REPORT OF THE VIRGINIA
DEPARTMENT OF ENVIRONMENTAL QUALITY

Analysis of Projected Health Co-Benefits in EPA's Proposed Clean Power Plan: Report in Response to Virginia Senate Joint Resolution No. 273 (2015 Session)

TO THE GOVERNOR AND
THE GENERAL ASSEMBLY OF VIRGINIA

SENATE DOCUMENT NO. 15

COMMONWEALTH OF VIRGINIA
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COMMONWEALTH of VIRGINIA

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To: The Honorable Terence R. McAuliffe
Members of the General Assembly

From: David K. Paylor

Date: December 18, 2015

Subject: Analysis of Projected Health Co-Benefits in EPA's Proposed Clean Power Plan: Report in Response to Virginia Senate Joint Resolution No. 273 (2015 Session)

Attached is the report entitled "Analysis of Projected Health Co-Benefits in EPA's Proposed Clean Power Plan: Report in Response to Virginia Senate Joint Resolution No. 273 (2015 Session)" prepared by the Virginia Center for Coal and Energy Research (VCCER) at Virginia Tech. This report was prepared in accordance with Senate Joint Resolution No. 273 (2015) which required a study of "the projected health benefits of the proposed federal Clean Power Plan in comparison with the projected health benefits of existing regulations," by analyzing and considering "other analyses of, the projections for ozone and particulate matter reductions in the Plan and (i) determine the accuracy of such projections and the likelihood that such projections will lead to air quality improvements; (ii) compare projections of the national cost of the Plan to the health benefits projected to result from the Plan and complete a cost-benefit analysis; (iii) determine the likelihood that the health benefits attributed to the Plan by the EPA would arise in the absence of the Plan; and (iv) determine the extent to which the EPA uses otherwise-expected benefits to public health as a justification for the Plan.

If you have any questions concerning this report or if you would like a hard copy of this report, please contact Angie Jenkins, Policy Director, at (804) 698-4268.

Analysis of Projected Health Co-Benefits in EPA's Proposed Clean Power Plan: Report in Response to Virginia Senate Joint Resolution No. 273 (2015 Session)

Submitted to

The Virginia Department of Environmental Quality

by

The Virginia Center for Coal and Energy Research, Virginia Tech

December 10, 2015

VIRGINIA CENTER FOR COAL AND ENERGY RESEARCH

http://www.energy.vt.edu

The Virginia Center for Coal and Energy Research was created by an Act of the Virginia General Assembly on March 30, 1977, as an interdisciplinary study, research, information and resource facility for the Commonwealth of Virginia. In July of that year, a directive approved by the Virginia Tech Board of Visitors placed the VCCER under the University Provost because of its intercollegiate character, and because the Center's mandate encompasses the three missions of the University: instruction, research and extension. Derived from its legislative mandate and years of experience, the mission of the VCCER involves five primary functions:

- Research in interdisciplinary energy and coal-related issues of interest to the Commonwealth
- Coordination of coal and energy research at Virginia Tech
- Dissemination of coal and energy research information and data to users in the Commonwealth
- Examination of socio-economic implications related to energy and coal development and associated environmental impacts
- Assist Commonwealth of Virginia in implementing the Commonwealth's energy plan.

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BACKGROUND AND INTRODUCTION

On June 18, 2014, the U. S. Environmental Protection Agency (EPA) published a proposed rule for "Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units" to reduce the impact of climate change from this emission source sector. Also known as the proposed Clean Power Plan (the "Plan"), this rule would require an overall 30% reduction in carbon dioxide (CO_2) from existing electricity generating units before 2030 by establishing state-specific emission rate and reduction goals.

The focus of the Plan is on achieving CO_2 reductions specifically to reduce potential future effects from climate change. In its regulatory impact analysis (RIA) of the estimated costs and benefits of the Plan, however, the EPA also included health benefits associated with the expected reduction of criteria pollutant emissions and ambient air pollution levels that are expected as a co-benefit of the Plan. For decades, the EPA has separately promulgated a number of national ambient air quality standards (NAAQS) for criteria pollutants and associated control programs that identify similar, and perhaps some of the same, emission reductions and resulting benefits. This situation could result in the "double counting" of these benefits by the EPA in the Plan and one or more of these other rules. The EPA in fact acknowledges this possibility in the Plan's RIA stating, "…it is possible that some costs and benefits estimated in this RIA may account for the same air quality improvements as estimated in the illustrative NAAQS RIAs."

During the 2015 Session of the Virginia General Assembly, Senate Joint Resolution No. 273 (SJR 273) was passed that directs the Virginia Department of Environmental Quality (VDEQ) to study the health benefits of the proposed federal Plan in comparison with the projected health benefits from other air quality regulations. VDEQ entered into an agreement with the **Virginia Center for Coal and Energy Research (VCCER) at Virginia Tech** to conduct this study and provide a report to the VDEQ allowing them to comply with SJR 273. To this end, the VCCER engaged the services of National Economic Research Associates, Inc. (NERA) to conduct primary research and analysis and report its findings.

SPECIFIC TASKS

The VCCER committed its team to undertake a number of tasks in preparation of the report to VDEQ. These were:

1. Analyze, and consider other analyses of, the projections for ozone and particulate matter emissions and ambient concentration reductions in the proposed Plan.
2. Determine the accuracy of such projections and the likelihood that such projections will lead to air quality improvements.
3. Compare projections of the national cost of the Plan to the health benefits projected to result from the Plan and complete a cost-benefit analysis.

4. Determine the likelihood that the health benefits attributed to the Plan by the EPA would arise in the absence of the Plan, and thus be, in the language of SJR 273, "otherwise expected."
5. Determine the extent to which the EPA uses these otherwise-expected benefits to public health as a justification for the Plan.

In performing these analyses, the VCCER/NERA team evaluated and compared the technical analyses that support these rules, including the RIAs, technical support documents, and associated modeling exercises regarding predicted air quality improvement, power sector impacts, and health and economic benefits.

During the preparation of this report, the EPA released the final regulations for the Plan. The final Plan has several modifications from the proposed Plan. The timing of implementation and the state-specific emissions targets are different, and EPA provides states with alternative implementation options, including mass-based targets. The RIA for the final Plan also includes lower costs, benefits, and co-benefits than those projected in the RIA for the proposed regulations. However, the VCCER/NERA team concludes that the issues related to the use of co-benefits are unchanged. This is based on the following key factors:

- The role of criteria pollutant reductions and co-benefits is unchanged.
- The methods and assumptions used to compute co-benefits are unchanged.
- The limitations of the methods are unchanged.
- The relationship of the final Plan RIA's co-benefit estimates to benefits in RIAs for existing regulations is unchanged.

Therefore, the analyses in this report would have resulted in the same conclusions if the final Plan had been reviewed rather than the proposed Plan.

SUMMARY OF REPORT AND FINDINGS

This VCCER report is based on the work of NERA, which was presented to, reviewed by, and endorsed by the VCCER. The entire NERA report is included as Section 2 of the VCCER report. Furthermore, the VCCER believes that the analyses requested by the Virginia General Assembly and by VDEQ are satisfied by the report. Its findings are summarized below.

- It is reasonable to expect coincidental reductions in $PM_{2.5}$ and ozone precursor emissions as a result of the Plan, although there is substantial uncertainty on their geographic location and magnitude.

- Although the literal form of double-counting of precursor emissions reductions is not a concern, the report does identify a concern with overstatement of likely co-benefits, which stems more from the way that the EPA computes its benefits per increment of criteria pollutant reduction than from the way that the EPA quantifies the criteria pollutant changes attributable to the Plan.

- The coincidental reductions of precursor emissions fall into two categories, either (1) they will occur even if the Plan were not to be implemented, or (2) they are in locations that are already well below their respective NAAQS levels. Each category represents a distinct issue.
    - *Misplaced attribution of otherwise-expected benefits* is the concern for emissions reductions that fall in category (1). Reductions that will occur regardless of whether the Plan is implemented are more reasonably attributed to the benefits of the NAAQS rather than as co-benefits of the Plan.
    - *Inappropriate calculation of health risk* is the problem for emissions reductions that fall in category (2). Given EPA's science-based evaluations of evidence regarding health effects of the criteria pollutants, benefits from reductions that occur in areas with ambient pollution levels already well below their respective NAAQS levels should be viewed as having an expected value close to zero.
- Almost all of the Plan's co-benefits are calculated in a manner that is inconsistent with EPA's previous regulatory statements that it has set the NAAQS at the legally-required protective level. Such emission reductions should not be treated as direct benefits of a NAAQS any more than they should be counted as co-benefits of the Plan.
- Widely-expressed concerns about potential double-counting should be replaced with concerns about appropriate attribution of benefits to the regulations that ensure them. The focus should also shift to maintaining consistency between the science-based judgments of EPA and the assumptions it uses to calculate benefits in its RIAs for regulations such as the Plan.
- As a result of the findings summarized above, it would be reasonable for the estimated co-benefits in the Plan's RIA to be ignored or substantially discounted for purposes of evaluating the Plan's costs and benefits.

<u>RECOMMENDATIONS FOR FURTHER STUDY</u>

Based on the work in this study and several questions raised that were beyond the scope of the current work, the VCCER team concluded that there are several areas where additional work is appropriate to further examine key issues. These are:

- Use data from Fann *et al.* (2012) study to recalculate benefits per ton under alternative assumptions about potential level of an effects threshold.
    - The VCCER/NERA team has capability to do this using BenMAP and available data files.
    - Produce a probability distribution on benefits per ton estimates using NERA's tool to perform integrated uncertainty analysis on EPA risk calculations.

- Use NERA's electric sector model (called "N$_{ew}$ERA") to analyze sensitivity to locations and quantity of co-reductions under alternative ways of implementing the Plan.

- Perform comparable computations and maps for the Final Plan costs and benefits.

NERA
ECONOMIC CONSULTING

Analysis of Projected Health Co-Benefits in EPA's Proposed Clean Power Plan

Report in Response to Virginia Senate Joint Resolution No. 273 (2015 Session)

Prepared for:

The Virginia Center for Coal and Energy Research of
Virginia Polytechnic Institute and State University

December 10, 2015

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Report Qualifications/Assumptions and Limiting Conditions

Information furnished by others, upon which all or portions of this report are based, is believed to be reliable, but has not been independently verified, unless otherwise expressly indicated. Public information and industry and statistical data are from sources we deem to be reliable; however, we make no representation as to the accuracy or completeness of such information. The findings contained in this report may contain predictions based on current data and historical trends. Any such predictions are subject to inherent risks and uncertainties. NERA Economic Consulting accepts no responsibility for actual results or future events.

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EXECUTIVE SUMMARY

On June 18, 2014, the U.S. Environmental Protection Agency (EPA) published a proposed rule, *Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units,* to reduce the impact of climate change from this emission source sector.[1] It is also known as the Clean Power Plan Proposal, and, for consistency with the legislative language requesting this report, is referred to hereafter as "the Plan." This proposed rule would require an overall 30% reduction in carbon dioxide (CO_2) emissions from existing electricity generating units by 2030, compared to 2005 emissions. It would achieve that target by establishing state-specific emission rate goals, while states would prepare their own state implementation plans for approval by EPA.

The purpose of the Plan is to reduce climate change risks, specifically through reduction of one of the key greenhouse gas emissions, CO_2. However, in its Regulatory Impact Analysis (RIA), which is required by an Executive Order of the President to assess the costs and benefits of all major Federal regulations, EPA (2014a) also included estimates of health benefits associated with reductions of two ambient criteria pollutants that EPA projects will coincidentally result from implementation of the Plan – fine particulate matter ($PM_{2.5}$) and ozone. These benefits are called "co-benefits" because they are not a direct benefit of reducing the targeted pollutant (which is CO_2, in the case of the Plan). The Plan's RIA estimated that the $PM_{2.5}$ and ozone co-benefits are approximately as large in magnitude as the direct climate benefits from the Plan; when added to the RIA's estimates of direct benefits, they cause the apparent total benefits of the Plan to appear to greatly exceed its costs.[2]

The criteria pollutants that are the basis for the Plan's co-benefits are already subject to stringent regulation under the Clean Air Act, in the form of National Ambient Air Quality Standards (NAAQS). NAAQS must be set at a level that the EPA Administrator determines will protect the public health with an adequate margin of safety, based on the best available scientific evidence on health effects. Costs of attaining a NAAQS cannot be considered in that determination. The margin of safety is intended to address scientific uncertainties, but each NAAQS also must be reviewed every five years to account for possible new evidence. As a result, several revisions of the $PM_{2.5}$ and ozone NAAQS have been made over the past three decades, each revision being accompanied by its own RIA. This situation could result in the "double counting" of these benefits by the EPA in the Plan and one or more of these existing

[1] 79 Fed. Reg. 34830.

[2] Over 90% of the Plan's estimated co-benefits are from $PM_{2.5}$ rather than ozone. While this report addresses both the ozone and $PM_{2.5}$ co-benefits, any apparent emphasis on issues associated with $PM_{2.5}$ risk calculations reflects its much greater importance in the issues at hand. In the case of both, premature mortality risk accounts for well over 90% of each pollutant's estimated co-benefits, and thus the discussion at times may address only mortality risk calculations, although the other very small contributions to co-benefits due to non-fatal forms of morbidity are subject to very similar issues, as they are computed using nearly identical risk analysis methods.

RIAs.[3] The EPA in fact acknowledges this possibility in the RIA for the Plan when it notes "it is possible that some costs and benefits estimated in this RIA may account for the same air quality improvements as estimated in the illustrative NAAQS RIAs."[4]

During the 2015 Session of the Virginia General Assembly, Senate Joint Resolution No. 273 (SJR 273) was passed that directs the Virginia Department of Environmental Quality (VDEQ) to conduct a study to compare the Plan RIA's projected health benefits with those projected for existing air quality regulations. The Virginia Center for Coal and Energy Research (VCCER) at Virginia Tech was engaged to lead such a study and provide VDEQ a report to allow the agency to comply with SJR 273. VCCER requested National Economic Research Associates (NERA) to assist in study preparation by conducting a detailed analysis of the co-benefit estimation methodology used in the RIA and to address the following specific study objectives identified in SJR 275:

1. Determine the accuracy of and likelihood of the RIA's projections of criteria pollutant air quality improvements attributed to the Plan;

2. Compare projections of the national cost of the Plan to the health benefits projected to result from the Plan and complete a cost-benefit analysis;

3. Determine the likelihood that the health benefits attributed to the Plan by the EPA would arise in the absence of the Plan; and

4. Determine the extent to which the EPA uses otherwise-expected benefits to public health as a justification for the Plan.

This report provides NERA's summary of the data and assumptions that were used in the Plan's RIA, and compares them to information used in other EPA assessments of criteria pollutant benefits. It reviews the benefits calculations in RIAs that EPA prepared for the current $PM_{2.5}$ and ozone NAAQS rules (EPA, 2012 and 2015b, respectively). It also makes relevant comparisons with the data in the RIA for the Mercury and Air Toxics Standard (MATS) rule for electricity generating units that was promulgated in 2011 (EPA, 2011). The MATS rule RIA, like the Plan's RIA, included substantial quantities of $PM_{2.5}$ co-benefits, the appropriateness of which has also been raised by other parties.[5]

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[3] Additionally, at the time that the Plan RIA was released, EPA was actively reviewing the ozone NAAQS, which was on a track to be revised in 2015, not long after the Plan was to be finalized. A decision on whether to revise the $PM_{2.5}$ NAAQS, which was last set in 2012, is due to be made before 2020.

[4] Plan RIA, p. 4-15.

[5] The questionability of the exceptional degree of reliance of the MATS RIA on $PM_{2.5}$ co-benefits rather than direct benefits was discussed in 2015 oral arguments before the Supreme Court in *Michigan v. EPA*, the case that produced the Court's decision to invalidate the finding on which the MATS rule was based.

The MATS rule was of interest in this study because some commenters have raised the possibility that co-benefits in the MATS RIA are being counted again in the Plan's RIA. Although NERA's analyses of the relevant RIA data indicate that such a literal form of double-counting is not extensive, the same analyses bring to light important concerns with the co-benefits calculations in the Plan RIA. Specifically, this report shows that the reason co-benefits play such a prominent role in the benefit-cost justifications of non-NAAQS rulemakings such as the Plan is because EPA is assuming that each increment of $PM_{2.5}$ and ozone is just as risky to the public health in areas that have very clean air (*i.e.*, well below their NAAQS limits) as in areas that exceed the NAAQS limits. As is made clear in a peer-reviewed paper by Smith (2015), these co-benefit calculations are being made *inconsistently* with EPA's own science-based determinations for setting the NAAQS at levels that are protective of the public health with an adequate margin of safety. This report shows that if consistency were to be added, almost all of the co-benefits of the Plan are eliminated.

The main conclusions of this report are as follows:

- It is reasonable to expect coincidental reductions in $PM_{2.5}$ and ozone precursor emissions as a result of the Plan, although there is substantial uncertainty on their geographic location and magnitude.

- Although we find that the literal form of double-counting of precursor emissions reductions is not a concern, we do find concern with overstatement of likely co-benefits. These stem more from the way that EPA computes its benefits per increment of criteria pollutant reduction than from the way that EPA quantifies the criteria pollutant changes attributable to the Plan.

- The coincidental reductions of precursor emissions fall into two categories, either (1) they will occur "anyway" even if the Plan were not to be implemented, or (2) they are in locations that are already well below their respective NAAQS levels. Each category presents a separate concern:

    - *Misplaced attribution of otherwise-expected benefits* is the concern for emissions reductions that fall in category (1). Reductions that will occur regardless of whether the Plan is implemented are more reasonably attributed to the benefits of the NAAQS rather than as co-benefits of the Plan. We find that less than 10% of the co-benefits are of this type. The precise fraction cannot be determined within the scope of this study because it would require a complex air-quality modeling exercise, but it would be a small portion of the total co-benefits because it would affect only the ozone co-benefits, which account for less than 10% of total estimated co-benefits of the Plan.

    - *Inappropriate calculation of health risk* is the concern for emissions reductions that fall in category (2). Given EPA's science-based evaluations of evidence regarding health effects of the criteria pollutants, reductions that occur in areas with ambient pollution levels already well below their respective NAAQS levels should be viewed as having an expected value of benefits close to zero. However, EPA's methodology for estimating the benefit per ton of emission has assumed that a unit of additional pollutant exposure is equally risky whether an area has very clean air or very polluted air. The vast majority of the co-benefits in the Plan's RIA (including essentially all of the $PM_{2.5}$ co-benefits) fall in category (2).

- We conclude that almost all (*e.g.*, more than 90%) of the Plan's co-benefits are calculated in a manner that is inconsistent with EPA's assurances that it is setting the NAAQS at the legally-required protective level. Such emission reductions should not be treated as direct benefits of a NAAQS any more than they should be counted as co-benefits of the Plan. This is the inaccuracy in the co-benefits calculation that should give policy makers the greatest concern. Its roots are hidden in the complex process by which EPA has calculated a fixed "benefit-per-ton" for valuing any change in a precursor's emissions, no matter where that ton is emitted.

As a result of the above assessment, it would be reasonable for the estimated co-benefits in the Plan's RIA to be ignored or substantially discounted for purposes of evaluating that proposed rule's costs and benefits.

This study was mandated under a resolution of the Virginia General Assembly, SJR 273, to address the RIA for the proposed Plan. Since that time, the final Plan has been released,[6] along with a new RIA (EPA, 2015a). The final Plan's CO_2 targets are very different, particularly in their geographic distribution and timing. It also offers more explicit variants on implementation approaches. It was outside of the scope of SJR 273 to prepare an evaluation of the final Plan's RIA. However, we have reviewed the final Plan's RIA sufficiently to determine that the general patterns and issues associated with the proposed Plan's treatment of co-benefits, direct benefits, and costs are similar in the final Plan's RIA. Thus, we expect that the same conclusions that are made in this report would also be made if we were to have been engaged to review the final rather than the proposed Plan's co-benefits estimates.

[6] 80 Fed. Reg. 64661.

I. INTRODUCTION

On June 18, 2014, the U.S. Environmental Protection Agency (EPA) published a proposed rule, *Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units,* to reduce the impact of climate change from this emission source sector.[7] It is also known as the Clean Power Plan Proposal (referred to in this report, for consistency with legislative language, as "the Plan"). Virginia Senate Joint Resolution No. 273 of the 2015 session (SJR 273) directs the Virginia Department of Environment Quality (VDEQ) to conduct a study to compare the projected health benefits of the Plan with those projected for existing air quality regulations. That is, SJR 273 seeks an evaluation of the role that estimates of health co-benefits from coincidental reductions of the criteria pollutants ozone and fine particulate matter ($PM_{2.5}$) play in the benefit-cost comparisons of EPA's Regulatory Impact Analysis (RIA) for the Plan.[8]

The Virginia Center for Coal and Energy Research (VCCER) at Virginia Tech was engaged to lead this study, and VCCER, in turn, engaged National Economic Research Associates (NERA) to assist in the study. This resulting report builds the groundwork for and then responds to four specific objectives listed in SJR 273, which are:

- Determine the accuracy of and likelihood of the RIA's projections of criteria pollutant air quality improvements attributed to the Plan;
- Compare projections of the national cost of the Plan to the health benefits projected to result from the Plan and complete a cost-benefit analysis;
- Determine the likelihood that the health benefits attributed to the Plan by the EPA would arise in the absence of the Plan; and
- Determine the extent to which the EPA uses otherwise-expected benefits to public health as a justification for the Plan.

To create the necessary groundwork to address the above issues, this report first summarizes the central elements of benefit-cost comparisons in RIAs and the concept of "co-benefits." Turning to RIAs for air pollutant regulations, it describes how EPA estimates health benefits and co-benefits from projected changes in emissions that contribute to ambient concentrations of criteria pollutants. This includes an explanation of a simplified "benefit-per-ton" methodology that is used in the Plan RIA's calculations, and the heightened uncertainties that this simplified method introduces. It also reviews EPA's history of use of health co-benefits from criteria pollutants in RIAs for regulations not addressing criteria pollutants, such as it has done in the case of the Plan.

[7] 79 Fed. Reg. 34830.

[8] This RIA (EPA, 2014a) was released at the same time as the publication of the Plan, on June 18, 2014. In this report we also refer to it as the "Plan RIA."

The report then turns to the Plan's RIA.[9] To orient readers to the co-benefit estimates that are the concern of SJR 273, it first provides a high-level summary of the benefit-cost comparisons in that RIA. The report then provides a detailed evaluation of the assumptions and data behind the Plan RIA's co-benefits calculations and discussion of their implications. It discusses how double-counting can occur and reviews data from multiple RIAs to explore the potential for double-counting, both in the literal sense and, more subtly, by understating the criteria pollutant improvements can be expected to occur even without the Plan. It then discusses how EPA's methodology creates even greater potential for overstatement and unreliability of co-benefit estimates by relying on assumptions that are inconsistent with the science-based policy judgments made by the EPA Administrator when setting the $PM_{2.5}$ and ozone National Ambient Air Quality Standards (NAAQS).

Section II of this report provides a general introduction to costs, benefits, and co-benefits that EPA typically includes in its RIAs and its methods of calculating co-benefits from criteria pollutants. Section III focuses in on the co-benefits of the Plan's RIA. It summarizes the benefit-cost comparison in the Plan's RIA, then provides data and analyses developed by NERA relevant to assessing the co-benefits' accuracy, likelihood, and implications for the Plan's benefit-cost evaluation. Section IV synthesizes these data and analyses in the context of the four specific issues listed in SJR 273.

[9] Although EPA published its final Plan on October 23, 2015 (80 Fed. Reg. 64661), this report is focused on the proposed Plan and its RIA (EPA, 2014a), which are the subject of SJR 273.

II. BENEFITS AND CO-BENEFITS IN EPA REGULATORY IMPACT ANALYSES

A. The Concept of Co-Benefits in RIAs

A standard feature of the RIAs that are required of major Federal regulations under Executive Order of the President is a comparison of compliance costs associated with meeting the requirements of a regulation with the benefits that the regulatory agency expects would result. An RIA might also identify a number of beneficial but coincidental impacts of a regulation, which are known as "co-benefits," and include them in the benefit-cost comparison.

In the case of EPA's air regulations, benefits are the societal value of the health and environmental outcomes of reductions in emissions of the air pollutant(s) that is (are) the specific target of a regulation. For the Plan, direct benefits would be the societal value of its incremental CO_2 reductions. In contrast, co-benefits result when, in efforts to reduce the targeted emission(s), other non-targeted pollutants are coincidentally reduced. In the case of the Plan, efforts to reduce CO_2 from electricity generation are projected to also alter sulfur dioxide (SO_2), nitrogen oxides (NO_X), and primary $PM_{2.5}$ emissions in some locations. All three of these contribute to ambient concentrations of two criteria pollutants, which are regulated under NAAQS – $PM_{2.5}$ and ozone. Primary $PM_{2.5}$ emissions contribute directly to ambient $PM_{2.5}$, while SO_2 and NO_X do so secondarily.[10] Both SO_2 and NO_X are precursors for formation of ambient $PM_{2.5}$, and NO_X is also a precursor for formation of ambient ozone. Neither SO_2 nor NO_X contributes to climate change, which is the concern targeted by the Plan. However, because EPA attributes potential health effects to the two criteria pollutants, the coincidental changes that EPA projects in these precursor emissions lead to estimates of criteria pollutant co-benefits that are included in the Plan's RIA.

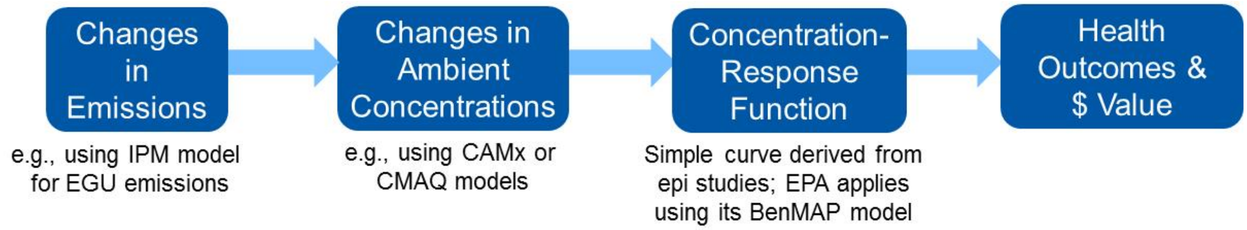
The focus of this report is on the estimation and use of co-benefits from these criteria pollutant precursor emissions in the Plan's RIA. The remainder of this section addresses general issues, including how EPA calculates criteria pollutant health co-benefits and the overall pattern of EPA's use of them in RIAs that target other pollutants. Section III then addresses the specific estimates of co-benefits in the Plan's RIA and how they compare to RIAs for existing air regulations.

B. EPA's Derivation of Benefits and Co-Benefits for Criteria Pollutants

Whether the criteria pollutant change is a direct result of a regulation or a co-incidental result, EPA uses the same general method of computing benefits. It is based on a bottom-up sequence of computations known as a damage-cost approach, the steps of which are illustrated in Figure 1.

[10] Emissions that transform into another ambient pollutant after entering the atmosphere are known as "precursors" to their respective secondary ambient pollutant forms.

Figure 1: Steps of Full Damage-Cost Approach for Assessing Criteria Pollutant Benefits



In the first step of the full damage-cost approach in Figure 1, changes in precursor emissions due to the regulation are estimated. For example, in the case of electricity generating unit emissions, EPA typically uses the IPM model of the U.S. electricity sector, but other models would be used for other sectors. These emissions changes are projected to occur at specific stacks in specific locations across the U.S.

In the second step of the full damage-cost approach, the emissions changes are input into an atmospheric fate and transport model to estimate the location, timing, and degree of change in ambient concentrations of the criteria pollutants of concern. Models that EPA commonly uses for projecting criteria pollutant changes are named CAMx and CMAQ, but other models might be used.

The third step uses what EPA calls a concentration-response function to estimate in physical metrics what the change in various human health impacts would be as a result of altered ambient concentrations. The health effects estimated for $PM_{2.5}$ and ozone vary widely in perceived severity. They include estimates of days of minor restricted activity as well as numbers of premature deaths.[11] Changes in health effects from this step are calculated at a locational level, so that location-specific ambient pollution baseline levels and changes, populations (by age group), and baseline health effects incidence rates can be accounted for.

The concentration-response relationships that EPA uses are simple curves that state percentage change in a specific health effect per unit of change in ambient concentration. The key input is a curve's slope. Estimates of the slope are usually taken from "epidemiological" studies, which assess the presence of statistical associations between observed health effects on a population-scale and observed ambient pollutant concentrations. There are many analyst judgments and sources of uncertainty in defining a concentration-response function for predicting risks from such statistical associations. Section III will provide more details of the sources of assumptions used for the concentration-response functions in the Plan RIA, and their key limitations. EPA

[11] That is, deaths deemed to be earlier than would have otherwise occurred but for exposure to the pollutant in question. It is worth emphasizing here that EPA's estimates of premature deaths should be thought of as a statistical expectation based on estimated changes in annual probability of dying. No deaths that are specifically related to current levels of these criteria pollutants have been observed or reported.

usually performs these calculations in a model it calls BenMAP, but they are simple enough that they can be done in a basic spreadsheet.[12]

Risk assessments may end at the third step, but RIAs use monetized estimates of the societal value of the changes in health effects. In fact, the term "benefits" is reserved for the monetized result of this process. Thus, in the fourth step the changes in physical measures of impact are monetized. This is usually done using a fixed multiplier for dollars of value per effect. In the case of premature mortality, for example, a "value of a statistical life" (VSL) is multiplied by the change in deaths estimated to occur "prematurely" due to ambient pollution. Although assumptions used to monetize estimated quantities of physical health risk changes can be quite controversial (particularly for VSL), this report does not discuss or critique those methods because monetization choices have no bearing on the question of double-counting and other concerns raised in SJR 273.

For both $PM_{2.5}$ and ozone, premature mortality is one of the risks that EPA includes in its analyses, and (not surprisingly) it ends up dominating the benefits estimates. For example, the percentage of $PM_{2.5}$ benefits due to premature mortality is usually well over 90%, and can be as much as 98%, even though EPA's calculations of benefits include several types of non-mortal health effects (called "morbidity" effects).

Although the above steps comprise the traditional method for calculating criteria pollutant health effects, EPA does not actually perform the full process to estimate the co-benefits in the Plan RIA. EPA instead uses a simplified "benefit-per-ton" approach to estimate the $PM_{2.5}$ and ozone health co-benefits in the Plan's RIA. The benefit-per-ton is an estimate of the human health co-benefits from reducing one ton of emission of a $PM_{2.5}$ or ozone precursor. Pre-existing $/ton values are simply multiplied by the net number of tons of change projected to occur in each type of precursor emission. Changes in the ambient concentrations of the criteria pollutants are never estimated at all in this simplified approach.

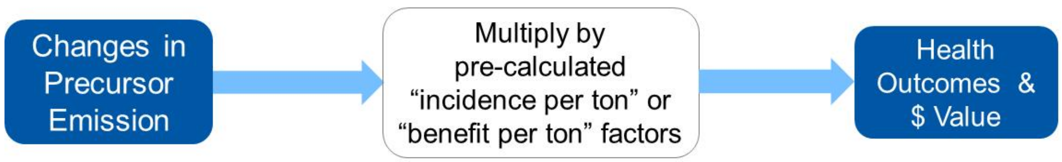
The nature of this simplification is illustrated in Figure 2. The benefit-per-ton values used in the Plan RIA were calculated in an earlier, generic exercise using an air quality model and a particular choice of concentration-response slope.[13] The analysis method and resulting dollar-per-ton ($/ton) values were first described in Fann *et al.* (2012), and later further adapted by EPA

[12] BenMAP is a publicly-available PC-based program that enables users to compute health risks associated with changes in emissions of criteria pollutants using the standard formulas that EPA uses in its own RIAs, and using EPA's or their own input files and other assumptions. More information is available at http://www2.epa.gov/benmap. For a detailed explanation of the concentration-response formula, how it is applied to estimate health effects risks in the BenMAP model, and the attending uncertainties, see Smith and Gans (2015).

[13] EPA also reports an "incidence-per-ton" multiplier for estimating the level of physical health effects associated with the monetized benefit-per-ton value. Using a back of the envelope calculation, the mortality incidence-per-ton can be approximated by dividing the dollar benefit-per-ton value by the VSL that was used to produce that benefit-per-ton value. (It is not exactly equal to this calculation in part because approximately 2% of the benefit per ton is from estimated morbidity effects.)

as described in an EPA-authored technical support document (EPA, 2013).[14] In brief, a full benefits calculation was run for the U.S. as a whole, starting with a base year projection of all the precursor emissions and their total impact on ambient concentrations across the country. On a sector by sector basis (and for each precursor species), the portion of base case ambient concentrations due to that sector's total emissions was estimated, along with the associated health effects (using a single concentration-response assumption). The total sector/precursor health impacts were then divided by the total tons of emissions of that precursor from that sector. The result is a set of $/ton and health effect incidence-per-ton values. These values are then used in RIAs such as that of the Plan, which thereby avoid having to perform their own regulation-specific air quality modeling while still generating projections of health benefits or co-benefits. EPA has used the simplified benefits-per-ton method in many of its air RIAs.

Figure 2: Steps of the Simplified Benefit-Per-Ton Approach



One of the key implications of using the simplified benefit-per-ton method is that almost all of the locational detail that is accounted for in the full approach is lost. This lack of location-specific calculations makes an evaluation of the credibility of the Plan's co-benefits estimates very difficult and injects important additional uncertainties to any benefits estimates from this method.

One potential error in benefits estimates under the simplified method stems from the fact that a ton of reduction upwind of a relatively rural area is assumed to produce the same benefit as a ton of reduction upwind of a highly populated area. To give a simple example of the amount of variation that this masks, NERA used EPA's BenMAP model to perform some $PM_{2.5}$ risk calculations. Using the same mortality risk concentration-response function used to generate the Plan RIA's lower bound co-benefit estimates, NERA computed the reduced mortality associated with a 1 $\mu g/m^3$ reduction in annual average $PM_{2.5}$ occurring over a 144 square kilometer area surrounding the center of Blacksburg, Virginia, and did the same for the same $PM_{2.5}$ change occurring over a 144 square kilometer area surrounding Manhattan in New York City.[15] The result was 1.26 avoided deaths for the reduction over Blacksburg and 70.98 avoided deaths for the reduction over New York City. The range of a factor of 56 applies to monetized benefits as well, since EPA uses the same value per statistical life in all locations. This range, of course, primarily reflects population differences, but this numerical example illustrates just how much

[14] However, the benefit-per-ton values for the ozone co-benefits appear to have been developed for the first time for the Plan RIA (Plan RIA, p. 4A-16). NERA has found no documentation of those ozone values other than a few words in the Plan RIA.

[15] We used the Krewski *et al.* (2009) concentration-response slope. We used projected populations for the year 2020 in BenMAP.

variation in location-specific benefits might be washed out when using EPA's simplified approach. (Although EPA's approach lets the benefit-per-ton value to differ for emissions in the East, West, and California, the 56-fold variation found in this example occurs entirely in the East.) Thus, the location of projected emissions reductions do matter to co-benefits estimates, but these locations are not even identified in RIAs that use the simplified approach.

Another issue of concern stems from the fact that the benefit-per-ton value is assumed to be identical whether a given quantity of reduction would reduce ambient $PM_{2.5}$ from 3.0 $\mu g/m^3$ to 2.9 $\mu g/m^3$, or would reduce ambient $PM_{2.5}$ from 13.0 $\mu g/m^3$ to 12.9 $\mu g/m^3$. This is the result of a very strong assumption EPA makes that the concentration-response curve's slope is essentially constant over all levels of concentration from pristine to highly-polluted levels that are not even observed in the U.S. anymore. Although this is EPA's standard assumption even when applying a full, location-specific benefits calculation, its use of a pre-existing benefit-per-ton value makes it impossible for reviewers such as NERA to conduct sensitivity analyses to directly demonstrate the numerical implications of the assumption. Section III will provide an indication of the substantial uncertainty and likely overstatement that it implies.[16]

C. Use of Criteria Pollutant Co-Benefits in EPA's Past Air RIAs

The use of criteria pollutant co-benefits in the Plan RIA is just one more manifestation of a long-term practice on the part of EPA. For over 15 years, EPA has relied on reductions of ambient $PM_{2.5}$ as the primary source of benefit-cost justification in most of its RIAs for regulations under the Clean Air Act – even for regulations not specifically aimed at protecting public health from exposures to ambient $PM_{2.5}$. EPA's first estimates of mortality benefits from reducing ambient $PM_{2.5}$ were developed as part of its 1997 $PM_{2.5}$ NAAQS policy decision. Since that time EPA has, with increasing frequency, included health co-benefits from reductions in $PM_{2.5}$ even for air regulations that are targeting air objectives other than $PM_{2.5}$. This trend was first documented in NERA (2011). An update of a summary table in that report is provided in Table 1 which shows that $PM_{2.5}$ co-benefits have represented more than half of all benefits in almost all non-PM air RIAs since 1997. It also shows that co-benefits accounted for 100% of the co-benefits for a majority of the non-PM air rules finalized since 2009.

[16] The functions that the EPA uses also assume that all fine particles, regardless of their chemical composition, are equally potent in causing mortality risk (Plan RIA, p. ES-16). This also is a controversial assumption that obscures a great deal of true uncertainty in the risk calculations. This uncertainty is not discussed in detail in this report, as it has only tangential relevance to the concerns raised in SJR 273. A numerical illustration of how much this assumption can lead to overstatement of benefits from policies to reduce $PM_{2.5}$ can be found in Smith and Gans (2015).

Table 1: Summary of Degree of Reliance on $PM_{2.5}$-Related Co-Benefits in RIAs for Major Non-PM Air Rulemakings Finalized Between 1997 and 2013.

(RIAs with no quantified benefits at all are not in this table. Where ranges of benefit and/or cost estimates were in an RIA, percentages are based on upper bound of both the benefits and cost estimates. Estimates using the 7% discount rates are used in all cases. See NERA, 2011, for an original version of this table and its documentation.)

Year	RIAs for Final Rules Not Targeting Ambient $PM_{2.5}$	PM Co-Benefits Are >50% of Total	PM Co-Benefits Are Only Benefits Quantified
1997	Ozone NAAQS (.12 1hr=>.08 8hr)	×	
1997	Pulp & Paper NESHAP		
1998	NOx SIP Call & Section 126 Petitions		
1999	Regional Haze Rule	×	
1999	Final Section 126 Petition Rule	×	
2004	Stationary Reciprocating Internal Combustion Engine NESHAP	×	
2004	Industrial Boilers & Process Heaters NESHAP	×	×
2005	Clean Air Mercury Rule	×	
2005	Clean Air Visibility Rule/BART Guidelines	×	
2006	Stationary Compression Ignition Internal Combustion Engine NSPS		
2007	Control of HAP from mobile sources	×	×
2008	Ozone NAAQS (.08 8hr =>.075 8hr)	×	
2008	Lead (Pb) NAAQS	×	
2009	New Marine Compress'n-Ign Engines >30 L per Cylinder	×	
2010	Reciprocating Internal Combustion Engines NESHAP - Compression Ignition	×	×
2010	EPA/NHTSA Joint Light-Duty GHG & CAFÉ Standards		
2010	SO2 NAAQS (1-hr, 75 ppb)	×	>99.9%
2010	Existing Stationary Spark Compression Ignition Engines NESHAP	×	×
2011	Industrial, Comm, and Institutional Boilers NESHAP for Area Sources	×	×
2011	Indus'l, Comm'l, Institutional Boilers & Process Heaters for Major Sources NESHAP	×	×
2011	Comm'l & Indus'l Solid Waste Incineration Units NSPS and Emission Guidelines	×	×
2011	Control of GHG from Medium & Heavy-Duty Vehicles		
2011	Reconsideration of Ozone NAAQS	×	
2011	Utility Boiler MACT Rule ("MATS")	×	≥99%
2011	Sewage Sludge Incineration Units NSPS & Emission Guidelines	×	×
2012	Petroleum Refineries NSPS Subpart Ja	×	×
2012	EPA/NHTSA Joint Light-Duty GHG & CAFÉ Standards for Model Years 2017+		
2012	Reconsideration NESHAP Indus'l, Comm'l, and Institutional Boilers & Process Heaters at Major Sources	×	×
2013	Reconsideration Existing Stationary CI Engines NESHAP	×	×
2013	Reconsideration Existing Stationary SI RICE NESHAP	×	×

As noted at the beginning of Section II, the practice of including co-benefits in RIAs is not new, nor even always inappropriate. However, the current use of criteria pollutant co-benefits is significantly different from the typical use of co-benefits in benefit-cost analyses. First, the pollutants for which co-benefits are being claimed, $PM_{2.5}$ and ozone (and their precursors), are already stringently regulated under the NAAQS requirement of the Clean Air Act. (NAAQS must be set at a level that protects the public health with an adequate margin of safety, without consideration of the costs of attaining such a standard.) Second, criteria pollutant co-benefits (and most particularly those for $PM_{2.5}$) dominate the benefit-cost case presented in EPA's RIAs for non-criteria pollutant rules; in many of those RIAs, these co-benefits are the *only* beneficial effect of a regulation that is quantified at all. These differences raise serious concerns about the appropriateness of using criteria pollutants as co-benefits. These concerns have been explained in detail in NERA (2011), but analyses specific to the Plan's co-benefits estimates that are provided in Section III may bring life to some of the general points in NERA (2011).

III. EVALUATION OF EPA'S ESTIMATES OF THE PLAN'S CO-BENEFITS

A. Overview of Benefits, Co-Benefits, and Compliance Costs in the Plan's RIA

As noted in Section II, a key element of RIAs is to compare costs of a regulation to its benefits, to determine whether each major Federal regulation might be justified on benefit-cost grounds. Table 2 summarizes this information for the Plan's Option 1 under the assumption that it would be implemented at the state level. This case will serve as the basis of all the data analyses we provide in this report.[17] Table 2's ranges of estimated climate benefits are based on the three SCC values that represent mean estimates.[18] As the table shows, the co-benefits range is comparable in magnitude to the Plan's direct climate benefits. The lower bound of co-benefits estimates is, however, much higher than the lower end of the climate benefits range.

Table 2: Summary of Estimated Monetized Benefits, Co-Benefits, Compliance Costs, and Net Benefits of the Proposed Plan's Option 1 - State Implementation Case (billions of 2011$)

(Source: Plan RIA, Tables ES-8 through ES-10; Climate Benefits are for all three mean SCC values used in the RIA, for discount rates ranging from 2.5% to 5%; Co-Benefits are for the 3% discount rate, which is most consistent with discount rates for the SCC values.)

	2020	2025	2030
Climate Benefits (all mean SCC values)	$4.9 to $26	$7.6 to $37	$9.5 to 44
Criteria Pollutant Health Co-Benefits (3%)	$17 to $40	$23 to $54	$27 to $62
Total Compliance Costs	$7.5	$5.5	$8.8

Table 2 does not provide a net benefits range due to the difficulty of determining the appropriate combinations of values from the respective benefits and cost ranges. However, by any metric, net benefits are positive even if *only* the criteria pollutant health co-benefits are considered. Naturally, the net benefit is even stronger when climate benefits and co-benefits are considered. If the health co-benefits are ignored, the RIA still suggests a case that benefits may exceed costs based on climate benefits alone, although not under all of the RIA's range of climate benefit estimates and by a much smaller margin in all cases with positive net benefits. Thus, it is reasonable to conclude that the role of co-benefits is not insignificant in the benefit-cost comparisons for the Plan.

[17] The Plan RIA contains two regulatory options. Option 1, the more stringent option, was noted to be the preferred option. For both options, the Plan RIA also presents two forms of illustrative implementation, "State" and "Regional." These are only illustrative, as the final form of implementation would be a state-level decision, not part of the Federal regulatory decision itself. Because the differences between the two implementation cases that the RIA analyzes are not extraordinary, and for simplicity, we use only the State Implementation case for Option 1 to illustrate our points in this report.

[18] These differ in that they assume discount rates from 2.5% to 5%. Climate benefits based on a much higher SCC value that represents a 95th percentile worst case estimate of climate impacts are not shown in this table, as a 95th percentile value is not comparable to all the other benefits and co-benefits estimates in the RIA, which are not presented with their respective confidence intervals.

How EPA has calculated each component of the table is explained below, to provide additional background relevant to the rest of the analyses presented in this section of the report.

The compliance costs in the Plan RIA are calculated using a model of the U.S. electricity generating sector called the IPM model.[19] These costs are the incremental electricity sector costs to meet the Plan's requirements, relative to a base case without the requirements. For the Plan, EPA also adds in annualized costs for energy efficiency that is used for compliance with the Plan, but is not included within the IPM model. In 2025, EPA estimated compliance costs as the sum of the annualized energy efficiency costs of $29 billion and a reduction in costs within the electricity sector of $23 billion, for a total compliance cost of $5.5 billion (stated in 2011$).[20] It is beyond the scope of this study to comment on the cost estimates in the Plan RIA.

The same IPM model runs also produce the RIA's estimates of emissions reductions of CO_2 and of the $PM_{2.5}$ and ozone precursor emissions, both of which then drive the benefits side of the RIA.

The Plan's estimates of direct benefits are based on the IPM model's projection of CO_2 emissions reductions, which are valued using a "social cost of carbon" (SCC). The SCC is a present value of damages estimated over a 300-year period into the future from an incremental ton of CO_2 emissions in a given year. The SCC includes far more than climate-related health impacts, but the actual set of impacts it includes is not defined, and the portion of the SCC due to individual types of impacts known to be included is not possible to determine. Several different $/ton SCC value estimates are multiplied by the RIA's estimate of the Plan's reductions in CO_2 tons emitted to obtain the RIA's range of estimates of climate-related benefits estimates.[21] The range of resulting climate benefits estimates is very wide, even using only mean SCC values. However, the upper end of the climate benefits range is approximately doubled if the extremely pessimistic 95th percentile SCC estimate is used.[22] It is beyond the scope of this report to comment on the climate portion of the benefits.

The health co-benefits estimated in the Plan's RIA are based on reductions in ambient $PM_{2.5}$ and ozone that the IPM model projects will result coincidentally from the CO_2 reductions that are the target of the Plan. These health co-benefits are unrelated to any climate-related benefits. To

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[19] The IPM Model is a multi-region linear programming model of the U.S. electricity sector that provides projections for electricity sector results such as generation, emissions, new capacity, and other investment decisions. The model was developed by ICF Consulting, Inc. and EPA has used the model to evaluate many environmental policies.

[20] Costs within the electricity sector decline because the assumption of energy efficiency results in less generation within the electricity sector, which produces lower total operating costs, though not necessarily lower costs per megawatt-hour (MWh).

[21] The Plan's RIA uses SCC values for several discount rates and climate outcome probabilities.

[22] It is not used in the table presented here because co-benefits estimates also would have much higher upper bounds, if EPA had not used its benefit-per-ton approach, which provides no confidence ranges. It also is questionable whether a high end of a statistical confidence interval should be reported without also reporting a low end of the same confidence interval.

calculate the co-benefits, EPA multiplies the IPM estimates of net reductions in each type of $PM_{2.5}$ and ozone precursor emission (*i.e.*, directly-emitted $PM_{2.5}$, SO_2, and NO_X) by a region-specific and precursor-specific benefit-per-ton value. The sum of these products over the different regions and precursor emissions produces the total health co-benefits estimate in the Plan's RIA. These health co-benefits are the focus of this study, and are the subject of the rest of Section III.

B. Evaluation of EPA's Estimates of Reductions in $PM_{2.5}$ and Ozone Precursors

EPA used the IPM model to estimate the emissions reductions to be achieved through implementation of the Plan. EPA considered two potential implementations of the Plan, state-level compliance and regional-level compliance. In this report we focus on the state-level compliance (also referred to as the Option 1 – State Implementation case). To estimate the reductions in emissions of CO_2, SO_2, and NO_X, EPA first modeled a base case. This base case includes existing electricity sector policies such as the Mercury and Air Toxics Standard (MATS) rule, state renewable portfolio standards, and base case projections for electricity demand and fuel prices (*e.g.*, natural gas and coal). This produces a base case projection of electricity sector outputs, including unit-level dispatch, electricity prices, and emissions of CO_2, SO_2, and NO_X by unit.

EPA then imposed the requirements of the Plan in another IPM run (which we call the "policy case"). To comply with the CO_2 reduction requirements in the Plan, the electricity system must operate differently, including decreased dispatch of higher CO_2 emitting coal-fired generators, increased operation of natural gas combined cycle generators, and increased builds and operation of new renewable generators (*e.g.*, wind and solar). In determining a least-cost solution to meeting the CO_2 reduction requirements of the Plan, the projected changes in the operation of generating units also lead to changes in criteria pollutant precursor emissions at each plant. In total, precursor emissions decline in the U.S., however, while some units have lower levels of SO_2 and/or NO_X emissions, other units do not experience any changes, or actually increase their emissions.[23] Table 3 shows the net U.S.-wide emissions projections for the base case, policy case, and net change due to the Plan for its Option 1 – State Implementation case.

[23] The IPM model does not compute primary $PM_{2.5}$ emissions, which EPA estimates separately. NERA did not attempt to confirm the $PM_{2.5}$ emissions estimates. However, NERA did use raw IPM output files (the "parsed" files) to obtain unit-specific emissions before and after the Plan, and checked that these results add up to the totals reported in the Plan RIA. There was a discrepancy between EPA's 2025 national NO_X levels for both the base case and the policy case. NERA's unit by unit summation for 2025 NO_X reductions is 424 tons compared to the RIA's reported 436 tons. However, other totals and reductions were exactly replicated, and this one discrepancy is too small to affect any of this report's conclusions.

Table 3: Summary of Net U.S.-Wide CO_2, SO_2, and NO_X Emissions Impacts of the Plan under Option 1 – State Implementation Case (millions of metric tons for CO_2; thousands of short tons for others)

(Source: Plan RIA, Table ES-2)

	2020	2025	2030
CO_2 Base Case	2,382	2,459	2,486
CO_2 Policy Case	1,939	1,880	1,854
CO_2 Reductions	443	579	632
SO_2 Base Case	1,476	1,515	1,530
SO_2 Policy Case	1,140	1,090	1,059
SO_2 Reductions	335	425	471
NO_X Base Case	1,559	1,587	1,537
NO_X Policy Case	1,191	1,151	1,109
NO_X Reductions	367	436	428
Primary $PM_{2.5}$ Base Case	212	209	198
Primary $PM_{2.5}$ Policy Case	154	145	142
Primary $PM_{2.5}$ Reductions	58	63	56

The CO_2 reductions, which are the direct objective of the Plan, increase from 443 thousand short tons in 2020 to 632 thousand short tons in 2030. These tons form the basis for the climate-related benefits. The primary $PM_{2.5}$, SO_2, and NO_X reductions form the basis of the health-related co-benefits. The SO_2 reductions increase from 335 thousand tons in 2020 to 471 thousand tons in 2030 and the NO_X reductions increase from 367 thousand tons in 2020 to 436 thousand tons in 2025 before declining slightly to 428 thousand tons in 2030. Primary $PM_{2.5}$ emissions reductions are smaller and less variable over time.

Since existing air policies are included in the base case, the reductions are supposed to be entirely attributable to the Plan. Literal double-counting would occur if some existing policies' impacts on emissions failed to appear in the Plan's base case. There have been some public comments that the Plan might be double-counting benefits that were already attributed to the MATS rule. In our review of the various RIAs and related data, we have concluded that the MATS rule has been properly included in the Plan's base case, implying that such a literal form of double-counting of the MATS's co-benefits is not occurring in any extensive way in the Plan RIA. That is, SO_2 and NO_X emissions in the Plan's 2020 base case are consistent with (and lower than) the projected 2015 emissions in the MATS RIA *after implementation of the MATS rule*. (These emissions projections are compared in Table 8, several pages hence.) Thus, we find no evidence that the MATS rule's co-benefits are being counted again in any significant manner in the Plan RIA.[24]

We also studied the data regarding potential double-counting of emissions from the existing NAAQS rules for $PM_{2.5}$ and ozone, which directly target the emissions that serve as the basis for the Plan RIA's co-benefits. While the Plan's base case does not include emissions reductions associated with the 2012 $PM_{2.5}$ NAAQS, EPA projected a need for such reductions only in California and there are only very limited reductions of SO_2 and NO_X in California in the Plan. For example, for 2025, the Plan RIA projects SO_2 reductions in California of less than 1,000 tons and NO_X reductions of approximately 5,000 tons. Thus, literal double counting of reductions in the existing $PM_{2.5}$ NAAQS RIA are unlikely and/or very small.

The Plan's base case also does not include any reductions from the then-proposed (now current) ozone NAAQS in the Plan's base case. However, this does not lead to an extensive degree of literal double counting for a different reason than we see for the $PM_{2.5}$ NAAQS RIA. In fact, neither the proposed nor final ozone NAAQS RIAs (EPA, 2014b and 2015b) count any of the ozone precursor emission reductions that are attributed to the Plan as its own (direct) benefits. Both the proposed ozone NAAQS RIA and the final ozone NAAQS RIA assumed that the proposed Plan's emissions reductions would occur anyway, as part of the ozone rule's base case. That is, the proposed ozone NAAQS RIA assumed NO_X reductions in the electricity sector that totaled 230,000 tons for a 60 ppb standard, 205,000 tons for a 65 ppb standard, and 25,000 for a 70 ppb standard.[25] We have reviewed these estimates of electricity generating unit NO_X reductions at the unit-specific level and found that each generator's base case emissions were consistent with their respective post-Plan levels of NO_X emissions in the IPM modeling outputs for the Plan's RIA.

While NERA's analyses find no significant amount of co-benefits in the Plan RIA that have been previously counted as benefits or co-benefits in an existing air quality regulation, they do raise issues about the appropriate *attribution* of some of its co-benefits. This is particularly the case for the NO_X-related ozone co-benefits. To properly evaluate the health co-benefits associated with the reductions in SO_2 and NO_X, it is necessary to have an understanding of the locations where the reductions were made. To explore this issue more deeply, we now turn to results of our analyses that have identified the actual locations of the net emissions reductions of SO_2 and NO_X reported in the Plan RIA. As noted earlier, because it used the simplified benefit-per-ton approach to estimate co-benefits, the Plan RIA does not identify the locations of the Plan's

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[24] It seems that this concern with the MATS rule may stem from the fact that the analysis to compute the benefits-per-ton values used in the Plan RIA (as discussed in Section II.B) was performed using a future $PM_{2.5}$ projection that pre-dated the MATS rule. While that is true, the no-threshold concentration-response functions assumed in that analysis make it irrelevant. The reasons for this statement, and concerns with that no-threshold assumption, will be discussed in detail later in this section of the report.

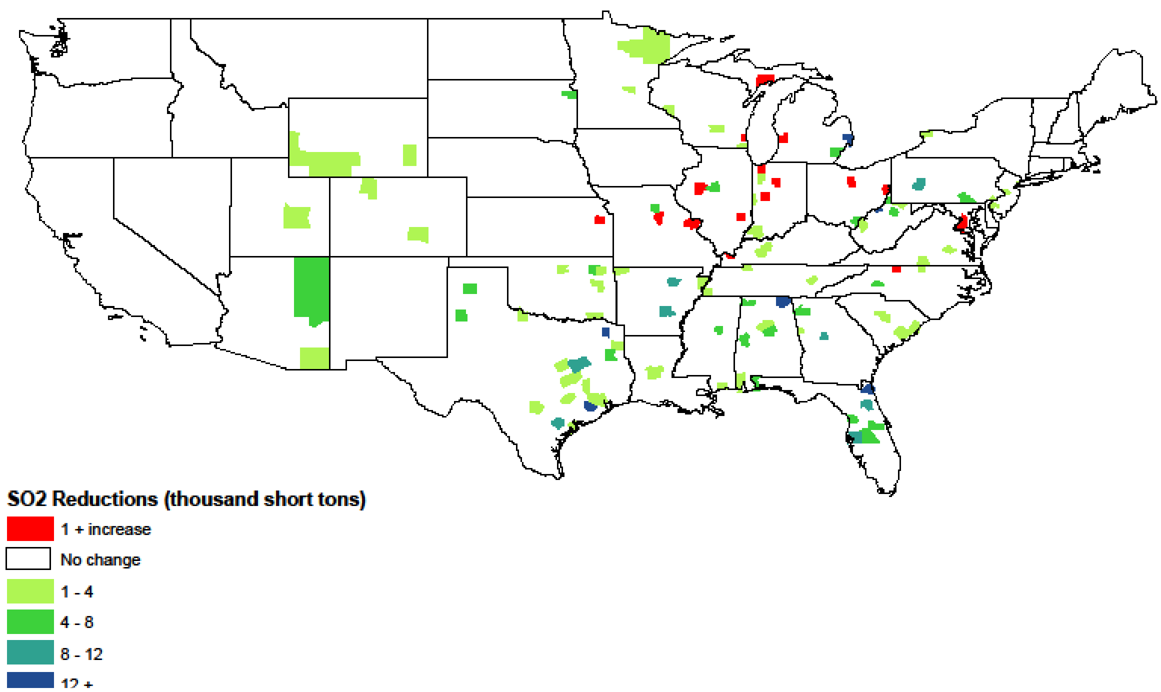
[25] EPA's lists of controls for electric generators under the ozone NAAQS rule are available at www.regulations.gov. Specific docket files are: EPA-HQ-OAR-2013-0169-0024, EPA-HQ-OAR-2013-0169-0025, and EPA-HQ-OAR-2013-0169-0028.

projected reductions, other than to place them in one of three broad regions (East, West, and California). However, NERA was able to determine these locations using the detailed IPM output files in the Plan docket.[26]

After processing the IPM output data into a more manageable form, NERA mapped the 2025 SO_2 and NO_X reductions by county, as shown in Figures 3 and 4. (Note that changes of 1,000 tons in either direction are denoted as no change in these maps, to avoid visual clutter from many relatively insignificant reductions.) Showing the changes by county allows one to see where the reductions are occurring, but also to see that there are locations where emissions are actually increasing (areas in red). The fact that some areas are projected to experience disbenefits due to increased criteria pollutant concentrations is not possible to determine from the contents of the Plan's RIA, which summarizes only net emissions changes by region.

Figure 3: 2025 SO_2 Reductions from the Plan, by County

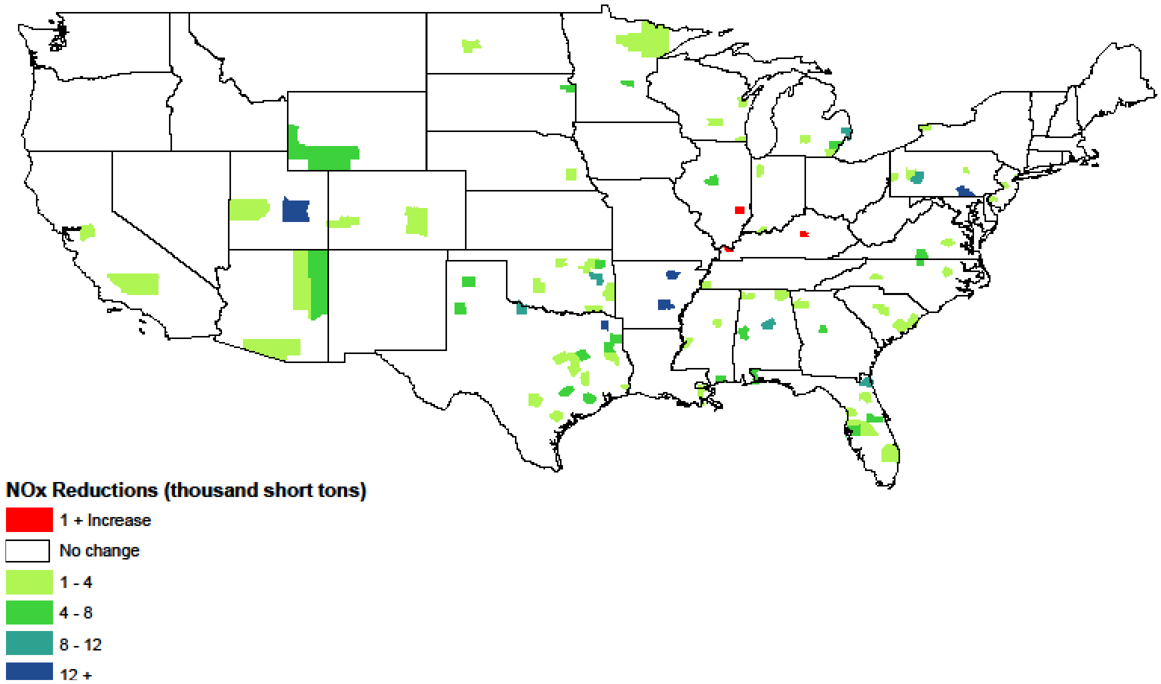
(Source: NERA analysis as described in the text. Note that changes of 1,000 tons in either direction are denoted as no change in these maps, to avoid visual clutter from many relatively insignificant reductions.)



[26] Unit-specific information for the base case and policy case for the Plan is available at www.regulations.gov. Specific docket files are: EPA-HQ-OAR-2013-0602-0219 and EPA-HQ-OAR-2013-0602-0221. EPA only provided parsed files with the unit-specific information necessary for location-specific reductions for 2025 for the base case and policy case for the Plan.

Figure 4: 2025 NO_X Reductions from the Plan, by County

(Source: NERA analysis as described in the text. Note that changes of 1,000 tons in either direction are denoted as no change in these maps, to avoid visual clutter from many relatively insignificant reductions.)



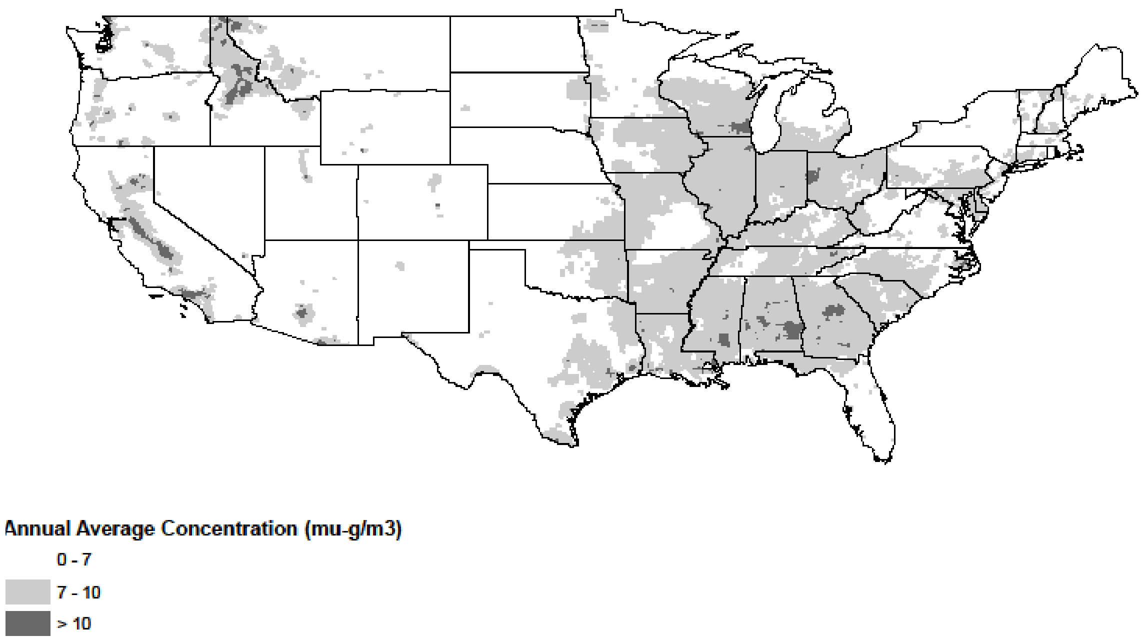
Before proceeding with a comparison of these precursor emissions changes to data in RIAs for existing regulations, we note that the *actual* location of SO_2 and NO_X reductions that would occur under the Plan could bear little resemblance to the location of the *projected* reductions. As EPA notes in the Plan's RIA, "Similar to NAAQS RIAs, the emission reduction scenarios estimated for the proposed guidelines [the Plan] are also illustrative."[27] There is uncertainty in the quantity and location of emissions in both the base case and the policy case. Base case uncertainties include the level of electricity demand, natural gas prices, and other local/state/regional/national policies that could be implemented in the coming years. Policy case uncertainties include the same uncertainties for the base case, plus uncertainties about how states would ultimately implement the Plan and the availability of energy efficiency. Under the Plan, states were provided substantial flexibilities in how they may achieve the required goals of the Plan, and this flexibility produces significant uncertainty as to the specific location of the Plan's precursor emissions reductions (and their total quantity).

[27] Plan RIA, p. 4-15.

Figure 5 provides a map of the $PM_{2.5}$ concentration by county in 2020 based on compliance with the 2012 PM NAAQS of 12 µg/m^3.[28] We have no data to produce such a map for 2025 (to be consistent with the 2025 SO_2 and NO_X emissions reductions in Figure 4 and Figure 5), but the expectation is that in 2025 the $PM_{2.5}$ concentrations will be lower still because of projected reductions in U.S. NO_X and SO_2 emissions. (At a minimum, additional reductions are expected to result from the Tier 3 motor vehicle emission and fuel standards regulations of 2014, which were not included in this analysis for the 2012 PM NAAQS, but which will implemented starting in 2017 and continuing to phase in throughout the 2020s.[29])

Figure 5: 2020 Annual Average $PM_{2.5}$ Concentration (µg/m^3)

(Source: Data used by EPA in EPA (2012), mapped by NERA)



The data illustrated in Figure 5 are important because they enable an assessment of the $PM_{2.5}$ concentration levels in the areas in which the SO_2 and NO_X reductions are projected to occur. Using data illustrated in this map, and the data on locations of 2025 SO_2 and NO_X reductions illustrated in Figures 3 and 4, NERA classified the Plan's precursor emission reductions based on the $PM_{2.5}$ concentration level of the county in which the reductions are projected to occur. Results are summarized in Tables 4 and 5.[30] For SO_2, 97% of the reductions are projected to be

[28] These data, which NERA obtained from EPA, are the BenMAP input files that EPA used in its $PM_{2.5}$ NAAQS RIA (EPA, 2012) to estimate the $PM_{2.5}$ health benefits of that regulation. This data file was also used in the assessment of the uncertainty of that RIA's $PM_{2.5}$ benefits estimates in Smith (2015).

[29] See: ftp://ftp.epa.gov/EmisInventory/2011v6/ozone_naaqs/reports/.

[30] A more precise comparison would be the location of the air quality changes (rather than the location of the emission reductions) to the $PM_{2.5}$ concentration in that same location. However, EPA did not perform any air quality modeling to allow us to make the more refined comparison. We believe the comparisons shown in Tables 4 and 5 are representative of the outcomes if air quality modeling were to exist.

realized in counties where the $PM_{2.5}$ concentration in 2020 is projected to be less than or equal to 10 μg/m^3 (*i.e.*, 2 μg/m^3 below the $PM_{2.5}$ NAAQS standard of 12 μg/m^3). Similarly, for NO_X, 98% of the reductions are projected to be realized in counties where the $PM_{2.5}$ concentration in 2020 is projected to be less than or equal to 10 μg/m^3. The significance of this finding is discussed in Section III.C below. (Similar tables that categorize the emissions reductions separately for each region – East, West, and California – are included in Appendix A.)

Table 4: Classification of 2025 SO_2 Emission Changes (Thousands of Tons) by County $PM_{2.5}$ Concentration (μg/m^3) – U.S.

County-Level 2020 $PM_{2.5}$ Concentration	SO_2 Reductions	SO_2 Increases	Net SO_2 Reductions	% of Net SO_2 Reductions
≤ 7 μg/m^3	190	19	171	40%
> 7 and ≤ 10 μg/m^3	292	49	243	57%
> 10 μg/m^3	10	2	8	2%
No County Information	5	2	3	1%
Total	497	72	425	

Table 5: Classification of 2025 NO_X Emission Changes (Thousands of Tons) by County $PM_{2.5}$ Concentration (μg/m^3) – U.S.

County-Level 2020 $PM_{2.5}$ Concentration	NO_X Reductions	NO_X Increases	Net NO_X Reductions	% of Net NO_X Reductions
≤ 7 μg/m^3	198	13	185	44%
> 7 and ≤ 10 μg/m^3	264	35	229	54%
> 10 μg/m^3	8	0	8	2%
No County Information	5	3	2	0.4%
Total	475	51	424	

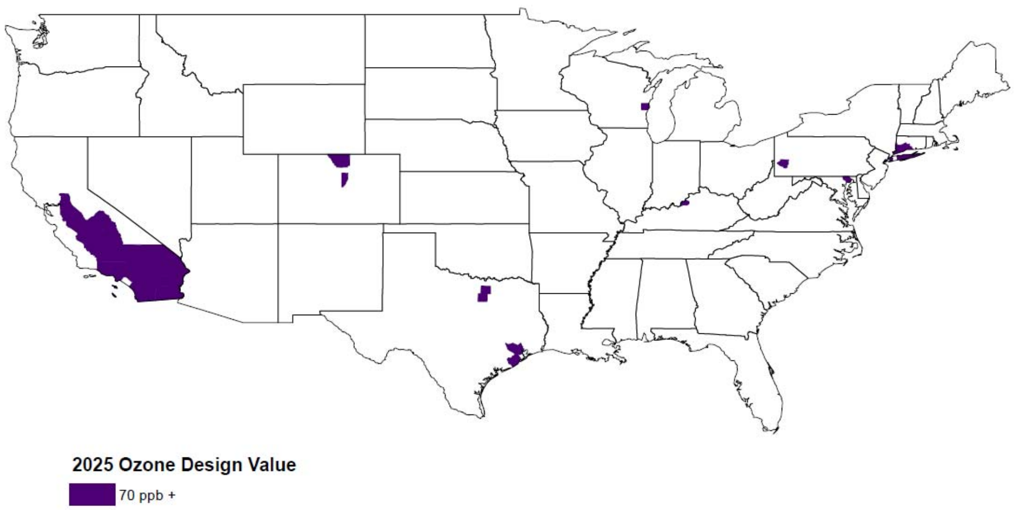
Turning now to the ozone-related health co-benefits, NERA created a map of 2025 base case projected ozone nonattainment with the recently-released ozone NAAQS of 70 ppb (Figure 6). This is based on county-level projected design values for the base case from EPA's final ozone NAAQS RIA (EPA, 2015b). The base case does not reflect any emission reductions from the Plan, yet does reflect the projected reductions by 2025 of all other currently-existing regulations. (EPA incorporated the proposed Plan's reductions into what it calls the "baseline" projection; however this map reveals projected nonattainment areas prior to the Plan's incorporation.) Figure 6 indicates 30 counties projected to be in nonattainment (15 in and 15 outside of California).[31] Comparison of nonattainment areas projected in Figure 6 with areas projected in

[31] In releasing its final ozone NAAQS rule, EPA has announced it expects all but 14 counties (excluding California) to achieve 70 ppb. EPA's statement is based on its baseline rather than its base case. The difference between the

Figure 4 to have NO_X reductions under the Plan indicates that significant reductions attributed to the Plan are likely to take place anyway under the existing ozone NAAQS. These reductions would be more appropriately attributed to the ozone NAAQS than to the Plan. This can be interpreted as an example of overstatement of ozone co-benefits in the Plan's RIA because such reductions would still be expected to occur even if the Plan is never implemented.

Figure 6: 2025 Projected Base Case Ozone Nonattainment with 70 ppb Standard

(Source: NERA mapping of data in EPA (2015b), Tables 2A-7 and 2A-8)



C. Evaluation of EPA's Benefit-Per-Ton Estimates

Section II.B has introduced the concept of the benefit-per-ton values that are multiplied against the projected precursor emissions reductions to produce the RIA's co-benefits estimates. These were originally developed by Fann *et al.* (2012) using EPA's BenMAP model. This section now describes the assumptions and numerical results for the benefit-per-ton values that resulted and discusses their implications.

The Plan's estimated health co-benefits from $PM_{2.5}$ are derived using two epidemiological estimates of avoided premature mortality risk in adults (which are reflected as a range of values). The $PM_{2.5}$ co-benefits also include epidemiologically-based estimates of infant mortality risk and several types of morbidity risks, such as respiratory symptoms or non-fatal heart attacks. The estimated health co-benefits from ozone are also based on a range reflecting two epidemiological

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15 non-California counties in the base case and the 14 reported by EPA when releasing its final rule is due to inclusion of NO_X reductions from the Plan. The incremental reductions of NOx estimated to be needed by the other 14 counties to attain the 70 ppb ozone NAAQS have also been reduced by inclusion of the Plan in EPA's baseline scenario, even though the Plan alone is not sufficient to convert those counties from nonattainment into attainment.

estimates of avoided premature deaths plus several types of morbidity risks. Of the 17 different sectors for which benefit-per-ton values were estimated, as described in Fann *et al*. (2012), the values for the electricity generation sector are used for the Plan RIA co-benefits calculations. The estimated health co-benefits related to $PM_{2.5}$ reductions are roughly 10 times larger than those from ozone reductions. Further, EPA estimates that 98% of the $PM_{2.5}$-related health co-benefits are associated with avoided mortality related to reductions in $PM_{2.5}$ precursors. Thus, the following discussion focuses on the mortality-related health co-benefits from $PM_{2.5}$ reductions.

Fann *et al.* (following EPA preferences) used coefficients from two epidemiological studies of large population cohorts: 1) the American Cancer Society cohort (used by Krewski *et al*., 2009), and 2) the Harvard Six Cities cohort (used by Laden *et al*., 2006). The coefficients from each study produce a different number of avoided deaths from reduced $PM_{2.5}$ exposure, and this provides a range for the number of deaths. (The two separate $PM_{2.5}$ epidemiological studies are the *only* determinants of the range in values.) Although the Plan RIA's benefit-per-ton values are based on the original Fann *et al.* analysis, EPA has since revised and updated that analysis (EPA, 2013) and uses somewhat different values than in the original paper. One of the changes was to replace the Laden *et al.* concentration-response function with a more recent estimate from Lepeule *et al.* (2012).[32]

The avoided mortality estimates are multiplied by EPA's choice of VSL, which is an estimate of an individual's willingness-to-pay to reduce the risk of death. The VSL used in the Plan's RIA is $9.9 million in 2020 and $10.1 million for 2025 and 2030 (2011$).[33] The number of avoided deaths in each region (East, West, and California) was multiplied by the VSL to determine a total health co-benefit in each region. Similar calculations are completed for the various morbidity risks and added to the mortality co-benefit. This dollar value is then divided by the regional reduction in the applicable $PM_{2.5}$ precursor emission (e.g., SO_2 or NO_X) to arrive at the estimated benefit-per-ton values used in the Plan's RIA. (An estimate of the deaths per ton of precursor emission is also available and used in the RIA to estimate numbers of deaths associated with the co-benefits estimates.)

Table 6 shows the doubling of the benefit-per-ton values from the lower end to the upper end of the range, which reflects the range of concentration-response slope estimates of the two $PM_{2.5}$ mortality risk epidemiological studies only. This range reflects none of the many other sources of uncertainty about the true concentration-response relationship (discussed in Smith and Gans, 2015), nor the many sources of locational variability (discussed in Section II.B above). The range also reflects only the *mean* slope estimate of the two epidemiological studies referenced.

[32] Lepeule *et al.* (2012) is also based on the Harvard Six Cities cohort, and has a very similar risk coefficient to Laden *et al.* (2006). Both produce risk estimates more than twice as high as Krewski *et al.* (2009), which is why the benefit-per-ton and resulting co-benefits ranges span a factor of more than two.

[33] Plan RIA, p. 4-22.

Table 6: Examples of the Benefit-Per-Ton Values Used in the Plan RIA (for 2025 Emissions, 3% Discount Rate, 2011$/ton)

(Source: Plan RIA, Table 4-8)

Region	SO_2	NO_X (as $PM_{2.5}$)
East	$44,000 to $98,000	$7,200 to $16,000
West	$8,800 to $20,000	$1,300 to $2,900
California	$180,000 to $410,000	$19,000 to $42,000
National	$41,000 to $93,000	$6,000 to $14,000

In evaluating the benefit-per-ton approach used in the Plan's RIA, it is important to note that EPA's benefit-per-ton values are applied regardless of the starting point of ambient pollution (and hence of the precursor emissions). This is because the concentration-response function used in the original development of those estimates was assumed to have no threshold, implying a nearly linear relationship from the starting point ambient concentration down through zero concentration. The immutability of the per-ton benefits estimates over time is seen in Table 7, which compares the benefit-per-ton estimates from Fann *et al.* to those used in the MATS Rule RIA (EPA, 2011) and those now used in the Plan RIA.

Table 7: Examples of Estimates of Benefit-Per-Ton Values over Time (2011$/ton, for Electricity Generating Emissions)

(Sources: Fann *et al.* (2012); EPA (2011), Table 5C-3; Plan RIA, Table 4-7 for 3% discount rate)

Emissions Forecast	Year	SO_2	NO_X
Fann *et al.* (2012)	2016	$36,000 (U.S.)(*)	$5,300 (U.S.)(*)
MATS RIA	2016	$31,000 - $79,000 (East) $9,000 - $23,000 (West)	NA(**)
Plan RIA	2020	$38,000 - $86,000 (U.S.) $40,000 - $90,000 (East) $7,800 - $18,000 (West)	$5,600 - $13,000 (U.S.)

(*) Although Fann *et al.* report having used two concentration-response studies, the paper only provides benefit-per-ton values estimates for the study that produces the lower end of the range, Krewski *et al.* (2009).

(**)The MATS Rule included only small projected reductions in NO_X emissions and therefore EPA did not estimate any $PM_{2.5}$ co-benefits associated with NO_X emissions.

The benefit-per-ton values from Fann *et al*. (2012) are for the lower bound study, Krewski *et al.*, only, and should be compared only to the lower bounds of the ranges used in the two RIAs also shown in Table 7. In brief, the per-ton benefit values have not changed as time has passed, even though ambient pollutant levels have declined. The slightly higher values in the Plan's RIA are due solely to projected income growth from 2016 to 2020, which increases EPA's VSL assumptions. (It may also reflect updates to Census population data that EPA has made since the results of the emissions forecasts were published in 2012 and 2011, respectively.)

The degree to which criteria pollutant levels are lower in the Plan RIA compared to the MATS RIA and the original benefit-per-ton estimation process can be inferred from Table 8. Table 8 shows forecasted SO_2 and NO_X emissions from electric generating units in different years that underlie the respective analyses shown in Table 7. It reveals that the original Fann *et al*. (2012) estimation process had comparable emissions levels to those in the MATS RIA base case. However, the Plan RIA's base case has a much lower starting point for precursor emissions, consistent with the MATS RIA's policy case. This is a sign that there is likely little or no literal double-counting of the MATS RIA's co-benefits in the Plan's co-benefits; however, it also brings to light a concern with overstatement of co-benefits. As Table 7 shows, the Plan RIA assumes the same amount of health benefit *per unit* of emissions reduction. This reveals the implications of the assumption embedded in the benefit-per-ton estimation process that the health risk per unit of pollutant exposure never reaches a point where it starts to diminish as the ambient air becomes increasingly clean. It is a strong assumption that merits more discussion in this report because it is the primary reason the co-benefits estimates of the Plan RIA are so high. This is not a concern that the reductions are being double-counted, but instead a concern that all reductions are assumed to have equal benefits, no matter how low the ambient pollution levels have become.

Table 8: Forecasts of Electric Generating Unit SO_2 and NO_X Emissions Used in Recent Estimates of Co-Benefits (thousands of tons)

Emissions Forecast	Forecast Year	SO_2	NO_X
Fann *et al.* (2012)	2016	3,793	1,827
MATS RIA Base Case	2015	3,267	1,809
MATS RIA Policy Case	2015	1,931	1,759
Plan RIA Base Case	2020	1,476	1,559
Plan RIA Policy Case(*)	2020	1,140	1,191

(*) For Option 1 – State Implementation case

There are many uncertainties that underlie EPA's estimates of total co-benefits. These include the estimated emissions reductions from the IPM modeling, the determination of the number of avoided deaths attributable to the declines in $PM_{2.5}$ precursor emissions, and the willingness-to-pay estimates that form the VSL. While the uncertainties for each of these are significant, our analysis indicates that the uncertainties in the estimated number of avoided deaths are the most significant. We therefore discuss those uncertainties in the remainder of this section.

EPA cites three key assumptions that underlie their estimated avoided deaths in the Plan's RIA:

1. EPA assumes that all fine particles are equally potent in leading to premature mortality;[34]

2. The health impact functions used to estimate premature mortality have a log-linear form and a threshold of zero. This means "the estimates include health co-benefits from reducing fine particles in areas with varied concentrations of $PM_{2.5}$, including both areas that do not meet the fine particle standard and those areas that are in attainment, down to the lowest modeled concentrations;" and

3. There is a lag between $PM_{2.5}$ exposure and all of the realized avoided deaths.[35]

Assumption 2 is of high importance in the case of the Plan RIA co-benefits. As was reported in Section III.A, (Tables 4 and 5), over 97% of all SO_2 and NO_X reductions estimated in EPA's modeling of compliance with the Plan are projected to occur in counties with a $PM_{2.5}$ concentration that will already be less than 10 $\mu g/m^3$. In 2012, the EPA Administrator set the annual $PM_{2.5}$ NAAQS at 12 $\mu g/m^3$. Thus, as much as 97% of the $PM_{2.5}$ health co-benefits may be associated with small reductions in $PM_{2.5}$ concentrations in areas that will already be well below the EPA-determined health standard for $PM_{2.5}$, a standard that is set at a level to "protect the public health" including provision for an "adequate margin of safety."

By calculating health benefits for reductions of $PM_{2.5}$ concentrations below the NAAQS level in the Plan's RIA, EPA is effectively assuming an equal probability of health risks below the standard as above it. This assessment is inconsistent with the EPA Administrator's statements and judgment related to setting the annual $PM_{2.5}$ standard in 2012.

To better understand the issue, it is important to understand how NAAQS standards, like that for $PM_{2.5}$, are set by the EPA Administrator. NAAQS standards must be set "requisite to protect public health" while "allowing an adequate margin of safety."[36] Cost to achieve any standard is not a consideration; instead the considerations historically were based upon 1) the size of the affected population, 2) the severity of effect, and 3) the certainty of the effect.[37] Since 1997, there has been a greater reliance on a series of epidemiological studies, particularly for $PM_{2.5}$, where studies have not identified a threshold, or lower bound, below which effects become significantly less likely. Without any threshold, the first consideration (the size of the affected population) becomes the entire U.S. population and the second consideration (the severity of the effect) becomes irrelevant because without a threshold the severity of the effects are assumed not

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[34] As shown in quantitative studies (Smith and Gans, 2015; Fraas and Lutter, 2013), the equal-potency assumption overstates likely risks from $PM_{2.5}$ changes. The potential for overstatement rises when the co-benefits estimate is based on changes in just one of the many chemical types of $PM_{2.5}$ constituents. That is much the situation in the Plan, where a very large portion of the health co-benefits is derived from a single $PM_{2.5}$ constituent, sulfate.

[35] Plan RIA, pp. ES-16 – ES-17, emphasis added.

[36] Section 109 (b)(1), Clean Air Act; 42 USC §7409.

[37] *Lead Industries Association Inc v. Environmental Protection Agency,* 647 F.2d 1130 (1980).

to change based on the level of the standard. This leaves the third consideration as the only relevant criterion for the Administrator to set a NAAQS. The rationales provided to justify two recent NAAQS decisions have emphasized identifying a level below which the statistical associations are too tenuous to justify setting a lower level for the NAAQS.

In the 2012 decision setting the $PM_{2.5}$ NAAQS, the EPA Administrator set an annual $PM_{2.5}$ standard of 12 $\mu g/m^3$. The justifications for setting the standard are included throughout the preamble to the 2012 $PM_{2.5}$ NAAQS. EPA wrote,

> *In reaching decisions on alternative standard levels to propose, the Administrator judged that it was most appropriate to examine where the evidence of associations observed in the epidemiological studies was strongest and, conversely, where she had appreciably less confidence in the associations observed in the epidemiological studies.*[38]

and, following an extended discussion of the recent epidemiological studies, continued:

> *The Administrator views this information as helpful in guiding her determination as to where her confidence in the magnitude and significance of the associations is reduced to such a degree that a standard set at a lower level would not be warranted to provide requisite protection that is neither more nor less than needed to provide an adequate margin of safety.*[39]

Smith (2015) applied a decision-analytic interpretation of the rationale for setting the recent NAAQS for $PM_{2.5}$ and ozone. She concluded:

> *In order for a selected NAAQS level to be deemed as requisite to protect the public health, EPA's subjective probability that the relationship exists at and below the selected NAAQS level must, logically, be very nearly zero. (Indeed, the subjective probability of continued effects must fall to nearly zero at an ambient concentration somewhere above the selected NAAQS level. This is because the NAAQS needs to include at least some margin of safety, and thus must be set at least somewhat lower than the level where expected risk is deemed to become too small to be considered a public health concern.)*[40]

In other words, if the NAAQS is set at a level requisite to protect the public health, then levels below the NAAQS standard must have a near-zero probability of having negative health consequences. This implication has been ignored in the use of health co-benefits in EPA RIA's since 2009, including that for the Plan. Prior to 2009, EPA assumed that reductions in $PM_{2.5}$

[38] 78 Fed. Reg., 3086, at 3139.

[39] 78 Fed. Reg., 3086, at 3161, emphasis added.

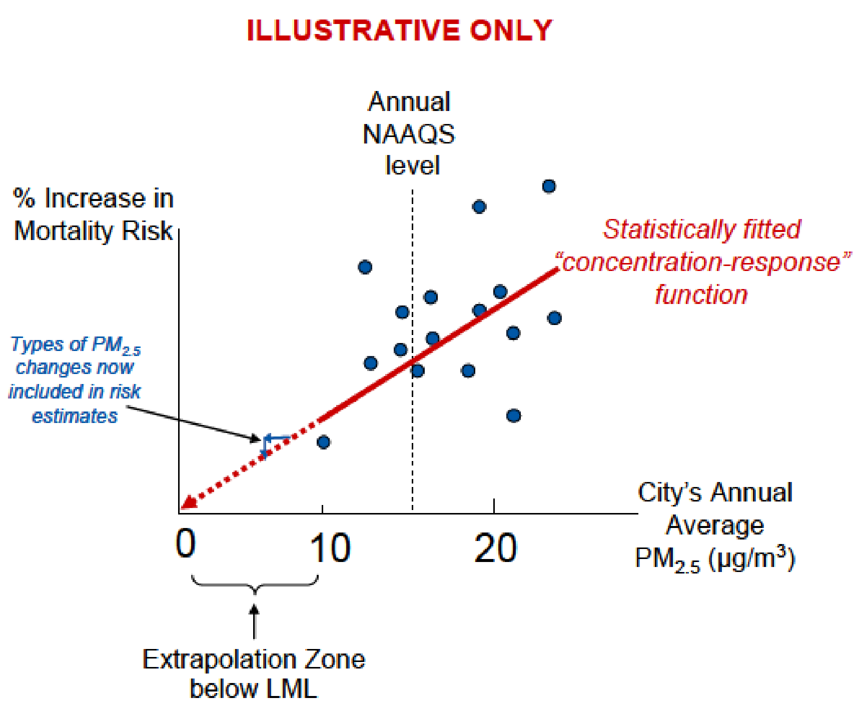
[40] Smith (2015).

precursors would not reduce the mortality risks associated with $PM_{2.5}$ exposure if an area has a $PM_{2.5}$ concentration below the lowest measured level (LML) in the epidemiological studies. The reason for this was that there is no information on relative risks at $PM_{2.5}$ concentration levels below the LML.

Figure 7 (replicated from NERA, 2011), which is illustrative, can help to demonstrate this point. In the figure, the dots represent different percentage changes in mortality risk given a city's annual average $PM_{2.5}$ concentration. There are data points for several different illustrative cities, and together these data are used to statistically estimate a concentration-response function. In this example, there are data on $PM_{2.5}$ concentrations as high as 25 µg/m^3 and as low as 10 µg/m^3. (10 µg/m^3 is thus the LML for this illustrative example.) Prior to 2009, risks below the LML were not given any weight because there was no statistical evidence as to the concentration-response function below that level. Starting in 2009, however, EPA extrapolated the concentration-response function to continue below the LML, extending to $PM_{2.5}$ concentrations of 0 µg/m^3, although there was not any statistical evidence to demonstrate the shape of the function at such levels.

Figure 7: Illustration of Extrapolation of Concentration-Response Function in Risk Calculations

(Source: Figure 4 of NERA (2011))



Since 2009, by extrapolating the concentration-response function linearly below the LML, EPA's methodology for estimating the benefits-per-ton has assumed that each unit of pollutant exposure is equally risky whether an area has very clean air or very dirty air – an approach that is contrary to EPA's science-based evaluations of evidence regarding health effects of criteria pollutants. Those evaluations indicate a greatly diminished likelihood that risks continue to exist at levels below the NAAQS. In turn, this implies that co-benefits estimates based on a no-threshold extrapolation assumption are likely overstated.

As a result, going back to Tables 4 and 5, NERA concludes that as much as 97% of the health co-benefits from $PM_{2.5}$ that EPA has claimed in the Plan's RIA are calculated in a manner that is inconsistent with EPA's assurances that it is setting the NAAQS at the legally-required protective level. Such emission reductions should not be presented as a reliable expectation of the co-benefits of the Plan.

Finally, any of the $PM_{2.5}$ and ozone co-benefits that might result from exposures to baseline levels that exceed a NAAQS would be eliminated by compliance programs to ensure attainment with that NAAQS. This portion of the co-benefits (up to 3% of the estimated $PM_{2.5}$ co-benefits) should be attributed to the NAAQS rules. Such reductions can be expected to occur otherwise, as a result of compliance with NAAQS regulations.

IV. SYNTHESIS

A. What Can Be Said About the Accuracy of the Plan's Projections of Emissions Reductions Leading to $PM_{2.5}$ and Ozone Air Quality Improvements?

Given generation technologies available over the next 20 years, any policy that will result in reductions of electricity sector CO_2 emissions of between 20% and 30% will have to involve a reduction in generation from at least some coal-fired power plants. Reductions in coal-fired generation will involve simultaneous reductions in SO_2, NO_X, and direct particulate emissions at those locations. Whether those are large or small reductions in precursor emissions depends on whether the most-affected plants already have significant controls on those pollutants. Generally, direct particulate emissions are highly controlled at all plants in the U.S., but this is not always the case for SO_2 and NO_X, for which existing control requirements are more varied by location. Also, it is certain that replacements for the reduced coal-fired generation will not have any significant SO_2 emissions and will on average have much lower NO_X and direct particulate emissions. Thus, one must expect that the Plan will result in net reductions of emissions contributing to ambient $PM_{2.5}$ and ozone. The primary questions are, "How much reduction?" and "Where?" Answers to those questions may not be exceptionally robust.

The projections of emissions reductions in the Plan are based on simulations of the response to the policy that must be characterized as "illustrative," even if the Plan were to be finalized exactly as proposed. This is because of the flexibility that is provided to states in how they may choose to implement the Plan. The Plan RIA has provided only two illustrative implementations, one being for each state to meet its own rate limit independently, and the other assuming that states group together in broad regional aggregates for purposes of compliance. These two alternative implementation assumptions produce relatively similar projections about the location and quantity of changes in emissions that affect ambient $PM_{2.5}$ and ozone concentrations (and which translate into potential co-benefits). However, this should not be taken to indicate that the projections of air quality improvements are robust, because these two alternative implementation assumptions are actually very similar relative to the entire field of potential implementation paths that states may adopt. For example, both assume that states employ the flexibility available to them to a maximal degree in order to achieve their limits in the least-cost manner. Breaking down the barriers to greater flexibility by allowing optimization to occur across many contiguous states is unlikely to create much difference in the ultimate outcome, except for states that are exceptionally constrained in a critical dimension of response, such as very limited access to natural gas. Greater variations in projected $PM_{2.5}$ and ozone precursor emissions could appear under dramatically different implementation assumptions, such as the use of mass-based trading, requiring individual companies within a state to meet the state's rate limit on their individual systems, failure of a state to enable demand-side energy efficiency programs to be validated for compliance, or trading between states that are not contiguous, but have more complementary options for compliance. None of these more substantive differences in implementation have been analyzed in the RIA (but all are possible under the Plan), and so it is impossible to assess the robustness of the RIA's emissions projections.

Also, the emissions projections are highly dependent on modeling input assumptions other than Plan implementation choices. Higher natural gas prices, constraints on natural gas deliverability to certain regions, higher costs for energy efficiency improvements, different costs of new generation technologies, consumer resistance to energy efficiency measures that may appear cost-effective on a purely financial basis, and higher or lower load growth could all result in very different responses to the Plan for any given implementation method. Impacts of such varied market conditions on projected precursor emissions changes also are not analyzed in the RIA.

Another important consideration when assessing co-benefits from the Plan is what additional controls of the precursor emissions should be assumed in the analytic baseline of the RIA. The standard construction of an RIA's baseline is to assume only regulations already promulgated will take effect in the absence of the regulation being evaluated in an RIA. However, in the case of criteria pollutants, which are the basis for the Plan's co-benefits, this assumption leads to an overstatement of precursor emissions that will exist in future years if the Plan were not to be implemented. This can result in criteria pollutant reductions being attributed to the Plan that will occur "anyway," and not only if the Plan is implemented. For example, at the time the Plan was being evaluated, activities were underway to revise the ozone NAAQS. Indeed, that revision is now final, and the lower ozone levels of the new ozone NAAQS should be attained everywhere except for California by the time the Plan is in full effect. Thus, a portion of the estimated ozone co-benefits of the Plan will probably occur in any case, even without the Plan. One must question whether it is reasonable for those co-benefits to be *attributed* to the Plan, even though they were never "double-counted" in the literal sense of counting them in more than one of the EPA's RIAs for existing regulations. If the Plan were to be eliminated tomorrow, some of its so-called co-benefits will still occur – as *benefits* of the tighter ozone rule.

The same may be true of the Plan's $PM_{2.5}$ co-benefits. The baseline forecast for the Plan probably already accounts for all of the $PM_{2.5}$ reductions that will be needed to attain the existing $PM_{2.5}$ NAAQS, which was promulgated in 2012. However, the next review of the $PM_{2.5}$ NAAQS is starting now, and if a tighter $PM_{2.5}$ NAAQS is to be set, it will likely result in further $PM_{2.5}$ reductions before 2030. Although some future NAAQS-mandated reductions may post-date the period over which the Plan's co-benefits are being calculated, it would only be a matter of a few years before those reductions would occur anyway, even if the Plan were to be eliminated. The focus of the RIA on just a few points in time, rather than a full present value of costs and benefits, hides the fact that those co-benefits are sped up by at most a few years and should not be viewed as a permanent co-benefit of the Plan.

The most important point, however, is that it appears that the vast majority of the co-benefits that have been attributed to the Plan appear to be due to reductions in $PM_{2.5}$ and ozone that are in areas well below both the present NAAQS and any future reasonably expected NAAQS. In other words, those are estimates of benefits that perhaps should not be calculated, because they are in areas that the EPA considers (and will likely continue to consider) to be free of unacceptable public health risk due to ambient $PM_{2.5}$ and ozone.

In summary, the projections of precursor emissions changes are inaccurate due to modeling and implementation uncertainties. The choice of what to include in the emissions baseline creates conceptual "inaccuracies" with respect to whether some of the emissions reductions should be attributed to the Plan (as its co-benefits) or recognized as future reductions that will occur in any case because those pollutants are subject to stringent control under existing law. However, a larger potential source of inaccuracy associated with the remainder of the Plan's co-benefits estimates is not due to the computation of precursor emissions reductions, but due to the computation of public health benefits from precursor emissions reductions in locations where EPA expresses no confidence that there is a health risk from criteria pollutants.

B. To What Extent Does EPA Use Otherwise-Expected Public Health Benefits As a Justification for the Plan? What is the Likelihood That the Health Co-Benefits of the Plan Will Arise in the Absence of the Rule?

The RIA contains an accounting of costs and benefits that includes benefits from climate impacts and from co-benefits. When the two categories of benefits are combined, the RIA concludes that benefits far exceed the costs of the Plan. Indeed, the co-benefits alone are estimated to exceed the reported costs of the Plan. For example (using Option 1, State implementation, and the 3% discount rate), co-benefits from coincidental reductions in $PM_{2.5}$ and ozone alone are projected to be between $17 billion and $40 billion in 2020 and between $27 billion and $62 billion in 2030, which are compared to annualized costs of less than $10 billion in all years.[41] If the co-benefits are ignored, the RIA still suggests a case that benefits may exceed costs based on climate benefits alone, although not under all of the RIA's range of climate benefit estimates and by a much smaller margin in all cases with positive net benefits.[42] Thus, the estimates of co-benefits that the RIA attributes to the Plan are important in bolstering its justification, making it a relevant question whether those public health benefits might be "otherwise-expected" (*i.e.*, would occur even if the Plan were not to be implemented), and the likelihood that they will arise at all.

As Section III.A has documented, some portion of the estimated co-benefits will occur even in the absence of the Plan, and thus can be categorized as "otherwise-expected." Specifically,

- A portion of the ozone-related co-benefits would occur during the same time frame as the Plan's implementation to meet the tighter ozone NAAQS that was in the process of being revised at the same time the Plan was being developed. The new ozone NAAQS has now been finalized and was tightened from a level of 75 ppb down to 70 ppb.[43] The tighter ozone NAAQS is supposed to be attained over the period 2018 through 2023 in all of the U.S. except California (and possibly Utah), which is before and during the Plan's

[41] It is outside of the scope of this study to comment on the estimates of Plan costs.

[42] It is outside the scope of this study to comment on the estimates of the climate benefits.

[43] The ozone NAAQS level is for the 3-year average of the 4th highest maximum 8-hour average of monitored ozone concentrations.

implementation period. Almost all of the Plan's ozone co-benefits in the Plan's RIA are projected to occur outside of California.

- The $PM_{2.5}$ NAAQS, the annual average level of which is presently set at 12 $\mu g/m^3$, is now entering its next review cycle. The decision on whether to revise the $PM_{2.5}$ NAAQS is due to be made before 2020, which means that additional $PM_{2.5}$ precursor controls due to that NAAQS, if tightened, would be taking effect before 2030. Thus, to the extent that EPA determines that new scientific evidence indicates a public health risk from ambient $PM_{2.5}$ concentrations below annual average levels of 12 $\mu g/m^3$, some of the $PM_{2.5}$ co-benefits that are being attributed to the Plan (*i.e.*, those associated with $PM_{2.5}$ levels above the level of a revised standard) also could be categorized as "otherwise expected."

The precise fraction of the Plan's co-benefit estimates that fall into the "otherwise expected" category is not possible for us to determine with presently-available data. Accomplishing this would require that emissions reductions that serve as the basis of the Plan's co-benefits be individually subjected to an air quality modeling exercise to determine which are likely to be necessary for attainment of the 70 ppb ozone NAAQS or for a potentially tightened $PM_{2.5}$ NAAQS. Such an exercise was outside of the scope of this study, but it would also not be warranted; it would be an uninformative exercise given the difficulty of accurately predicting the methods of implementation of the Plan that states will choose or the ways that electricity generation would respond to each possible implementation path. However, as Section III.B illustrates, the more serious concern is with the much larger fraction of the Plan's co-benefits occurring in areas projected to be easily attaining the $PM_{2.5}$ and ozone NAAQS by the time the Plan is being implemented. This large majority of the Plan's estimated co-benefits is greatly overstated.

Our analysis of the locations of the Plan's emissions reductions demonstrates that the vast majority of the co-benefits EPA calculated would be associated with ambient $PM_{2.5}$ reductions in areas of the country already far below the current annual $PM_{2.5}$ NAAQS of 12 $\mu g/m^3$. EPA has averred there is insufficient scientific evidence to expect a public health risk from exposure to ambient $PM_{2.5}$ in those areas, and yet EPA's RIA assumes the opposite, and calculates benefits from any reduction of emissions, regardless of where the reductions occur. As a result, essentially all of the Plan's $PM_{2.5}$ co-benefits are not "otherwise expected" co-benefits, but are better characterized as having a very low likelihood of being real. In fact, the vast majority of the Plan's $PM_{2.5}$ co-benefits would continue to fall into the "very low likelihood" category even if the newly-started review of the $PM_{2.5}$ health effects science ultimately deems it appropriate to tighten the NAAQS to as low as 10 $\mu g/m^3$. Note also that any portion of the co-benefits that may, as a result of that science review, be assigned a higher likelihood of existence than one might currently assign them would then be reassigned to the category of otherwise-expected benefits because the NAAQS itself will drive those emissions reductions.

In sum, all the co-benefits being attributed to the Plan fall into one of two mutually-exclusive categories. They either (a) will occur even if the Plan is never implemented or (b) should be considered to have a low likelihood of being real benefits. Our analysis indicates the vast majority of the co-benefits in the Plan's RIA fall into the second category. It is a result of EPA's benefit-per-ton methodology that assumes that every increment of ambient $PM_{2.5}$ or ozone poses a comparable risk of premature mortality regardless of whether the current ambient concentrations are very high or very low. However, even if new scientific evidence were to move some of the estimated co-benefits out of category (b), they would simply reappear in category (a).

C. What Can Be Said About the Cost-Benefit Comparisons of the Plan in Light of the Issues Raised in This Report?

This report has closely examined the basis for the $PM_{2.5}$ and ozone co-benefits estimates in the RIA for the proposed Plan and placed them in the context of the overall cost-benefit comparisons that are the goal of the RIA. We find no evidence that EPA has counted any substantial portion of the co-benefits as benefits or co-benefits in some other RIA. Nevertheless, we find that *all* of the co-benefits fall into one of two categories, neither of which should be attributed to the Plan's RIA.

In the first category are co-benefits that will occur in any case as a result of either the $PM_{2.5}$ or ozone NAAQS. Given the levels of the NAAQS that were in effect at the time the Plan's RIA was released,[44] very few of the ozone and effectively none of the $PM_{2.5}$ co-benefits would fall into this category. A larger portion (but not a majority) of the Plan's ozone co-benefits likely fall into this category when accounting for additional reductions needed to meet the new ozone NAAQS of 70 ppb. Although it was not within the scope of this study to estimate that fraction, it is important to note that these overlapping reductions have not been literally "double-counted" because they were *not* counted as benefits in either the proposed or final ozone NAAQS RIAs. However, it is a given that they would occur "anyway" due to the ozone NAAQS, and thus their inclusion in the Plan's RIA, as if they should be attributed to the Plan and not to the ozone NAAQS, is questionable. Properly, they should be removed from any comparison of the costs and benefits of the Plan now that the ozone NAAQS has been finalized.[45] To avoid creating such confusion, EPA could simply omit co-benefits of already-regulated pollutants such as ozone and $PM_{2.5}$ in RIAs for regulations that do not address those pollutants directly.

Similarly, one might anticipate a fraction of the $PM_{2.5}$ co-benefits reported in the Plan will also occur "anyway" if the $PM_{2.5}$ NAAQS is tightened as a result of its currently starting review cycle. Given the schedule for that rulemaking, it is reasonable to expect that additional $PM_{2.5}$ reductions that may be needed beyond those in the Plan's current baseline would start to occur during the period from 2020 through 2030, overlapping with the Plan's period of co-benefits calculations. (Even if some of those potential future $PM_{2.5}$ NAAQS reductions occur after 2030,

[44] In other words, with the ozone NAAQS level set at 75 ppb for the maximum daily 8-hour average, and the $PM_{2.5}$ NAAQS set at its 2012 levels of 12 $\mu g/m^3$ annual average and 35 $\mu g/m^3$ daily average.

[45] At the same time, they should be *added* to any discussion of the benefits and costs of the new ozone NAAQS.

they would be occurring very soon afterwards, such that the most incremented benefit that could be attributed to the Plan would be that they would occur a few years earlier than otherwise.) Given that we do not know if or how much the $PM_{2.5}$ NAAQS will be tightened, it is not possible to determine how many of the $PM_{2.5}$ co-benefits fall in this category. What-if computations can be made: Table 4 and Table 5 have shown that roughly 2% of the Plan's $PM_{2.5}$ co-benefits reductions might fall into this "anyway" category if the annual $PM_{2.5}$ NAAQS were to be tightened as low as 10 $\mu g/m^3$. Again, however, the entire confusion would be readily eliminated if EPA were not to include co-benefits of already-regulated pollutants such as ozone and $PM_{2.5}$ in its RIAs for non-NAAQS rules. Presumably, if those potential benefits are deemed to be highly likely, EPA will ensure that they occur in any case, under its legal responsibility in setting the NAAQS.

In the second category of co-benefits are health benefits calculated from reductions in ambient $PM_{2.5}$ and ozone concentrations in areas projected to be in attainment with their respective NAAQS. As this report shows, the vast majority of the Plan's co-benefits are in this category, even if a substantial future tightening of the $PM_{2.5}$ NAAQS were assumed. Under the Clean Air Act, EPA must set the NAAQS at levels that protect the public health with an adequate margin of safety, given the most current scientific information. The margin of safety is intended to account for scientific uncertainty about what level is actually safe. As a result, any health risk reduction that EPA could calculate based on projected changes in already-low ambient pollution has a very low likelihood of being real. Such risk estimates are not considered "likely enough" to warrant a tighter NAAQS, and hence have no place in a co-benefits estimate used to justify an entirely different type of regulation such as greenhouse gas reductions.

In light of this assessment, none of the co-benefits in the Plan's RIA should be considered appropriate grounds for justifying that particular regulation even though there is no major pattern of literal double-counting.

In conclusion, it is important to mention again that this study was mandated under a resolution of the Virginia legislature to address the RIA for the proposed Plan. Since then, the final Plan has been released, along with a new RIA. The final Plan's CO_2 targets are very different, particularly in their geographic distribution and timing. It also offers more explicit variants on implementation approaches. It was outside of the scope of this study to prepare an evaluation of the final Plan's RIA. Furthermore, many of the critical technical support documents and data files used for this study of the proposed Plan were not publicly available for the final Plan at the time this study was conducted. However, we have reviewed the RIA sufficiently to determine that the general patterns and issues associated with the Plan's treatment of co-benefits, direct benefits, and costs remain unchanged. Thus, we expect the same conclusions made in this report would also be made if we were to have been engaged to review the final rather than the proposed Plan's co-benefits estimates.

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APPENDIX A. REGION-SPECIFIC CLASSIFICATIONS OF PRECURSOR REDUCTIONS BY AMBIENT $PM_{2.5}$ LEVELS

Table A-1: Classification of 2025 SO_2 Emission Changes (Thousands of Tons) by County $PM_{2.5}$ Concentration ($\mu g/m^3$) – East

County-Level 2020 $PM_{2.5}$ Concentration	SO_2 Reductions	SO_2 Increases	Net SO_2 Reductions	% of Net SO_2 Reductions
≤ 7 $\mu g/m^3$	160	19	141	36%
> 7 and ≤ 10 $\mu g/m^3$	292	49	243	61%
> 10 $\mu g/m^3$	10	2	8	2%
No County Information	5	2	3	1%
Total	467	72	395	

Table A-2: Classification of 2025 NO_X Emission Changes (Thousands of Tons) by County $PM_{2.5}$ Concentration ($\mu g/m^3$) – East

County-Level 2020 $PM_{2.5}$ Concentration	NO_X Reductions	NO_X Increases	Net NO_X Reductions	% of Net NO_X Reductions
≤ 7 $\mu g/m^3$	140	10	130	35%
> 7 and ≤ 10 $\mu g/m^3$	262	35	227	62%
> 10 $\mu g/m^3$	8	0	8	2%
No County Information	4	3	2	0.3%
Total	414	48	366	

Table A-3: Classification of 2025 SO_2 Emission Changes (Thousands of Tons) by County $PM_{2.5}$ Concentration ($\mu g/m^3$) – West

County-Level 2020 $PM_{2.5}$ Concentration	SO_2 Reductions	SO_2 Increases	Net SO_2 Reductions	% of Net SO_2 Reductions
≤ 7 $\mu g/m^3$	30	0.3	30	100%
> 7 and ≤ 10 $\mu g/m^3$	0.1	0	0.1	0.4%
> 10 $\mu g/m^3$	0	0	0	0%
No County Information	0	0	0	0%
Total	30	0.3	30	

Table A-4: Classification of 2025 NO_X Emission Changes (Thousands of Tons) by County $PM_{2.5}$ Concentration ($\mu g/m^3$) – West

County-Level 2020 $PM_{2.5}$ Concentration	NO_X Reductions	NO_X Increases	Net NO_X Reductions	% of Net NO_X Reductions
≤ 7 $\mu g/m^3$	54	2	52	98%
> 7 and ≤ 10 $\mu g/m^3$	1	0	1	1%
> 10 $\mu g/m^3$	0.1	0	0.1	0.3%
No County Information	0.2	0	0.2	0.4%
Total	55	2	53	

Table A-5: Classification of 2025 SO_2 Emission Changes (Thousands of Tons) by County $PM_{2.5}$ Concentration ($\mu g/m^3$) – California

County-Level 2020 $PM_{2.5}$ Concentration	SO_2 Reductions	SO_2 Increases	Net SO_2 Reductions	% of Net SO_2 Reductions
≤ 7 $\mu g/m^3$	0.4	0	0.4	60%
> 7 and ≤ 10 $\mu g/m^3$	0.3	0	0.3	40%
> 10 $\mu g/m^3$	0	0	0	0%
No County Information	0	0	0	0%
Total	1	0	1	

Table A-6: Classification of 2025 NO_X Emission Changes (Thousands of Tons) by County $PM_{2.5}$ Concentration ($\mu g/m^3$) – California

County-Level 2020 $PM_{2.5}$ Concentration	NO_X Reductions	NO_X Increases	Net NO_X Reductions	% of Net NO_X Reductions
≤ 7 $\mu g/m^3$	4	1	3	65%
> 7 and ≤ 10 $\mu g/m^3$	1	0	1	28%
> 10 $\mu g/m^3$	0	0	0	0%
No County Information	0.4	0	0.4	7%
Total	6	1	5	

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