Prepared Statement of
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at a Hearing on
Impacts of U.S. Environmental Protection Agency Regulations
by the
Committee on Oversight and Government Reform
United States House of Representatives
Washington, DC

February 26, 2015

Mr. Chairman and Members of the Committee:

Thank you for your invitation to participate in today's hearing. I am Anne E. Smith, a Senior Vice President of NERA Economic Consulting. I am also co-head of NERA's global environmental practice with Dr. David Harrison.

I am a specialist in environmental risk assessment and economic impact analyses to support environmental policy decisions. I have performed air quality cost and benefits analyses and risk assessments over my entire career, including as an economist in the Office of Policy, Planning, and Evaluation of the U.S. Environmental Protection Agency (USEPA), as a consultant to the USEPA, and in many consulting engagements since then for government and private sector clients globally. I also have served on several committees of the National Academy of Sciences focusing on risk assessment and risk-based decision making, and on advisory boards of the USEPA.

Specific air quality issues I have analyzed include greenhouse gases, fine particulate matter ($PM_{2.5}$), ozone, mercury, regional haze, and others. I have been involved extensively in assessment of the evidence on risks from ambient $PM_{2.5}$ and

ozone for twenty years, and have performed analyses of the impacts of climate change and climate policies for even longer.

I hold a Ph.D. in Economics from Stanford University, with a Ph.D. minor in Stanford's School of Engineering, a M.A. in Economics from Stanford University and a B.A. in Economics from Duke University, *summa cum laude*.

I thank you for the opportunity to share my perspective today on the benefits and costs of major proposed rulemakings of the USEPA. My written and oral testimonies reflect my own opinions, and do not represent any position of my company, NERA Economic Consulting, or of any of its clients.

My colleague, Dr. David Harrison, is also submitting testimony in this hearing that summarizes analyses on which we have collaborated regarding the costs and economic impacts of two major regulations that USEPA is presently proposing: the proposed Clean Power Plan (CPP)[1] and the proposed tightening of the national ambient air quality standard (NAAQS) for ozone.[2] USEPA's own analyses indicate that both of these rules will have significant costs; we agree but, as Dr. Harrison testifies, we find that these rules have the potential to be far more costly than USEPA reports. In my testimony, I turn to the issue of what USEPA has reported as the potential benefits of these proposed rules, and explain why I conclude that USEPA's benefit and net benefit estimates are overstated and misleading.

[1] 79 *Fed. Reg*. 34830, June 18, 2014.

[2] 79 *Fed. Reg*. 75233, December 17, 2014.

Synopsis of Key Points in My Testimony

- USEPA's comparisons of costs and benefits of the proposed CPP are presented in a very misleading manner, falsely suggesting climate benefits will exceed costs in the period 2020-2030.

- When correctly presented, USEPA's estimates indicate the present value of CPP spending through 2030 will exceed $180 billion while climate benefits are not expected to exceed that cost until about 100 to 125 years after the spending has been sunk.

- The CPP's estimated benefits to U.S. populations is not expected to exceed the CPP's costs under even the most pessimistic projections of climate impacts.

- The proposed ozone NAAQS is likely to be much more expensive than the proposed CPP, yet USEPA does not project that its ozone-related benefits will ever exceed its costs.

- USEPA has claimed that both of these proposed air rules will produce benefits far in excess of their costs, but in both cases, those statements are based on projected coincidental changes (so-called "co-benefits") in a completely different pollutant that is not the target of these regulations – $PM_{2.5.}$

- To make its estimates of $PM_{2.5}$ co-benefits, USEPA uses assumptions that are inconsistent with the Administrator's own stated conclusions about that pollutant's health effects. The Administrator's conclusions imply that the co-benefits estimates in the RIAs are vastly overstated, and may be nearly zero.

- Estimates of co-benefits of an already regulated pollutant such as $PM_{2.5}$, even if they were trustworthy, should not provide the justification for regulations of different pollutants. That is a recipe for creating an unnecessarily complex web of air regulations that can only lead to economically-inefficient management of the public health.

1. Misleading Comparisons of Benefits and Costs in the RIA for the Proposed Clean Power Plan

The regulatory impact analysis (RIA) of the proposed CPP[3] contains estimates of climate-related benefits from the reduction in CO_2 emissions. These estimates are made by multiplying the number of tons of reduction of CO_2 predicted to occur under the CPP by a "social cost of carbon" (SCC) estimate. The Federal SCC estimates are supposed to reflect the present value of the monetized global benefits over a 300-year period into the future due to a reduction of one metric ton of CO_2.[4] It is stated in dollars per ton ($/ton). Estimates of the SCC vary enormously with the choice of discount rate that is used when calculating the SCC. The $/ton SCC estimates that USEPA uses vary by a factor of more than five when moving from a 2.5% discount rate to a 5% discount rate. The range would exceed a factor of ten if discount rates recommended in RIA guidance were to be used.[5]

This high sensitivity to the choice of discount rate is a strong indicator that a very large portion of the SCC's value comes from changes in climate impact that are many decades in the future. It also highlights a significant conceptual flaw in the way USEPA is using the SCC in its comparisons to costs of a regulation. That is, the SCC produces a

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[3] USEPA, *Regulatory Impact Analysis for the Proposed Carbon Pollution Guidelines for Existing Power Plants and Emission Standards for Modified and Reconstructed Power Plants*. EPA-542/R-14-002, June 2014. (Hereafter, the "CPP RIA".)

[4] Interagency Working Group of U.S. Government on Social Cost of Carbon. *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866*, February, 2010. (Available: http://www.epa.gov/oms/climate/regulations/scc-tsd.pdf.)

[5] The Office of Management and Budget's guidance for preparing RIAs, known as "Circular A-4," calls for use of a 3% and 7% discount rate. I have done my own replications of the Federal SCC values and find that if an SCC value using 7% were to be included, it would be more than a factor of 10 less than the SCC for the 3% discount rate.

present value of benefits, while the RIA compares those benefits estimates to costs that are stated in annualized terms, and makes the comparison for just three individual years. This creates a significant overstatement of the apparent net benefits of the rule, as I explain below.[6]

The RIA provides estimates of net benefits for each of three years during the rule's implementation phase (2020, 2025, and 2030), based on a "slice in time" method in which costs in each of those years are compared to benefits in each of those years. Doing this, the RIA concludes that the CPP's net benefits will be large and positive. For example, for the proposed "Option 1", and using a 3% discount rate for climate and co-benefits, USEPA suggests that benefits will exceed the regulation's costs by between $27 billion and $50 billion in 2020, and increase to a range of $48 billion to $84 billion by 2030.[7] Approximately half of the benefits in these calculations are from "co-benefits" from coincidental reductions projected in ambient $PM_{2.5}$. These are highly problematic and inappropriate to include in the RIA, as I will explain in Section 3. However, even if one ignores the co-benefits in these tables (which I will return to in Section 3), and considers only the climate-related benefits, the net benefits implied by the RIA are about $11 billion in 2020, and rise to about $22 billion by 2030 (still using the 3% discount rate). These estimates are misleading as I explain in the rest of this section.

[6] A more complete exposition of my points regarding the CPP benefits and benefit-cost comparison in the RIA is in my technical report prepared on behalf of the Texas Commission on Environmental Quality (TCEQ), which is available in the CPP docket as Attachment 1 at http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2013-0602-23305.

[7] RIA, pp. ES-21 to ES-23.

1.a. A Corrected Comparison of CPP's Costs and Climate Benefits

The net climate benefits in the CPP's RIA summarized above are misleading because they compare a present value for the climate benefits to a single year's portion of the costs of the policy. An appropriate assessment of a major regulation's net benefits should compare present values to present values. Also, when the timing of the spending of an investment is substantially different from the timing of its return (*i.e.*, the benefits) one should provide an assessment of the payback period. I did such an analysis using USEPA's own cost and climate benefits data, and following is the very different story that emerges:[8]

- EPA's estimates of the costs of the CPP vastly exceed its estimates of the climate benefits in the specific years 2020, 2025 and 2030. For example:
    - Benefits estimated to occur in 2020 will be less than $0.1 billion globally, compared to U.S. CPP compliance spending during 2020 of $21 billion.
    - Estimated benefits in 2030 will be in the range of $1.0 to 1.4 billion globally, while U.S. compliance spending in that year is projected to be $11 billion.
- By 2030, the U.S. will have spent approximately $182 billion to comply with the CPP, yet the present value of climate benefits that will have accumulated by that time (globally) are estimated to be only $3.5 to 4.6 billion.
- Even by 2050, the estimated global benefits from the spending through 2030 are projected to be less than $36 billion, at a point when all $182 billion of costs has been expended.
- Because there are such small expected climate benefits until long after the compliance spending is sunk, the present value of accumulated net benefits does not become positive until sometime between 2131 and 2155. This implies a

[8] All of the following comparisons use the 3% discount rate for the SCC values. My report for TCEQ (see footnote 6) provides results for the other Federal SCC values and discount rates.

payback period of 100 to 125 years on a societal investment about $200 billion dollars. That is, the global societal return on the CPP investment will still be negative more than a century after the regulation has been completely implemented.

- The ultimate present value of global benefits eventually accumulates to $214 billion, which is only $32 billion higher than the present value of costs ($182 billion). This implies an internal rate of return of less than one-tenth of one percent per year even 250 years after the $182 billion investment in the CPP has been made.

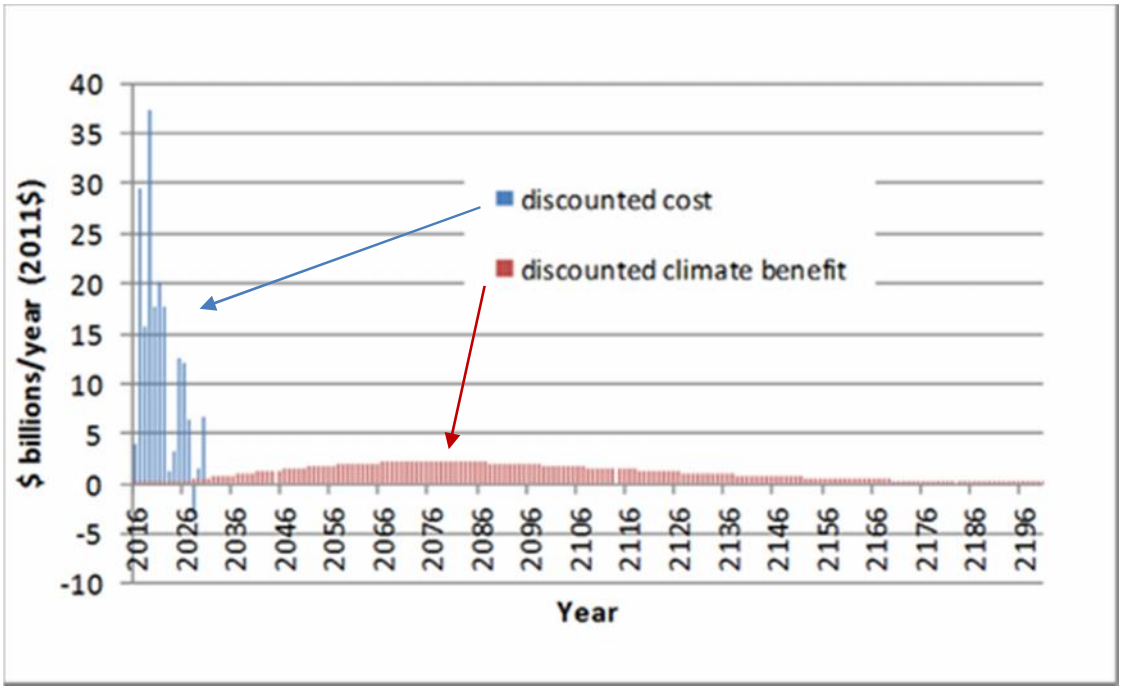
The above calculations make it clear that the RIA's "slice in time" approach that indicates net benefits of $11 billion in 2020, and rising to $22 billion by 2030 is a very misleading way to describe the benefits and costs of a climate policy. USEPA's estimates of those climate benefits are actually projected to materialize decades to centuries in the future, whereas the RIA creates a false impression that those reductions in climate impacts are imminent and large. In fact, the CPP represents a very significant near-term spending program that has a highly uncertain long-term pay-off. The one point on which *all* the various estimates of SCC agree is that potential benefits from avoided climate damages will occur many decades after the spending has been sunk.[9]

Figure 1 presents the estimates of the timing and magnitude of USEPA's estimates of spending for the CPP (blue bars) with the timing and magnitude of the estimates of climate-related benefits (red bars) for the 3% discount rate case summarized in the bullets above. Again, these estimates are based entirely on USEPA's own cost and benefit estimates. The only thing I have done differently from USEPA has been to place

[9] For example, even using the 95th percentile pessimistic SCC values, the policy's benefits would not exceed the costs until about 40 years after the spending is completed. (See Figure C-5 of my report for TCEQ cited in footnote 6.)

both the cost and the benefits estimates in their respective years, and account for the additional years in the period 2017-2300.

Figure 1. Present Value of Spending (blue) and Climate Benefits (red) by Year ($ billions per year, 2011$, using 3% discount rate)



1.b. U.S. Climate Benefits of CPP Do Not Exceed the CPP's U.S. Costs

An important limitation of the benefit-cost case above is that the values for the SCC are for *global* benefits, even though all of the costs of the regulation will be borne by the U.S. alone. However, it is standard procedure in benefit-cost analysis of a domestic program to focus on a comparison of the domestic benefits to that program's costs. The Technical Support Document for the derivation of the SCC $/ton estimates notes if an SCC were to reflect only domestic benefits from reducing U.S. emissions, it

may be between 7% and 23% of the SCC values that USEPA has used.[10] This indicates that the climate benefits that will be gained by U.S. populations (now and in the future) are so much smaller that even the highest set of suggested Federal SCC values would not result in net domestic benefits greater than zero for the U.S., even by the year 2300. That is, using the worst case (95th percentile) SCC and assuming at the high end that domestic damages are 23% of those estimated global damages, the net benefits of the CPP will be negative even through 2300. The RIA should present these facts to its readers but does not.

1.c. Additional Concerns with USEPA's Estimates of CPP Costs and Climate Benefits

Individuals familiar with USEPA's cost estimates may notice that I stated in the bullets above that the CPP spending in 2020 will be $21 billion, whereas the RIA states that spending in 2020 will be $7.5 billion. The $21 billion estimate is in fact USEPA's cost estimate for actual spending in that year, which can be found by reviewing the USEPA's spreadsheets that it provides as technical support documents to the RIA. The costs inserted into the RIA's cost tables for the years 2020, 2025 and 2030 have inappropriately annualized the spending on energy efficiency programs projected to be spend in those three years – even though these costs are not annualized by the utility companies that pay for them.[11] By annualizing that large part of the CPP's costs, they

[10] Interagency Working Group of U.S. Government on Social Cost of Carbon. *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866,* February, 2010, p. 11. (Available: http://www.epa.gov/oms/climate/regulations/scc-tsd.pdf.)

[11] Explanation of how this can be found in USEPA technical support documents for its cost estimates is explained in Appendix A of my report for TCEQ referenced in footnote 6. One can also observe in the USEPA spreadsheets that USEPA did use the full (not annualized) costs to calculate the electricity rate impacts also reported the CPP RIA.

were pushed off into years beyond 2030. This is inappropriate in a societal cost analysis because it is inconsistent with when society will actually have to incur the capital spending. It is particularly inappropriate for a benefit-cost analysis when the full present value of the benefits *have* been assigned to that year. My analysis summarized above has made this correction, to provide a proper "apples to apples" comparison of benefits and costs of the CPP.

As Dr. Harrison explains in his testimony, NERA has made its own estimates of the costs of the CPP. Our estimates are substantially higher than USEPA's.[12] I have not used any of NERA's cost estimates of the CPP in the above benefit-cost comparisons. I note, however, that the above estimates of present values of net benefits would be lower and the payback periods longer, if I were to have used NERA's own estimates.

2. Costs of the Proposed Ozone NAAQS Alternatives Exceed Their Ozone-Related Benefits

Another major rule currently being proposed by USEPA is to tighten the current ozone NAAQS of 75 ppb to a level in the range of 65 to 70 ppb. Even by USEPA's analysis, this ozone rule could be more costly than the proposed CPP. For example, USEPA estimates in the current RIA for the proposed ozone NAAQS[13] that the 60 ppb NAAQS alternative could cost about $40 billion per year. The benefit-cost case for this

[12] My analysis for TCEQ finds that the present value (through 2030) of EPA's CPP cost estimate for Option 1 is $182 billion (see Appendix A, p. 28); NERA's analysis finds that Option 1 of the CPP will cost over $350 billion (see Table 5 of testimony of Dr. Harrison, February 26, 2015).

[13] USEPA, *Regulatory Impact Analysis of the Proposed Revisions to the National Ambient Air Quality Standards for Ground-Level Ozone*, EPA-452/P-14-006, Office of Air and Radiation, Research Triangle Park, NC, November 2014. Available: http://www.epa.gov/ttnecas1/regdata/RIAs/20141125ria.pdf. (Hereafter, the "Ozone NAAQS RIA".)

rule, however, is even weaker than for the CPP. This is true even using USEPA's current RIA data, but the case is even weaker when underestimates that EPA introduced into this current RIA's costs estimates are considered.

2.a. How USEPA Has Reduced Its Ozone Cost Estimates since the Last Ozone RIA

This same set of alternative ozone NAAQS levels were evaluated by USEPA in a rulemaking ending in 2008, and in a reconsideration initiated in 2010. USEPA provided estimates of the cost of attaining these same alternative NAAQS in RIAs released then.[14] In the earlier RIAs, USEPA estimated that the 60 ppb alternative could cost as much as $90 billion per year, compared to about $40 billion per year in the current ozone RIA. The costs for the 65 ppb and 70 ppb standards have similarly declined in the current RIA.

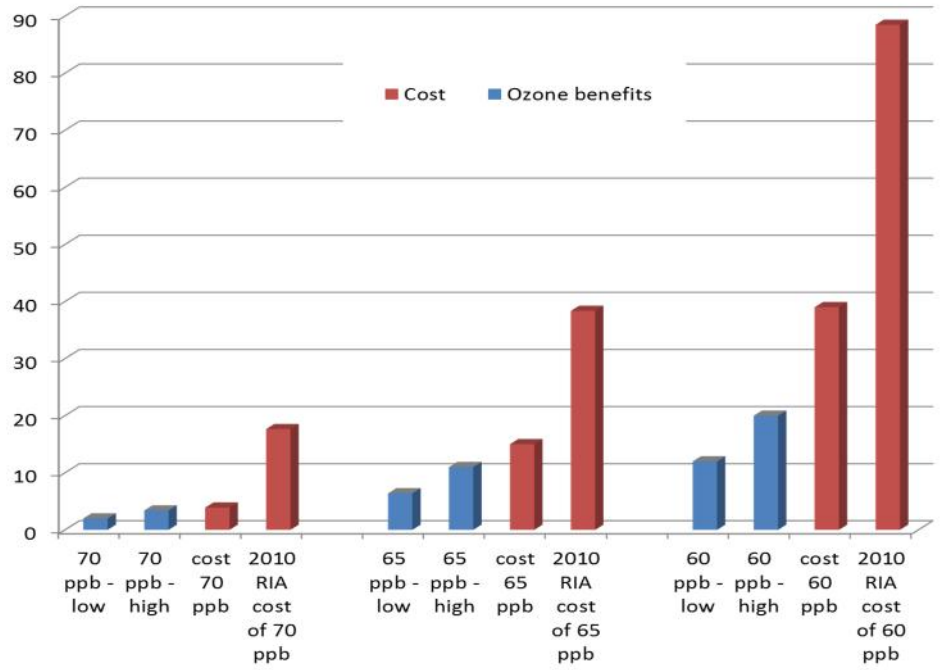
This is illustrated in the sets of two red bars in Figure 2.[15] The red bar on the right for each alternative NAAQS level reflects the costs of that rule estimated in the 2010 RIA. The red bar on the left for each alternative NAAQS shows the costs that USEPA now estimates for the same standard. Many people have asked what accounts for this large reduction in the cost estimates. Although many changes in regulations, baselines, and air quality modeling have occurred between the 2010 RIA and the current RIA, NERA has found that *almost all of the reduction in the costs in the current RIA can be*

[14] USEPA. *Summary of the updated Regulatory Impact Analysis (RIA) for the Reconsideration of the 2008 Ozone National Ambient Air Quality Standard (NAAQS).* January 2010. Available at: http://www.epa.gov/ttnecas1/regdata/RIAs/s1-supplemental_analysis_full.pdf.

[15] If viewing these figures in black and white, the red bars are the two rightmost bars in each set of four bars, and are labeled "cost" beneath the bar, along with an indication of which alternative NAAQS level and from which ozone NAAQS RIA (*i.e.*, from the current RIA, or from the 2010 RIA).

traced to a change in USEPA's assumption about the cost per ton to reduce the very large share of emissions that USEPA calls the "unknown" control actions.

Figure 2. Comparison of Estimates of Ozone Benefits and Costs for 3 Alternative Ozone NAAQS (Source: Ozone NAAQS RIA, Tables ES-6 and 5-1)



What are "unknown controls"? They make up the portion of total reductions in ozone precursor emissions that USEPA has determined need to be removed for attainment to occur, but which USEPA has declined to attempt to identify in its RIA. Obviously, the cost for this set of actions is highly uncertain, but as long as the control actions are left unidentified, it is very difficult to challenge any estimate that USEPA may choose to provide for this estimate. However, there is some basic logic that can be applied to determine whether any given estimate is realistic, and we find that the current estimates are less realistic than USEPA's earlier ones.

For example, the list of controls that EPA *has* identified is insufficient even to attain the least stringent alternative of 70 ppb. However, because the number of tons of reduction needed to achieve each incrementally tighter standard increases, the fraction of controls that USEPA treats as "unknown" rises with more stringent alternative NAAQS levels. In the case of the 65 ppb NAAQS, approximately half of the needed reductions in emissions are left unidentified by USEPA. It is a matter of intuition (and economic reality) that reductions that cannot be identified in a cost analysis probably become increasingly more costly than those that can more readily be identified.

In its 2008 and 2010 RIAs, USEPA made efforts to roughly approximate this increasing cost per ton; in the current RIA, however, USEPA has simply assumed that all of those unknown control measures will be available at an average of only $15,000 per ton – no matter how deeply one has to cut back on total baseline emissions. NERA staff have performed calculation replicating USEPA's cost estimates and we have found that if one simply replaces the current RIA's flat $15,000 per ton for the "unknown" reductions with the same upward-sloping cost per ton assumption that USEPA used in its two prior ozone RIAs, *the estimated costs for the alternative rules today will be essentially the same as they were before*.

As we find no good reason in USEPA's RIA to make a more simplistic assumption than it made in 2008 and in 2010, the higher earlier costs (the red bars on the right in Figure 2) should not be treated as outdated, and should be viewed as more realistic.

As Dr. Harrison explains in his testimony for this hearing, NERA has made a more evidence-based study to identify what these "unknown" control actions would have to comprise and to then make estimates of those actions' costs. That analysis finds that even the earlier higher USEPA cost estimates shown in Figure 2 are potentially vastly understated. Where USEPA is suggesting that a tighter ozone standard may cost tens of billions of dollars per year, NERA's more evidence-based cost estimates are hundreds of billions of dollars per year.

2.b. USEPA's Estimates of Ozone Benefits Are Less than the Ozone NAAQS Costs

Figure 2 also graphs the RIA's estimated range of ozone-related benefits next to the RIA's estimates of the cost, for each alternative standard included in the RIA. It shows that the USEPA's estimates of the ozone-related benefits of those alternative potential NAAQS levels cannot match its estimates of their costs. A range of ozone-related benefits estimates is provided in the current RIA, with annual values as shown by the two blue bars shown in Figure 2 for each of the three alternative NAAQS levels analysed. Only if the highest of the benefit estimates is compared to the current RIA's cost estimate does one alternative standard -- the least stringent alternative of a 70 ppb NAAQS -- potentially have a breakeven level of net benefit. When the more realistic earlier cost estimates are compared to the RIA's ozone benefits, even the 70 ppb alternative NAAQS is found to have ozone-related benefits far less than its costs.

One might then ask, why does the USEPA press release for this proposed rule claims large net benefits, as quoted below:

> *EPA estimates that the benefits of meeting the proposed standards will significantly outweigh the costs. If the standards are finalized, every dollar we invest to meet them will return up to three dollars in health benefits*.[16]

The answer is the use of estimates of "co-benefits" from another pollutant altogether, $PM_{2.5}$. While the CPP RIA uses co-benefits from criteria pollutants to bolster its rather weak benefit-cost case from its climate-related benefits, the ozone NAAQS RIA's benefit-cost case depends entirely on an appeal to co-benefits. The role of co-benefits in both of these rules is discussed in Section 3, providing reasons to expect that all such co-benefits are being overstated, and in a manner that is inconsistent with the judgments of the USEPA Administrator about where to set a NAAQS.

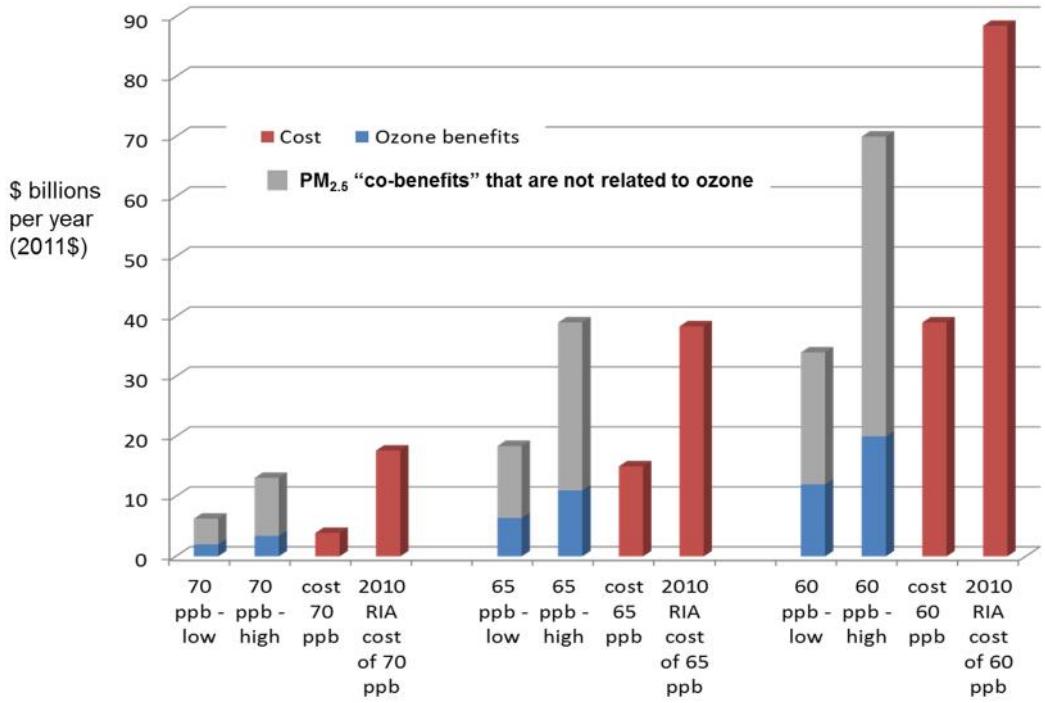
3. Problems with Use of "Co-Benefits" in the RIAs for the Proposed CPP and Ozone NAAQS

The proposed ozone NAAQS RIA includes large numbers of co-benefits from coincidental reductions in ambient $PM_{2.5}$ that it projects will result when reducing NO_x emissions to reduce ozone. As with the proposed CPP RIA, these co-benefits are larger than the estimates of the ozone NAAQS's actual own direct (*i.e.*, ozone-related) benefits. Figure 3 adds the ozone NAAQS RIA's estimates of co-benefits from $PM_{2.5}$ to Figure 2 (*i.e.*, co-benefits are shown as the grey portions of the benefits bars, stacked on top of the blue bars from Figure 2 that show the ozone benefits). As Figure 3 shows, the co-benefits estimates in the ozone NAAQS RIA are much larger than the ozone rule's estimated ozone benefits. Only when the co-benefits are included in the analysis do the

[16] USEPA, "EPA Proposes Smog Standards to Safeguard Americans from Air Pollution," press release, November 26, 2014. Available: http://yosemite.epa.gov/opa/admpress.nsf/596e17d7cac720848525781f0043629e/6ce92be958c8149285257d9c0049562e!OpenDocument.

benefits of the alternative ozone NAAQS levels appear to exceed their costs, even when accepting the much lower cost estimates in the current ozone NAAQS RIA.[17]

Figure 3. Comparison of Benefits and Costs in USEPA's Ozone NAAQS RIA with PM2.5 Co-Benefits Included (Source: Ozone NAAQS RIA, Tables ES-6 and 5-1)



As I noted in Section 1, the CPP RIA also makes a case that the rule will have near-term benefits exceeding its costs due to estimated benefits that have nothing to do with climate change. These are the co-benefits estimated to be derived from coincidental reductions in the criteria pollutant levels of $PM_{2.5}$ and ozone.[18] According to the CPP

[17] As Dr. Harrison explains in his testimony for this same hearing, all of these ozone NAAQS cost estimates are understated in a very significant degree. If the more evidence-based costs estimates that NERA has produced were to be used, none of the alternative ozone NAAQS options would have benefits exceeding their costs, *even if the $PM_{2.5}$ co-benefits are included*. (NERA's more evidence-based cost estimates are discussed in Dr. Harrison's testimony, and the results for a 60 ppb alternative NAAQS are found in our July 2014 report at http://www.nera.com/publications/archive/2014/assessing-economic-impacts-of-a-stricter-national-ambient-air-qu.html.)

[18] Such coincidental reductions may occur if there is less coal-fired generation as a result of efforts to limit CO_2 under the CPP – the reduced generation is also likely to reduce NO_x and SO_2 emissions that are

RIA, co-benefits from Option 1 are estimated to range from $16 billion to $40 billion in 2020 and rise to the range of $25 billion to $62 billion by 2030.[19] These co-benefits estimates exceed the estimated cost of the CPP, and might tempt some people to argue that the CPP is justified on the basis of these co-benefits alone. (Doing so might allow one to thereby sidestep discussions about the weakness that I described in Section 1 of the benefit-cost case for the CPP based on its climate benefits.) In fact, emphasizing the co-benefits instead of the climate benefits is pretty much what USEPA is doing when it claims that the CPP will save hundreds of lives per year and myriad other health benefits. For example, USEPA's Fact Sheet for the CPP states:

> ***Americans will see billions of dollars in public health and climate benefits, now and for future generations***.
> *The Clean Power Plan will lead to climate and health benefits worth an estimated $55 billion to $93 billion in 2030, including avoiding 2,700 to 6,600 premature deaths and 140,000 to 150,000 asthma attacks in children.*[20]

The claimed "climate and health benefits" in the above quote from USEPA have *nothing to do with reduced climate change at all* – they are entirely due to estimated co-benefits from reductions in ambient $PM_{2.5}$ and ozone that USEPA has estimated will occur as a result of meeting the CPP's CO_2 targets.

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precursors to the formation of ambient $PM_{2.5}$ and ozone (in the case of NO_x). Where exactly these reductions will occur geographically, and by how much, are more uncertain than whether less coal-fired generation will result in such reductions. However, sound estimates of potential co-benefits would take into account where and how much, not just whether.

[19] Tables ES-8 to ES-10 in CPP RIA, pp. ES-21 to ES-23.

[20] http://www2.epa.gov/carbon-pollution-standards/fact-sheet-clean-power-plan-overview. Emphasis in original.

There are good reasons why the estimates of co-benefits in both the proposed CPP and proposed ozone NAAQS RIAs should be viewed as overstated. There are also reasons why estimates of co-benefits from already-regulated pollutants such as the criteria pollutants should not be included in an RIA. I summarize my reasons in the rest of this section, while a more thorough discussion and analysis is available in papers that I refer interested readers to also read.[21]

3.a. The Overstatement in USEPA's Co-Benefits Estimates.

All of the estimated health co-benefits in these two proposed rule RIAs are associated with minor reductions in ambient concentrations of criteria pollutants that are already subject to their own Federal health standards -- *i.e*., their respective NAAQS. Each NAAQS must be set at a level that protects the public health from each criteria pollutant with an adequate margin of safety. Although a health-based NAAQS is not considered to be free of any remaining health risk, it *is* considered to be stringent enough that USEPA lacks confidence that statistical associations between health and pollutant levels continue to exist at lower levels.

The USEPA Administrator's articulation of this lack of confidence can be found in the preambles for both the current $PM_{2.5}$ and the current ozone NAAQS.[22]

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[21] Smith, AE. *An Evaluation of the $PM_{2.5}$ Health Benefits Estimates in Regulatory Impact Analyses for Recent Air Regulations*, prepared for the Utility Air Regulatory Group, December, 2011 (available: http://www.nera.com/publications/archive/2011/an-evaluation-of-the-pm25-health-benefits-estimates-in-regulato.html); Smith, AE. "Inconsistencies in Risk Analyses for Ambient Air Pollutant Regulations," manuscript submitted to *Risk Analysis* (accepted for publication with revisions), 2014. Copy of manuscript available from author on request.

[22] See 78 *Fed. Reg*. 3086, January 15, 2013 for the $PM_{2.5}$ NAAQS rationale, and 76 *Fed. Reg*. 16436, March 27, 2008 for the ozone NAAQS rationale. For example, in 78 *Fed. Reg*. 3086 at 3139: "In reaching decisions on alternative standard levels to propose, the Administrator judged that it was most

Essentially all of the co-benefits estimates are due to projected changes in $PM_{2.5}$ and ozone in areas already attaining their health-based NAAQS. These are the very conditions under which the Administrator has stated he/she has no confidence that the health-pollutant relationships continue to exist; however, these co-benefits estimates are made by assuming 100% certainty in the continued existence of those relationships. This is outright logical inconsistency; if the Administrator has properly set those NAAQS, all of these co-benefits estimates are, at best, major overstatements.[23]

Further, USEPA's estimates of $PM_{2.5}$ benefits are predicated on a presumption that the statistical ("epidemiological") associations between chronic ambient $PM_{2.5}$ concentrations and mortality risk are causal in nature, and that all $PM_{2.5}$ constituents are equally potent. Even the presumption of causality is still subject to question, as has been

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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;" and at 3161: "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." Similarly, for the current ozone NAAQS, the District Court for District of Columbia recently upheld USEPA's rationale for the current ozone NAAQS in 76 *Fed. Reg*. 16436 that an ozone NAAQS did not need to be lower than 0.075 ppm despite clinical evidence of some health responses at lower concentrations "because it 'would only result in significant further public health protection if, in fact, there is a continuum of health risks in areas with 8-hour average O_3 concentrations that are well below the concentrations observed in the key controlled human exposure studies and if the reported associations observed in epidemiological studies are, in fact, causally related to O_3 at those lower levels.' *Id* [at 16,483]. Based on the uncertainties EPA had identified 'in interpreting the evidence from available controlled human exposure and epidemiological studies at very low levels,' USEPA was 'not prepared to make these assumptions.' *Id*." (U.S. Court of Appeals for the District of Columbia Circuit, State of Mississippi v. Environmental Protection Agency, No. 08-1200, decided July 23, 2013.)

[23] To the extent that any of the $PM_{2.5}$ and ozone co-benefits that might result from exposures to baseline levels that exceed the NAAQS, these will be eliminated by compliance programs to ensure attainment with that NAAQS; this tiny portion of the co-benefits (if any at all) should be attributed to the NAAQS rules, because they will be enforced without the CPP (even if current baseline regulations may not yet address them).

demonstrated by a $PM_{2.5}$ chronic risk study published in 2011.[24] Uncertainty about the causality presumption means there is a reasonable possibility that there will be no benefits at all from reductions of $PM_{2.5}$, whether above or below the NAAQS. USEPA's science assessment for the $PM_{2.5}$ NAAQS, which is the source of USEPA's assertion that the chronic mortality risk associations are causal, was written before the 2011 paper was published.

3.b. An Overly Simplistic Calculation Method Further Undercuts the Credibility of These Co-Benefits Estimates.

Besides the problems of logical inconsistency, implying overstatement, I note that USEPA has relied on a very simplistic method to make its co-benefits calculations in these RIAs. That is, USEPA uses rough average $/ton multipliers to approximate the co-benefit from each ton of reduction in a criteria pollutant precursor emission. Such simplistic $/ton estimates are unable to account for the level of criteria pollutant in the areas where the tons are reduced.[25] Indeed, USEPA does not even develop a baseline projection of the $PM_{2.5}$ and ozone levels against which the projected coincidental precursor emission reductions are assumed to occur. This highly simplistic method creates large uncertainties in an already dubious and uncertain risk analysis process.[26]

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[24] Sonja G, Dominici F, and Zeger S, "An Approach to the Estimation of Chronic Air Pollution Effects Using Spatio-Temporal Information," *Journal of the American Statistical Association* 106(494): 396-406, June 2011.

[25] CPP RIA, pp. 4-23 to 4-24.

[26] For a detailed exploration of the uncertainties in the $PM_{2.5}$ risk analyses that are used to generate the $/ton estimates used to generate the benefits estimates in these RIAs (as well as in EPA's other, less simplistic criteria pollutant benefits analyses), see Smith AE and Gans W, "Enhancing the Characterization of Epistemic Uncertainties in $PM_{2.5}$ Risk Analyses," *Risk Analysis* 35(3) (forthcoming March 2015; available in early release on-line at DOI: 10.1111/risa.12236).

Additionally, it is highly likely that each of the criteria pollutant precursor emissions will increase in some locations, while decreasing in others. This is the standard result of policies like the CPP and the ozone NAAQS that affects emissions from the electricity generating system, which is a network of many geographically dispersed electricity generating units. As some generating units are shut down to meet an emissions limit, others that do not shut down may increase their generation to make up for the lost load. This geographical distribution of emissions changes could greatly alter the RIA's total co-benefits estimates – they could potentially be much smaller if the increases in emissions occur in more populated areas than where the decreases occur. However, the RIAs do not explore this possibility. Instead, USEPA states that it has no ability to determine where the air quality changes will occur.[27] (Even this statement is not factually correct. The estimates of precursor tons reduced that are the basis for the co-benefits estimates come from IPM model outputs. The IPM model has unit-specific detail, which means that locational information on the emissions reductions also could be obtained from its outputs.[28])

3.c. Reasons Why Co-Benefits of Already-Regulated Pollutants Should Not Justify Regulations of Other Types of Pollutants.

Even if individuals other than the USEPA Administrator were to claim confidence in the continued existence of the health-pollutant relationships for $PM_{2.5}$ and ozone far

[27] CPP RIA, p. 4-40.

[28] Because all of the SO_2 emissions changes under the CPP will be from currently existing coal-fired power plants, the precise location of the SO_2 changes can easily be identified from IPM model results, including where the increases occur and where the decreases occur. The only minor complication for estimating the location of emissions increases would apply to NO_x, a small quantity of which will come from future new generating capacity as well. The IPM model does not identify the precise location of new capacity, but only where it would be within one of 64 electricity market regions of the U.S.

below the "adequate margin of safety" that a NAAQS must provide, to let regulations for totally different types of pollution issues be justified based on such co-benefits is a recipe for an unnecessarily complex web of air regulations that can only lead to economically-inefficient management of the public health.[29] For this reason, the co-benefits of already-regulated pollutants such as the criteria pollutants should not be included as benefits in regulations that are intended to manage altogether different risks, such as climate change. The merits of the proposed CPP should be determined on whether it produces an acceptable degree of climate change risk management. The merits of the proposed ozone NAAQS should be evaluated based on its ozone-related benefits.

[29] I provide a thorough case for this statement in Smith, AE. *An Evaluation of the $PM_{2.5}$ Health Benefits Estimates in Regulatory Impact Analyses for Recent Air Regulations*, prepared for the Utility Air Regulatory Group, December, 2011 (available: http://www.nera.com/publications/archive/2011/an-evaluation-of-the-pm25-health-benefits-estimates-in-regulato.html).

Committee on Oversight and Government Reform
Witness Disclosure Requirement – "Truth in Testimony"
Required by House Rule XI, Clause 2(g)(5)

Name: ANNE E. SMITH

1. Please list any federal grants or contracts (including subgrants or subcontracts) you have received since October 1, 2012. Include the source and amount of each grant or contract.

N/a

2. Please list any entity you are testifying on behalf of and briefly describe your relationship with these entities.

None

3. Please list any federal grants or contracts (including subgrants or subcontracts) received since October 1, 2012, by the entity(ies) you listed above. Include the source and amount of each grant or contract.

n/a

I certify that the above information is true and correct.

Signature: Anne E Smith

Date: February 25, 2015

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Dr. Anne Smith is an economist and decision analyst specializing in regulatory impact assessment, economic impact analysis, and benefits analysis. Dr. Smith has conducted major analyses on costs, benefits, and macroeconomic impacts of many important environmental issues, including air quality standards (e.g., $PM_{2.5}$, ozone, SO_2, NO_x, VOC, mercury, visibility), global climate change, and natural resource damage assessment (NRDA).

Since 1995, Dr. Smith has been continuously engaged as an expert in multiple different NAAQS proceedings. She has prepared innovative analyses, published research papers, and submitted technical comments on risk analysis, on the link between epidemiological studies and risk assessment, and on weight of evidence techniques for addressing uncertainties in the health science. Dr. Smith has been engaged as an expert witness in major litigation, including New Source Review (NSR) litigation against several utilities, and the air quality nuisance suit *State of North Carolina v. TVA*, in which she was a central testifying expert on benefit-cost analysis and valuation of mortality risks for air pollution (VSL vs. VSLY). She testified before the Colorado Public Service Commission in the significant proceedings regarding the utility system costs of alternatives for meeting the requirements of the Colorado Clean Air – Clean Jobs Act in 2010. She has testified numerous times before the US Congress. Dr. Smith also helps private corporations devise business strategies to address changing regulatory and business environments.

Before joining NERA, Dr. Smith headed the Climate & Sustainability Group at Charles River Associates. Prior to that, she headed the Environmental Policy Practice and served on the Board of Directors at Decision Focus Incorporated, and earlier served as an economist in the Office of Policy Planning and Evaluation at the USEPA.

Dr. Smith received her BA degree in Economics from Duke University in 1977, *summa cum laude*, and is a member of Phi Beta Kappa. She received her MA and PhD degrees in Economics from Stanford University, where her studies concentrated in industrial organization, decision sciences, and labor economics. Her PhD degree included a minor in Stanford's Engineering-Economic Systems Department (presently known as the Department of Management Sciences and Engineering).

Education

Stanford University
PhD, Economics (with minor in Engineering-Economic Systems), 1984

Stanford University
MA, Economics, 1981

Duke University
BA Economics, *summa cum laude*, 1977

Professional Experience

	NERA Economic Consulting
Current	Senior Vice President
	Charles River Associates
1998-2011	Vice President and leader of the Climate & Sustainability Group
	Decision Focus Incorporated (later DFI-Aeronomics)
1984-1998	Principal, Vice President, and leader of the Environmental Policy Practice; Member of DFI Board of Directors from 1997-1998.
	SRI International
1981-1982	Research Analyst
	Economic Analysis Division of the Office of Policy Planning and Evaluation of the U.S. Environmental Protection Agency
1977-1979	Economist

Some Examples of Relevant Projects

Gibson Dunn and Crutcher. Prepared an expert report on uncertainties in the application of BenMAP to the estimation of health impacts from $PM_{2.5}$ and on techniques for estimating willingness to pay for changes in mortality risk (VSL and VSLY evidence). Work as done for testimony in litigation related to a New Source Review lawsuit.

Electric Power Research Institute (EPRI)—Prepared review and weight-of-evidence summary of relative risks from all published epidemiological papers on chronic, long-term exposure mortality risk in the U.S. from ambient $PM_{2.5.}$ Reviewed how EPA's BenMAP model can be enhanced to serve better function as a risk analysis support tool. Results, with quantitative sensitivity analyses, reported in a paper now accepted for publication pending minor clarifying revisions.

Utility Air Regulatory Group—Performed a review of RIA benefits for all major EPA air-related rulemakings since 1997, and of EPA's regulatory impact analysis practices dating back to the 1980s that identified the emergence and expansion of EPA's reliance on $PM_{2.5}$ co-benefits in non-PM rulemakings, such as ozone. Prepared a report identifying areas for improvement in EPA's regulatory impact analyses and for improving the credibility of EPA's $PM_{2.5}$ health risk calculations.

American Petroleum Institute—Reviewed the RIA for the ozone NAAQS reconsideration that demonstrated the extent to which $PM_{2.5}$ co-benefits were driving the appearance that a tighter ozone NAAQS would have benefits greater than its costs. Also demonstrated the techniques by which EPA had adjusted its benefits calculations to increase ozone and $PM_{2.5}$ mortality benefits estimates since the time of the 2008 ozone RIA. Results of analysis were presented before OIRA just prior to the President's decision to return the reconsideration rule to the EPA.

Utility Air Regulatory Group—Reviewed and technically critiqued health effects literature for ambient $PM_{2.5}$, with focus on potential errors in the statistical inferences being used as the basis for risk and benefits estimates associated with the proposed PM NAAQS. Supported UARG with expert testimony on risks and risk management in public hearings and in front of the EPA Science Advisory Committee (CASAC). Also made technical presentations to senior EPA staff in a non-public setting on risk assessment methodology.

Utility Air Regulatory Group—Reviewed and technically critiqued EPA's risk analyses for ozone health effects associated with the 2014 ozone NAAQS rulemaking proceedings.

U.S. Environmental Protection Agency—Performed risk assessment of the health effects of ambient carbon monoxide, using physiological modeling and decision analysis, in support of the National Ambient Air Quality Standards-setting process.

Southern Appalachian Mountains Initiative—Led a team of expert economists and sociologists to advise SAMI's multi-stakeholder group on the state of the art in valuing changes in air quality-related values, and provided guidance for SAMI to plan a comprehensive socioeconomic impact assessment of alternative emissions management options for the southeastern region of the United States. Valuation techniques covered included ecosystem-related changes, visibility, recreation, health, materials, agro-forestry, lifestyle changes, and reliability. Also provided guidance on options and techniques for assessing economic impacts and distributional impacts.

Electric Power Research Institute—Prepared a framework integrating scientific and economic models and data to assess the cost-effectiveness of alternative mercury emissions control policies. Prepared paper demonstrating the framework for two alternative utility sector emissions policies, including emissions trading versus a MACT standard.

EPRI—Managed the design and implementation of a full-scale contingent valuation survey to estimate willingness to pay(WTP) for improvement in regional haze conditions in scenic vistas in the Eastern U.S. The survey explored the sensitivity of stated willingness to pay to different questionnaire formats. Results were found to be sensitive to alternative ways of reminding respondents of their personal budgets.

Stoel Rives—Provided expert testimony in legal proceedings on valuation of visibility benefits associated with a power plant's emissions in legal proceedings.

U.S. Department of Energy—Assessed risks to public and workers at and surrounding sites within DOE's nuclear weapons complex, for input into a DOE Report to Congress. Compared occupational safety and health impacts associated with alternative site remediation plans and review of OS&H programs.

US Department of Agriculture, Food Safety and Inspection Service. Worked closely with USDA staff to develop a risk ranking system to support a risk-based procedure for allocating Department resources for sampling for contaminants across the entire US food supply.

Electric Power Research Institute—Participated in a group of experts advancing the state of knowledge regarding appropriate ways of estimating societal value associated with ecosystem impacts of global climate change.

U.S. Environmental Protection Agency—Interdisciplinary review and critique of considerations for valuing ecosystem-related damages associated with climate change.

Nuclear Electric, plc, U.K.—Reviewed and critiqued existing and on-going efforts to value the environmental impacts of electricity fuel cycles. Prepared a research plan in this area for the client to address data gaps in evaluating environmental externalities of power.

Stanford University—Developed laboratory worker protocol for air toxics health risk management plan, including statistical design for ambient monitoring program.

Edison Electric Institute, EPRI, other industry organizations, and private corporations—Developed an integrated modeling framework for assessing costs and economic impacts of multi-pollutant emissions trading policies in the U.S. Framework incorporates a bottom-up, unit-level model of U.S. electricity sector with a top-down macroeconomic model of the U.S. economy at large. Led the implementation of data for assessing mercury emissions and controls for input to the model. Submitted formal comments on cost and impact analyses for rulemaking process leading to the Clean Air Mercury Rule (CAMR), and also on the Clean Air Interstate Rule (CAIR), both of which were finalized in 2005.

EPRI—Adapted a general equilibrium model to analyze alternative ways of achieving greenhouse gas targets, including emissions trading and hybrids of trading with technology standards. Added distortions of existing taxes to allow evaluation of efficiency-distributional trade-offs associated with alternative allowance allocation schemes.

Several clients—Since 2003, have analyzed the costs and economic impacts of most of the climate bills being proposed to cap U.S. greenhouse gas emissions. Analyses have included estimates of impacts to society at large, and to value of assets owned by individual companies. Also projected carbon allowance prices and demand for carbon credits/offsets.

Reason Public Policy Institute—Assessed health benefits, costs, and regional economic impacts of proposed national air quality standards for particulate matter and ozone. Used the multi-region REMI national model to assess economic impacts, including regional competitiveness effects, job loss/creation by sector, income impacts, and equity/distributional impacts. Uncertainty analysis on health damage functions and benefits valuation was also part of this assessment.

U.S. Environmental Protection Agency—Investigated practical implementation issues for using emissions trading to address global climate change goals, and compared emissions trading to other incentive mechanisms.

Grand Canyon Visibility Transport Commission—Led the development of the GCVTC's integrated assessment system, its associated database of emissions control measures, and projected baseline of visibility conditions in the southwestern region of the United States; also applied a 15-region REMI model of the western United States to assess the macroeconomic impacts of alternative visibility management strategies generated through use of the integrated assessment system.

Testimony in Regulatory and Judicial Proceedings

Court and Hearings Boards

Expert witness on economic incentives associated with opacity exceedances and alleged PM violations in Sierra Club v. Energy Future Holdings Corp. et al., Case No. 6:12-cv-108 (W.D.Tex.), U.S. District Court for the Western District of Texas, Waco Division. Written expert report filed June 13, 2013; declaration filed October 10, 2013; trial February 24-26, 2014.

Expert witness on economic incentives associated with opacity exceedances in Sierra Club v. Energy Future Holdings Corp. et al., Case No. 5:10-cv-156 (E.D.Tex.), U.S. District Court for the Eastern District of Texas, Texarkana Division. Written expert report filed May 21, 2013; rebuttal report filed June 20, 2013.

Expert witness on emissions-related damages estimates in United States of America v. Westvaco Corporation, Civil Action No. MJG 00-CV-2602, U.S. District Court for the District of Maryland. Written expert report filed February 21, 2012; deposition March 22, 2012; trial testimony January 17, 2013.

Expert witness on cost to utilities and associated state macroeconomic and state revenue impacts of sectoral carbon limits, State of New Mexico Environment Improvement Board, EIB 11-16(R), in the matter of Proposed Repeal of Regulation 20.2.100 NMAC – "Greenhouse Gas Reduction Program." Written expert report filed October 7, 2011; testimony and cross examination December 13, 2011.

Expert witness on cost to utilities and associated state macroeconomic and state revenue impacts of multi-state GHG cap-and-trade policy, State of New Mexico Environment Improvement Board, EIB 11-15(R), in the matter of Proposed Repeal of Regulation 20.2.350 NMAC –

"Greenhouse Gas Cap and Trade Provisions." Written expert report filed September 15, 2011; testimony and cross examination November 8, 2011.

Expert witness in international arbitration on business damages under the auspices of the Permanent Court of Arbitration, Case No. 2009-18. Expert report on markets for Kyoto Protocol compliance instruments filed June 29, 2010; expert report on business damages and discount rates filed December 8, 2010; cross examination on September 2, 2011.

Expert witness on present value of economic benefits to a company from delayed compliance in PennEnvironment and Sierra Club v. GenOn Northeast Management Company, Civil Action No. 07-00475, U.S. District Court for Western District of Pennsylvania. Expert report finalized May 6, 2011, but not filed due to settlement of case.

Expert witness on costs and risks, Public Utilities Commission of the State of Colorado, Docket No. 10M-245E, in the matter of the Commission consideration of Public Service Company of Colorado Plan in compliance with House Bill 10-1365, "Clean Air – Clean Jobs Act." Written answer testimony filed September 17, 2010; written cross-answer testimony filed October 8, 2010; written supplemental answer testimony filed November 9, 2010; written supplemental cross-answer testimony filed November 15, 2010. Cross-examinations on October 28, 2010 and November 19, 2010.

Expert witness on cost and economic impacts, State of New Mexico Environment Improvement Board, EIB 10-04(R), in the matter of Proposed Regulation 20.2.350 NMAC – "Greenhouse Gas Cap and Trade Provisions." Written expert report filed August 16, 2010; testimony and cross examination September 29, 2010.

Expert witness on cost-benefit analysis in State of North Carolina *ex. rel*. Roy Cooper, Attorney General (Plaintiff) v. Tennessee Valley Authority (Defendant), Case No. 1:06-CV-20, U.S. District Court for the Western District of North Carolina, Asheville Division. Written expert report filed February 27, 2007; deposition June 19, 2007; testified July 29, 2008.

Expert witness on utility company compliance costs and emissions impact of an alternative emissions control approach to the proposed mercury control policy for the State of Illinois, (in the matter of proposed new Ill. Adm. Code 225, *Illinois Pollution Control Board Hearings on the matter of Control of Emissions from Large Combustion Sources (Mercury)*). Written testimony filed July 28, 2006; cross examination at IPCB hearings on August 14-17, 2006 (Chicago IL).

Expert witness on estimating economic benefits of visibility improvements, *State of Washington Pollution Control Hearings Board*, expert report filed December 1998 (summary judgment in favor of client before testimony occurred).

Congressional Hearings

"Discussion Draft of 'Energy Consumers Relief Act of 2013' " *U.S. House of Representatives Committee on Energy and Commerce, Subcommittee on Energy and Power,* April 12, 2013.

"The American Energy Initiative – A Focus on EPA's New Proposal to Tighten National Standards for Fine Particulate Matter in the Ambient Air" *U.S. House of Representatives Committee on Energy and Commerce, Subcommittee on Energy and Power,* June 28, 2012.

"The American Energy Initiative – A Focus on What EPA's Utility MACT Rule Will Cost U.S. Consumers" *U.S. House of Representatives Committee on Energy and Commerce and Subcommittee on Energy and Power*, February 8, 2012.

"Innovative Practices to Create Jobs and Reduce Pollution" *U.S. Senate Committee on Environment and Public Works, Subcommittee on Green Jobs and the New Economy,* October 13, 2011.

"Quality Science for Quality Air" *U.S. House of Representatives Committee on Science, Space, and Technology, Subcommittee on Energy and the Environment*, October 4, 2011.

"Auctioning under Cap and Trade: Design, Participation and Distribution of Revenues" *U.S. Senate Committee on Finance*, May 7, 2009.

"Legislative Hearing Regarding the American Clean Energy and Security Act" *U.S. House of Representatives Committee on Energy and Commerce and Subcommittee on Energy and Environment*, April 24, 2009.

"Economic Impacts of Florida Executive Order 07-127" before Florida Energy Commission (November 19, 2007), and at hearings held by House and Senate Committees of the Florida State Legislature (both on December 12, 2007).

"America's Climate Security Act of 2007, S.2191" *Legislative Hearing of the Senate Committee on Environment and Public Works*, November 8, 2007.

"Counting the Change: Accounting for the Fiscal Impacts of Controlling Carbon Emissions" *House Committee on the Budget*, November 1, 2007.

"Lessons Learned from Existing Cap and Trade Programs" *House Committee on Energy and Commerce, Subcommittee on Energy and Air Quality,* March 29, 2007.

"Energy Market and Economic Impacts of a Proposal to Reduce Greenhouse Gas Intensity with a Cap and Trade System," *U.S. Senate Committee on Energy and Natural Resources,* January 24, 2007.

"Science and Risk Assessment behind the EPA's Proposed Revisions to the Particulate Matter Air Quality Standards," *U.S. Senate Environment and Public Works Committee,* July 19, 2006.

"Economic Impacts of Various Proposals to Reduce Domestic Greenhouse Gas Emissions," *U.S. Senate Committee on Energy and Natural Resources,* September 20, 2005.

"The Proposed Regional Haze Regulation and its Relationship to the Work of the Grand Canyon Visibility Transport Commission," *U.S. Senate Committee on Energy and Natural Resources, Subcommittee on Forests and Public Land Management*, October 1997.

"Scientific Foundations for U.S. EPA's Proposed New National Ambient Air Quality Standard for $PM_{2.5}$," *U.S. Senate Committee on Environment and Public Works, Subcommittee on Clean Air, Wetlands, Private Property, and Nuclear Safety,* February 1997.

Professional Activities

Director on Board of Directors, Society for Benefit-Cost Analysis, 2013-2014.

Panel of Experts on "Lessons Learned from the European Union's Emissions Trading Scheme and the Kyoto Protocol's Clean Development Mechanism," U.S. General Accountability Office, 2008. (Report: GAO-09-151, released November 2008).

Congressionally Mandated Committee on Management of Certain Radioactive Waste Streams Stored in Tanks at Three Department of Energy Sites, National Academy of Sciences, 2005-2006.

Committee on Risk-Based Approaches for Transuranic and High-Level Radioactive Waste, National Academy of Sciences, 2003–2005.

Committee on the Characterization of Remote-Handled Transuranic Waste for the Waste Isolation Pilot Plant, National Academy of Sciences, 2001–2002.

Programmatic Review of EPA's $PM_{2.5}$ Research Program, Subcommittee on Risk Management, Board of Scientific Counselors, U.S. Environmental Protection Agency, 1999.

Technical Expert to Committee on Idaho National Engineering and Environmental Laboratory High-Level Waste Alternative Treatments, Board on Radioactive Waste Management, National Academy of Sciences, 1998.

Committee to Evaluate Science, Engineering, and Health Basis of DOE's Environmental Management Program, Subcommittee on Priority Setting, Timing and Staging, National Academy of Sciences, 1995–2002.

Panel on DOE's Environmental Restoration Priority-setting System, National Academy of Sciences, 1992–1993.

Dialogue on Global Climate Change and National Energy Policy, Keystone Foundation, Keystone, CO, 1989–1990.

Working Group on Assessment of the Impact of Pollutants on the Marine Environment, Group of Experts on Scientific Aspects of Marine Pollution (GESAMP), United Nations, Bangkok, Thailand, 1984.

Working Group on Biological Aspects of Thermal Pollution of the Marine Environment, GESAMP, United Nations, Rome, Italy, 1983.

Ad-hoc Committee on Cost-Benefit Analysis, United Nations Economic Commission for Europe, Geneva, Switzerland, 1982.

Publications and Relevant Major Project Reports

"Inconsistencies in Risk Analyses for Ambient Air Pollutant Regulations," manuscript submission to *Risk Analysis* (June 2014).

"Enhancing the Characterization of Epistemic Uncertainties in $PM_{2.5}$ Risk Analyses" (with W. Gans), *Risk Analysis*, in press (2015).

"An Evaluation of the Robustness of the Visual Air Quality 'Preference Study' Method," *Journal of the Air and Waste Management Association*, Vol. 63(4), April, 2013, pp. 405-417.

An Evaluation of the $PM_{2.5}$ Health Benefits Estimates in Regulatory Impact Analyses for Recent Air Regulations. Report prepared for Utility Air Regulatory Group, December 2011.

"Climate Engineering – Alternative Perspective," Chapter 1.2 in *Smart Solutions to Climate Change – Comparing Costs and Benefits*, Bjorn Lomborg (ed.), Cambridge University Press, 2010.

"Evaluation of Health Effects of Ambient Ozone," (with Roger O. McClellan, Mark W. Frampton, and others), *Inhalation Toxicology*, Vol. 21(S2), September 2009, pp. 1-36.

"R&D Policy," (with W. David Montgomery and Lee Lane), Chapter 1.5 in *A Taxing Debate: Climate Policy Beyond Copenhagen*, Ian Marsh (ed.), Growth No. 61, CEDA – the Committee of Economic Development of Australia, August 2009

"Macroeconomic Analysis of American Clean Energy and Security Act of 2009," (with Robert Baron, Scott Bloomberg and others), *USAEE Dialogue*, Vol. 17(2), August 2009, pp. 12-16.

"A Top-Down Bottom-up Modeling Approach to Climate Change Policy Analysis," (with Sugandha D. Tuladhar, Mei Yuan, and others), *Energy Economics*, Vol. 31(S2), July 2009, pp. S223-S234.

"A Statement on the Appropriate Role for Research and Development in Climate Policy," (with Kenneth J. Arrow, Linda R. Cohen and others), *Economists' Voice*, February 2009.

"Price, Quantity, and Technology Strategies for Climate Change Policy," (with W. David Montgomery), Chapter 27 in *Human Induced Climate Change: An Interdisciplinary Assessment,* M. Schlesinger *et al.* (eds.), Cambridge University Press, 2007.

"Methods and Results from a New Survey of Values for Eastern Regional Haze Improvements," (with Michael A. Kemp, Timothy H. Savage, and Catherine L. Taylor), *Journal of the Air and Waste Management Association*, Vol. 55, November 2005, pp. 1767-1779.

"Implications of Trading Implementation Design for Equity-Efficiency Trade-offs in Carbon Permit Allocations" (with Martin Ross and David Montgomery), CRA Working Paper, December 2002.

"Not All Problems Have Been Solved in Emissions Trading." *Natural Gas*, John Wiley & Sons, Inc., December 2001, pp. 15–20.

"An Empirical Mechanistic Framework for Heat Related Illness," (with Nathan Chan, Mark Stacey, and others), *Climate Research*, Vol. 16, January 2001, pp. 133–143.

"Global Climate Change and the Precautionary Principle," (with W. David Montgomery) , *Human and Ecological Risk Assessment*, Vol. 6, No. 3, 2000, pp. 399–412.

"Analysis of the Reduction of Carbon Emissions through Tradable Permits or Technology Standards in a CGE Framework," (with E. Balistreri, P. Bernstein, and others), *AERE/Harvard Workshop on Market-Based Instruments for Environmental Protection*, Cambridge, MA, July 18–20, 1999.

"An Integrated Assessment Framework for Climate Change and Infectious Diseases," (with N. Chan, K. Ebi, and others), *Environmental Health Perspectives*, Vol. 107, No. 5, May 1999.

"Preserving Flexibility in the Kyoto Protocol." *Journal of the Forum for Environmental Law, Science, Engineering, and Finance*, August 1998.

"Making Appropriate Comparisons of Estimated and Actual Costs of SO_2 Emissions Reductions under Title IV," Paper 98-TP49.01, *Air and Waste Management Association Conference,* San Diego, CA (June 14–18, 1998).

"The Costs of Reducing Utility SO_2 Emissions—Not As Low As You Might Think," (with Jeremy Platt and Denny Ellerman), Massachusetts Institute of Technology, Center for Energy and Environmental Policy Research, WP-98010, August 1998; a shorter version of the paper was published in *Public Utilities Fortnightly*, May 15, 1998.

"Statistical Shell Game," *EEI's Electric Perspectives*, May-June 1997, pp. 38–52.

"The Real Particulate Matter Culprit: EPA's Flawed Assumptions," Commentary, *Inside EPA's Risk Policy Report*, Vol. 3, No. 2, February 21, 1997, pp. 35–38.

"The GCVTC Integrated Assessment: Putting All the Science Together." Paper 96-TP46.04, *Air and Waste Management Association Conference*, Nashville, TN, June 23–28, 1996.

"Energy Modeling with Environmental Constraints." *Nuclear Energy in the 21st Century—An Environmental Bonus?* Proceedings of the International Conference of the British Nuclear Energy Society, Bath, U.K., April 14–15, 1994.

"Integrated Environmental/Energy Policy Analysis for the U.K," (with Stephen M. Haas), *Global Climate Change: Science, Policy, and Mitigation Strategies*, C.Mathai and G. Stensland, eds., Air and Waste Management Association, 1994.

"A Multi-attribute Approach to Choosing Adaptation Strategies," (with H. Quan Chu), *Global Climate Change: Science, Policy, and Mitigation Strategies*, C.V. Mathai and G. Stensland (eds.), Air and Waste Management Association, 1994.

"The Effect of Daytime Running Lights on Crashes between Two Vehicles in Saskatchewan: A Study of a Government Fleet," (with G. Sparks, R. Neudorf, and others), *Accident Analysis and Prevention*, Vol. 25, No. 5, 1993, pp. 619–625.

"Issues in Implementing Tradable Allowances for Greenhouse Gas Emissions." Paper 91–169.4, *Proceedings of the Air & Waste Management Association Conference*, Vancouver, BC, June 1991.

"Environmental Policy Assessment in the 1990s," (with J. D. Scheraga), *Forum for Social Economics*, Autumn 1990.

"A Probabilistic Model for Assessing Damages of Acid Deposition to Painted Surfaces." *Acid Rain: Scientific and Technical Advances*, Selper Ltd., London, 1987.

"TANKS: A Software Tool for Managing the Risks of Underground Storage Tanks." *Managing Environmental Risks*, Air Pollution Control Association, Washington, D.C., 1987.

"The Costs and Benefits of Sulphur Oxide Control," (with R. Barnes and G. Parkinson), *Journal of the Air Pollution Control Association*, 1983.

Development of Decision Analysis Methodology for Health Risk Assessment – An Illustrative Application to Alternative Air Quality Standards for Carbon Monoxide, (with P. McNamee and M. W. Merkhofer). SRI International Report prepared for U.S. Environmental Protection Agency under Contract 68-02-3575, 1983.