Any Which Way the Wind Blows: Estimating Air Emissions Externality Costs

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Introduction

Air emission reductions are often a major driver of utility investments in energy efficiency programs. Yet there have been few, if any, recent documented attempts to estimate the dollar value of emission reduction benefits associated with specific utility portfolios at the state level.

In this paper, we discuss and expand on methodological issues and findings from a recent analysis of air emissions damage cost reductions resulting from the EmPOWER Maryland utility energy efficiency programs.[1] The Maryland Public Service Commission (PSC) oversees the programs, with support from PSC staff. The EmPOWER Policy Group (EPG) is a stakeholder group chaired by the Maryland Energy Administration (MEA) and PSC staff, which provides vetted guidance to the Commission.[2] Most of this analysis was done to support EPG deliberations.[3]

Our analysis adapts national level damage cost estimates to be specific to electric generation associated with Maryland electric consumption. Our focus is on uncompensated damages (externality costs) resulting from electricity consumption and the corresponding emissions associated with power generation -- specifically, carbon dioxide (CO_2), sulfur dioxide (SO_2) and nitrogen oxide (NO_x) emissions.

Adaptation of national study results to Maryland-specific generation involved many steps, including: adjustment of national criteria emissions damages estimates to reflect past and future changes in national and state emissions policies, characteristics of fuels and other factors; adjustment to reflect existing taxes or fees on emissions in Maryland; and application of various assumptions of the impact of emissions specifically on Maryland residents.

In crafting this analysis, we relied on the most recent and most thoroughly peer reviewed national-level studies we were able to identify. We have tried to be transparent in our adaptation of those national damages estimates to Maryland. Where we had questions about the methods or reporting of results in the national studies or other sources, we made adjustments to our estimates to address those concerns or flagged them clearly. We presented our methods, assumptions and findings to the EPG and other Maryland stakeholders on multiple occasions.

[1] EmPOWER Maryland energy efficiency programs comprise a wide range of programs operated by the five largest utilities with spending totaling $284 million in 2014, according to personal correspondence from PSC staff, May 6, 2015.
[2] EPG participants include the PSC staff, MEA, the EmPOWER utilities, the Office of Peoples Counsel, and various public interest and trade organizations.
[3] Much of the analysis in this paper was funded by the five EmPOWER Maryland utilities with support and oversight from Maryland PSC staff. The opinions expressed in this paper are the authors and may or may not reflect the positions of PSC staff and the EmPOWER utilities. We received comments from many people at various stages of this analysis, including: Crissy Godfrey and Dan Hurley (PSC Staff), Kevin Lucas (Maryland Energy Administration), Jack Mayernik (National Renewable Energy Lab), Mike Rufo and Mike Messenger (Itron), David Hill (Vermont Energy Efficiency Investment Corporation), and Lisa Skumatz (Skumatz Economic Research Associates). The analysis also benefited greatly from meetings and correspondence with the EmPOWER Policy Group.

Uncertainty

PSC staff and some stakeholders have responded cautiously to recommendations by Itron, MEA and other stakeholders to expand the list of non-energy benefits that are included in the EmPOWER cost effectiveness analyses. At least three concerns about including additional benefits were expressed in EPG discussions: 1) the addition of highly uncertain benefits could undermine credibility with some stakeholders and ratepayers; 2) if the benefits are not real, they could lead to overinvestment in programs; and 3) ratepayers can see impact of the EmPOWER programs in the form of line item surcharge on their bills, but they cannot see, or perhaps even understand, many of the largely intangible non-energy benefits.

There is some merit to these concerns; many non-energy impacts cannot be measured directly and are difficult to estimate in a reliable manner. Two of the more confounding and sensitive methodological questions we encountered pertain to the temporal and locational impacts of the total damage reductions. To what extent do emissions reductions from programs result in avoided damages specifically to Maryland residents as opposed to others in the region, nation or even world? And to what extent should damages to future generations be counted and borne by current ratepayers? These are difficult questions even for SO_2 and NO_x emissions, which have relatively short atmospheric residence times and whose regional dispersion can be reasonably estimated. These questions are all the more challenging with respect to CO_2 emissions, which can remain in the atmosphere for decades or even centuries and for which damages are distributed globally, irrespective of where the emissions are created.

Simply put, there is no single right or wrong answer to these temporal or locational issues. The relevant assumptions depend on highly subjective weightings of the importance of other generations and regions. But, uncertainty seems a weak argument for excluding air emissions benefits from program benefit cost analyses. Excluding them entirely only guarantees that the benefits of the program are systematically being understated.

The focus of EmPOWER evaluations and cost effectiveness analyses has traditionally been on expected value, even if certain parameters or methods lead to highly uncertain results. This analysis presumes that the decision whether to include uncertain benefits, such as air emissions, should be based on the following four questions:

1) Has a clear and conceptual case been made for the existence of the non-energy impact?
2) Is the proposed non-energy impact valuation as likely to be too low as too high?
3) Is the proposed non-energy impact valuation the best available in terms of quality analysis and cost trade-off?
4) Are the analysts, sources and assumptions generally credible?

We considered these questions every step of the way while developing estimates of air emissions benefits that could be included in the ex-ante and/or ex-post cost effectiveness analyses for the EmPOWER Maryland energy efficiency programs.

Air Emissions Scope and Background

The scope of the EmPOWER air emissions analysis was limited to nitrogen oxide (NO_x), sulfur dioxide (SO_2) and carbon dioxide (CO_2). Despite numerous federal and state policy actions over several decades to reduce these emissions and mitigate their impacts, these three air emissions still comprise a large share of the uncompensated environmental costs associated with electricity consumption. Obviously, many other types of uncompensated damages are not discussed here.[4]

SO_2 and NO_x

NO_x is emitted from the combustion of gas, oil and coal by electric utilities, industrial boilers and motor vehicles. NO_x, along with volatile organic compounds, is a major precursor for ground level ozone, which can cause and/or aggravate acute and chronic respiratory problems, damage crops, and cause premature aging of paint and rubber.[5]

SO_2 is emitted from fuel burning sources including electric utilities, industrial boilers, and vehicles. SO_2 emissions are a major contributor to fine particle pollution, thus increasing the severity of respiratory diseases. SO_2 emissions also react with water to cause acid rain, contributing to the acidification of forests and waterways, damaging vegetation and depleting fish populations.[6]

NO_x and SO_2 emissions from electric generators and other large sources are regulated as "criteria pollutants" under the federal Clean Air Act administered and enforced by the U.S. Environmental Protection Agency (EPA). In Maryland, the Healthy Air Act prescribed emissions regulations that became effective in 2007 and were intended to attain compliance with federal regulations. According to the Maryland Department of the Environment, the Healthy Air Act has reduced NO_x and SO_2 emissions in Maryland by about 70 percent and 80 percent, respectively, relative to 2002.[7]

CO_2

CO_2 emitted from the combustion of fossil fuels is the primary anthropogenic cause of global warming. Carbon dioxide can remain in the atmosphere for anywhere from 5 to 200 years and represents "a quasi-irreversible commitment to sustained radiative forcing over decades, centuries, or millennia, before natural processes can remove the quantities emitted."[8]

Historically, federal and state regulation of CO_2 has been minimal. Maryland, however, has been a member of the Regional Greenhouse Gas Initiative (RGGI) since its inception in 2009. RGGI is a CO_2 cap and trade program in which member states commit carbon dioxide emission caps for electric power generators. RGGI distributes allowances primarily through auctions – 94 percent of RGGI allowances through 2013 had been distributed via auctions. The RGGI caps to date have generally been non-binding – i.e., allowances have exceeded actual emissions.[9] This could change as a new model rule announced in

[4] Other uncompensated environmental damages include, for example: mercury, particulates, methane from natural gas extraction and distribution; sulfur hexafluoride from electric transformers; coal and uranium extraction and transportation; and disposal of nuclear waste and coal ash.

[5] http://www.mde.state.md.us/programs/Air/AirandRadiationInformation/Pages/air/air_information/nitrogendioxide.aspx

[6] http://www.mde.maryland.gov/programs/pressroom/documents/sulphur.pdf

[7] http://www.mde.maryland.gov/programs/Air/Documents/GoodNewsReport2012/GoodNews2012finalinteractive.pdf. Thanks to similar regulations in other jurisdictions, comparable NO_x and SO_2 reductions have been observed throughout the country. A 2011 report of the National Science and Technology Council (NTSC) touts the significant human health benefits that have resulted from SO_2 and NO_x emissions reductions and reports that some previously damaged areas (acidification) are showing signs of recovery. See National Science and Technology Council, National Acid Precipitation Assessment Program Report to Congress: An Integrated Assessment, 2011, p. 87.

[8] Intergovernmental Panel on Climate Change, *The Physical Science Basis*, Table1, http://www.ipcc.ch/ipccreports/tar/wg1/016.htm based on IPCC AR4 WG1 (2007), Solomon, S.; Qin, D.; Manning, M.; Chen, Z.; Marquis, M.; Avery, K.B.; Tignor, M.; and Miller, H.L., ed., *Climate Change 2007: The Physical Science Basis* Chapter 3 and Chapter 4, Table 4.1

[9] RGGI, Inc., *RGGI 2012 Program Review: Summary of Recommendations to Accompany Model Rule Amendments*, p.1,

2012 will lower the RGGI caps by 2.5 percent annually through 2020.[10]

More powerful federal regulations on carbon emissions also could be forthcoming. On June 2, 2014, EPA issued a proposed rule (the Clean Power Plan) that would reduce power sector CO_2 emissions from 2005 levels by 30 percent by 2030. The proposed rule, slated to take effect in the summer of 2020, would allow a portion of the required reductions in power plant emissions intensity to be offset by energy efficiency improvements and investments in renewable energy.[11]

Analysis Methods and Data

This section describes in detail the overall approach, methods and assumptions that we used to estimate total and per kWh air emissions benefits for the EmPOWER energy efficiency programs. The following equation summarizes our estimation of EmPOWER air emissions benefits:

Total Air Emissions Benefits ($) = [Unit Damage Costs ($/pound)] x Emissions Intensity (pounds/MWh) x MWh Savings

We calculated benefits separately for NO_x, SO_2, and CO_2. Benefits per kWh saved from the programs were then calculated. The present value of benefits is calculated over the 12-year weighted average life of the EmPOWER program measures. We describe the methods and data used to develop parameters for each of these equation parameters below.

NO_x and SO_2

Our NO_x and SO_2 damage cost inputs were based on National Academy of Sciences (NAS) *Hidden Costs Study* from 2010.[12] The study investigated a wide range of externality costs associated with electricity and fuel use.[13]

The vast majority of air emissions damages were related to health impacts, and mortality was by far the largest category of health impacts.[14] Human mortality was valued using the *Hidden Costs Study's* value of statistical life (VSL), equal to $5.9 million, which is the value attributed to various chronic and

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http://www.rggi.org/docs/ProgramReview/_FinalProgramReviewMaterials/Recommendations_Summary.pdf, viewed June 2, 2014. The RGGI allowance auctions generated proceeds because of an auction floor price, however. RGGI, Inc. claims reductions from investments of 2009-12 auction proceeds will reduce greenhouse gas emissions by 8 million short tons over the lives of the various measures.

[10] RGGI, *Annual Report on the Market for RGGI CO_2 Allowances: 2013*, prepared by Potomac Economics, May 2014, p.5, http://www.rggi.org/docs/Market/MM_2013_Annual_Report.pdf.

[11] http://www2.epa.gov/carbon-pollution-standards/fact-sheet-clean-power-plan-carbon-pollution-standards-key-dates

[12] National Research Council Study, *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use, Committee on Health, Environmental, and Other External Costs and Benefits of Energy Production and Consumption*, 2010.

[13] The analysis of electricity generation was based on plant emissions data from 406 coal-fired and 498 gas-fired power plants in 2005. Monetized damages per ton of EPA criteria pollutant were estimated using the Air Pollution Emissions Experiments and Policy (APEEP) model, which calculates the monetized damages resulting from exposure by populations to various pollutants. For a detailed description of the APEEP model and its relative strengths and weaknesses, see *Hidden Costs of Energy*, pp. 64-125 and pp. 423-31.

[14] *Hidden Costs of Energy*, p. 84-85. Other health impacts included chronic bronchitis, asthma, and emergency hospital admissions for respiratory and cardiovascular disease. While impacts on visibility, crop and timber yields, buildings and infrastructure, and recreation were also considered, they were small in comparison to health impacts. Some ecosystem damages were not estimated, including impacts of acid rain from SO_2 and NO_x on forests and fish populations and the eutrophication of water ecosystems from nitrogen deposition.

acute health events.[15] While a variety of non-market valuation studies were used for other health impacts, the dominance of human mortality in the damages estimates makes the results sensitive to the mortality valuation. If a human life was valued at $3.9 million rather than $5.9 million, for example, the weighted average damages from coal would be about one-third lower.[16] For reference, the EPA Clean Power Plan assumes a VSL of $8.1 million.[17]

Damages associated with coal and gas plants throughout the United States varied widely in the *Hidden Costs Study*.[18] For our analysis, we first calculated average *Hidden Cost Study* SO_2 and NO_X damages per kWh for coal and gas generation plants weighted by electric generation. Since the *Hidden Cost Study* estimates were based on 2005 vintage coal and gas generation, we adjusted damage cost to reflect significant reductions in emissions intensity between 2005 and 2013 due to investments in pollution controls.[19] We then converted the *Hidden Cost Study* values from 2007 dollars to 2014 dollars.

Finally, we adjusted total damages per kWh to reflect projected changes through 2025 in the average fuel mix.[20]

Table 1 summarizes our adjustment to the *Hidden Costs* criteria emissions damages per kWh values for coal and gas. As shown, our adjusted damages for total generation was 0.07 cents per kWh for NO_x and 0.48 cents per kWh for SO_2.

Table 1: Summary of Criteria Emissions Unit Damage Calculations

Fuel Type	Hidden Costs Simple Average cents/kWh Damages ($2007)		Ratio of Total Weighted Average to Average $/kWh	Ratio 2013 to 2005 Emissions Intensity		Adjusted cents per kWh Damages ($2007)		Adjusted cents per kWh Damages ($2014)	
	NOx	**SO2**	**Combined**	**NOx**	**SO2**	**NOx**	**SO2**	**NOx**	**SO2**
Coal	0.34	3.8	73%	54%	35%	0.13	0.97	0.15	1.12
Gas	0.23	0.02	37%	23%	5%	0.02	0.00	0.02	0.00

[15] VSL is characterized in the Hidden Costs Study, p.52 as "the rate at which people are willing to trade increased risk of death for other goods and services. Mortality estimates do not include deaths of workers in coal or gas production or distribution, since these valuations are assumed to be included in the wages charged by labor and passed through to electricity prices."

[16] *Hidden Costs of Energy*, pp. 93-95.

[17] Fann, N., Baker, K., and Fulcher, C., "Characterizing the PM2.5-related health benefits of emission reductions for 17 industrial, area and mobile emission sectors across the U.S.," *Environment International* 49 (2012) p. 141-151.

[18] For coal plants the SO_2 per kWh damages of plants in the top 95th percentile (11.9 cents per kWh) were 50-times the damages of the bottom 5th percentile (0.24 cents per kWh); the average SO_2 damages for coal plans was 3.8 cents per kWh. See *Hidden Costs of Energy*, Table 2-9, p. 92. For gas plants, NOx emissions in the top 95th percentile (1 cent per kWh) were 714-times the damages of the bottom 5th percentile (0.0014 cents per kWh); the average NO_x damages for gas plants was 0.23 cents per kWh. See *Hidden Costs of Energy*, Table 2-15, p118.

[19] PJM, *Environmental Information Services Electricity Generation Attribute Tracking System (EGAT)*, https://gats.pjm-eis.com/gats2/PublicReports/PJMSystemMix.

[20] We did not adjust for future reductions in emissions intensity resulting from additional emissions controls. As new requirements are established for Maryland and upwind states in coming years, SO_2 emissions benefits will need to be adjusted. Projected PJM fuel shares from EPA's forecast in its analysis of the Clean Power Plan were compiled and sent via personal correspondence by Kevin Lucas, Maryland Energy Administration, April 30, 2015. Estimation of marginal emissions reductions was beyond the scope of this analysis, but should be considered in the future. The PJM average generation profile is far less coal and fossil intensive than the marginal generation profile. All other things equal, using the average PJM average generation profile likely results in an underestimate of emissions benefits. PJM, *State of the Market Report: 2013*, Table 3-6 and PJM Generation Attribute System, https://gats.pjm-eis.com/gats2/PublicReports/PJMSystemMix.

Total	0.07	0.48

CO_2

For our CO_2 damage costs inputs, we used the latest social cost of carbon estimates developed by the Interagency Working Group on Social Cost of Carbon (IWGSCC) in 2013.[21] These values are used by federal government agencies for regulatory analyses. The IWGSCC values include social costs of carbon incurred globally.

The IWGSCC reports three estimates for the social cost of carbon, based on 2.5, 3.0 and 5.0 percent discount rates. For each discount rate, the IWGSCC reports the average result from three different integrated assessment models and five different socioeconomic scenarios. A fourth reported carbon cost estimate is the 95th percentile of the model estimates using a 3-percent discount rate and underscores the amount of variability within each discount rate scenario.[22] The IWGSCC's refers to the average 3-percent discount rate scenario as its "central value," but at the same time emphasizes "the importance and value of including all four [carbon cost] scenarios."[23]

The IWGSCC presents the four carbon cost estimates in 1-year intervals starting in 2014.[24] The four IWGSCC carbon cost estimates, adjusted to 2014 dollars, are reported in Table 2 for select years. The weighted average estimated useful life of the EmPOWER program measures is 12 years so we based our analysis on the average CO_2 values for 2014 through 2025.[25]

Table 2: IWGSCC Social Cost of Carbon Dioxide ($2014 per Metric Ton) [26]

	Discount Rate			
Discount Rate Year	**5%**	**3%**	**2.5%**	**3% -- 95th percentile**
2014	14	46	70	131
2025	17	59	87	178
2050	33	88	121	273
2014-25 Average	**15**	**53**	**79**	**156**

[21] Interagency Working Group on Social Cost of Carbon, United States Government, *Technical Support Document – Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis – Under Executive Order 12866*, May 2013. The social cost of carbon estimate is "intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change."

[22] The IWGSCC used three different integrated assessment models, three discount rates, and five socioeconomic emissions scenarios to estimate 45 separate distributions for the global social cost of carbon. Each modeled result is a distribution, rather than a point value, because the integrated assessment models use "damage functions" to capture the large uncertainty in global damages resulting from a one degree Celsius temperature rise. The 45 distributions were combined giving equal weight to each model and socioeconomic scenario, resulting in a distribution for each of the three discount rates. The damages in the 95th percentile of the three-percent discount rate scenario are nearly three times higher than the mean, highlighting the variability in the damage functions.

[23] Interagency Working Group on Social Cost of Carbon, United States Government, Technical Support Document – Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis – Under Executive Order 12866, May 2013, p.12.

[24] Interagency Working Group on Social Cost of Carbon, *Technical Support Document – Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis – Under Executive Order 12866*, May 2013, p.18.

[25] The IWGSCC does not provide a 2013 value, so we used the average of values in 2014 through 2025.

[26] IWGSCC values adjusted to 2014 dollars from 2007 dollars using Producer Price Index.

We subtracted RGGI allowance purchases ($3.26 per metric ton), which are already included in utility avoided generation cost forecasts, from the average 2014-25 per unit damages.[27] If we did not subtract allowance purchases from our air emissions benefits, they would be double counted.[28]

Table 3 compares the IWGSCC average 2014-25 estimates of global carbon cost per metric ton in 2014 dollars to our adjusted estimates.

Table 3: Adjustments to IGWCC Global Cost of CO_2 ($2014 per metric ton)

IGWCC CO_2 Average 2014-25 Damage Cost per Metric Ton ($)			RGGI Allowance Price per Metric Ton ($)	Adjusted (minus RGGI allowance price) CO_2 Damage Cost per Metric Ton ($)		
5%	3%	2.5%		5%	3%	2.5%
15.46	52.55	78.93	3.26	12.19	49.29	75.67

We calculated PJM average CO_2 emissions per kWh for coal, gas and overall generation from 2014 through 2025.[29] These values were multiplied by the average CO_2 damage costs per ton for each IWGSCC discount rate scenario for coal, gas and overall generation.[30] The resulting values are damage costs per kWh reported in Table 4.

Table 4 Estimated CO_2 Damage Cost - Cents per kWh ($2014)

Fuel Type	5%	3%	2.5%
Coal	1.2	4.7	7.2
Gas	0.5	2.1	3.2
Total	0.6	2.4	3.6

MWh Savings

We calculated the annual emissions reduction resulting from the 2013 EmPOWER Maryland energy efficiency programs using verified annual net savings (accounting for free riders and spillover), which totaled 562 GWh.[31] The total lifetime emissions reduction is equal to the annual net emissions reduction multiplied by the weighted average estimated useful life for EmPOWER program measures in 2013, which was 12 years.

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[27] Based on data compiled and/or calculated from the following RGGI website reports: http://www.rggi.org/market/co2_auctions/results/auctions-1-22; http://www.rggi.org/docs/Auctions/23/MD_Proceeds_By_Auction.pdf; and http://www.rggi.org/market/co2_auctions/results. Price adjustments were made using USInflationCalculator.com.

[28] To the extent that utilities satisfy any new EPA requirements through purchase of carbon allowances that are not included in the utilities' avoided cost projections, we would need to subtract the tax or allowance costs from our uncompensated air emissions benefits estimates, similar to RGGI allowance prices.

[29] From 2013 through 2024, the share of coal is expected to go from 44 percent of total generation down to 41 percent, while gas is projected to increase from 16 percent to 19 percent. Projected PJM fuel shares were compiled and sent via personal correspondence by Kevin Lucas, Maryland Energy Administration, April 30, 2015. Since the IWGSCC CO_2 damage values are provided on a per-ton of CO_2 basis, we did not need to adjust IWGSCC damages to reflect past changes in intensity or fuel mix.

[30] PJM, *Environmental Information Services Electricity Generation Attribute Tracking System* (EGAT), https://gats.pjm-eis.com/gats2/PublicReports/PJMSystemMix.

[31] Itron, *Verification of Reported Program Impacts from 2013 EmPOWER Maryland Energy Efficiency Programs*, August 1, 2014, p. 1-5. Evaluation of 2014 program impacts had not been completed when this analysis was conducted.

Discount Rate

Our analysis of EmPOWER Maryland air emissions benefits considered a range of discount rates corresponding to the varied opinions of the EPG participants. The rate currently used for ex ante and ex post cost effectiveness analyses is the average of the five EmPOWER utilities' real weighted average cost of capital (WACC), which is 5.4 percent. Two additional discount rates were included by the EPG as scenarios in a potential study that is currently underway: a real risk-adjusted WACC of 4.9 percent and a real societal rate of 2.9 percent.[32]

The choice of discount rate has by far the greatest impact on the value of CO_2 damages, since some CO_2 damages may occur over a century or more in the future. Since CO_2 benefits are most heavily impacted by discount rates and we did not have access to the models used for the IWGSCC analysis, we based our analysis on the two IWGSCC discount rate scenarios that correspond most closely to the discount rate scenarios requested by the EPG -- i.e., the 5 percent and 3 percent real discount rates.[33] The 5-percent real discount rate is just slightly more than the average of EPG's risk-adjusted and unadjusted weighted average costs of capital for the EmPOWER utilities – 4.4 percent and 5.4 percent, respectively. The 3 percent real discount rate approximates the EPG's 2.9 percent societal discount rate.

Allocation of Air Emissions Benefits to Maryland

The air emissions damages estimates above assume that all of the damages associated with electricity consumption in Maryland are incurred by Marylanders. Of course, this is not the case.

A locational analysis of criteria emissions benefits would require development of concentration response functions and analysis of air emissions transport into and out of the region in question. While challenging and beyond the scope of this study, such an analysis is at least conceptually grounded in existing models, including models used for the *Hidden Costs Study*. Though it would require significant investment, developing reasonably accurate estimates of the benefits to a given region from reductions in criteria emissions is feasible.

Whether a locational analysis would be worthwhile for criteria emissions depends in part on the extent to which CO_2 emissions damages reductions associated with future generations and people outside Maryland are counted as benefits to Maryland. If benefits to future generations are valued highly – i.e., low discount rates are used – and global benefits are included, the carbon dioxide reduction benefits far outweigh the criteria emissions benefits. In this case, efforts to estimate Maryland-specific criteria emission benefits are probably not worthwhile. If, however, modest to high discount rates are used and/or CO_2 benefits are confined to Maryland residents, the criteria emissions – more specifically, the SO_2 benefits – are a far more prominent share of the benefits. In this latter case, a more rigorous analysis of the location of the criteria air emissions benefits could be justified.

Allocating Maryland-specific benefits from EmPOWER CO_2 reductions is challenging even at a conceptual level. CO_2 emissions originating in Maryland (or the PJM) flow into the global stock of atmospheric CO_2. Maryland residents will be affected as much by a ton of CO_2 emitted in Asia as in

[32] Some efficiency proponents (including several EPG participants) argue that the risk associated with energy efficiency programs is less than the risk associate with supply-side alternatives. We have not attempted to support or refute this assertion here.

[33] Using different discount rates would require rerunning the FUND model that was used for the Interagency Task Force economic calculations, which was beyond the scope of this analysis. Pursuing further refinement and alignment of the potential study scenarios with the social cost of carbon values could be useful in the future. To date there has not been sufficient policy direction for how the air emissions values should be used in various EmPOWER Maryland cost effectiveness analyses to know the specific details of that analysis and whether the additional analytical cost would be warranted.

Maryland. Most studies of CO_2 benefits do not attempt to allocate CO_2 damages to sub-global jurisdictions. The few benefits studies that even acknowledge the issue, including the IWGSCC study, discuss it only cursorily and then count the entirety of the per-ton global damages.

Counting the global societal cost of CO_2 overstates the benefits to Maryland. It also diverges sharply from most other types of regulatory benefit cost analyses, which only count benefits to domestic residents. Gayer and Viscusi (2014) argue that by counting the global social cost of carbon in the EPA Clean Power Plan and other regulatory analyses affecting CO_2 emissions, the Obama Administration has departed from decades of precedent.[34] They point out that if global benefits were counted as part of immigration and poverty policy analyses, national borders would be open to all and no distinction would be made between poverty assistance to U.S or non-U.S. citizens.[35]

The IWGSCC explains its decision to count the global benefits as follows:[36] "The climate change problem is highly unusual in at least two respects. First, it involves a global externality: emissions of most greenhouse gases contribute to damages around the world even when they are emitted in the United States… Second, climate change presents a problem that the United States alone cannot solve… Other countries would also need to take action to reduce emissions if significant changes in the global climate are to be avoided. Emphasizing the need for a global solution to a global problem, the United States has been actively involved in seeking international agreements to reduce emissions… When these considerations are taken as a whole, the interagency group concluded that a global measure of the benefits from reducing U.S. emissions is preferable."

The public goods nature of global climate change mitigation creates some interesting quandaries. For one, the sum of benefits to any sub-global jurisdiction – including Maryland - from a one-ton reduction in CO_2 is much smaller than the total global benefits. Taking an extreme example, say the global damage cost per ton of emitted carbon is $40 and that climate change harms every person in the world equally. If the United Nations (for example), representing the world's population, took collective action to reduce CO_2 emissions by 7 billion tons, the value to the world's population would then be $280 billion ($40 x 7 billion).

In stark contrast, a one ton reduction of CO_2 would be worth only 0.6 millionths of a cent per ton ($40/7 billion) to a self-interested individual who is uninterested in benefits that accrue to others. If every person in the world was self-interested and reduced his carbon footprint by one ton, the individually perceived total global benefit, from the perspective of all of those self-interested individuals, would be just $40 (7 billion x 0.6 millionths of a cent). By extension, since Maryland's population is approximately 0.086 percent of the global population (6 million out of 7 billion), then the benefit to Maryland resident of a CO_2 reduction occurring anywhere in the world could arguably be as low as $0.034 per ton ($40 x 0.086 percent).[37]

Gayer and Viscusi acknowledge that counting some additional share of the global carbon benefits could be justified if the citizens are ascribed either an altruistic or reciprocity benefit. Altruism

[34] Ted Gayer and W. Kip Viscusi, *Determining the Proper Scope of Climate Change Benefits,* June 3, 2014, pp. 5-6.

[35] Ted Gayer and W. Kip Viscusi, *Determining the Proper Scope of Climate Change Benefits*, June 3, 2014, pp. 21.

[36] Interagency Working Group on Social Cost of Carbon, United States Government, Technical Support Document – Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis – Under Executive Order 12866, May 2013, pp.14-15.

[37] A similar principle, but different values, would apply if CO_2 damages were apportioned based on state Gross Domestic Product (GDP) as a share of global GDP. At $40/global ton, Maryland benefits per ton would be roughly $0.17/ton, US benefits per ton would be roughly $9.44/ton, and China's benefits per ton would be roughly $5 per ton. While population and GDP are the most obvious methods of apportioning damages, there are a myriad of other factors that could be considered, such as geographic location (e.g. proximity to coast, desertification, loss/increased agricultural productivity, etc.).

is the willingness to pay for a benefit to someone else or something else (e.g., a polar bear). It is conceivable that the gift of giving is worth more to the giver than the recipient, but more likely any altruistic benefit will be a small and unknown share of the global benefit.[38] A reciprocity benefit makes sense if a unilateral reduction in CO_2 emissions is expected to induce a reciprocal reduction in emissions. Again, this is likely far less than the global benefit. Assuming full reciprocity for a one-ton reduction in Maryland implies that actions will be taken somewhere else in the world to obtain 1,163 tons of CO_2 reductions (1/0.00086).

There is little evidence of such reciprocity with respect to climate policy. Many jurisdictions have tried to blaze paths over the last 20-plus years. Attempts to bring along a significant share of the world's economies have proven futile to date and most jurisdictions have exit routes in case the going gets too tough. It is frankly hard to make a compelling case for reciprocity benefits for Maryland. Without national and global cooperation on CO_2 emissions, investments in reducing Maryland's CO_2 emissions will be largely for naught.

EPG participants offered several opinions on the question of allocation of criteria emissions and CO_2 to Maryland residents. Some felt this was an additional point of major uncertainty that further undermines any attempt to estimate and apply an air emissions benefit to the EmPOWER program cost effectiveness. They argue, for example, that Maryland ratepayers should not be expected to pay higher electricity prices to benefit people in other states or countries.

At the other end of the spectrum, some EPG participants insisted that all emissions should be counted. If the emissions are the result of Maryland electric consumption, whether they affect children and elderly in Maryland, Ohio, North Carolina or China is unimportant. Some participants argued that Maryland's leadership could be reciprocated. The Healthy Air Act demonstrates Maryland's willingness to take early action on criteria pollutants and participation in RGGI, along with a range of other climate related policies, demonstrates the State's willingness to take early action on CO_2.

The EPG was unable to reach consensus on the appropriate allocation of EmPOWER criteria or CO_2 emissions reduction to Maryland residents. In this paper we developed scenarios around five different percentage allocations: 0.086 percent (MD percent of global population), 10 percent, 50 percent, 90 percent and 100 percent.

Results

The objective of our analysis was to estimate an expected value per-kWh benefit that could be applied to all EmPOWER program kWh savings over the lives of the program measures.[39] For this paper, we estimated benefits for 72 different cases (i.e., sets of assumptions).[40] In these cases, we tested several important and controversial assumptions, namely:[41]

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[38] Ted Gayer and W. Kip Viscusi, *Determining the Proper Scope of Climate Change Benefits*, June 3, 2014, pp. 20.

[39] The air emissions benefit could be applied alone or in conjunction with other non-energy benefits. Some non-energy benefits -- such as increased comfort and lower bill arrearages -- apply to specific types of programs or measures. For example, increased comfort is applicable to the home performance programs, arrearages to low income programs. In contrast, the air emissions benefit would be applied to all EmPOWER kWh savings, regardless of the program or measure.

[40] The spreadsheet tool developed by the authors for this analysis can easily apply different global damage shares and different discount rates as needed.

[41] One obvious factor missing from this list is the social cost of CO_2, but in the IWGSCC analysis, the CO_2 valuation is heavily dependent on the assumed discount rate, with the 5-percent discount rate equating to an average CO_2 value of $15 per metric ton through 2025 and the 3-percent discount rate equating to a societal cost of CO_2 of $53 per metric ton.

- Real discount rate – 3 percent and 5 percent.
- Percentage of EPA criteria emissions benefits allocated to Maryland residents – 10 percent, 50 percent, and 100 percent.
- Percentage of CO_2 emissions benefits allocated to Maryland residents – 0.086 percent, 10 percent, 50 percent, 90 percent and 100 percent.
- Value of a Statistical Life (VoSL) – \$3.9 million, \$5.9 million and \$7.9 million.[42]

Based on our analysis and the varied perspectives of the EPG, all of the tested assumption values seem well within reason. A reasonable and informed person could argue for any one of these cases. Ultimately, these are individual judgments about the value of human life and the desirability of intergenerational and interregional equity.

For each case, we report the present value cents per kilowatt-hour (in real 2014 dollars) of the reduction in air emissions damages (i.e., benefits) resulting from the EmPOWER programs. As shown in Table 6, the per kWh air emissions benefits range from 0.05 cents per kWh (upper left hand corner of table) to 2.48 cents per kWh (lower right hand corner), a 50-fold difference.

Table 6: EmPOWER Maryland Estimated Air Emissions Benefits under Different Assumptions (real 2014 cents per kWh)

NO_x and SO_2 Emissions Counted (%)		**10**					**50**					**100**				
CO_2 Emissions Counted (%)		**0.086**	**10**	**50**	**90**	**100**	**0.086**	**10**	**50**	**90**	**100**	**0.086**	**10**	**50**	**90**	**100**
Disc Rate (%)	**VSL ($m)**															
5	**3.9**	0.05	0.08	0.22	0.36	0.39	0.24	0.27	0.41	0.55	0.59	0.48	0.51	0.65	0.79	0.83
	5.9	0.07	0.11	0.25	0.38	0.42	0.36	0.39	0.53	0.67	0.71	0.72	0.75	0.89	1.03	1.07
	7.9	0.10	0.13	0.27	0.41	0.44	0.48	0.51	0.65	0.79	0.83	0.96	0.99	1.13	1.27	1.31
3	**3.9**	0.06	0.19	0.75	1.32	1.46	0.27	0.41	0.97	1.53	1.67	0.54	0.68	1.24	1.80	1.94
	5.9	0.08	0.22	0.78	1.34	1.48	0.41	0.54	1.10	1.67	1.81	0.81	0.95	1.51	2.07	2.21
	7.9	0.11	0.25	0.81	1.37	1.51	0.54	0.68	1.24	1.80	1.94	1.08	1.22	1.78	2.34	2.48

Such a wide range of estimates provides little guidance for policymakers, except to acknowledge the high level of uncertainty. As with many policy decisions, the final valuation must be made on informed judgment of experts and stakeholders. Many simple methods could be used to arrive at a final estimate, a few of which are reported in Table 7, namely:

- Average - The average of all the values.
- Split - The average of the lowest and highest values.

[42] Here, we make the simplifying assumption that varying the VSL only affects criteria pollutant damage costs. While the VSL dominates the damage costs of criteria pollutant emissions (see Hidden Costs Study, p. 94), the VSL has a relatively small impact on CO2 damage costs in the IWGSCC models.

- Median - The median of all the values.
- Second Order Average - The average of the average, split and median values.
- 50-50-5.9 Case – Assume 50 percent of criteria emissions, 50 percent of $C0_2$ emissions and a $5.9 million statistical value of life.

Each of these can be calculated for each discount rate individually or for the two discount rates combined.

Table 7 Selected Methods for Aggregating Scenarios (2014 cents per kWh)

Discount Rate	Average	Split	Median	2nd Order Avg	50-50-5.9
5%	0.56	0.63	0.51	0.57	0.53
3%	1.13	1.21	1.22	1.19	1.10
Combined	0.84	1.22	0.71	0.92	-------

Our recommendation for EmPOWER Maryland was to add 1.1 cents per kWh saved to the present value benefits used in all ex ante and ex post cost effectiveness analyses. This was based on the 50-50-5.9 scenario and a 3 percent real discount rate (4.8 percent nominal). Based on our analysis and the deliberations of the EPG, this best reflected the varied opinions and perceptions of Maryland stakeholders.

As shown in Table 8, the estimated present value (PV) benefit of reduced air emissions from the EmPOWER programs in the 50-50-5.9 scenario would total just under $77 million over the lives of the program measures. The 1.1 cents per kWh adder would increase program and portfolio Total Resource Cost (TRC) benefits and benefit/cost ratios by 16 percent.

Table 8: Recommended EmPOWER Air Emissions Benefit

Air Emission Type	Emissions Reductions	PV Measure Life ($ million)	PV Cents per kWh Saved	% Change in TRC B/C Ratio
CO_2 (metric tons)	1,708,180	48.6	0.70	10%
NO_x (pounds)	1,598	1.8	0.03	1%
SO_2 (pounds)	3,681	26.1	0.38	6%
Total	NA	76.6	1.10	16%
Assumptions:	*Real Discount Rate*		3.0%	
	CO_2 Price/Metric Ton		$53	
	Value of Statistical Life		$5.9 million	
	% Emissions Counted		50%	

As of spring 2015, the PSC had not made a determination about the appropriate air emissions benefit to use in EmPOWER cost effectiveness analyses, nor whether any value should be added. Two of the five EmPOWER utilities included our recommended value in their TRC estimates for their 2015-17 plans and expressed support for including the air emissions benefit in annual ex post TRCs. The other utilities and PSC staff expressed moderate to strong reservations to inclusion in the TRC, but generally seemed receptive to including an air emissions benefit in the Societal Cost Test (SCT).

In Closing

In this paper, we discussed and expanded on a variety of methodological issues and findings from a recent analysis of air emissions damage cost reductions in Maryland. The analysis involved many steps, including: projection of Maryland generation fuel intensities throughout the weighted average life of the EmPOWER program measures; adjustment of NRC criteria emissions damages estimates to reflect past and future changes in national emissions policies, characteristics of fuels and other factors; adjustment of national social costs of carbon to reflect existing taxes or fees on carbon emissions in Maryland; and estimation of the impact of criteria and CO_2 emissions specifically on Maryland residents.

Two particularly confounding and sensitive issues pertain to the discount rates and the locational impacts of the total damage reductions. Discount rates are particularly impactful due to the long duration of CO_2 emissions in the atmosphere. Estimating locational impacts is particularly confounded by the fact that a ton of CO_2 will have global impacts and thus allocation of benefits to Maryland depends on one's expectations of reciprocity and/or desire to engage in altruistic investment.

Analysis can and should be used to inform the discussion, but these types of issues ultimately must be decided in a political setting. This paper highlights the uncertainty around estimation of air emissions benefits, acknowledging that even our limited set of assumptions could arrive at a 50-fold difference in the estimated cents per kWh air emissions benefit.

We nevertheless recommend that EmPOWER Maryland ex ante and ex post cost effectiveness analyses should include a 1.1 cents per kWh air emissions benefit. While there is considerable uncertainty, we find no decisive and compelling arguments for continuing to implicitly assume the air emissions benefit value is zero. Moreover, providing a wide range of possible values would give little guidance to policymakers. We therefore recommended a point value that is based on insights gleaned from our analysis and that we believe best reflects the varied opinions and perceptions of Maryland stakeholders. But we must grant that many other sets of assumptions could be defensible.

Uncertainty pervades the evaluation of energy efficiency program impacts and cost effectiveness. Air emissions and other non-energy benefits are not unique in this regard. In our view, the key to addressing stakeholder concerns about uncertainty is to inform them with rigorous and transparent analysis and find ways to minimize conscious or unconscious biases of the experts. Perhaps the next frontier for EmPOWER evaluations and cost effectiveness analyses will be the use of expert panels to attach probability distributions to various sources of high impact analytical uncertainty and use those probabilities to arrive at estimates based on greatest likelihood.

In sum, we conclude that estimates based on the mid-range of our estimates would improve the accuracy of future cost effectiveness analyses and better align those analyses with EmPOWER Maryland statutory objectives: "to provide affordable, reliable, and clean energy for consumers of Maryland."[43] Hopefully, this discussion will help foster and inform future discussions about ways to estimate and include air emissions benefits in Maryland and other state's cost effectiveness analyses.

[43] General Assembly of Maryland, *EmPOWER Maryland Act of 2008*, Public Utilities Section 7-211 (b), http://mgaleg.maryland.gov/webmga/frmStatutesText.aspx?article=gpu&section=7-211&ext=html&session=2015RS&tab=subject5.