Quantifying Emissions Benefits for Wisconsin's Focus on Energy Programs

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ABSTRACT

With the expansion of energy efficiency (EE) and renewable energy (RE) programs in North America, evaluation of these programs primarily emphasizes their energy-savings impacts. More recently, a different set of impacts—environmental benefits resulting from displaced power plant emissions[1]—has received increased attention as policy and legislation related to global warming gains momentum. Over 10 years, the authors refined a method for estimating displaced emissions, employing the U. S. Environmental Protection Agency's (EPA) "Acid Rain Hourly Emissions" data series, with guidance from the World Resources Institute's protocols. This paper details this approach, which balances the need for precision against the costs to attain evaluation and public policy objectives. The paper also reports new results from estimating displaced emissions for electric generation affected by EE programs in Wisconsin during 2012.

Further, the authors compare emission factor results from the approach we used in Wisconsin with results using a new EPA tool—a statistical dispatch simulator. This research results from collaboration between the evaluation team, the state agency overseeing the EE and RE programs, and EPA. Comparisons between emission factor results contribute to efforts to design rigorous, defensible, and clear benchmarking methodologies for assigning emissions effects credits to programs.

The paper concludes with a critique of the value and limitations of rigorously estimating displaced emissions for EE and RE programs.

Introduction

For the past several years, in evaluating Wisconsin's Focus on Energy (Focus) programs, the authors have estimated emission factors (i.e., pounds of pollutant per MWH of avoided generation) to calculate environmental impacts from Focus net energy savings. We based our factor estimates for CO_2, NO_X, SO_X, on the Environmental Protection Agency's Office of Air and Radiation "Acid Rain Hourly Emissions" data series (which derives from actual stack monitoring). We then used appropriate allowance prices for displaced emissions in conducting the benefit-cost and economic impact analyses. Focus results in substantial energy savings, with program activities in 2012 resulting in estimated annual net electric savings of 466,204 MWh.

On an ongoing basis, we have sought to improve these estimates of emissions impacts, aligning our approach with the World Resources Institute's "Guidelines for Quantifying GHG Reductions from Grid-Connected Electricity Projects." The guidelines particularly require the identification of plants operating on the margin of the system supply as the source of emission reductions. Thus, we have used each generating unit's average duration of operation—calling this approach the time of savings (TOS) emission factors—to approximate the dispatch order, and to identify plants likely to operate on the margin.

[1] We use the term "displaced" because it is typically not feasible to verify that power generation has been reduced and associated emissions have been avoided. See the "Conclusions" section for additional related discussion.

Employing EPA's Acid Rain Hourly Emissions dataset, this technique produces data specific to the programs' geography—based on emissions from the generating plants most likely to be affected by program impacts (i.e., plants at the operating margin)—for every hour of the year.

For a default emission rate, averaging across all hours of the year may adequately serve some purposes. Applying this value to actual program savings, however, ignores a critical dimension: the timing of savings. Savings do not distribute equally across the year, but are timed to the use of energy-consuming technologies. Accommodating this fundamental principal proves important as the marginal emission rate also fluctuates significantly—and systematically—over each day and across the year.

The movement of the emission rate and savings rate, relative to one another, creates a complex pattern, not addressed by applying an average annual emission factor to annual savings.

Moreover, specific programs promote different technologies to different types of consumers; therefore, they save energy at different times of day. The size of error (and even the direction of error) in an estimate of avoided emissions that does not account for the timing of savings will likely differ from one program to another. Therefore, to produce a correct estimate, we must allocate savings and emissions across all 8,760 hours of the year. Until recently, common practice has been to apply a single emission factor to all savings. The approach we developed partially accounts for the timing of savings.

Background

Evaluation of Wisconsin's Focus programs requires estimating emission factors for electric generation that the Focus programs affect. These emission factors can then be applied to program net energy savings. This estimation process arises as part of ongoing development of inputs for the overall benefit-cost analyses of the Focus programs.

Estimating environmental impacts from the Focus EE and RE programs net energy savings uses emissions factors reported in pounds of pollutant per megawatt hour of generation. The EPA acid rain data series provides stack-level data for most power generators for CO_2, NO_x, and SO_2 (identified by company and unit name, and by specific stacks). We also use information from the data series regarding emission control devices at each generating unit, together with Energy Information Agency (EIA) data about sources of coal burned, to estimate mercury (Hg) emissions, which prove of particular interest in Wisconsin (in part because of deposition in the state's lakes).[2] Developing the factors proves challenging due to the volume of data involved and the complexity of the EPA's data structure.[3]

To identify marginal plants, we calculate the average length of time, in hours, that a generating unit remains on, once it has been brought online. Peaking units, brought on briefly, have short average operation times, while base-load plants, on for hundreds of hours or more, naturally have longer average times on. We divide the population of generating units into five groups, per their average periods of activity for each time they are dispatched: less than six hours; six to 12 hours; 12 to 24 hours; 24 to 96 hours, and more than 96. We define marginal emissions in each hour as those produced by the set of generating units in the group with the shortest average time on for that hour. These units are modulated to follow demand at any time.

[2] These data, submitted to the Federal Energy Regulatory Commission (FERC) by electric utilities on form FERC 423 (also EIA 423), include the state of origin of coal and its energy content. This information is combined with data on the Hg content of coal collected in an extensive study conducted by the EPA in 2000 (EPA 2000).

[3]The complexity of the EPA data structure derives in part from emissions data spread across multiple records, with different reporting requirements for different types of plants.

Methods

In initially estimating emission factors, we calculated the average marginal emission rate for each hour of the year, and then averaged this rate across hours for an annual emission factor that could be applied to all energy savings. As noted, we have since refined this approach, but, before we can present a more detailed discussion of the approach used to estimating TOS emission factors, we must provide additional information. Thus, we discuss the following, underlying aspects of the overall method.

The Wisconsin Grid

We define the grid serving Wisconsin as coterminous with the two North American Electric Reliability Corporation (NERC) regions bisecting the state: Midwest Reliability Organization (MRO) and ReliabilityFirst corporation (RFC). Although the RFC covers a smaller territory—primarily the state's southeastern corner—Wisconsin's energy consumption splits roughly in half. The combined NERC region territories stretch from eastern Montana, across the north plains and Midwest, to the mid-Atlantic coastal states of New Jersey, Delaware, and Maryland.

Energy Impacts of Focus Programs

Near-term program energy impacts prove critical to the success of Focus programs. As a core responsibility, evaluation activities identify, document, quantify, and monetize these impacts. For all Focus programs with energy impact objectives, the evaluation team designed and conducted program-specific data collection and reporting that supported unbiased, independent estimations of verified gross and verified net-energy impacts for all programs with the following qualifications: (1) independent verification of implementation of energy-efficiency improvements, and of engineering calculations used to estimate the energy saved; and (2) independent verification of the extent that energy savings could confidently be attributed to Focus efforts.

Semiannual (technical) reports (plus an annual overview) report these energy impacts, by: program area (Business and Residential, which also incorporate RE); specific program; the program year-to-date; and the cumulative program-to-date. Reports also divide geographically, by county, utility territory, and Assembly and Senate Districts.

Using the marginal emission rates (the emissions factors) and evaluation-verified electricity savings estimates, the Focus program evaluation reports total displaced emissions. Focus economic and benefit-cost analyses use calculated avoided emissions based on *net* energy impacts.[4]

TOS Emission Factors

Using an average hour approach to emissions quantification presents an inherent weakness, in that it does not equally allocate energy savings from EE programs across hours. As EPA data allow an 8,760 hour accounting of pollutants (insofar as energy savings can be assigned to hours of the day and days of the year), an accurate emission rate can be estimated more accurately by matching the amount of energy savings in a given hour to the emission rate for that hour. Hence, we term the approach: TOS emission factors.

[4] The use of net energy impacts is consistent with markets for greenhouse gases (GHG), and the protocols for quantifying and reporting GHG effects, which stringently require net emissions impacts.

Availability of accurate savings loadshapes, which allocate energy savings as a percentage across the hours of the year, proves essential to this refinement. Utilities often develop savings loadshapes for use in planning tools such as PortfolioPro™ and DSMore™. We acknowledge the only savings loadshapes used here present a rather coarse aggregation level. For instance, available load shapes for residential programs typically may include lighting, heating, and cooling, and possibly an HVAC heating-and-cooling load shape, along with an aggregate or total residential loadshape. However, this presents a significant improvement to the flat savings loadshape implied by the average hour approach.

Renewables pose special problems when allocating savings over the year. For solar hot water, energy savings occur when energy would have been consumed (but has not), and not when energy is collected or generated. When we do not have a residential hot water loadshape, we substitute the residential lighting loadshape. Though this does not fit perfectly, it proves more favorable than the residential total load shape—which would be the other option—as it is less dominated by the cooling load and generally reflects hours of the day when household consumption takes place. For solar electric, we estimate an insolation load shape using the National Solar Radiation Database.[5] We assign a flat load shape for renewable categories, such as wind, biomass combustion, and biogas (and others). For these savings, we apply the average annual emission rate for the appropriate sector—business or residential, depending on the sector predominating program activity for a given technology.

Using these load shapes, emission factors for the relevant NERC region can be calculated as follows. We multiply annual energy savings for the year (2007, in this example), per each measure category, by the annual percent savings in each hour of the appropriate load shape. The resulting hourly savings can then be multiplied by the emission factor in each hour to obtain a quantity of avoided emissions for each hour. We estimate the emission factor as the total avoided emissions, divided by the total energy savings. These load-shape-based TOS factors, expressed in pounds of pollutant per MWh energy savings, can be aggregated across programs to represent a portfolio-level rate. Table 1 shows emission factors by load shape for one set of residential programs.

Table 1. Emission Factors by Load Shape, 2007

Load Shape	CO_2	NO_x	SO_2	Hg
RES_COOL	1,641	2.7	4.5	0.0000109
RES_FLAT	1,817	2.7	4.1	0.0000147
RES_HEAT	1,908	2.6	3.6	0.0000158
RES_HVAC	1,783	2.6	3.9	0.0000134
RES_LGHT	1,801	2.6	3.8	0.0000135
RES_SOLAR	1,662	2.5	3.3	0.0000092
RES_TOTL	1,783	2.6	3.9	0.0000135

NO_x emission factors vary relatively little from one load shape to another—only about a one-tenth of a pound per MWh around the mean. This pollutant is less sensitive to the fuel predominant on the margin. Values for CO_2, SO_2, and Hg vary somewhat more by load shape (on the order of: 7% to 8% around the mean for CO_2; 15% for SO_2; and 22% to 30% for Hg). These pollutants vary according to the predominant fuel on the margin. In particular, coal generation produces more pollutants than

[5] We gathered hourly insolation data in watts per square meter from three data-gathering stations, located in cities where the majority of residential photovoltaic projects had been installed, and averaged the hourly data across all locations and years to obtain an average hourly insolation in watts per square meter. We then calculated the percentage of annual watts occurring in each hour of the year to estimate an insolation load shape. See: http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/hourly/list_by_state.html.

natural gas, oil, wood, or other fuels. Higher emission rates result when coal-powered generation is on the margin. Hence, the timing of savings drives the emission factor for each end use.

The TOS approach intrinsically provides a more precise way to represent the emission factor than the other approach, which averages across all units and all hours. What effect, however, does it have on emission factors?

Table 2 compares three different approaches to estimating emission factors.[6] The top row shows rates, calculated as an hourly average of all generation (all emitting electric generating units, including stack level continuous emissions monitoring, where the pollutants emitted and measured are NOx, SOx, and CO_2), without accounting for the margin (the average of emission rates across all emitting generators and across all annual generation). The second row shows the calculated rate, discussed at the beginning of this paper, as an average across all units on the margin in any hour, and then across all hours. The third row shows the TOS emission rate, calculated as the kWh saved in every hour, multiplied by the emission rate for that hour.

Table 2. Emission Factors from Three Different Accounting Approaches (Generation lbs/MWh)

Estimation Approach	**CO_2**	**NO_x**	**SO_2**	**Hg**
Average of all load	2,346	4.1	10.9	0.0000570
Average of marginal load	1,957	2.7	4.2	0.0000153
Time of savings	1,801	2.6	3.8	0.0000080

Effects of the estimation approach vary quite significantly by pollutant. Going from *all load* to *average marginal load* (the 2007 factors reported in Table 1) results in: a 61% reduction in emission rates for SO_2 and Hg; about a 52% reduction for NO_x; and a 17% reduction for CO_2. Going from *average marginal load* to *TOS* yields a smaller but still meaningful reduction in the emission rate: 22% for Hg; 10% for SO_2; 4% percent for NO_x; and 8% for CO_2.

This finding underscores that emission factors derived from an average of all generation tend to exaggerate avoided emissions, as the estimate includes emissions of all base load generation, even though they are not displaced by energy savings during a large portion of the year. This base load generation generally contains higher pollutant emissions than the gas-fired generation that follows the load most of the year. We consistently have sought to better identify the operating margin to improve the accuracy of the emission factor estimate.

However, it is appropriate to ask whether the added effort of matching savings with emissions on an hourly basis—thus moving from an average across all hours to a TOS estimate—is worth the additional effort. Findings reported in Table 3 (below) suggest the value may not be worth the effort if load shapes must be developed specifically for the avoided emissions estimate.

For Focus, however, these load shapes have already been developed as an important input to the benefit-cost analysis more generally used to assign avoided costs to energy savings. Once these have been developed, one can also apply the load shapes to avoided emissions with relative ease. Hence, no strong argument exists against the resulting, added precision.

On balance, we believe the TOS approach represents a worthwhile improvement in emissions estimates; it has become standard for Focus evaluations. Beyond question, much of the value of this additional effort depends on the quality of load shapes available for apportioning savings. It also benefits from improved information regarding: plants on the margin; future efforts to control emissions

[6] These data reflect the TOS study reported above, but include the full portfolio of programs, not just residential programs.

through retirement of older, high-emission plants; and installations of emissions controls on existing plants.

Results for Focus Displaced Emissions: 2012 Program Year

Due to evaluation budgeting priorities, emission rates analyses are not conducted every year as part of the Focus evaluation activities. However, one benefit from observing a series of emission rate measurements over time—approximately alternating years since 2002, in the case of the Focus evaluation activities—arises in the ability to forecast trends. We estimated the generation emissions rates shown in Table 3 (below), and applied to the annual Focus direct energy impacts in 2012, based on hourly measured emissions data, drawn from EPA data used in the TOS model.

Emission Rate Forecasts for the Focus Programs

Since the estimation used earlier EPA data, and derived from an earlier Focus program year, the rates were projected forward for 2012 by estimating a time-series regression equation on each emission type. Two factors in our data over this particular time frame make estimating emission trends difficult, despite having taken measurements over time. First, we have selected a period of years where the conversion from coal to gas fuel has been particularly vigorous. DOE estimates suggest this trend will taper over the next ten years. Second, shifting NERC boundaries and our decision to follow those shifts in defining marginal emissions means changes over time are a complex result of operating changes and the mix of facilities on the grid.

However, the resulting models for all three emissions produce strong results, with good R2 values (ranging by emission type from 0.40 to 0.56) and significance levels (P-values less than 0.0001). The forecasting analysis omitted Hg, thus the emission rate in Table 3 reflects the value obtained from an earlier analysis for Focus.[7]

Table 3. Emissions Rates

Emissions	Generation lbs/MWh	On-site Therms lbs/Therms
NO_x	2.42	0.009804
SO_2	1.50	0.0000588
Hg	0.0000154	0.00000002549
CO_2	1,660	11.76

Generation factors used derived from *Quantifying Environmental Benefits of Focus on Energy: Emission-rate Estimates 2002 to 2006.* (Rambo, Ward, & Sumi 2008). Therm factors used derived from EPA's *E-Grid 2000 database*, with data for the MAIN and MAPP NERC regions from 1998 (EPA 1998). The update drew upon an Eric Rambo and Bryan Ward memo, dated January 5, 2007.

As shown in Table 4, using the marginal emission rates and evaluation-verified net electricity savings estimates, the Focus programs' energy impacts potentially displaced the following in 2012: 1,128,211 pounds of NO_x; 699,305 pounds of SO_2; almost 963 million pounds of CO_2; and 6 pounds of Hg.

[7] For details of the forecast analysis, please see "Quantifying Environmental Benefits of Focus on Energy: Emission Rate Estimates 2002 to 2006," Focus on Energy Evaluation, October 2008.

Table 4. Verified Net Emissions Displaced (Pounds) for 2012 Focus Energy Impacts

Focus on Energy	Verified Net MWh	Verified Net Therms	NO_x	SO_2	CO_2	Hg
Res/Non-Res Total	466,204	16,160,857	1,128,211	699,305	962,952,334	6.00

Comparison of Emissions Quantification Statistical Approaches

In an effort paralleling our current emissions research for Wisconsin, this section reports on a collaboration between the authors, the Public Service Commission of Wisconsin (the state agency overseeing the Focus programs), and the EPA.

Working with a contractor, EPA recently developed the AVoided Emissions and generation Tool (AVERT), which is a statistical dispatch simulator model using EPA's hourly generation and emissions data—the same data used in the Wisconsin research.[8] The model predicts hourly changes in generation, and associated changes in air emissions at individual electric generating units (EGUs), resulting from EE or RE resource impacts in a specific geographic region. This approach identifies a cohort of units on the margin, based on past unit behaviors at particular electricity load levels, combining the resulting emission rate for each hour with energy savings estimated for that hour.

Thus, in a method using the same underlying logic as the Wisconsin emissions quantification approach, the hourly emission factor is properly weighted by the timing of savings, a method expected to yield a more accurate estimate of displaceable generation. Comparing the emission factor results offers a useful benchmark for EPA's AVERT and its associated emission quantification approach, as developed in EPA's Roadmap for incorporating EE/RE policies and programs in air quality plans (DeYoung & Dietsch 2012).

Results From Initial Beta Testing of the EPA Statistical Dispatch Simulator Model

The first step in running EPA's AVERT is to input the regional data file corresponding to the region of interest, which in the case of Focus is the Upper Midwest region. The data file supplies AVERT's main module with the historical generation and emissions information for each EGU, as maintained by EPA in its Acid Rain Program unit level data (Air Markets Program Data). After loading the regional data file, the user must then provide one of two inputs:

(1) A load reduction schedule – a stream of load reduction values for every hour of the year; or
(2) A proxy load reduction shape developed using different options available in the tool.

With the available time and resources for this initial beta test, we could not develop a manual load reduction schedule—an 8,760 stream of load reduction values for the 2012 energy impacts attributable to Focus. Instead, with assistance from EPA's contractor, we developed a proxy load reduction shape that distributed the Focus 2012 impacts (net) across all hours as a percentage reduction in total load for the Upper Midwest EGU region. This distribution approximated the generation price curve, as set by the fossil-fired EGUs. Thus, the reduction shape assumed the Focus programs impacts essentially followed the load. As we now understand, this greatly affected the emission rate estimation,

[8] For the initial beta testing of this new EPA tool, the authors paper gratefully acknowledge the assistance of Robyn DeYoung of EPA's State and Local Climate and Energy Program. We also appreciate the guidance in this testing of EPA's contractor, Synapse Energy Economics, Inc., and the lead tool developer Dr. Jeremy Fisher.

as we obtained emission rates that, compared to our earlier Focus evaluation estimates, were two to three times higher for SOx and NOx, and about ten times higher for CO_2.

In considering EGUs on the grid supplying Wisconsin, the dominant generation fuels are fossil-based—coal and natural gas. In this situation, if an EE portfolio yielded load reductions that corresponded exactly to demand on the grid, higher emission factors would result (as we estimated with EPA's AVERT). However, Focus (or any other portfolio) is designed to be more "efficient" in reducing load (i.e., more load reduction occurs when it is most needed), which occurs for the Upper Midwest region when gas tends to be on the margin (producing lower emission factors). We have concluded the proxy load reduction shape we used (with no other choice available) caused the tool to identify more coal-fired marginal EGUs (rather than natural gas), hence higher emission rates resulted.

We expect to continue use of EPA's new tool AVERT for future Focus evaluations of emissions effects. However, the key finding from the initial beta testing has been a manual stream of hourly load reductions values *developed specifically for Focus on Energy* will be essential to achieve more accurate emission estimates using the tool. EPA has also anticipated this need, and—prior to public release of the tool— is developing a much expanded set of options for tailoring program-specific load reduction schedules, such as residential lighting, HVAC, and high-efficiency appliance programs, as well as commercial lighting and HVAC equipment programs that can be integrated into AVERT.

Conclusions

The Value of Rigorously Estimating Displaced Emissions for EE and RE Programs

As electric consumption decreases due to the benefits and costs flowing from EE and RE programs, such as those delivered by Focus, greater attention turns to the avoidance of pollution emissions from generating plants. These concerns coincide with state implementation plans (usually referred to as SIPs) for attaining federally mandated air quality standards, the primary purpose for EPA's development of its statistical dispatch simulator for quantifying emissions impacts.

With the prospect of a "cap and trade" market for CO_2 emissions a reasonable likelihood, quantification and monetization of pollution may help further shift the balance in favor of program-based energy savings. Critical to this development, however, will be a rigorous, defensible, and clear methodology for assigning credit to programs.

Rigorous estimation of EE and RE programs' effects on grid-connected electric generation offers several important values—primarily the near-certainty, based on scientific evidence, that problems caused by global warming and climate change will not abate without intervention. EE and RE programs produce environmental benefits by slowing the growth of electricity demand, thereby avoiding emissions that otherwise would be produced by increased power generation.

The EPA regulates criteria air pollutants under the Clean Air Act's National Ambient Air Quality Standards (NAAQS). EE programs have significantly reduced two NAAQS criteria pollutants emitted in generating electricity: SOx and NOx. The processes also emit CO_2 and other GHGs, such as methane. Thus, with greenhouse gases linked to global warming and climate change, and EE programs contributing to decreased power production, these programs can and should be credited with impacts on GHG mitigation. The extent of that credit will depend on the estimation of impacts.

Sources of Uncertainty and Limitations to Estimating Emission Reductions

Supporting documentation for EPA's statistical dispatch simulator includes an important and thought-provoking caveat addressing "limited resolution":

"…users should exercise caution when reviewing very small-scale projects. It is recommended that the smallest size project tested should be around 200-300 MW of capacity." (Fisher, Knight, Stanton & Biewald, 2013)

In dealing with this resolution issue (and the relative scale of EE/RE programs compared to the grid) while conducting the emissions quantification research for Wisconsin, we consistently included language such as: "We use the term 'displaced' because it is typically not feasible to verify that power generation is reduced and associated emissions have been avoided."

We find the caveat sobering, specifically in considering Wisconsin's Focus EE/RE programs. Funded at approximately $60M to $80M per year, Focus programs have never approached annual projected impacts of 200 to 300 MW. Only by considering *lifetime* measure energy impacts in aggregate (i.e., verified gross lifetime demand reductions) did the programs approach the 200 to 300 MW level, and that required the first six years of *cumulative* energy impacts.

Further, in modeling project outcomes, demand reductions typically do not cumulate across years. When modeling program impacts relative to the appropriate electric grid, the 200 to 300 MW resolution threshold may well offer a credible, empirically justified project size for statistically detecting emissions impacts. Thus, a legitimate question arises: what percentage of EE/RE programs nationally (total portfolios within a state or region) attain this project size?[9]

Quantifying and crediting emissions impacts to EE/RE programs also may have to account for other EPA emission budget programs (e.g., Clean Air Interstate Rule, Cross-State Air Pollution Rule). In applying displaced emissions results, it may matter if EGUs fall under the jurisdiction of a program for the same pollutant that the user utilizes for quantifying emission reductions.

For example, to the extent that cap and trade programs tend to become the primary mechanism for controlling emissions (e.g., NOx, SOx), reductions associated with voluntary programs, such as EE/RE programs, may no longer serve as a viable part of these emissions crediting systems. By limiting total mass emissions (for source categories, including electric generating units), cap and trade programs automatically account for any action reducing emissions, including EE and RE. In terms of cap and trade program protocol requirements for *net* impacts (whether termed "surplus" or "additional"), in the absence of retiring allowances commensurate with the EE program emission reductions, EE emissions may not be considered surplus to emissions reductions attributable to the cap and trade program.

Two Additional, Important Reasons for Rigorously Estimating Displaced Emissions for EE and RE Programs

EPA's plan to designate EE programming as a "best available control technology" (BACT) for GHG mitigation serves as a primary rationale for demonstrating the value of emissions credits. If EPA chooses to exercise regulatory authority in GHG mitigation, major emitting sources—prominently including electric generators—will be required to implement BACTs. This will enhance the value in estimating emission impacts of EE programs, as the programs will become a formally recognized and mandated GHG control technology. Proposed regulation of Hg will likely reinforce this BACT designation.

Finally, as applied in Wisconsin, use of expanded benefit-cost tests readily accommodates estimation of power generation emission impacts. Cost-effectiveness analysis provides a tangible means to include emissions effects as program benefits.

[9] California would perhaps be the only state with programs achieving this magnitude of energy impacts annually.

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