Selecting an Appropriate Approach for Calculating Displaced Emissions for Different Energy Efficiency Projects and Program Types

Dr. David Sumi, PA Consulting Group, Madison, WI
Bryan Ward, PA Consulting Group, Madison, WI

Abstract

Markets and regulatory initiatives are emerging that recognize as a quantifiable benefit the emissions displacement (or possibly avoidance) from energy efficiency (EE) projects and programs. However, in quantifying these benefits it is important to select a calculation approach that is linked to the objectives of the project or program.

There are various approaches to calculate displaced emissions, and the emissions can be associated with grid connected electricity generation, non-grid electricity generation, and site-specific avoided fossil fuel usage. The approaches vary importantly in rigor and reliability – and cost to implement. These are the primary reasons why the method should be appropriate to the program type and objectives. Some key differences in methods typically involve three important considerations from air emissions measurement protocols: *boundary issues, additionality,* and the rigor used in calculation of *emission factors*. The more rigorous (and reliable) approaches include boundary and additionality assessments as well as rigorous calculation of emission factors. This paper will discuss these considerations and describe how, depending on program type and objectives, they can be handled in the calculation of displaced emissions from EE programs.

This paper starts by identifying different project and program types based on their objectives, and then suggests approaches for estimating displaced emissions that are appropriate to the program type and objectives. These estimation methods are briefly summarized. Distinctions in emission mitigation objectives are described for EE projects (site-specific), regulatory mandated programs, voluntary programs (those where emissions are a secondary benefit vs. programs where the emissions are the primary objective). The methods used to calculate displaced emissions for Wisconsin's Focus on Energy Program are discussed as well as current efforts to refine those calculations. Focus currently has two separate objectives for calculating displaced emissions (both represent a secondary benefit to the primary goal of energy impacts) – one requiring less rigor and the other requiring greater rigor. In particular, the considerations of additionality and state-specific calculation of emission factors are described (estimating grid boundary average emission rates for marginal electric generating units – EGUs).

This paper will assist EE program sponsors in matching their objectives to appropriate approaches within resource constraints. When an EE program's objective is primarily saving energy (and/or demand), displaced emissions are a co-benefit that can be quantified with a simple approach. In contrast, where there is a regulatory mandate for emission mitigation – and especially if displaced or avoided emissions are to be monetized for a trading program – more sophisticated methods are needed.

Introduction

Energy efficiency can impact the emissions associated with the production of electricity and/or thermal energy from fossil fuels[1]. As noted above, however, emissions impacts from efficiency projects have typically been treated only qualitatively as a non-quantified benefit. This is changing as there is increasing interest in quantifying these benefits, both for conventional pollutants such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), mercury (Hg) and particulates (PM), as well as greenhouse gases (GHGs), primarily carbon dioxide (CO_2) from fossil fuel combustion. This discussion focuses on EE programs as opposed to site-specific EE projects done outside of any program.

Program Types and Emissions Objectives

The main program distinctions currently can be seen as:

1. Regulatory mandated programs targeting specific emissions

2. Voluntary programs – where emissions are a secondary benefit

3. Voluntary programs – where emissions are the primary objective

Regulatory mandated programs

In the U.S., these programs have tended to use the "cap and trade" mechanism to control specific emissions in the power generation sector. Perhaps the best examples are the Clean Air Act Title IV acid rain SO2 trading program, and current capping of NOx emissions during the summer for 21 states under the Clean Air Interstate Rule. These programs do not directly impact EE programs (or their evaluations) because considerations like *boundary issues*[2] and *additionality*[3] are pre-determined by the program, and EE programs cannot claim actual emission reductions for these capped pollutants – unless allowances are retired (or other "set-aside" arrangements are employed for the allowances).

If EE programs do not reduce total emissions under a cap and trade program – and allowances are not retired, what is their environmental value? The conventional argument is that the emission reduction effects of EE programs help to minimize the cost of compliance in cap and trade programs – a central goal of this mechanism. In addition, in EE program net benefit-cost analyses that include economic effects (e.g.,

---

[1] This paper uses the term "displaced" emissions. This derives from the fact that most investor-owned power plants are included in a federal cap and trade program (Clean Air Act Title IV, and the upcoming Clean Air Interstate Rule). In general, with cap and trade systems emissions cannot be considered "reduced" or "avoided" unless EPA lowers the cap.

[2] The term additionality is used in emission mitigation quantification protocols to refer to the question of whether a project or program will result in emissions changes that are additional to changes that would have occurred in the absence of the project or program activity.

[3] The term boundary issues refers to the defining of all of the emission sources affected by activities of a project or program. A common example is when reductions in emissions from one power plant (e.g., that are attributable to reduced energy demand because of an energy efficiency program) are displaced to another emission source.

economic modeling of dollar flows attributable to the program), the trading program value of allowances can be included as a monetized benefit accruing to the IOUs in the cap and trade program.

Voluntary programs – avoided emissions are secondary goal

This has traditionally included nearly all U.S. EE programs, and the calculation and reporting of displaced emissions – if done at all – helps to substantiate a program co-benefit (e.g., for benefit-cost analysis). More rudimentary approaches have typically been used to estimate the displaced emissions, with default values used to calculate the net savings and default emissions factors (e.g. national) used to calculate the displaced emissions.

EE programs can potentially qualify for emission mitigation programs (typically GHG) where a variety of different instruments are offered – registries, credits, offsets, certified reductions, or allowances – depending on the emissions program objectives. The types of projects that are eligible and M&V requirements for those projects can vary significantly across these emissions mitigation programs. Many of these programs are in the early stages of development. For energy efficiency projects (site-specific) and programs (aggregations of projects) to be an eligible source for tradable instruments, the relevant market must accept grid-connected purchased electricity reductions. The market will typically provide guidelines for GHG emission rates to be used for electricity production.

Voluntary programs – emissions are primary

In the future the trend could be toward EE programs with both energy impacts and emissions mitigation as primary goals, where the EE impact evaluation protocol must rigorously address additionality (i.e., net savings beyond what would have occurred in the absence of the program). Then, to quantify the associated emissions effects, a boundary assessment may need to address "leakage" (e.g., reduced emissions in the program area are being displaced to an adjacent territory). And, emission factor calculation would require greater rigor and precision (e.g., avoid system average rates in favor of mid-effort analyses – or perhaps even hourly dispatch modeling calculating EGU-specific emissions – more on this below).

In the U.S. this is the "leading edge" – and a policy front where the EE program evaluation community must reach out to environmental policy- and rule-making. Where national or regional cap and trade programs are the primary emissions control mechanism there is still the option of allowance retirement (e.g., set-aside allocations of allowances) for achieving actual emission reductions (see EPA guidelines). In Europe (and globally) different types of GHG programs are developing rules for rights of ownership to credits, fungibility of credits, liability, persistence and "delivery risk" for credited displaced emissions, double counting across programs, and other coordination issues potentially involving different trading philosophies in the U.S., Europe, and globally.

Establishing Credibility for EE-attributable Emission Impacts

For EE to translate into emissions that are viewed as credible requires: 1) verifiable energy impacts; and, 2) acceptable estimation of the emissions effects associated with those energy impacts.

Protocols for both of these are being applied in countries (sub-national regional jurisdictions) and are under development in others. The EU may be ahead of the US in many ways since they have been applying protocols that guide efforts utilizing EE as a mechanism for meeting their emissions reduction targets under they Kyoto protocol. An example of the protocols for verification of energy impacts is the California CPUC/CEC EE Protocols for Impacts and M&V. For estimation of emissions effects the GHG Protocol for Project Accounting (World Resources Institute and the World Business Council for Sustainable Development) is a standard, widely accepted protocol.

In order to help understand how these protocols establish credibility of the effects they quantify, we have simplified the protocols to the four steps proposed as essential to each – and some of the key questions that must be answered

1. Identifying intervention (project or program) activities and their primary and secondary effects
   - What is the intervention and its direct and indirect effects?
2. Specifying baseline conditions
   - What is the alternative(s) to the project or program activities?
   - Are the effects additional to the alternatives (i.e., free-ridership – the effects would have occurred even without the intervention and associated incentives; also seen as whether the intervention activity and its baseline scenario are effectively identical)?
   - What are the pre-intervention energy consumption and emissions associated with the baseline?

3. Post-intervention monitoring and quantification of project effects (see next subsection, below)

4. Documentation and reporting of quantified effects

Calculating Air Emission Impacts

When suitable EE impact evaluation protocols and air emissions quantification protocols have credibly established net program impacts (and have accounted for additionality and boundary assessment), there are then various ways to actually calculate the emissions impacts. For EE programs, a typical approach is to multiply the program's net energy savings by emissions factors (e.g. pounds of CO_2 per MWh) representing the operating characteristics of displaced emission sources to estimate annual, seasonal, monthly, or hourly emission values. The basic equation is:

Where t = time period of analysis,

Avoided Emissions_t = (Net Energy $\text{Savings})_t$ x (Emission $\text{Factor})_t$

Then, there is a continuum of analytic rigor for calculating emission factors which we simplify to three basic approaches:

- A simple approach – a "*system average*" obtained from a database (e.g., EPA has emission factors for each state).

- So called "middle ground" calculation methods, including methods for estimating *marginal hourly emission rates* (modeling plants that were actually marginal producers).

- And, likely the strongest case for maximizing the value of emissions credits from EE programs, calculating displaced emissions based on electricity *hourly dispatch modeling*.

As is usually the case in evaluation, more reliable approaches and methods cost more. Based on review of the GHG Protocol as an important example, the additional costs for obtaining larger emissions value from EE programs are likely to come from rigorous boundary and additionality assessments, as well as more complex calculation of emission factors.

EE program sponsors, together with evaluators, will need to assess program objectives and the environmental value sought to determine approaches that are appropriate. It is important to keep in mind that if emissions impacts must meet requirements specific requirements to be considered legitimate for programs external to the EE program it is vital to consult the regulations of the specific program to which the impacts will be applied (e.g., tradable offsets, allowances, or other program-specific credits). The remainder of the paper will look at these three approaches and summarize their strengths, weaknesses, and the key technical concepts inherent to each.

Voluntary Programs Where Emissions Are Secondary - The "System-average" Approach

For most EE programs the primary goal (perhaps sole goal) is saving energy (and/or demand). In these cases, where emissions benefits are at most a secondary goal, a simple approach is estimating emissions effects is usually most appropriate. In these situations, the EE impact evaluation may use either gross or net estimated energy impacts. Also, additionality would likely be simply assumed, and an emissions boundary assessment would not be done. And, as noted above, it may not be appropriate to report <u>avoided</u> emissions if the EE activities are associated with emissions from capped sources regulated within a cap and trade program.

The "system average" approach for calculating emissions effects from EE programs uses regional or system average emission factors. This would involve dividing total annual emissions from all electric generating units (EGUs) in a geographically specified region (or power system grid) by the total energy output of those units. Sources for these system average emission factors include EPA's eGRID database (U.S. EPA, 2007), and the Clean Air-Climate Protection Software (CACPS, ICLEI, 2003). These sources provide calculated emissions factors averaged at the utility, state, and regional levels. They also include rates that vary by time period.

While this emissions factor approach is easy and very low-cost to apply, there is greater uncertainty associated with the resulting estimated emissions impacts. The uncertainty tends to be attributable to one key factor: where marginal generating units displaced by EE programs have quite different emissions characteristics from the non-marginal (i.e., base load) generating units, the system average emissions factors will be biased toward reflecting the base load units.

Voluntary Programs Where Emissions Are Primary - The "Middle-Ground" Approach

When EE programs have both energy impacts and emissions mitigation as primary goals, the EE impact evaluation and the application of an emissions quantification protocol will need, respectively, to: (1) rigorously address additionality (i.e., net savings beyond what would have occurred in the absence of the program); and (2) conduct a boundary assessment that may need to address "leakage" (e.g., reduced emissions in the program area are being displaced to an adjacent territory). However, once such program-attributable energy impacts are produced by the evaluation, an approach for measuring displaced emissions is required – and the emission factor calculation will require greater rigor and precision, e.g., avoid system average emission factors. An alternative to the system average factors is the "middle-ground" approach.

The Wisconsin Focus on Energy "middle-ground" approach. In order to express the emissions-related effects of Wisconsin's public benefits programs, and potentially use this information in program design, the Focus on Energy evaluation's work on emission factors has included:

1. Calculating emissions factors for estimating power plant emissions that may be displaced because of Focus on Energy energy savings.
2. Calculating emission factors for on-peak and off-peak energy savings during the winter, summer, and shoulder months for estimating potential emissions impacts for measures that save energy disproportionately in specific seasons or times of the day.

The key deficiency of the system average approach to emission factor estimation is a central objective for the middle-ground approach: the calculations assume that the energy savings results in reduced or displaced generation at the power plant *for those power plants operating at the margin during a particular time of day or season.*

As indicated above, the EPA and others have produced emission factors for Wisconsin. These factors are typically calculated as an average of all generators in the state or region, or of all emitting generators (excluding, for example, hydro and nuclear). As such, they do not take into account two critical aspects. First, given the size of EE programs at present, their impact on generators is likely to be felt at the margin, rather than having an effect on base-load plants. In other words, any plant that might be shut off at any given hour because of savings from EE program participants is likely to be a marginal producer, one called into action to meet current changes in demand then shut off, rather than a base-load plant that operates much of the time. The emissions profile of a marginal power producer can be very different from base-load plants so removing it from the generation mix could cause emission savings that differ significantly from the average.

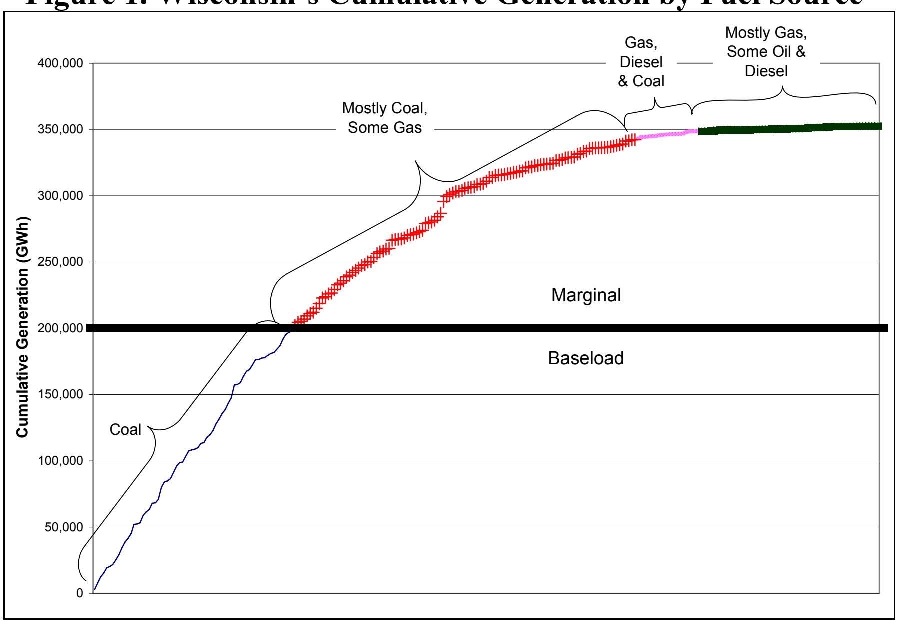
Second, if emission factors are ***yearly*** averages they do not tell us anything about emissions avoided at particular times of the year or times during the day. If an intervention in the market is to be designed specifically to reduce emissions, it is advantageous to target measures that produce savings during seasons and times where the marginal power plants are particularly dirty-that is times when the marginal plants are those that produce the most emissions per MWh.

To create a time-of-day and season emissions factors for Focus on Energy, we created a model that incorporates *hourly* monitored emissions and power generation data from EPA data. The model identifies plants that were actually operating in the specified seasons and times, predicts which were the marginal producers, and then calculates emission factors from all producers operating on the margin during the specific times and seasons.

We note that the effectiveness of targeting efficiency programs to specific parts of the load curve depends on the structure and operating constraints of the generation market involved, and is therefore based on the assumption that the power dispatch sequence and plant emission factors are sufficiently predictable from year to year. We think this assumption is warranted in Wisconsin's non-restructured electricity supply environment.

One of the key findings from the season and peak analysis was that in Wisconsin the highest emissions occur in off-peak hours and the lowest in on-peak hours. This is consistent with the general observation that coal provides most of Wisconsin's base load generation (ignoring nuclear and hydro since they emit no NOx, SOx, etc.) and natural gas plants are used more often as peaking plants. Thus, the key determinant of the emissions factors is the amount of power supplied by natural gas burning plants. Coal is the predominant fuel source in all hours and seasons (see Figure 1), but natural gas provides a significantly larger fraction of total power during times of high system peak compared to other times of the year.

Figure 1. Wisconsin's Cumulative Generation by Fuel Source[a]



[a] Does not include non-emitting sources such as nuclear, hydro, and wind.

In addition, in recent emissions research for Wisconsin we noted significant reductions in the factor estimates of the pounds/MWH for NO_x and SO_x – and an increase in CO_2 -- from an earlier analysis based on 2000 EPA data. These changes suggest other analyses that would further inform the state as to trends in generation fuels being used and resulting effects on emission factors applicable to Wisconsin's generation portfolio. This is another advantage of the middle-ground approach: with a time-series perspective on emissions data it becomes feasible to project changes in emissions factors into the future. This provides a better estimate of savings within the EE program's benefit-cost analysis horizon as changes in emissions affect the optimal mix of energy conservation measures.

A related advantage to the use of time varying emission factors with this middle-ground approach is that these factors can be matched with the time variability in EE program energy impacts. Even if an hourly load shape is not applied, to be able to use seasonal weekday, weekend, night, and daytime emission factor values matched to the equivalent time periods for the net energy impacts provides a more precise estimate of emission effects.

Finally, this middle-ground model can be customized to examine any subset of generators in the U.S. A key point is that the more accurately you can model the marginal emissions rate, the more accurately you can estimate the emissions profile of energy efficiency measures. The importance of this point is addressed next – expressing EE energy impacts in hourly (8760) terms to facilitate more accurate calculation of displaced emissions.

Voluntary Programs Where Emissions Are Primary – Hourly Dispatch Modeling

The strongest case for maximizing the value of emissions credits from energy efficiency programs depends upon the ability of EE program evaluators to demonstrate via detailed analysis of electricity dispatch the specific impact of the EE measures on the grid system. In the following paragraphs, we suggest why this may be the case, and how evaluators can address this challenge. [Note: we emphasize that the following describes the "strongest case." There are, however, voluntary carbon credit programs where this does not apply – with carbon offset programs perhaps the best alternative example to cap and trade regimes.]

In 2004 the U.S. Environmental Protection Agency (EPA) issued *Guidance on State Implementation Plan (SIP) Credits for Emission Reductions from Electric-Sector Energy Efficiency and Renewable Energy Measures.* This document focuses primarily on NO_x emission reductions, via a cap and trade program, as a means of achieving compliance with the Clean Air Act for ozone. However, an April 2007 Supreme Court decision signaled that the Clean Air Act could also regulate CO_2. However, in the guidance document cited above, EPA states that, "By limiting total mass emissions (for source categories including electric generating units), cap and trade programs automatically account for any action that reduces emissions, including energy efficiency and renewable energy." Their logic is as follows:

"If an energy efficiency program causes several EGUs that are part of a cap and trade program to scale back the amount of electricity they generate and therefore reduce overall emissions, it may be difficult to show that these reductions meet the 'surplus' criteria for crediting the measure. This is because the units are still allowed to emit up to the same number of allowances in the program even though the amount of electricity they need to generate has been reduced. The energy efficiency or renewable energy measure, in effect, allow the EGUs to comply with the cap and trade program with a slightly higher average emission rate and a theoretically lower allowance price. Therefore, the estimated emission reductions from the energy efficiency or renewable energy measure would typically not be surplus, and would essentially be double counted if we permitted the allowances that were freed up by the measure to be used and also provided additional SIP credit for the energy efficiency action" (page 10).

The guidance from EPA goes on to state that a way to clearly demonstrate that emissions decreased "despite the cap and trade program and the ability for plants to sell more electricity to other areas" will likely require "a detailed analysis of electricity dispatch and allowance markets to determine the specific impact of the measures on the system" (page 10).

So how might evaluators meet this challenge? The task is to convert the program impacts that are produced from the evaluation effort to load impact shapes across the 8,760 hours of the year, and then combine this with the marginal hourly emission rates (as described above). Fortunately this is not a difficult task; however, it does involve more effort than what is needed from the typical energy program impact evaluation effort[4].

First, the evaluation approach must be structured to deliver kW impacts over the 8,760 hours of the year. This can be established during the evaluation design stage, in which a study might employ hourly metering approaches, or when hourly impacts can be estimated via a building simulation model, or when program impacts can be distributed across 8,760 hours using technology-level, sector-specific, and climate-specific end-use load shapes that match the technologies covered by the program and the participants locations (climate zones). In these cases, it is possible to distribute the program's impacts across the hours using distributions that match the appropriate load shapes. The process of converting to an 8,760 load shape for a program is not an evaluation *revolution*, but rather a small *evolution* of what we already do most of the time. The evaluation revolution comes at the next step: converting the 8,760 program load impacts to a reduction in greenhouse gas emissions. Fortunately, as cited above, we also have these tools.

As a result of these developments, the evaluation field can now use dispatch information, or build dispatch models that reflect any given territory[5]. These dispatch models can then be periodically updated to match changes in the dispatch profiles as they occur over time. Thus, both today and in the future, most EE program evaluators will be able to determine the fuel source and generation mix that is not being used to match the demand reduction profile provided by the EE program. We suggest that this is a promising approach to satisfying both the displaced emissions calculations for the GHG Protocol – and the "additionality," or "surplus," requirements of both the GHG Protocol and cap and trade program sponsors (e.g., EPA).

Conclusions

In summary, a number of technical and market conditions make assessing the emission impacts of EE programs something that can be immediately developed, adopted and used to assess these emission impacts. These conditions include the following:

1. The environmental community and the public as a whole are supportive of EE programs as one of the most effective ways to reduce GHG emissions;

---

4 While evaluation approaches that determine energy impacts across the 8,760 hours in a typical year are permitted within the California Evaluation Protocols, they are not required and are seldom used. Most evaluations report annual kWh, peak kW, and the number of therms saved. Evaluations conducted under the California Evaluation Protocols must provide kW savings over four time periods, including noon-1PM, 1PM-2PM, 2PM-3PM and 3PM to 4PM during the months of June, July, August, and September, for each weather zone in which the program operates.

5 Or more easily, dispatch models can be built for any area of the United States and use software, such as DSMore, for a specific geographical area corresponding to the boundaries of the EE program.

2. A plethora of supportive public and private stakeholders across the country moving in the direction of focusing significant support and resources on GHG reduction efforts, with our without federal support or direction;
3. The Supreme Court re-emphasizing that it is part of the US-EPA's responsibility to regulate GHG emissions and setting an expectation that these issues are addressed;
4. The appearance of voluntary, regulatory and market-based local and regional structures for crediting value to emissions mitigation efforts through a number of plausible approaches, such as EE;
5. The ability of the EE program evaluation community to rapidly and reliably estimate emission impacts achieved through EE programs using net "middle-ground" or dispatch analysis approaches; and,
6. The presence of established standardized evaluation protocols that can evolve to incorporate the documentation of emission impacts using approaches that can support emission benefits of EE programs for various other regulatory and emission market purposes.

The emission quantification approach used by EE program administrators and evaluators will depend on the specific value an efficiency program seeks and will hinge on the question: What are the program's policy objectives? EE program sponsors, together with evaluators, will need to assess program objectives and the *environmental value sought* to determine approaches that are appropriate.

References

Broekhoff, D. 2007. *Guidelines for Quantifying GHG Reductions from Grid-Connected Electricity Projects.* Washington D.C.: World Resources Institute and World Business Council for Sustainable Development.

Guidance on State Implementation Plan (SIP) Credits for Emission Reductions from Electric-Sector Energy Efficiency and Renewable Energy Measures. 2004. http://www.epa.gov/ttn/oarpg/t1/memoranda/ereseerem_gd.pdf

California Energy Efficiency Evaluation Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals (California Evaluation Protocols): State Of California Public Utilities Commission's (CPUC) April 2006.