015 relative to present-day conditions. In most cases, the predicted improvement in $PM_{2.5}$ ranges from 10% to 20%.

The series of four sets of maps that follow provide further details of the current, proposed and alternative PM NAAQS attainment analyses results. The first maps in each set show the counties that would attain and would not attain the standards alternative in 2010 and 2015 under the baseline scenario summarized above. The maps are color coded to depict whether annual (orange), daily (yellow) or both NAAQS (red) would not be met and which counties would have not met the standards based on recent $PM_{2.5}$ data, but come into attainment under the baseline scenario (gray).

Table 2. Summary of County Nonattainment Counts: Current and Projected 2015

	Current			*Projected with CAIR/CAVR/CAMR**		
Standard Options	National	East	West	National	East	West
15/65—current standard	116	102	14	32	18	14
15/35	191	141	50	76	30	46
14/35	235	185	50	96	50	46
15/30	326	264	62	178	116	62

* See Technical Support Document for details on projection method used here (i.e., Speciated Modeled Attainment Test--SMAT). [[Will be placed in the docket upon signature]]

The third map for each alternative provides a quantitative estimate of how much each area would exceed thee daily/annual standards in 2015, after the implementation of the baseline programs, but before considering State programs designed to attain the current standards. The results in the table and maps indicate some regional differences in the relative impact of the proposed and alternative standards, in terms of numbers of residual non-attainment areas as well as increment above the standards levels:

- As compared to the current standards, the proposed tighter daily standard of 35 ug/m^3 appears to have a bigger impact in the West than in the East, particularly after the forecast CAIR/CAMR/CAVR controls are more fully implemented. Most of the eastern counties that would not attain the standard in 2015 are part of nonattainment areas that are required to adopt further controls under the current standards. The increment above the standard is generally below 5 ug/m^3.

- By contrast, most of the counties that would not attain the proposed daily standard in the northwestern quadrant of the US currently attain the annual and 24-hour NAAQS. These areas have lower annual averages, but can have high daily peaks during the winter months with more inversions as well as emissions from heating. The increment above the daily standard varies from under 7 ug/m^3 to less than 3 ug/m^3 in this region.

- The analysis of an annual standard of 14 ug/m^3 showed 235 counties out of attainment for both 24 hour and annual, 139 in attainment with both in 2015. The major effect of moving from the proposed alternative to a tighter annual standard of 14 ug/m^3 is observed in the East, adding 20 more counties not meeting the alternative in 2015 to total 27. This alternative increases by 1 ug/m^3 the increment above the annual NAAQS in all 32 counties forecast not to attain the current NAAQS.

- The move from the proposed alternative to a tighter 24 hour standard produces a substantially larger number of nonattaining counties nationwide than the tighter annual alternative above. At this concentration, the daily standard is projected to be controlling for most areas.

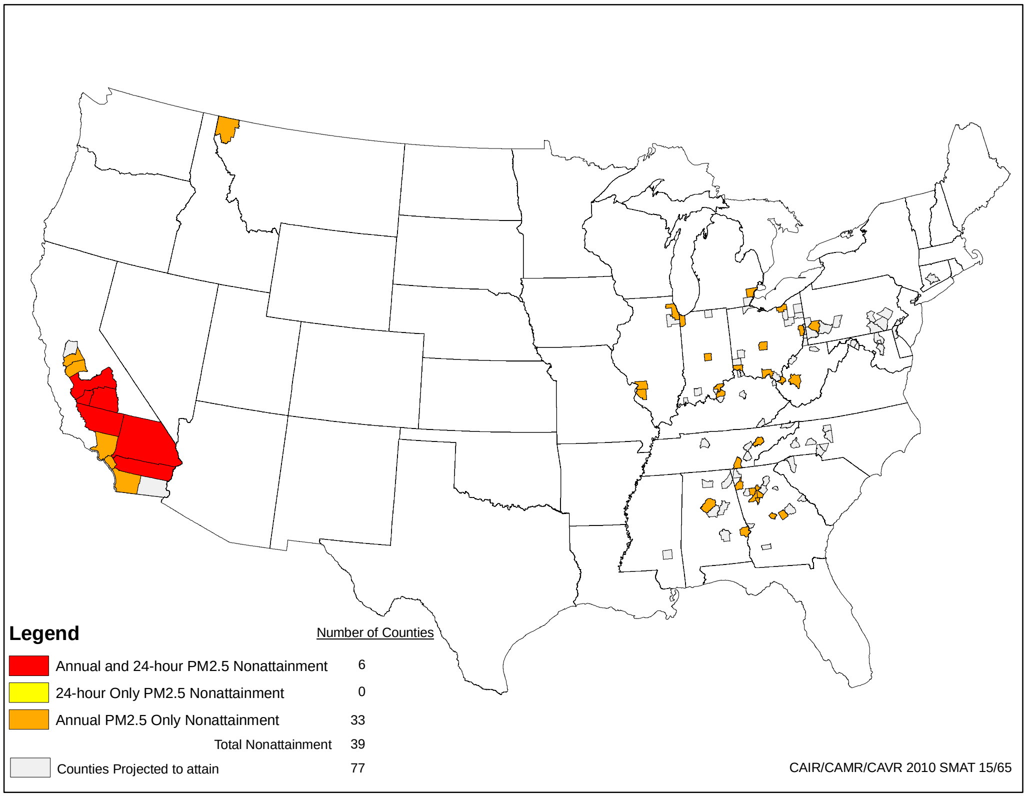

Figure 1: Counties Exceeding the $PM_{2.5}$ NAAQS under 2010 Base Case Scenario: Annual 15 µg/m^3 and 24-Hour 65 µg/m^3 (current standards).

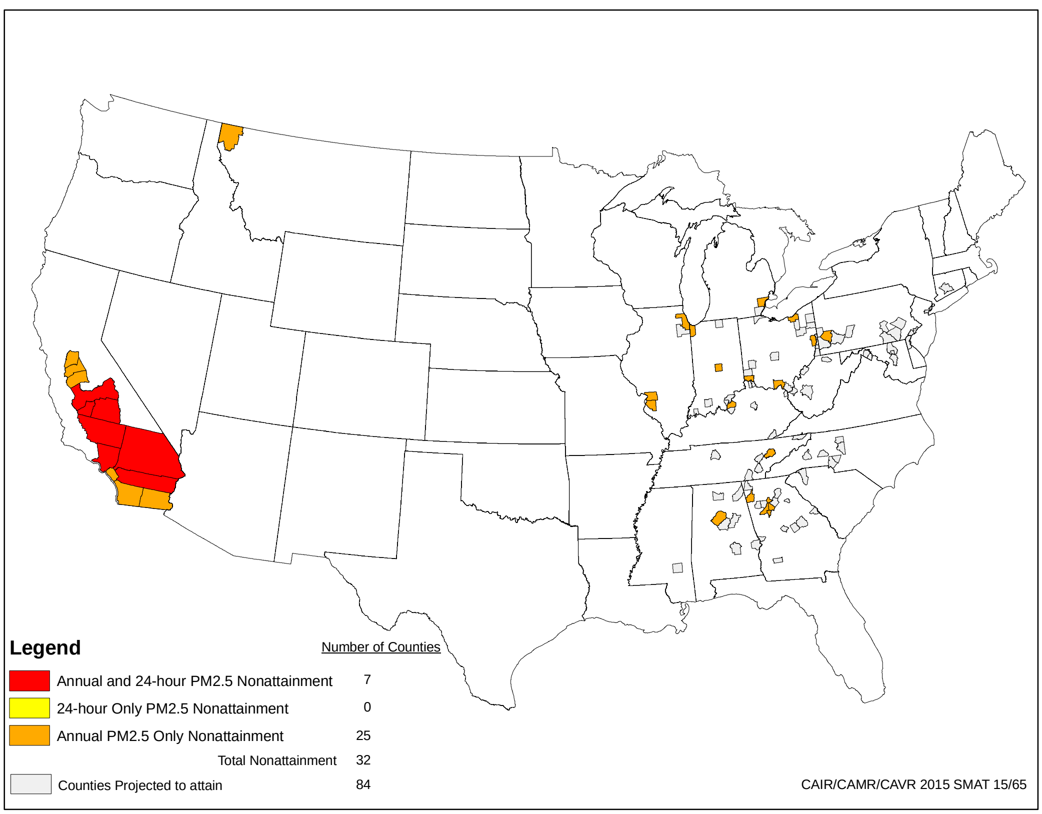

Figure 2: Counties Exceeding the $PM_{2.5}$ NAAQS under 2015 Base Case Scenario: Annual 15 µg/m^3 and 24-Hour 65 µg/m^3 (current standard).

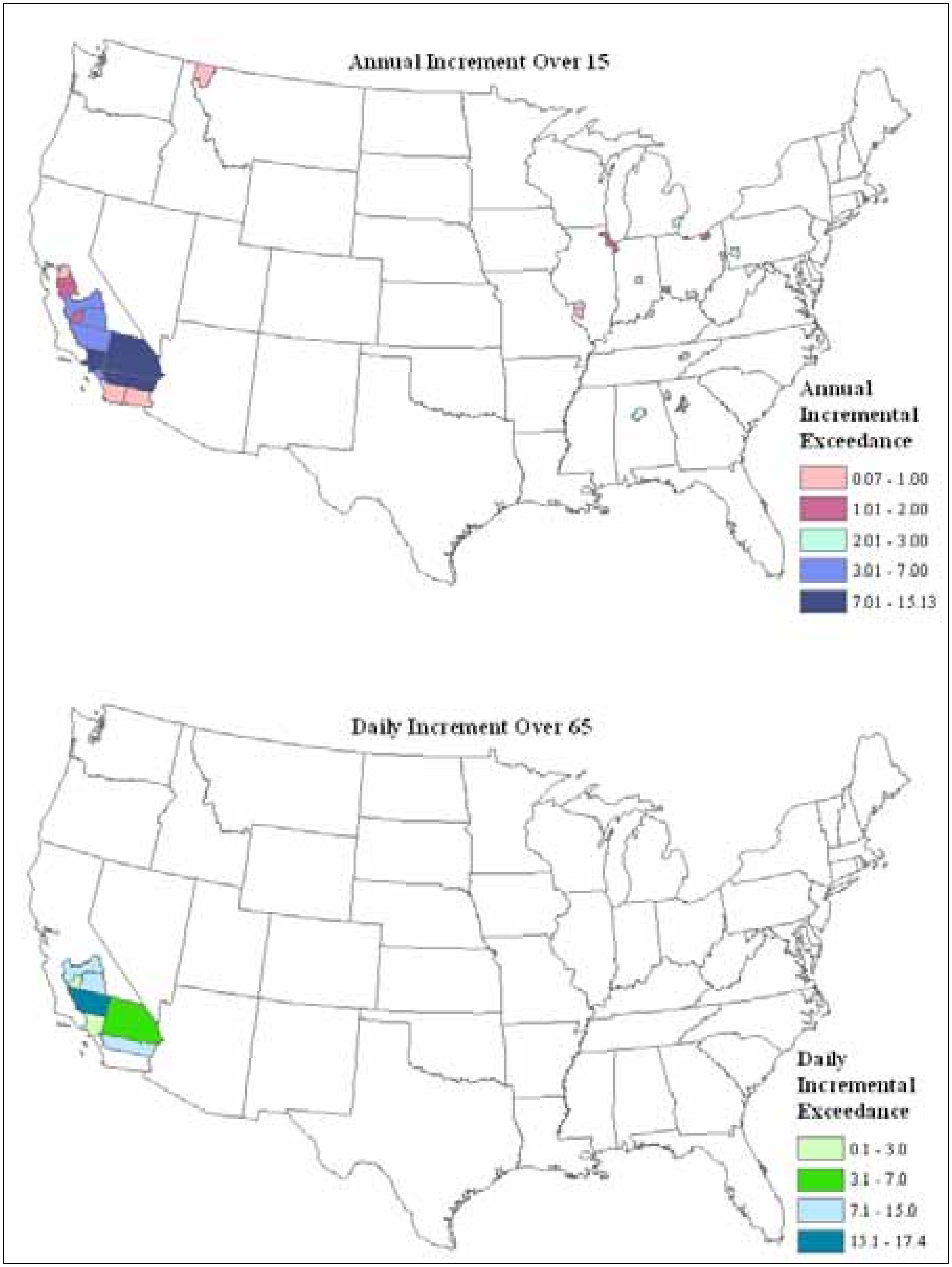

Figure 3: Increment by which projected non-attainment counties exceed the annual or daily standard for the 15/65 standard option in 2015.

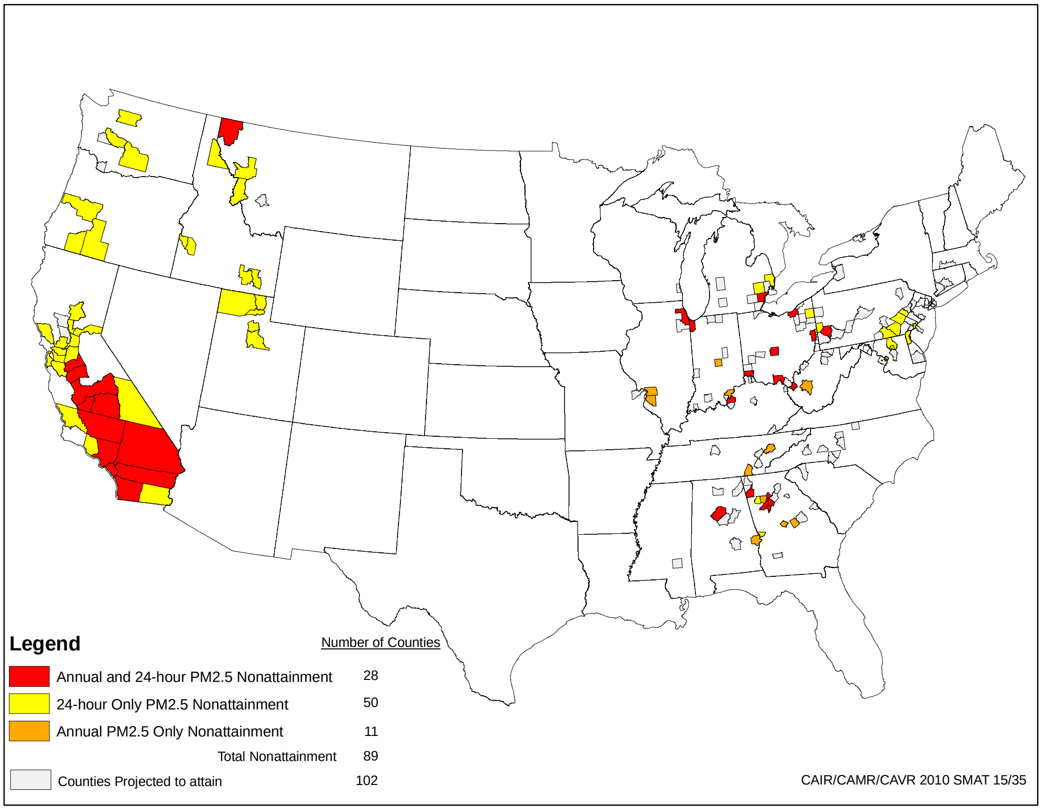

Figure 4: Counties Exceeding the $PM_{2.5}$ NAAQS under 2010 Base Case Scenario: Annual 15 μg/m^3 and 24-Hour 35 μg/m^3 (Proposed Revised NAAQS)

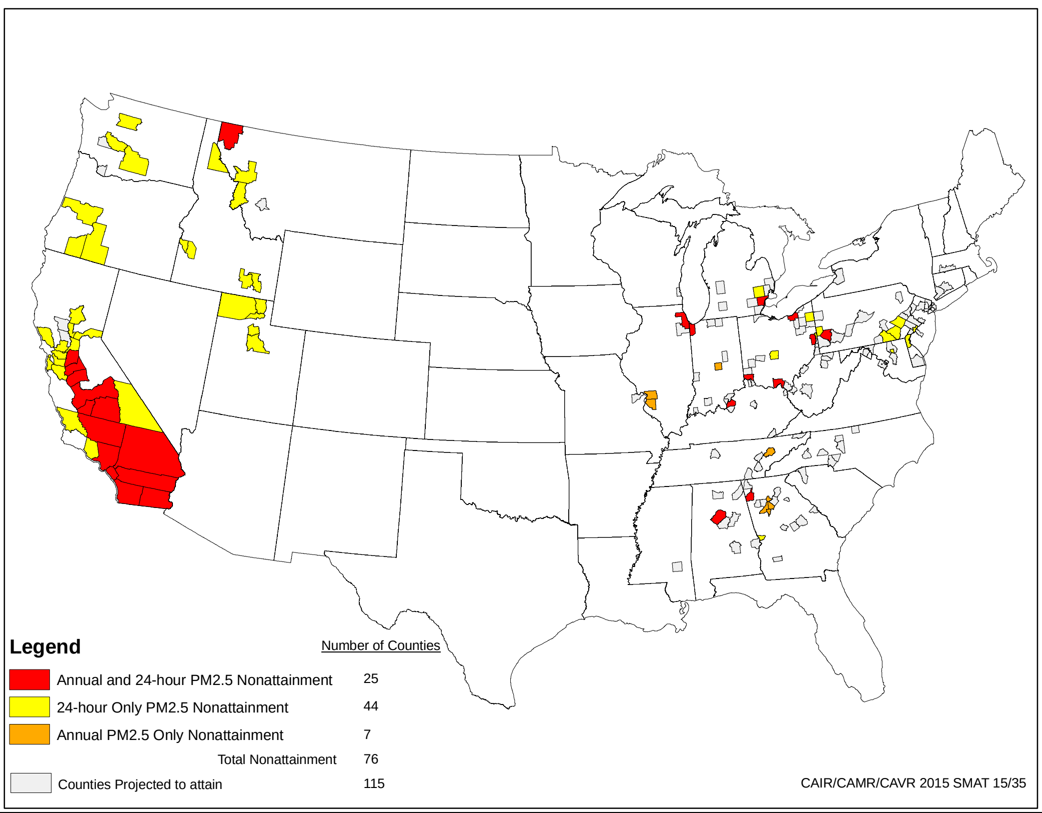

Figure 5: Counties Exceeding the $PM_{2.5}$ NAAQS under 2015 Base Case Scenario: Annual 15 μg/m^3 and 24-Hour 35 μg/m^3 (Proposed Revised NAAQS)

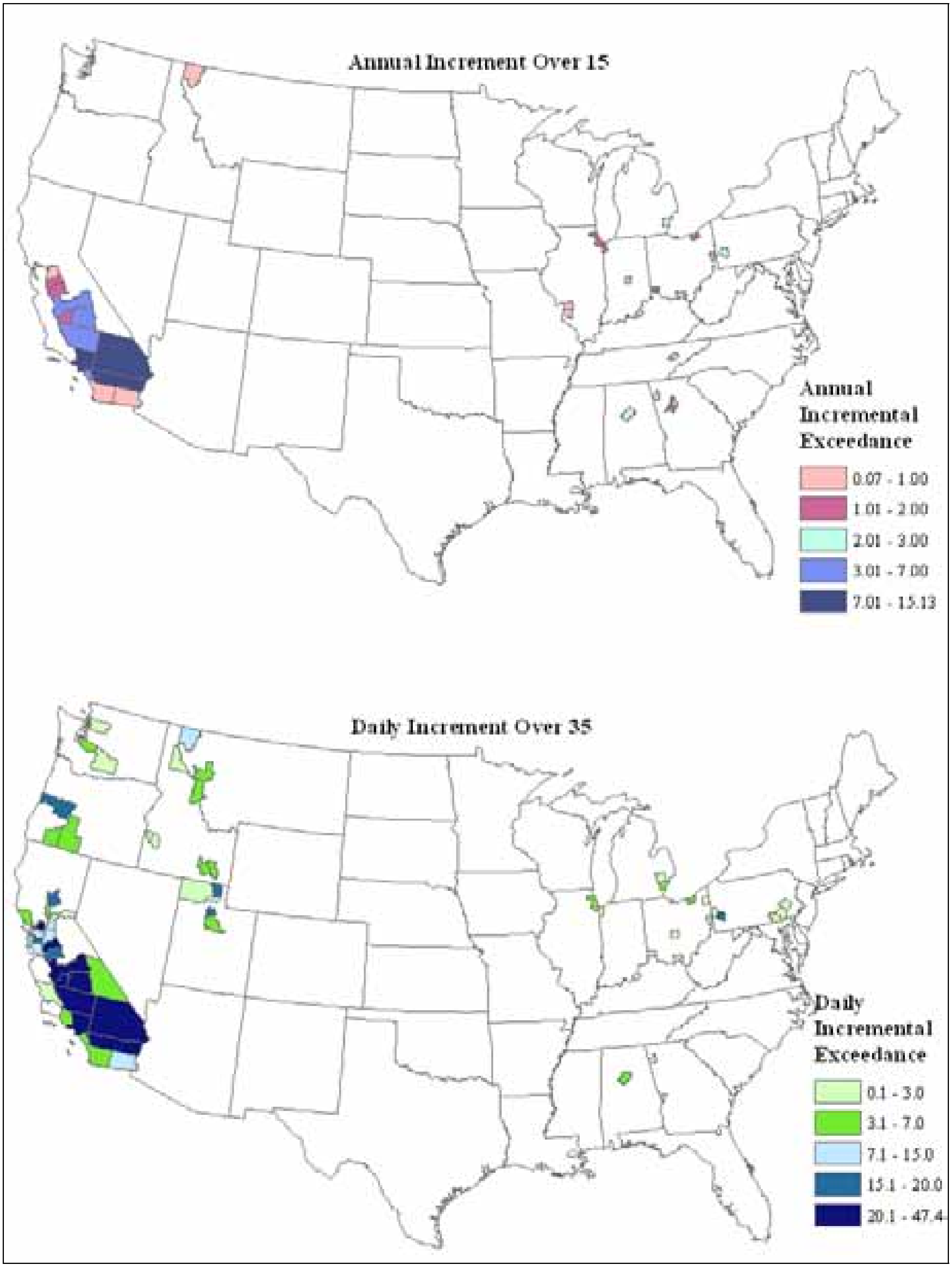

Figure 6: Increment by which projected non-attainment counties exceed the annual or daily standard for the 15/35 proposal in 2015.

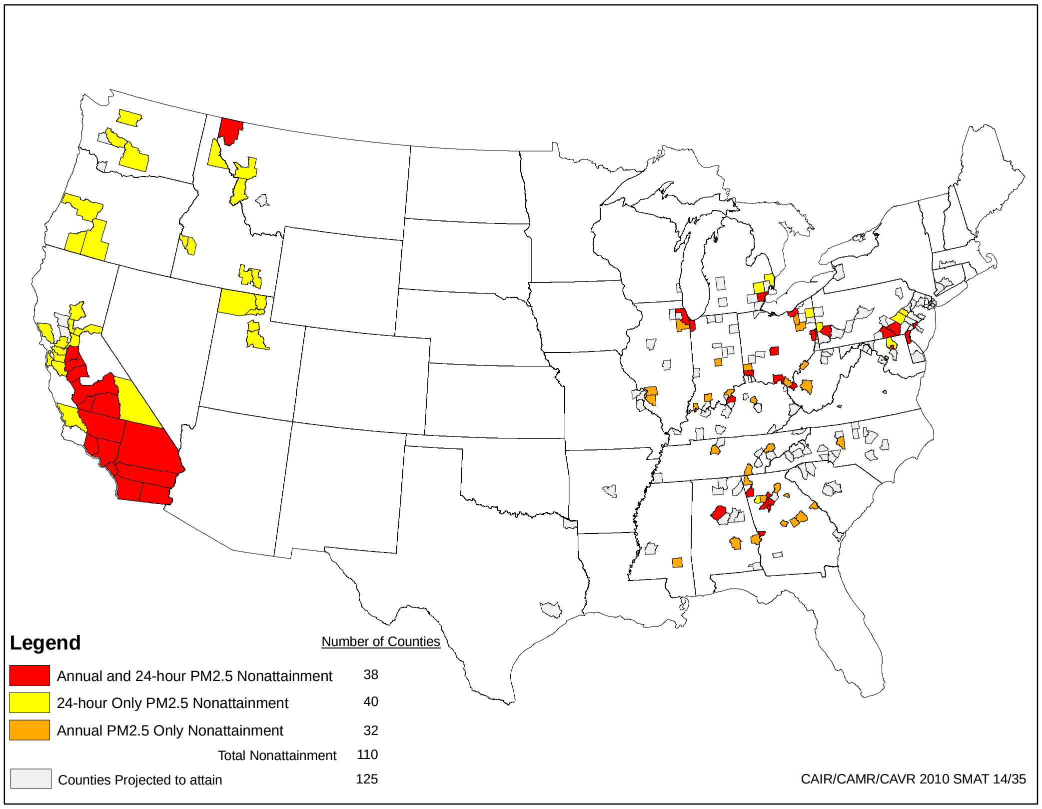

Figure 7: Counties Exceeding the $PM_{2.5}$ NAAQS under 2010 Base Case Scenario: Annual 14 µg/m^3 and 24-Hour 35 µg/m^3 standards option

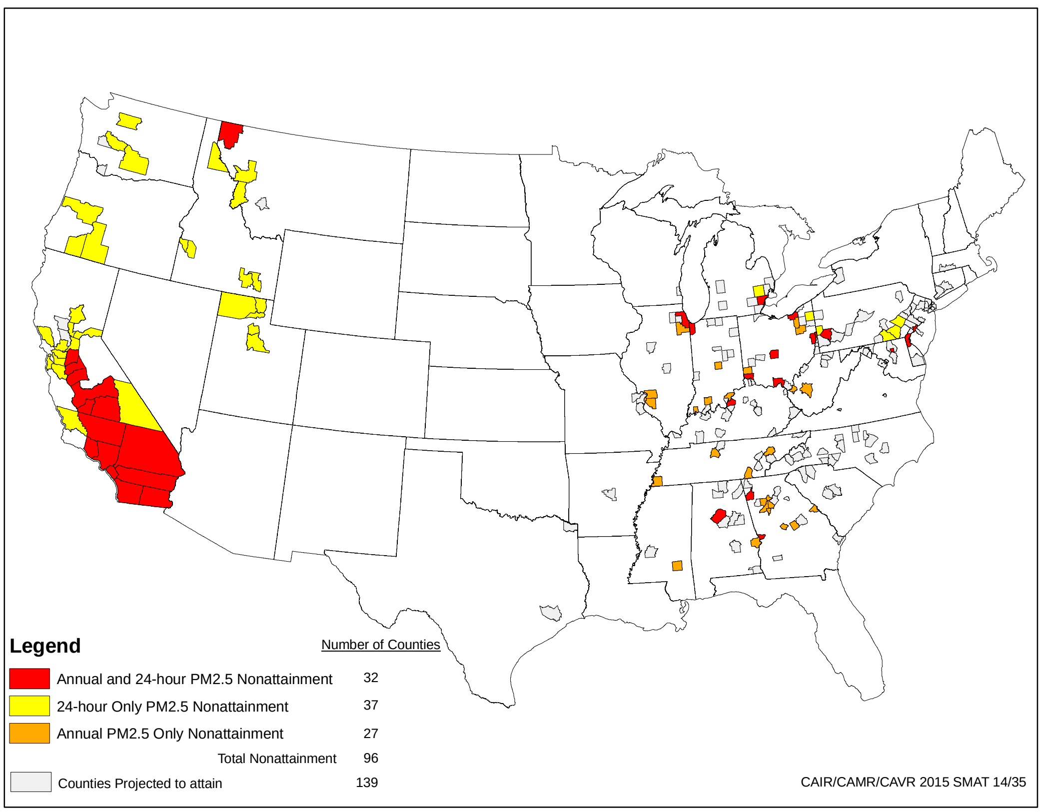

Figure 8: Counties Exceeding the $PM_{2.5}$ NAAQS under 2015 Base Case Scenario: Annual 14 µg/m^3 and 24-Hour 35 µg/m^3 standards option

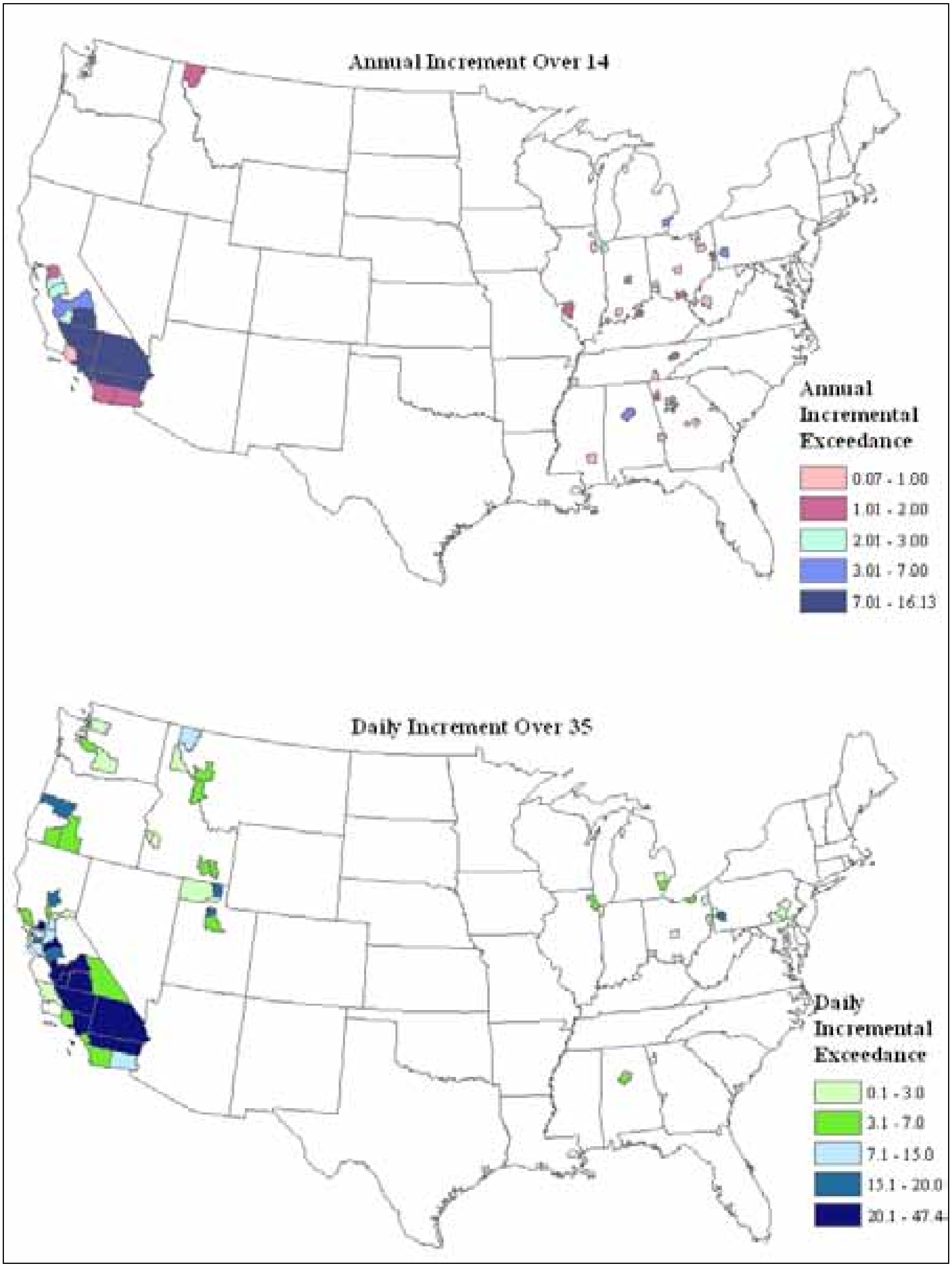

Figure 9: Increment by which projected non-attainment counties exceed the annual or daily standard for the 14/35 standards option in 2015.

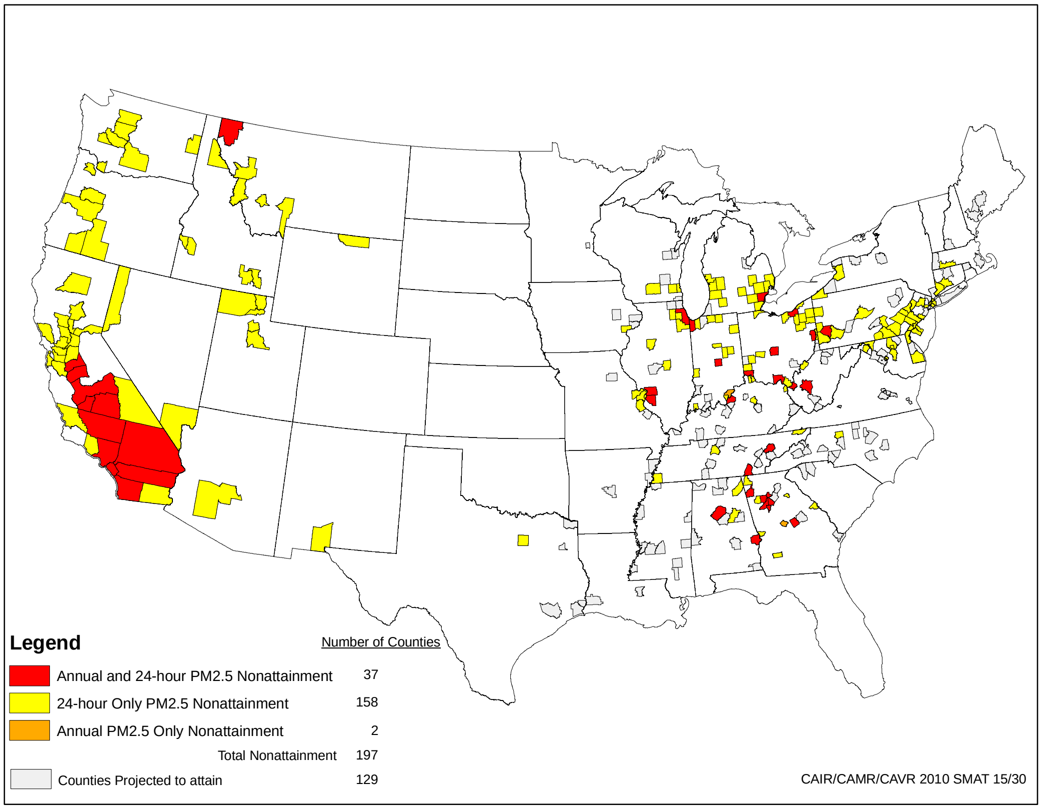

Figure 10: Counties Exceeding the $PM_{2.5}$ NAAQS under 2010 Base Case Scenario: Annual 15 µg/m^3 and 24-Hour 30 µg/m^3 standards option

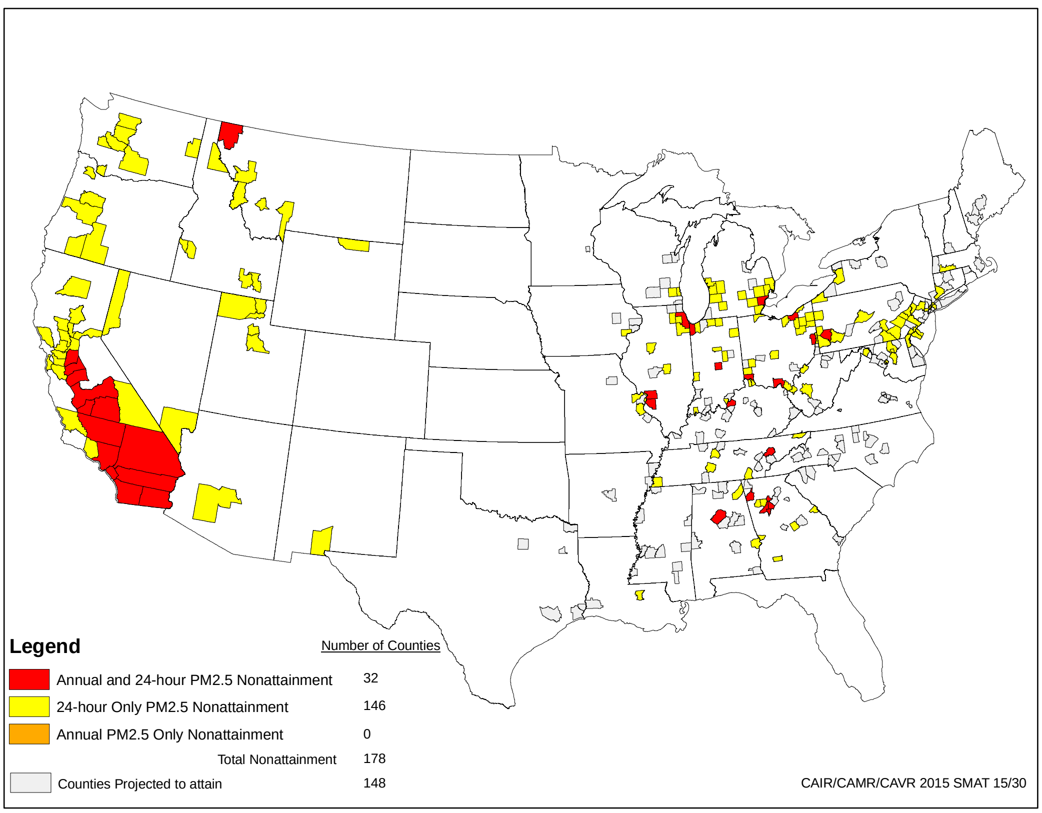

Figure 11: Counties Exceeding the $PM_{2.5}$ NAAQS under 2015 Base Case Scenario: Annual 15 µg/m^3 and 24-Hour 30 µg/m^3 standards option

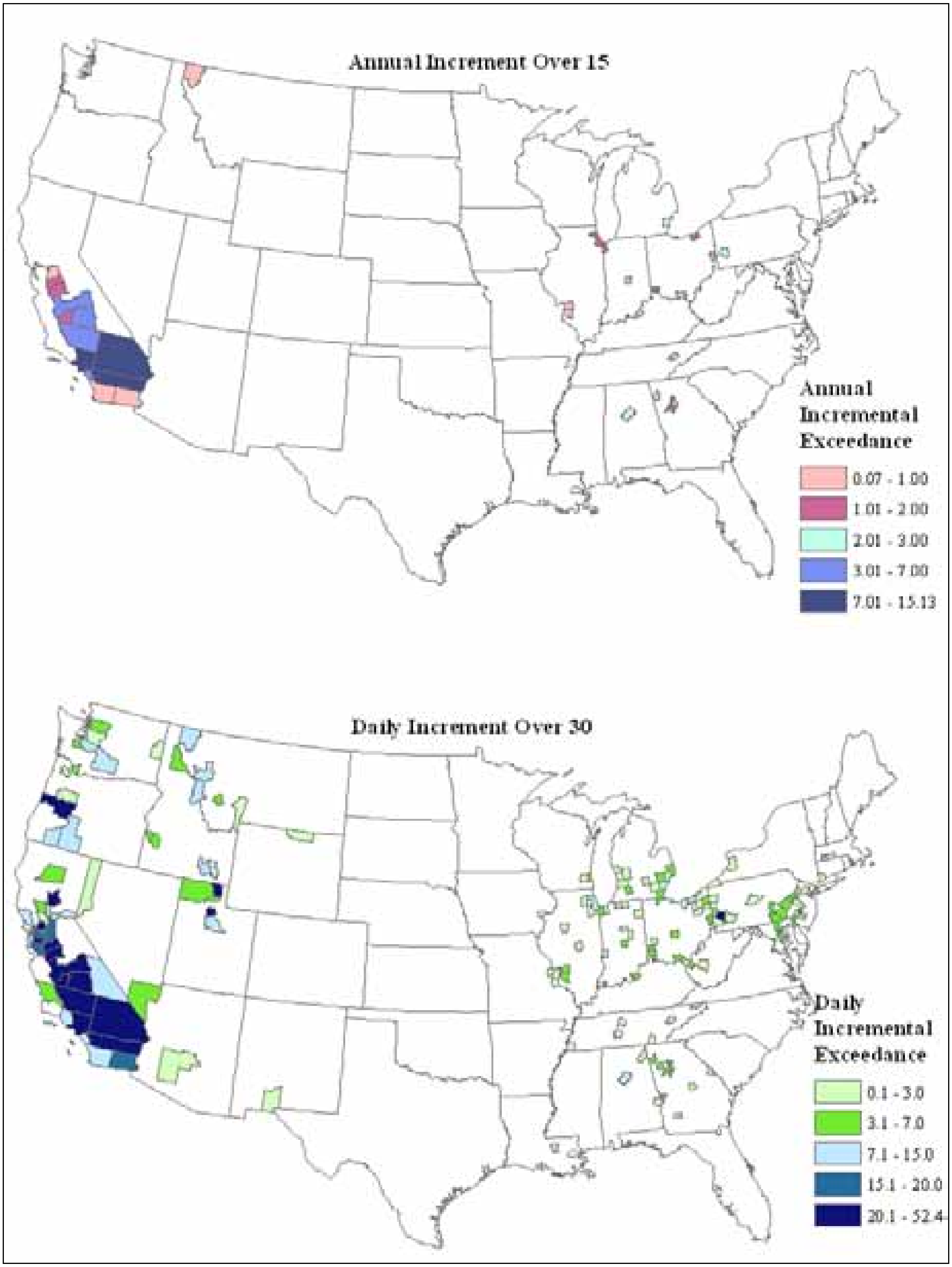

Figure 12: Increment by which projected non-attainment counties exceed the annual or daily standard for the 15/30 standard option in 2015.

Characterizing Fine Particles: Implications for Control Strategy Development

The discussion above summarized the our projections of the extent of non-attainment after baseline reductions in electric generation, mobile, and other sources are considered in the context of overall economic growth. The next portion of this White Paper discusses the nature of the $PM_{2.5}$ problem today, outlining what is known about the relative importance of regional and localized sources in various areas of the nation component.   This assessment finds significant regional and local differences between the eastern and western portions of the nation, in part. This difference was, of course, recognized in the CAIR program, which focused on the East where sulfates and nitrates from utilities were judged to be a significant contribution to $PM_{2.5}$ levels. The following analysis examines differences in the local sources and composition in different areas by providing results from 4 cities, Chicago, Seattle and the San Joaquin Valley of California, and New York City (Figure 13). Chicago and New York are eastern cities that we project, respectively, come close to attaining or attain the proposed $PM_{2.5}$ NAAQS through the basecase controls in 2015 and will have to take further local action to attain through their State Implementation Plans. Seattle is a western city whose remaining $PM_{2.5}$ air quality problem in 2015 is weighted towards local and regional sources of carbon. San Joaquin is a western city that has $PM_{2.5}$ levels well above the proposed standards and would therefore have a difficult challenge in reaching attainment.

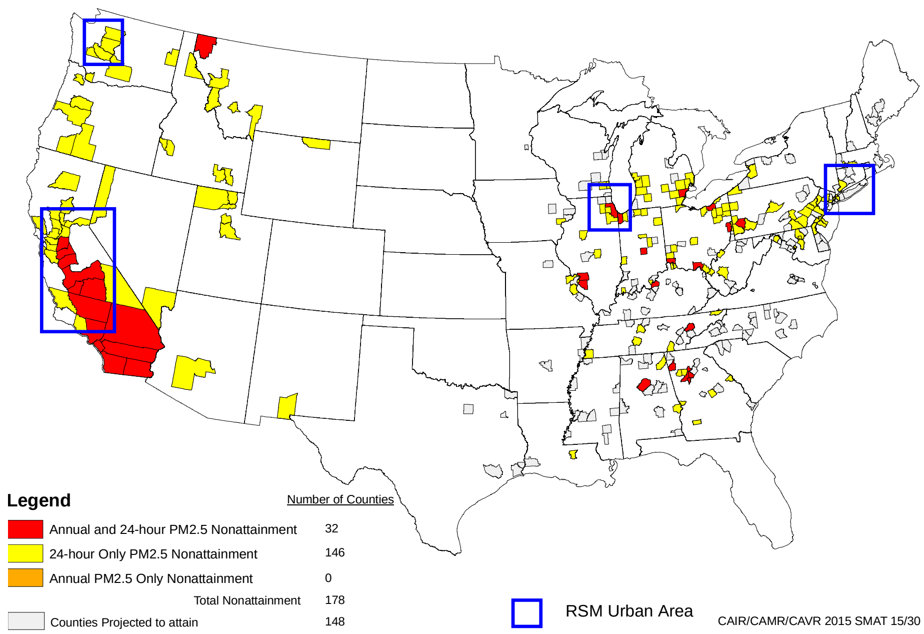

Figure 13: Urban Areas of Interest for this White Paper

Nature of the $PM_{2.5}$ Air Quality Problem

Particulate matter (PM) is a highly complex mixture of solid particles and liquid droplets distributed among numerous atmospheric gases that interact with solid and liquid phases. Particles span many sizes and shapes and consist of hundreds of different chemicals. Particles are emitted directly from sources and also are formed through atmospheric chemical reactions and often are referred to as primary and secondary particles, respectively. Particle pollution also varies by time of year and location and is affected by several aspects of weather, such as temperature, clouds, humidity, and wind. Further complicating particles is the shifting between solid/liquid and gaseous phases influenced by concentration and meteorology, especially temperature. Unlike daily ozone levels, which are usually elevated in the summer, daily $PM_{2.5}$ values at some locations can be high at any time of the year. For example, in Seattle, the highest levels of $PM_{2.5}$ concentrations occur during the winter months and are composed of carbon particles associated with wood and waste burning. Likewise, in Chicago, elevated levels of $PM_{2.5}$ were observed in 2003 during the colder months of February, March and April.

Our focus here is on “fine particles” classified as $PM_{2.5,}$ which have total particle size less than 2.5 micrometers. The major $PM_{2.5}$ components, or species, are carbon, sulfate and nitrate compounds, and crustal/metallic materials such as soil and ash. The different components that make up particle pollution come from specific sources and are often formed in the atmosphere. Particulate matter includes both “primary” PM, which is directly emitted into the air, and “secondary” PM, which forms indirectly from fuel combustion and other sources. Primary PM consists of carbon (soot)—emitted from cars, trucks, heavy equipment, forest fires, and burning waste, , and coke ovens, metals from coal combustion and industrial processes, ——and crustal material from unpaved roads, stone crushing, construction sites, and metallurgical operations. Secondary PM forms in the atmosphere from gases. Some of these reactions require sunlight and/or water vapor. Major secondary particles include:

- Nitrates formed from nitrogen oxide emissions from cars, trucks, and power plants

- Carbon formed from reactive organic gas emissions from cars, trucks, industrial facilities, forest fires, and biogenic sources such as trees.

- Sulfates, most of which come from atmospheric reactions of SO_2. Near strong sources, directly emitted sulfates and sulfur trioxide can be significant. Direct (or primary) sulfate emissions can come from sources such as power generation facilities and industries which burn residual oil.

- Ammonia from sources such as fertilizer and animal feed operations contributes to the formation of sulfates and nitrates that exist in the atmosphere as ammonium sulfate and ammonium nitrate. Note that fine particles can be transported long distances by wind and weather and can be found in the air thousands of miles from where they were formed.

The chemical makeup of particles varies across the United States (as shown in Figure 14). For example, fine particles in the eastern half of the United States contain more sulfates than those in the West, while fine particles in southern California contain more nitrates than other areas of the country. Carbon is a substantial component of fine particles everywhere. Note that particle mass and composition can vary substantially by season, so annual averages should not be considered representative of specific high $PM_{2.5}$ days.

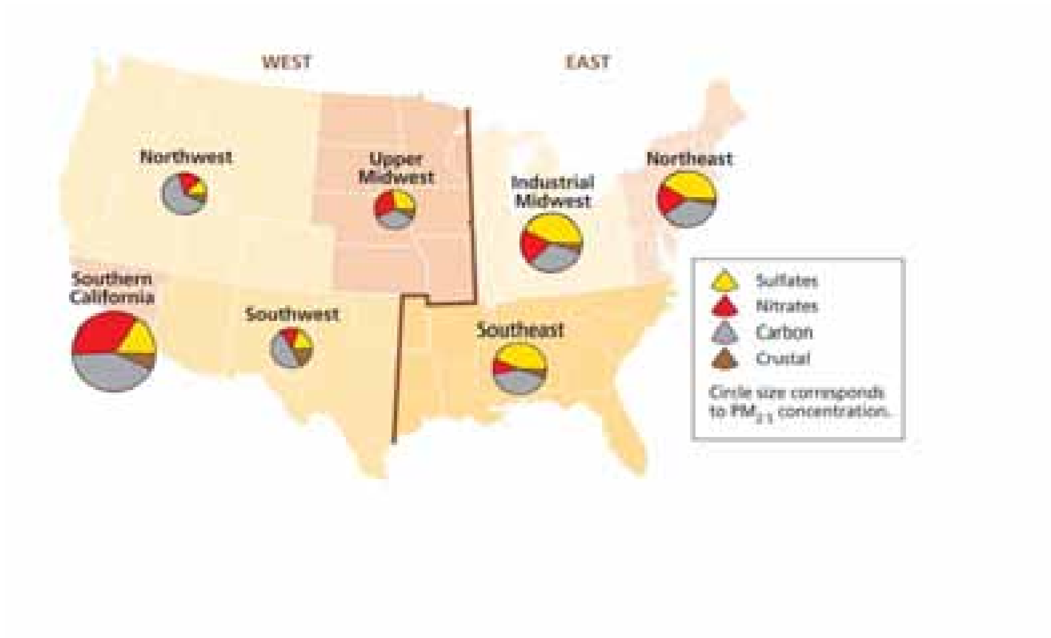

Figure 14. Average $PM_{2.5}$ composition in urban areas by region, 2003.

Figure 14 shows the differences in aggregated urban $PM_{2.5}$ species composition across seven regions of the United States. Figures 15 through 18 show variation in composition for both annual and daily $PM_{2.5}$ measures for 2003 for specific urban areas we are focusing on for illustration. For each area, the composition of the annual average differs somewhat from the average of the top 15 highest concentration days but is generally similar. The composition on the maximum concentration day can vary significantly from the annual and 15 highest day averages. This difference can be attributed to variation in source emissions and meteorological influences, e.g. temperature, wind direction and wind speeds. For Seattle, carbon dominates the $PM_{2.5}$ composition for annual average and average of the top 15 days; however, the worst day has more sulfate and nitrate contributions (Figure 15). In Seattle, residential wood and waste burning are the largest primary $PM_{2.5}$ contributors to the highest daily values at one monitor but a large kraft paper mill appears to be the largest contributor to daily values at another monitor. In Chicago, the sulfate and nitrate contributions to high daily values are mostly from regional point and areas sources, i.e., sources outside of the urban area. Nitrate, sulfate and total carbon each contribute significantly to $PM_{2.5}$ composition, whereas on the highest day, nitrate contributes a larger percentage, i.e., 46 percent vs. 27 percent (Figure 16). The average top 15 highest days reflects a sulfate and nitrate mass content of 9.3 $\mu g/m^3$ and 7.5 $\mu g/m^3$, respectively. In Fresno, total carbon and nitrate largely dominate the $PM_{2.5}$ composition for 2003 (Figure 17). For the highest $PM_{2.5}$ day in 2003, nitrate (33 $\mu g/m^3$) contributes a larger share than for the annual average (6.7 $\mu g/m^3$) or average of the top 15 highest days (20.7 $\mu g/m^3$). As is the case in a number of eastern areas, New York City $PM_{2.5}$ composition is significantly dominated by sulfate (Figure 18), particularly on the worst day. The highest concentration day in 2003 shows a sulfate and total carbon contribution of approximately 60% and 33%, respectively. The air quality modeling projections above predicts that sulfates will comprise approximately 50% of total $PM_{2.5}$ mass for 2015. Further detail on future-year speciation for NY and other urban areas may be found in the RIA. The annual average and average of the top 15 highest concentration days reflects a nitrate contribution of approximately 20%.

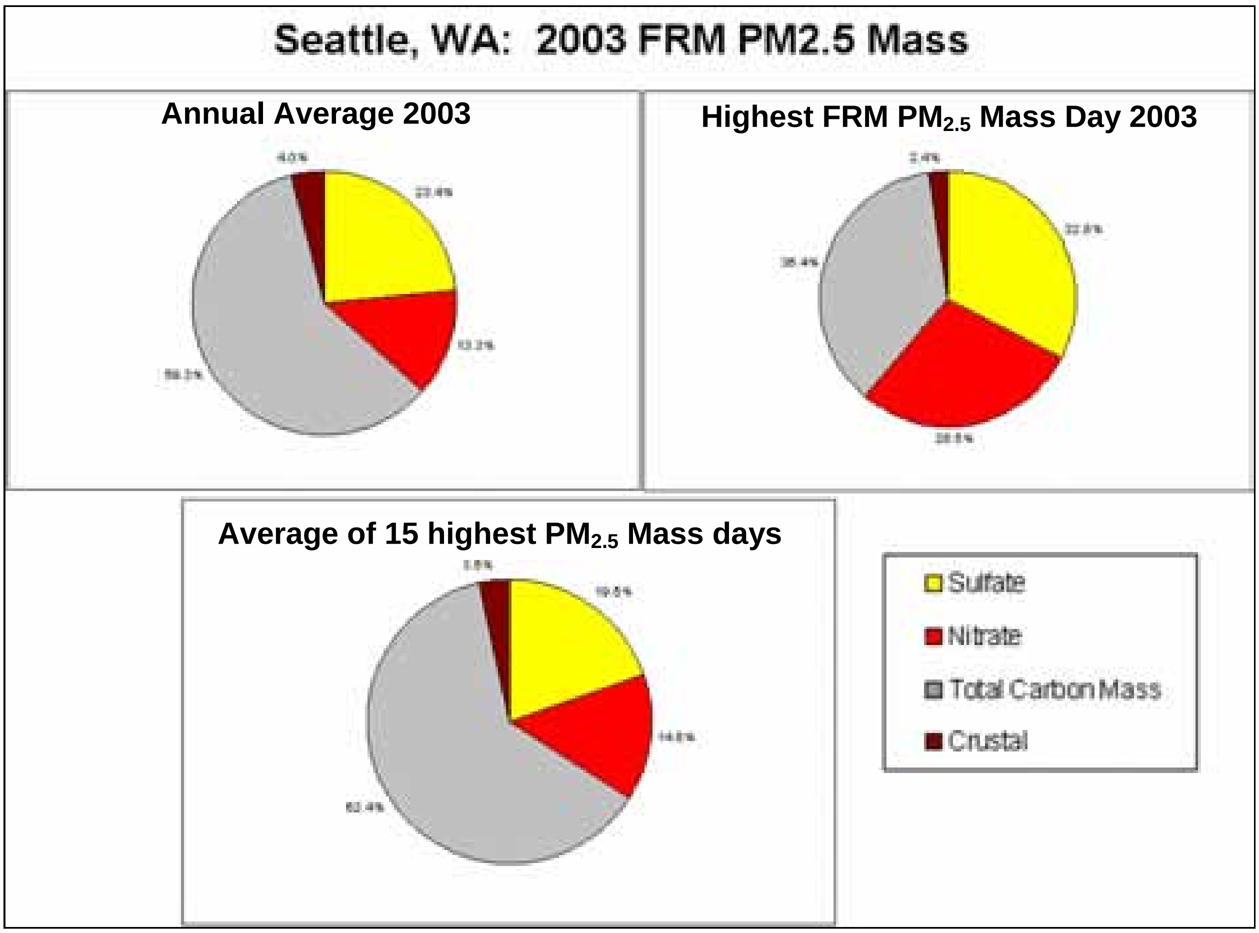

Figure 15. 2003 Daily $PM_{2.5}$ mass and speciation patterns for Seattle, WA**.**

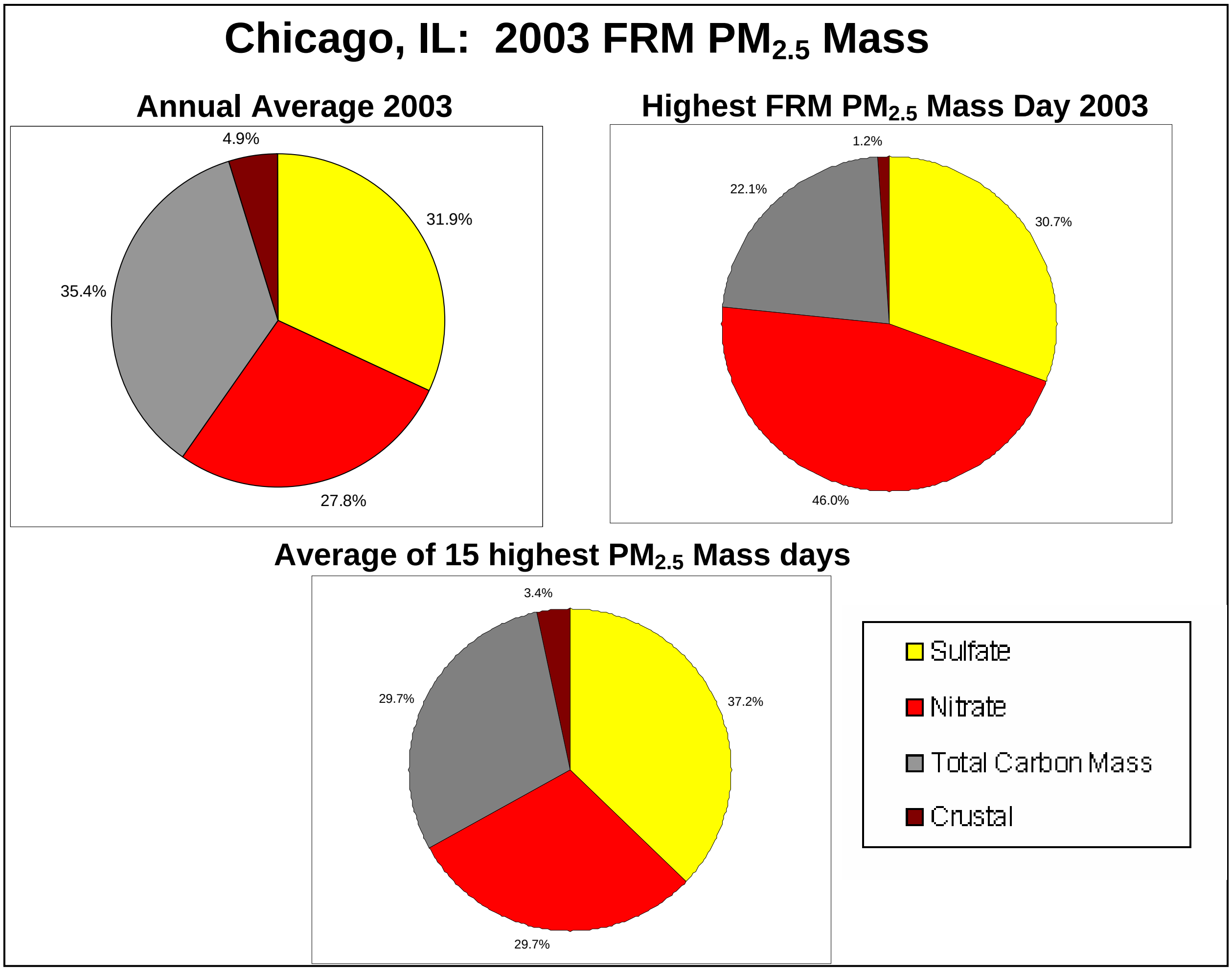

Figure 16. 2003 Daily $PM_{2.5}$ mass and speciation patterns for Chicago, IL**.**

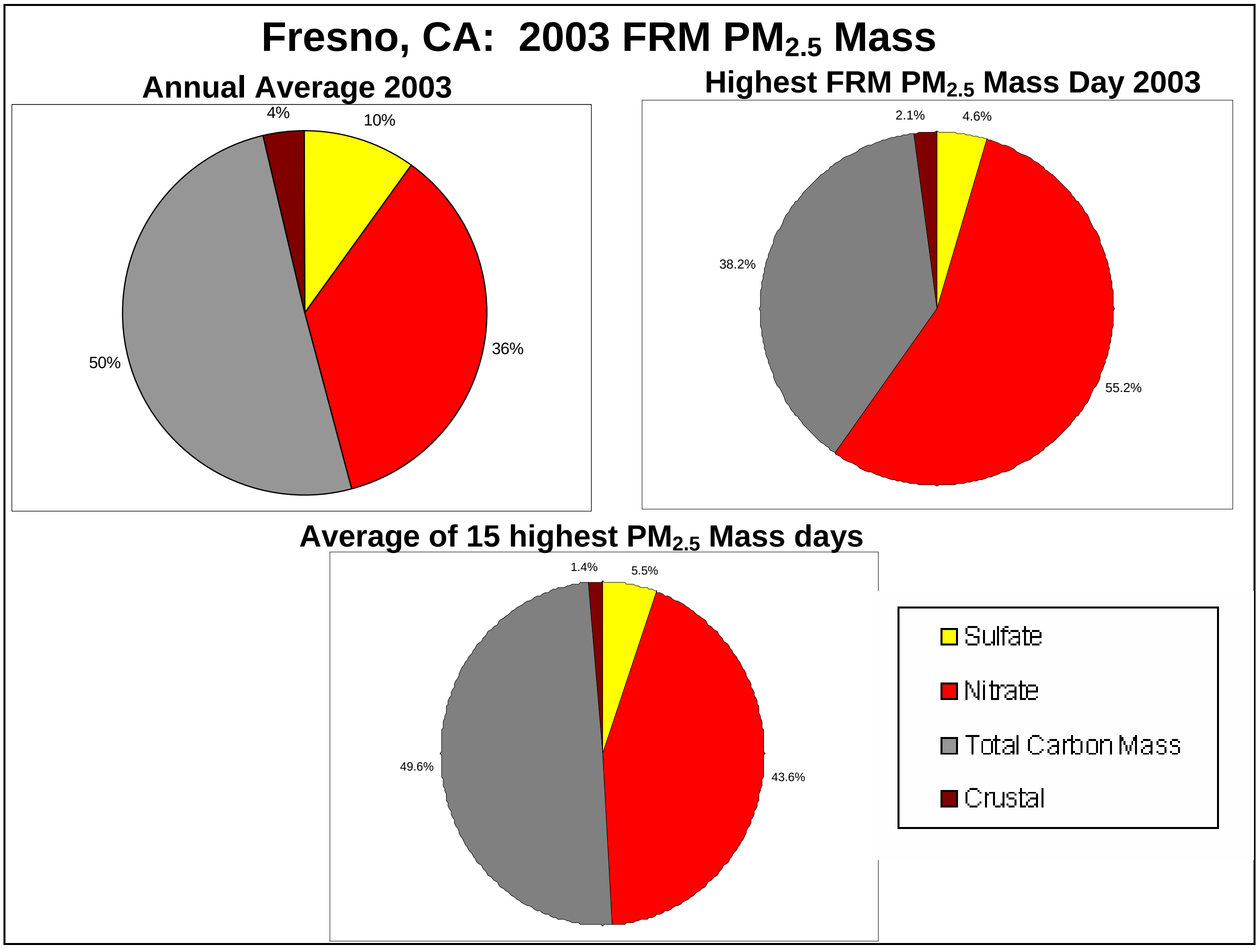

Figure 17. 2003 Daily $PM_{2.5}$ mass and speciation patterns for Fresno, CA**.**

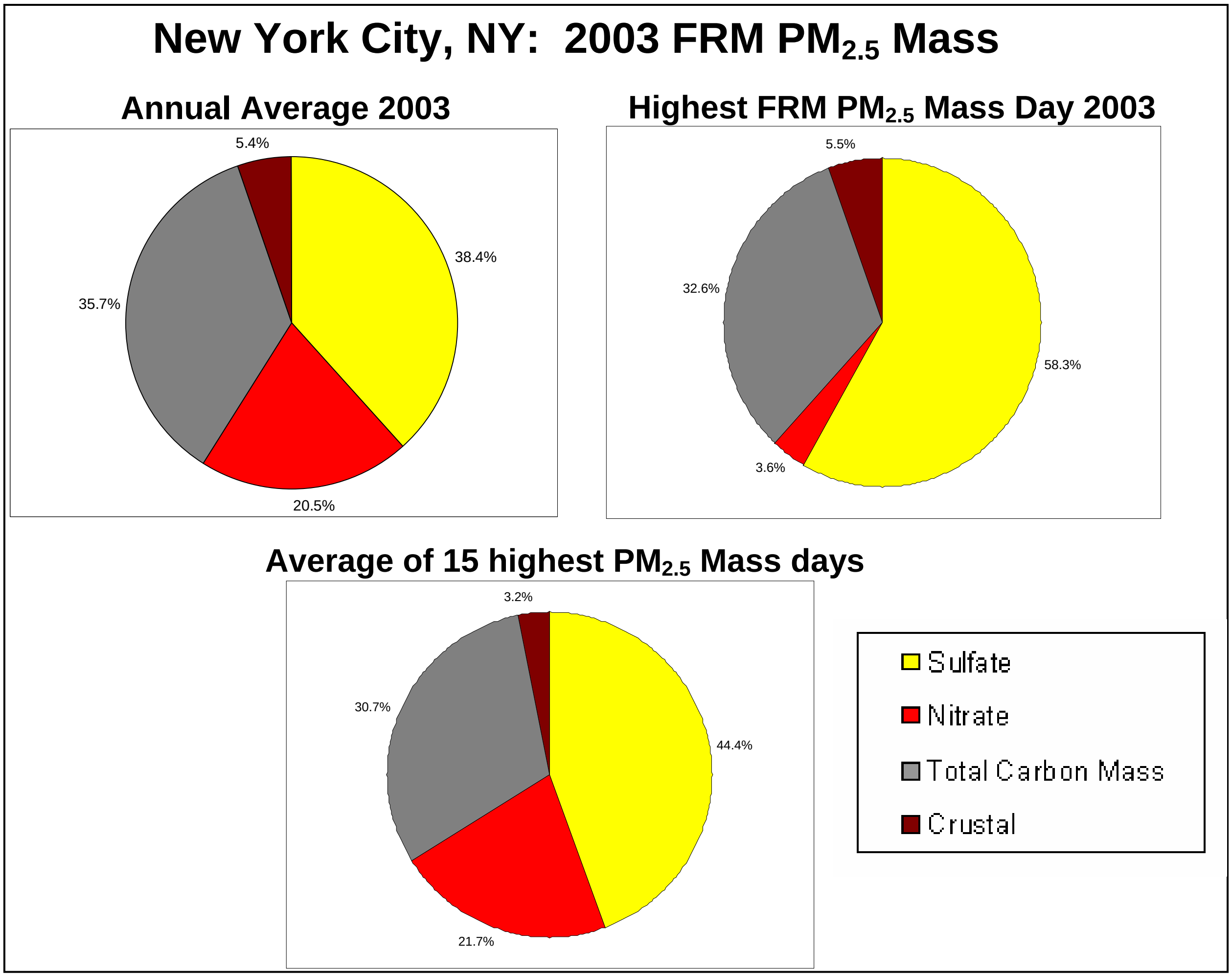

Figure 18. 2003 Daily $PM_{2.5}$ mass and speciation patterns for New York, NY**.**

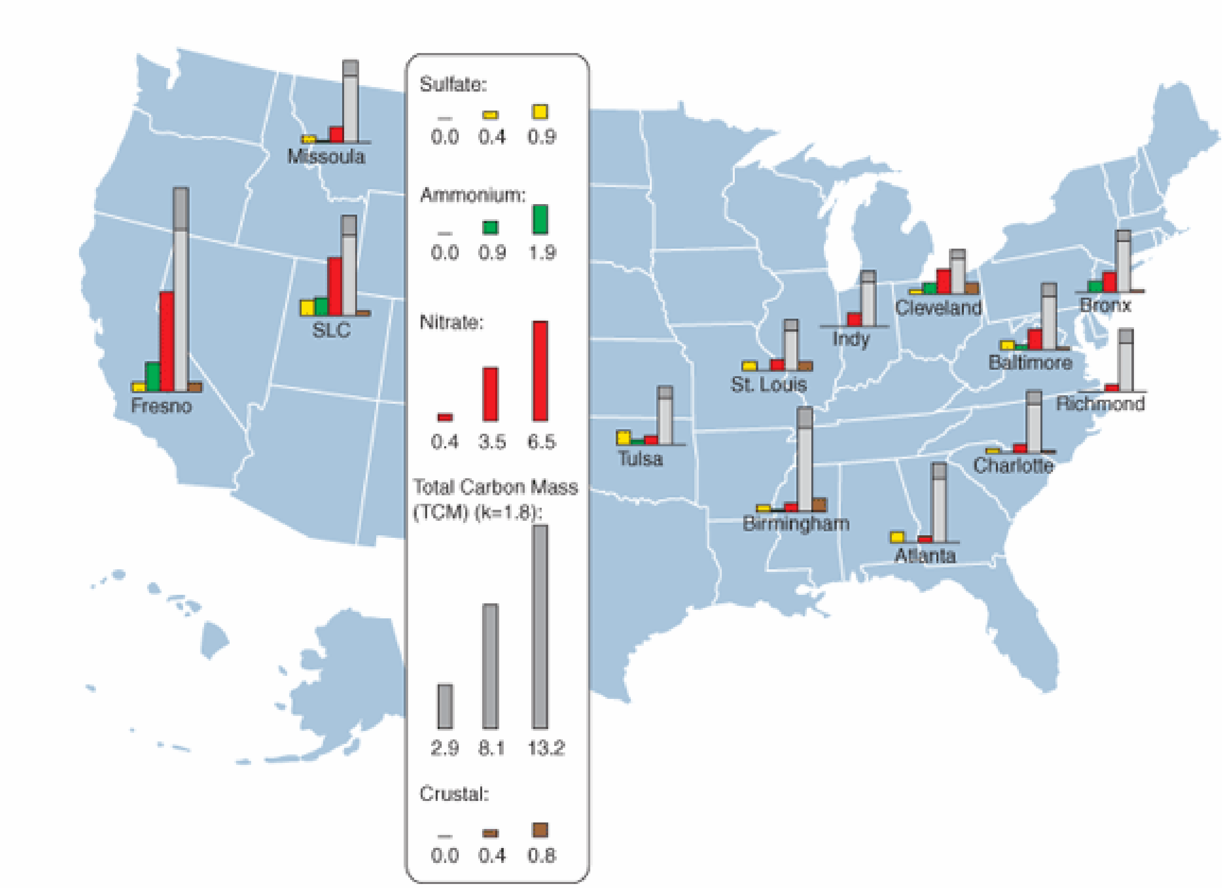

Figure 19. Estimated 'urban excess' of 13 urban areas by $PM_{2.5}$ species component. The urban excess is estimated by subtracting the measured $PM_{2.5}$ species at a regional monitor location (assumed to be representative of regional background) from those measured at an urban location.

As shown in Figure 19, we observe a large urban excess across the US for most $PM_{2.5}$ species but especially for total carbon mass. All of these locations have consistently high urban excess for total carbon mass with Fresno and Birmingham having the largest observed measures. Larger urban excess of nitrates is seen in the western US with Fresno and Salt Lake City being significantly higher than all other areas across the nation. These results indicate that local sources of these pollutants are indeed contributing to the $PM_{2.5}$ air quality problem in these areas. As expected for a predominately regional pollutant, only a modest urban excess is observed for sulfates.

Considerations in designing control strategies for areas to attain

In examining control alternatives to meet the current and alternative standards, our preliminary analyses have focused on a hierarchy of control strategies that takes into account regional differences in the nature of the air quality problems, as well as the results of national and regional strategies that have already been adopted to address some of them.

The available information regarding the scope and magnitude of the $PM_{2.5}$ air quality problem suggests that local strategies will be part of an effective strategy in addressing any tightening of the daily standard. This local-first strategy complements the suite of national rules that EPA has already put into place, including the Clean Air Interstate Rule (CAIR), the Clean Air Visibility Rule (CAVR) and the Clean Air Mercury Rule (CAMR). The combination of these national rules will provide significant reductions in the emission of regional $PM_{2.5}$ precursors including SO_2 and NO_x. In substantially reducing the regional contribution of $PM_{2.5}$ precursors, these rules enable states to focus first on reducing the localized "urban excess" of direct and secondarily formed $PM_{2.5}$ before looking to further regional control strategies.

Next Steps: Draft RIA for Selected Cites and Completing the Final RIA

A preliminary draft of the Regulatory Impacts Analysis (RIA) associated with the PM NAAQS proposal will be available by January 2006. Within the RIA EPA examines city specific case studies of the costs and benefits of attaining the current $PM_{2.5}$ standards as well as proposed and alternative standards that are more protective of human health and the environment.

The reliance on science and statutory prohibition against the consideration of cost in setting of the primary air quality standards does not mean that cost or other economic considerations are not important or should be ignored. The Agency believes that consideration of cost is an essential decision making tool for the cost-effective implementation of these standards. The implementation process is where decisions are made -- both nationally and within each community -- affecting how much progress toward attainment can be made, and what time lines, strategies and policies make the most sense. Pursuant to Executive Order 12866 and OMB Circular A-4, the forthcoming Regulatory Impact Analysis provides information on the nature of the $PM_{2.5}$ problem in this country and potential costs and benefits associated with illustrative scenarios for implementation of the proposed revisions to the NAAQS for $PM_{2.5}$.

There are important differences between the forthcoming RIA and recent EPA RIAs that analyze the costs and benefits of proposed regulations. First, this RIA analyzes the costs and benefits of implementing a series of illustrative control scenarios rather than a prescriptive national scale regulatory approach that reduces air pollution to desired levels. Like other RIAs, this document sets out the air quality challenge that the nation faces to reach tighter $PM_{2.5}$ NAAQS. However, the states must ultimately design and implement control strategies to meet a NAAQS. Because we cannot predict the composition of those controls, we analyze a series of control scenarios that we believe to be illustrative of what the states may ultimately implement for some city-specific case studies in lieu of broad national estimates of attaining the proposed standards and alternative standards options.

We had planned to provide national cost and benefit estimates of illustrative control strategies to assess the nation's ability to reach the proposed $PM_{2.5}$ standards and alternative standards options. As we developed that analysis, we reached the conclusion that, at present, our available data and tools are insufficient to develop cost and benefit information that would accurately reflect the range of possible options that the States may choose to implement. Most significantly, we concluded that the national-scale analysis based on our current data and tools would not properly reflect the incremental costs and benefits of moving from the current standards to progressively more health-protective standards. We are taking steps to ensure that we will complete this national-scale analysis in time for publication with the final rule (September 2006).