The Million Metric Ton Question:
Estimating National Carbon Impacts from State-level Programs

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ABSTRACT

While it has long been understood that energy efficiency and renewable energy programs can lead to the abatement of carbon emissions through a reduction in the use of fossil fuels, quantifying emission reduction impacts is something many evaluators, regulators, and program administrators are only starting to consider as part of main-stream evaluation objectives. The Environmental Protection Agency's proposed Clean Power Plan issued under the Clean Air Act section 111(d) could require each state to reduce its carbon emissions from fossil fuel-fired electricity generation. This could soon bring renewed urgency to understanding and verifying how energy programs lead to emission reductions around the nation. This paper explores how two recent national studies assessed the carbon impacts resulting from diverse energy programs.

These evaluations examined the national carbon impacts created by various state-level programs implemented across the U.S. In each study, we first evaluated the net energy efficiency savings and renewable energy generation attributed to these programs by state. Then, we estimated the carbon and associated societal impact benefits (the financial benefit to society of reducing carbon emissions) resulting from these net energy impacts using a methodology developed for these evaluations.

This paper begins with a brief review of the project scope to explain how the state-level energy impacts were assessed and then explores the data sources used and methods developed to create national-level carbon abatement estimates and economic impacts. We end with a discussion of the benefits and limitations of our approach to calculating national carbon impacts from state-level activities.

Introduction

The United States Department of Energy (DOE) has provided funding for energy efficiency and renewable energy programs through the State Energy Program (SEP) for many years. Between 2009 and 2011, this program was expanded substantially due to funds released through the American Reinvestment and Recovery Act (ARRA). Similarly, the DOE implemented the Energy Efficiency Conservation Block Grant (EECBG) program[1] during this time period as well; these two federal programs provided over five billion dollars of additional funding. These funds were provided to state energy offices (SEOs) who oversaw the development, administration and implementation of various energy programs in their state or territory. SEP activities were categorized into Broad Program Activity Categories (BPACs) while EECBG programs were similarly categorized into Broad Program Areas (BPAs).

From 2012 to 2014, DNV GL, with oversight from Oak Ridge National Laboratory, conducted evaluations of the national SEP and EECBG programs. We evaluated the energy, carbon, and job impacts associated with the energy activities supported across the United States and territories during SEP Program Year (PY) 2008 and the ARRA period. The activities supported by SEP and EECBG were

[1] The EECBG program was created for the ARRA period and did not exist prior to 2009

varied; the types of energy programs included in the evaluated BPACs and BPAs ranged from technical assistance and policy support to retrofit and incentive programs. The SEP evaluation estimated the impacts of four BPACs from the pre-ARRA period (PY 2008) and the ARRA period,[2] while the EECBG evaluation included six BPAs.[3] In total, the results of the evaluations represent 941 SEP Programmatic Activities (PAs) or EECBG Activities. These evaluations did not cover all funding provided by DOE, but instead focused on the largest BPACs and BPAs that represented approximately 80% of total program funding from SEP Program Year 2008 and ARRA funding.

This paper examines the approach used to develop estimates of the national-level carbon impacts associated with the evaluated BPACs and BPAs. First, we discuss how we developed estimates of national energy impacts from our evaluation of sampled PAs and Activities, as these energy impacts form the foundation for estimation the estimation of other impacts. Then we discuss the carbon and social cost analysis, including the data sources and methods used in the carbon estimation process as well as the benefits and limitations of our approach.

Methodology

The SEP and EECBG evaluations aimed to determine the national-level impacts resulting from varied-state level activities. These programs provided funding to individual SEOs, who oversaw activities occurring within their states; supported activities across the states varied substantially. Our estimates of national energy impacts were derived from state-level program information and expanded to represent the population of programs within each BPAC or BPA based on activity-level funding information. Therefore, a primary challenge to our analysis was to consider how impacts evaluated at the individual state-level could be expanded to estimate the national impact of these programs. Carbon and social cost impacts were estimated using the expanded net energy impacts by BPAC/BPA and an approach developed for these evaluations.

The methodology employed to estimate energy impacts for use in the carbon estimation process is summarized in Figure 1 and discussed in more detail throughout this section.

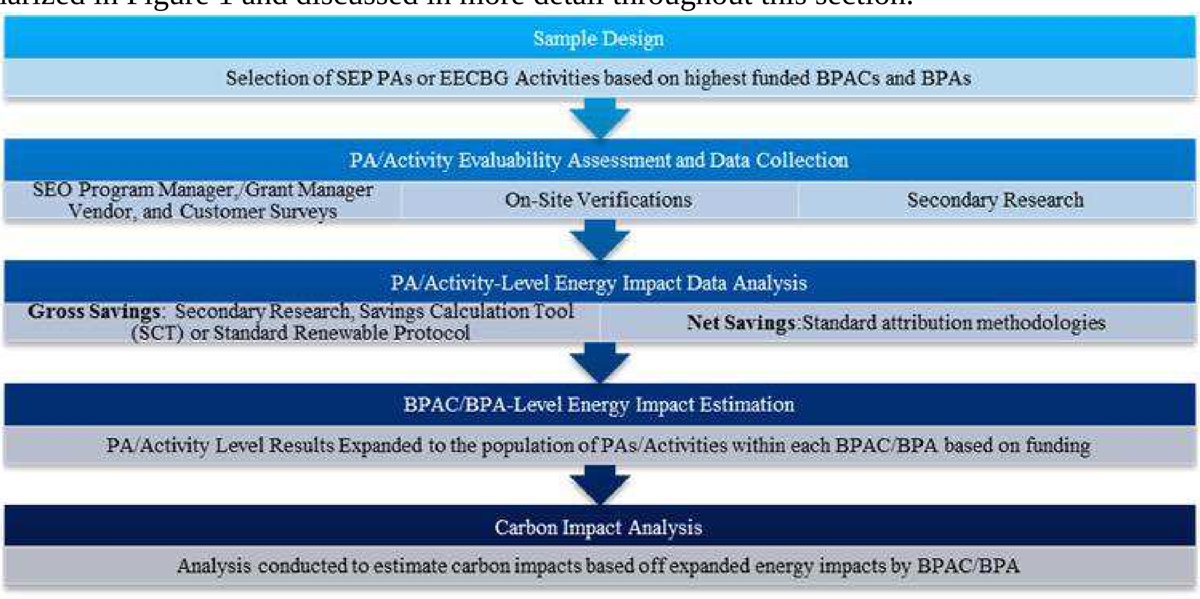

Figure 1. SEP and EECBG Evaluation Methodology

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[2] Evaluated PY2008 SEP BPACs: Technical Assistance; Clean Energy Policy Support; Building Retrofits; Loans, Grants and Incentives. Evaluated ARRA SEP BPACs: Building Codes and Standards; Renewable Energy Market Development, Building Retrofits; Loans, Grants, and Incentives.

[3] Evaluated EECBG BPAs: Energy Efficiency Retrofits, Financial Incentives, Buildings and Facilities, On-Site Renewables, Lighting, Energy Efficiency Conservation Strategy.

Energy Impact Methods and Expansion Process

Sample Design. As the SEP and EECBG programs funded over 900 separate projects, we could not feasibly evaluate the impacts of all state-level activities to understand the full impact of each program. Our team instead examined the complete population of BPACs and BPAs and determined an appropriate sample for each study which included the most heavily funded BPACs/BPAs and in total represented at least 80% of program funding. The selected BPACs and BPAs were treated as strata and a sample of PAs and Activities were chosen to represent each stratum. When the frame number of PAs/Activities in a stratum was equal to the target sample size, each was selected with certainty, when this was not the case, the sample was chosen randomly, but with a probability proportionate to funding.

PA/Activity Assessment and Energy Impact Analysis. After selecting our sample for each study we conducted an evaluability assessment of each PA/Activity which determined if the original BPAC/BPA classification was correct and whether the data needed to conduct our evaluation was available. We ultimately evaluated the impacts associated with 81 SEP PAs and 169 EECBG Activities. The team then calculated annual and lifetime[4] gross and net energy impacts for each evaluated PA/Activity through a variety of medium-high and high-rigor analyses, such as participant surveys, vendor surveys, and desk reviews.

BPAC/BPA Energy Impact Estimation. After these calculations were completed for all evaluated PAs/Activities within a BPAC/BPA, a final sample weight[5], based primarily on funding and adjusted for nonresponses, was assigned to each PA/Activity and the associated impact estimates were expanded to all PAs/Activities included in each evaluated BPAC/BPA. While the goal of the expansion process was to create estimates of national-level BPAC/BPA impacts, we generated state-level energy impacts as intermediate outputs of the expansion process to inform the carbon estimation model. To account for geographic variation, state-level estimates were created as follows:

- If a state had one or more evaluated PA/Activity in a specific BPAC/BPA, then the state-level estimate was created using data associated with the state.
- Otherwise we used national totals for each BPAC/BPA, such as the total SEP/EECBG-attributable energy savings associated with electricity or gas. These estimates of totals were proportioned to the states with no sampled PAs/Activities proportional to the funding that the state received within a BPAC/BPA.

Carbon Impact Analysis

Carbon impacts at the BPAC and BPA level were calculated by applying the appropriate emission rates to the verified and expanded net energy impacts. Annualized carbon reductions achieved as a result of SEP and EECBG-funded efforts were calculated and reported for each year over the effective useful life of the measures evaluated. The annual and lifetime social cost of carbon impacts were calculated by applying the aforementioned cost estimates to the annual aggregated carbon impacts. This process is shown in Figure 2.

[4] Lifetime savings are those realized over the effective useful life of the installed measure.
[5] PA/Activity weights consisted of several components. These included the inverse of the probability of selecting the PA/Activity at Stage 1, several adjustments to account for nonresponse at varying phases during the data collection process, and several components that were applied to calibrate the weighted funding estimates to the “best” estimate of total target population funding for each BPAC/BPA.

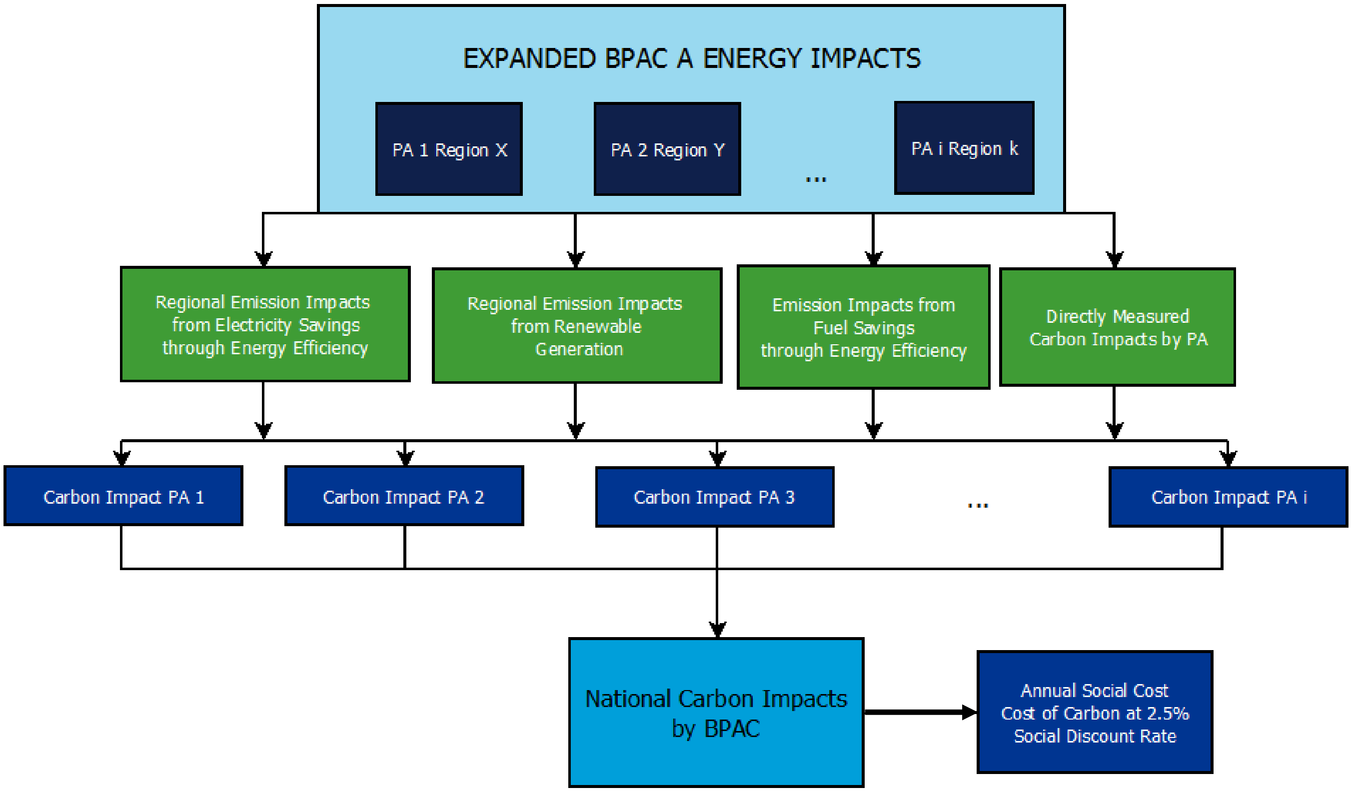

Figure 2. Analysis Approach for National Carbon Impact Estimation Process[6]

These evaluations considered carbon impacts from four modes of savings:

- *Electricity and fuel savings from energy efficiency*. When the consumption of energy from fossil fuel resources is reduced through energy efficiency, the carbon emissions that would have resulted from burning those fuels are avoided.
- *Renewable energy generation*. When renewable energy is used as an alternative to fossil fuels, the carbon emissions associated with the replaced fuels are avoided.
- *Direct carbon impacts associated with the use of alternative fuel vehicles and biomass generation*. The use of biofuels for transportation also leads to reduced carbon emissions as these biofuels often have lower carbon intensities than conventional transportation fuels. We also incorporated additional carbon savings for instances where a biomass source represents a carbon sink before being harvested for use in energy generation.

Table 1 summarizes the emission rate data sources we selected for these four savings categories. A more detailed explanation for the selection and use of these data sources follows. It is also important to note that the estimated avoided carbon emissions are expressed as million metric tons of carbon equivalent. Emission rates were calculated to include the carbon equivalent impacts of nitrous oxide and methane.

[6] The EECBG estimation process followed the same form as the SEP process shown in this figure. EECBG used the BPA/Activity terminology rather than BPAC/PA and did not include direct carbon impacts.

Table 1. Emission Rate Data Sources by Mode of Savings

Electricity Savings from Energy Efficiendy	Fuel Savings from Energy Efficiency
EPA's 2009 Emissions & Generation Resource Integrated Database (eGRID)	EPA's Climate Leaders Greenhouse Gas Inventory Protocol
EPA's Greenhouse Gas Reporting Program	
U.S. Energy Information Administration 2010 International Energy Statistics	U.S. Energy Information Administration, Annual Energy Review
Renewable Energy Generation	**Directly Measured Carbon Impacts**
EPA's 2009 Emissions & Generation Resource Integrated Database (eGRID)	Argonne National Laboratory Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model
	DOE National Energy Technology Laboratory Unit Process Library

Electricity Impacts from Energy Efficiency. The electricity-related emission rates used for this evaluation were derived from the EPA's 2009 Emissions & Generation Resource Integrated Database (eGRID) which provides non-baseload emission rates by state and emission type. While it is likely emission rates will vary over time, the scope of our evaluation did not include emission modelling. As such we chose to use emission rates from this database as it was the best available data, developed by a federal agency, and included well-documented data for the states in our evaluation.

EPA recommends that non-baseload emission rates be used to estimate emission savings resulting from energy efficiency and renewable energy programs[7]. Non-baseload emission rates estimate the emissions from marginal generation units, those most likely to be displaced by electricity energy efficiency and/or renewable energy generation. We used the state-level carbon dioxide, methane, and nitrous oxide non-baseload emission rates to calculate the carbon equivalent emission rates used for these evaluations.

eGRID only reports emission rates for the 51[8] states however; U.S. Territories are not included. We determined that the generation mix of the states was not comparable to the territories so we did not use emission rates from the 51 states as a proxy for the territories. Therefore, we calculated average

[7] E.H. Pechan & Associates, Inc., "The Emissions & Generation Resource Integrated Database for 2010 (eGRID2010) Technical Support Document," Prepared for the U.S. Environmental Protection Agency, Office of Atmospheric Programs, Clean Air Markets Division, Washington, D.C., December 2010.

[8] This includes the 50 states plus Washington DC

territory emission rates with territory-specific 2010 total facility emissions from EPA's Greenhouse Gas Reporting Program[9] and 2010 net electricity generation from EIA[10]. The estimated emission rates were the system average emission rate; it was not possible to calculate non-baseload emission rates with the available data. Furthermore, these data were only available for Guam, Puerto Rico, and the Virgin Islands; the calculated Guam emission rate was also used for The Mariana Islands and American Samoa based on their proximity to each other.

Finally, electricity savings from energy efficiency and on-site generation only represent what is saved by the consumer. Those savings do not include avoided line losses from transmission and distribution and therefore do not equal the total amount of energy displaced. We adjusted the electricity savings estimates to reflect the amount of energy saved at the generator by applying regional line loss factors from eGRID to the state-level energy savings[11]. We used the line loss factor from Hawaii for the territories as well. Table 2 shows the line loss factors used for the evaluation.

Table 2. Estimated Line Loss Factors from eGRID

Region	Line Loss Factor (%)
Eastern	5.82
Western	8.21
ERCOT	7.99
Alaska	5.84
Hawaii/Territories	7.81
U.S.	6.50

Other Fuel Impacts from Energy Efficiency. The SEP and EECBG evaluations also considered energy efficiency savings for other fuels: natural gas, oil, propane, kerosene, wood, diesel, ethanol, and gasoline. Emission rates for these fuels do not exhibit regional variation like the emission rates associated with electricity generation. We used national-level emission rates derived from the carbon dioxide, methane, and nitrous oxide emission rates included in EPA's Climate Leaders Greenhouse Gas Inventory Protocol.[12] Line losses of 7.00% were added to the natural gas savings as well.[13]

Impacts from Renewable Generation. To determine the appropriate emission rate(s) to be used for each renewable energy activity, we first determined the type of conventional generation (electricity, natural gas, wood, etc.) displaced for each evaluated renewable energy generation activity. We then applied eGRID emission rates for displaced grid electricity, as recommended by EPA[14] using the same process described above for electricity savings from energy efficiency. Similarly, we used the fuel emission rates discussed above from EPA's Climate Leaders Greenhouse Gas Inventory Protocol to

[9] U.S. Environmental Protection Agency. GHG Reporting Program Data Sets, http://www.epa.gov/ghgreporting/ghgdata/reportingdatasets.html. May, 2014.
[10] U.S. Energy Information Administration, International Energy Statistics, http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=2&pid=2&aid=12&cid=AQ,GQ,RQ,IQ,US,VQ,&syid=2010&eyid=2010&unit=BKWH. May, 2014.
[11] A line loss factor is a multiplier that can be used to extrapolate energy saved at the generator level from energy saved at the consumer level.
[12] U.S. Environmental Protection Agency, OAR, Climate Protection Partnerships Division. Climate Leaders Greenhouse Gas Inventory Protocol, http://www.epa.gov/climateleadership/documents/resources/stationarycombustionguidance.pdf, June, 2014.
[13] U.S. Energy Information Administration, Annual Energy Review, August 19, 2010.
[14] E.H. Pechan & Associates, Inc., "The Emissions & Generation Resource Integrated Database for 2010 (eGRID2010) Technical Support Document," Prepared for the U.S. Environmental Protection Agency, Office of Atmospheric Programs, Clean Air Markets Division, Washington, D.C., December 2010.

estimate the carbon impacts from renewable generation that displaced other fuel types, such as a wood pellet stove replacing an oil furnace.

Typically, biomass generation is assumed to be carbon neutral because the source would have emitted the same greenhouse gases through decay that were emitted when burned for generation purposes. As such, energy displacement from biomass generation was evaluated in the same way as other renewable generation—emission factors were applied based on the type of displaced energy. However, in some instances, we felt that the biomass source was not carbon neutral and recorded the difference as a direct carbon impact. More information on these calculations is included in the next section.

Directly Measured Carbon Impacts (SEP Only). Directly measured carbon impacts were included in this analysis to account for activities that led to carbon impacts through means other than energy savings. We included two sources of direct carbon impacts in these evaluations: biomass generation and alternative transportation fuels.

For each evaluated biomass activity, we considered whether there was an additional carbon impact associated with the project. If we determined the biofuels used for a particular activity represented a carbon sink (more carbon is emitted through burning for generation than natural decay) we included this impact as part of the evaluation. This typically occurred when we determined that the biomass source would not have decayed naturally, that is, was a source grown specifically for use in energy generation. We used the DOE National Energy Technology Laboratory Unit Process Library to calculate the direct carbon impacts[15].

Some SEP activities were also designed to promote and support alternative transportation fuels. In these activities, carbon impacts were realized through the use of a lower-carbon fuel in municipal or commercial vehicles. We used Argonne National Lab's GREET model[16] and PA-specific data to determine the amount of carbon saved from the use of alternative fuels. Since these savings occur in municipal or commercial transportation fleets, we assigned these impacts to the transportation sector.

Avoided Social Costs of Carbon Impacts. These evaluations also considered the future monetary impact associated with carbon emissions. The team monetized the carbon impacts associated with SEP and EECBG-funded programs by using the social cost of carbon (SCC) from the following sources:

- 2009: Evaluating Realized Impacts of DOE/EERE R&D Programs: Standard Impact Evaluation Method which provided the appropriate social cost of carbon values for 2009,[17]
- 2010-2050: Technical Support Document- Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis- Under Executive Order 12866[18]

The social cost of carbon estimates used in these sources were developed through a modelling process which considers the economic impacts associated with increases in temperature due to incremental carbon emissions. They are derived from three integrated assessment models: DICE,[19] PAGE,[20] and FUND.[21] While the methodology and calculations behind each model vary, the economic impacts are generally a function of climate processes, economic growth, and feedback between the climate and

[15] http://www.netl.doe.gov/research/energy-analysis/life-cycle-analysis/unit-process-library
[16] https://greet.es.anl.gov/
[17] The technical support document only provides social cost of carbon values for 2010-2050.
[18] http://www.whitehouse.gov/sites/default/files/omb/inforeg/social_cost_of_carbon_for_ria_2013_update.pdf
[19] DICE: Duration, Integrity, Commitment and Effort, http://dice.bcg.com/
[20] PAGE: http://www.jbs.cam.ac.uk/fileadmin/user_upload/research/workingpapers/wp1104.pdf
[21] FUND: Climate Framework for Uncertainty, Negotiation, and Distribution. http://www.fund-model.org/

global economy.

Table 3 shows how the social cost of carbon varies based on the social discount rate assumed and over time. The discount rates used in this table are social discount rates; a higher discount rate implies consumers place a lower value on the future impacts of carbon. The SCC increases over time due to the increased strain each marginal metric ton of carbon dioxide will have on the system; the three models assume that incremental emissions in later years cause more damage than previous emissions as they are added to an already stressed system.

Table 3: Social cost of carbon (2009 $/MMTCO$_2$)[22,23]

Discount Rate	5%	3%	2.5%	3%
Year	Average	Average	Average	95th Percentile
2009	11	32	51	87
2010	11	33	52	90
2015	12	38	58	109
2020	12	43	65	129
2025	14	48	70	144
2030	16	52	76	159
2035	19	57	81	176
2040	21	62	87	192
2045	24	66	92	206
2050	27	71	98	221

The annual monetary impacts of carbon emissions were calculated after the annual carbon impacts by BPAC and BPA were determined. The annual carbon impact by BPAC/ BPA was multiplied by the social cost of carbon value for each year to create annual cost estimates. We used the social cost of carbon estimates associated with the 2.5% discount rate because that is closest to the 2.7% 2009 real discount rate used for the evaluation.

Benefits and Limitations of this Approach

The SEP and EECBG evaluations aimed to determine the national energy, economic, and carbon impacts by BPAC/BPA based on data collected for a sample of unique energy activities administered at the state-level and the evaluated impacts associated with these activities. Because the scope of these evaluations was large, both geographically and analytically, and developing rigorous carbon estimates was not the primary objective of these studies, it was not possible to address all the nuances of carbon impact estimation that should or could be addressed for more local evaluations. Furthermore, our carbon estimation approach was developed prior to the release of EPA's proposed Clean Power Plan Section 111(d), so we did not include additional functionality, such as time of use or renewable specific emission rates, which would be useful in determining emission reductions associated with energy efficiency and renewable generation in this context. While it is still unclear what EM&V standards will be required under 111(d), we expect this additional functionality will provide more precise estimates of carbon reductions.

Despite the scope constraints of this project, the approach we employed allowed for a method of analysis that was consistent with the level of rigor required, effectively managed the large amount of

[22] Dollars were converted to 2009 using the following Inflation Adjustment Formula: Current Year Price x (Base Year CPI ('09)/ Current Year CPI); where CPI is GDP Chain-type Price index as reported by EIA for 2011 and 2012.
[23] The average options represent the average dollar economic impacts expected in each model. The 95th percentile option represents the social cost of carbon (with a 3% discount rate) from less likely, but more damaging, economic impacts resulting from increases in global temperature.

data contained within the evaluations and could feasibly use the best available data provided while working within scope limitations of this task. The following discussion of the recognized benefits and limitations is given in the context of lessons learned from the aforementioned approach and the identified next steps to increasing the level of rigor of this model given the renewed emphasis for calculating carbon impacts associated with 111(d).

Benefits

The team identified the following benefits of this approach. An enhancement of these aspects would allow for a more customized evaluation of carbon impacts in future evaluation efforts.

- The employed approach provided us with a systematic way to estimate carbon and social cost impacts across multiple states and multiple fuels. The methods and rigor of data sources used were consistent across all geographies and modes of savings.
- The emission and social cost data sources were the best available data from federal agencies and national laboratories. The data was defensible and sources are well documented. The emission rates did not require extrapolation or additional analysis that could have potentially introduced bias or error.
- The tool is scalable and can be modified to include more specific data such as customized emission rates by state or sector, time-of-use rates, and impacts for additional fuels. Although it was developed to estimate national-level savings, it can also be used for regional, state, or local evaluations as well.

Limitations

The team also identified the following limitations associated with the current approach. If we were to use a similar approach in the future we would seek to address these issues in order to make the approach more rigorous.

- The team decided not to evaluate carbon impacts based on time-of-use energy savings or emission rates due to scope constraints. As noted above, we used the non-baseload emission rate from marginal units to capture emissions from generators that would be displaced by electricity savings and renewable generation. In the future, if time-of-use energy impacts are available, the tool could include corresponding emission rates to more accurately estimate avoided emissions.
- We assumed that renewable generation replaced the marginal generating unit and used the non-baseload emission rates from eGRID to estimate the corresponding emission reduction. We did not consider the actual generation profile of specific renewable energy technologies as that would have been too difficult to determine given the scope of this task. As such, we may not have accurately characterized the displaced energy resulting from the use of renewable technologies. Future versions of the tool could be enhanced to include emission rates specific to various renewable technologies.
- eGRID's state-level emission rate data is based on generation units located within a state's boundaries. Although this was the best data available for each state, it does not reflect what is actually being displaced by energy efficiency or renewable energy where electricity is imported from other states or Canada. For example, energy displaced from an activity in Vermont could come from a generating unit located within Vermont, another New England state, Quebec, or New York. In future, localized evaluations, an analysis of the marginal units could be conducted done and the emission rates included in the tool can easily be updated.

- The emission rates used in this analysis were from 2009, when possible, as that was the base year for much of our analysis in this study. We did not vary emissions over time to reflect changing fuel mix or the potential effects of energy efficiency and demand response. Another step to improving the functionality of this model would be to include dynamic emission rates that can change over time. A sensitivity analysis that could allow for different emission rate scenarios could be particularly valuable as states and utilities evaluate their options for complying with 111(d).

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