COMPARISON OF ALTERNATIVE AVOIDED EMISSIONS METHODOLOGIES APPLIED TO SELECTED NORTHEAST POWER MARKETS

1.0 Introduction and Overview

This paper provides an overview of recent developments in improved methodologies for quantifying avoided air emissions from energy efficiency and renewable energy (EERE) in the U.S. electric power sector. The paper is focused primarily on new and improved methodologies and tools to assist government agencies to more accurately quantify the emissions reduction benefits of EERE programs in achieving air quality and greenhouse gas (GHG) emission reduction goals. The paper also compares these new methodologies with the quantification protocols currently employed by the Climate Registry and other governmental and non-government entities for reporting GHG emissions and GHG emissions inventories. The work discussed in this paper has been largely funded by the U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy under its Clean Energy/Air Quality Integration Initiative.

2.0 Summary

The main findings of the review are as follows:

1. Most commonly used methodologies for calculating air emission reductions from EERE technologies rely on avoided emission factors compiled by a contractor into the Environmental Protection Agency's (EPA) Emissions & Generation Resource Integrated Database (eGRID). Yet, our review found that the eGRID system average methodology that has been adopted by the Climate Registry and other entities **understates** the emission reduction benefits in the PJM and Upstate New York power markets of five EERE technologies by 70% or more when compared with a time-matched marginal (TMM) methodology.
2. A time-matched marginal (TMM) methodology provides a far more accurate estimate of emission reductions from EERE programs and projects than the eGRID system average. Moreover, the TMM method can be used to produce worksheet calculator tools that provide a low-cost approach that can easily be implemented by government officials.
3. Improved methodologies and calculator tools based on the TMM methodology can enable State and local governments to more accurately evaluate the cost-effectiveness of EERE programs in reducing emissions of GHGs and other air pollutants.
4. An investment of limited funds by the DOE, EPA, and/or State agencies to create calculator tools using the TMM methodology would empower government agencies and businesses to enhance the deployment of EERE technologies to meet State climate, energy, and air quality goals.

3.0 BACKGROUND

The electric power sector is responsible for approximately 40 percent of the carbon dioxide (CO_2) emissions in the U.S. According to leading energy experts, this sector will need to be dramatically transformed to meet national targets for GHG emission reductions during the next several decades. A key part of this transformation will be the adoption of strategies employing energy efficiency, conservation, and zero or low-GHG emission technologies, such as renewable energy. In order to provide comprehensive reporting of GHG emissions and to measure the cost-effectiveness of GHG reduction programs, it is necessary to improve the accuracy and lower the costs of the most widely used methodologies applied by State and local governments and the private sector.

In addition, many of the most promising, near-term strategies for reducing GHG emissions from the transportation sector, such as plug-in electric hybrids and advanced electric cars, will impact the electric grid. The implementation of these strategies will increase the importance of assuring accurate measurement of the effects of EERE technologies on the electric grid, particularly hourly and seasonal differences in GHG emissions.

Other air quality goals, including reductions in ozone nonattainment, also can be advanced by the application of EERE technologies and practices. Many of these air quality problems are most serious in certain seasons (e.g., summer ozone problems) and certain hours of the day (e.g., summer afternoons), and Federal, State, and local regulatory agencies require accurate and low-cost methodologies to measure the impact of EERE strategies in the air quality planning process.

In all energy sectors, it is important not only to use improved measurement methods but also to obtain agreement on consistent protocols for measurement and reporting of GHG emissions. This need will intensify as the Administration and the U.S. Congress begin more extensive discussions about national climate legislation and a new international climate framework.

Currently, there are widely accepted protocols setting forth a broad analytic framework to evaluate GHG emissions, such as the "Guidelines for Quantifying GHG Reductions from Grid-Connected Electricity Projects" developed by the World Resources Institute.[1] However, specific measurement standards and applications are not consistent across or within Federal and State government agencies, non-governmental organizations, and the private sector.

Moreover, there is a spectrum of measurement methodologies. At one end of the spectrum are highly inaccurate tools that measure the impact of EERE measures on the

[1] World Resources Institute and World Business Council for Sustainable Development, Guidelines for Quantifying GHG Reductions from Grid -Connected Electricity Projects, 2007. See http://www.wri.org/climate/pubs_description.cfm?pid=4277

average mix of emissions in the grid. On the other end of the spectrum are methodologies, such as power plant dispatch models, that are expensive and difficult to use and require highly trained staff. These dispatch models are out of reach for most State and local agencies, and they are also proprietary, thereby eliminating the ability to assure transparency to outside parties.

4.0 AVOIDED EMISSIONS METHODOLOGIES

EERE technologies,[1] such as wind power and solar photovoltaic systems, have zero direct air emissions and displace emissions from fossil fuel-fired electric power generation. These emission reductions occur because of the way the electric power system works. EERE technologies have zero fuel costs and very low operating costs. Thus, when renewable generation produces power, electricity supplies from other sources will be reduced or not brought online. When available, these technologies will displace generation at facilities with higher operating costs and which can be variably dispatched. Typically, these are fossil fuel-fired units, and the emissions from these units are then avoided.

At the same time, EERE technologies almost never displace nuclear power on the electric grid. Nuclear power plants are normally operated as baseload generators that run at full capacity because they have such low operating costs.

In addition, EERE technologies generally do not reduce hydroelectric power on the grid because of its low operating costs and flow constraints. Although hydroelectric generation may be shifted in time as a result of renewable energy generation, total generation at such hydroelectric plants is generally not reduced on average. The operating schedule of hydroelectric plants also may be limited by environmental constraints.

The specific types of fossil fuel-fired power units that will be displaced by EERE technologies vary significantly among states and regions of the country. Some states and regions rely on coal plants for a majority of their generation (e.g., West Virginia and parts of the Midwest) whereas other states and regions rely more heavily on natural gas fired units (e.g., California and most of New England) In addition, the total amount of emissions avoided by EERE varies by time of day and season.

In this paper, we review three alternative methodologies for quantifying avoided emissions from EERE and provide specific examples to illustrate the range of results. The three alternative methodologies produce data with the following parameters: system average emission rates, non-baseload emission rates, and time matched marginal (TMM) emission rates.

In addition, there are available proprietary electric grid system dispatch models designed for competitive market pricing purposes, and they have been used as a basis

[1] In this paper, EERE is used to refer to energy efficiency, conservation, and zero-emission renewable electric power generation. Other renewable energy technologies, such as biomass, waste-to-energy and landfill gas, do have some direct GHG emissions from combustion or other processes.

for calculating marginal emission rates from EERE. These models are not reviewed here because they are proprietary. They are not sufficiently transparent or replicable to be a suitable for use in public accounting of air emissions. They also are expensive to use.

4.1 EPA eGRID System Average Methodology

The Emissions & Generation Resource Integrated Database (eGRID) is a comprehensive inventory of environmental attributes of electric power systems in the United States. According to the EPA, eGRID is "[t]he preeminent source of air emissions data for the electric power sector."[1] The eGRID Database is derived from available plant-specific data for all U.S. electricity generating plants that provide power to the electric grid and report data to the U.S. government. This database contains air emissions data for several GHGs, including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). It also provides data for the following criteria and hazardous air pollutants: nitrogen oxides (NO_x), sulfur dioxide (SO_2), and mercury (Hg).

The eGRID database is provided in Microsoft Excel format and is publicly accessible on the EPA's web site. The U.S. EPA funds a contractor to compile various types of data, including aggregated emissions data by state, electric generating company, parent company, power control area, eGRID subregion, North American Electric Reliability Corporation (NERC) region, and U.S. total levels. Total emissions and emission rates, and total generation and resource mix are displayed for each of these levels. EPA provides the eGRID data in two major formats: (1) the system average or output emission rates; and (2) the non-baseload unit emission rates.

The system average emissions rate is calculated by taking the average emission rate of all electric generation units on the grid over a year. This system or grid average includes all units on the grid, including nuclear power plants, hydroelectric plants, and other zero-emission sources as well as fossil fuel-fired generation units. The system average emission rates rely on information from electric generation companies that are required to provide emissions data from Continuous Emissions Monitors (CEMS) to the EPA.

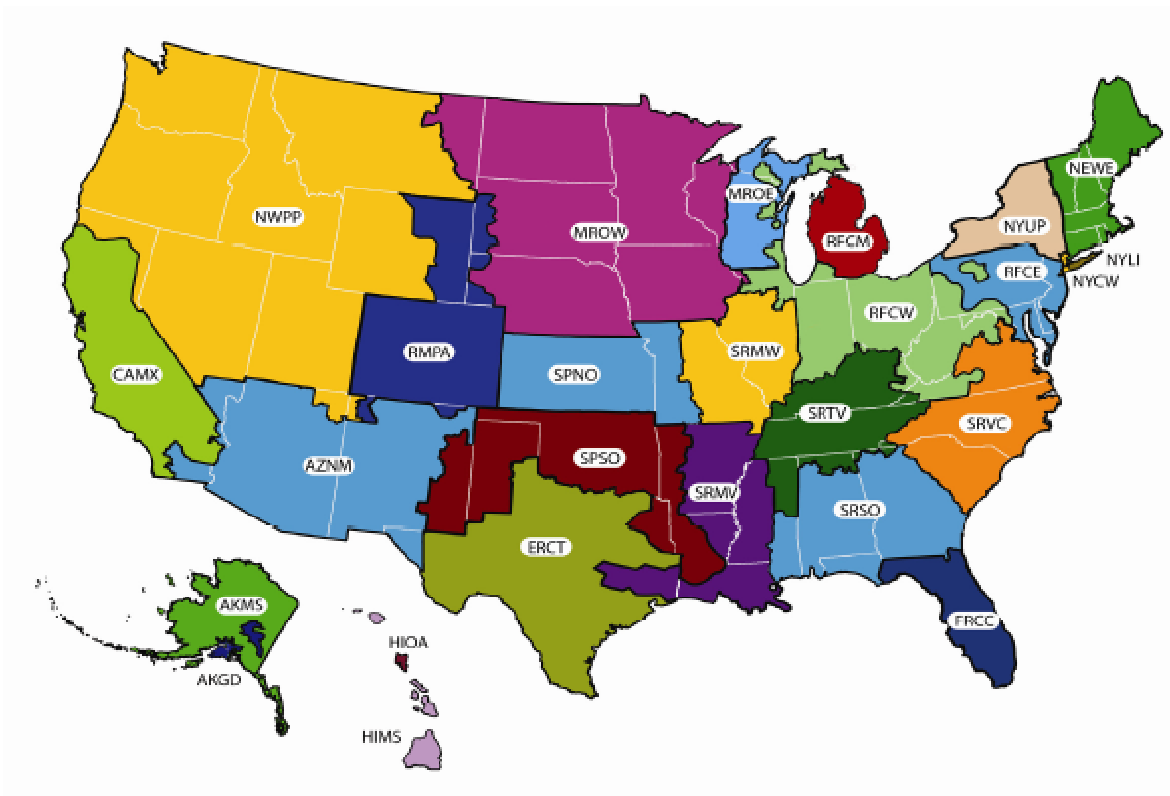
The EPA reports the system average emission rates for the eGRID regions and sub-regions shown in figure 1. These regions are based on the NERC regions and sub-regions. The sub-regions are approximately the same as the major electric power market areas in most parts of the U.S.

The eGRID Database that is currently available is based on 2005 emissions data. The sub-regional eGRID system average emission rates vary considerably depending on the amount of zero emissions sources, such as nuclear and hydroelectric power, in the regional mix. The system average emission rates in pounds per Megawatt-hour (lb/MWh) are always the lowest of the three methods discussed here.

[1] See http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html

The system average or output emission rate methodology is the accepted standard for determining the CO2 emissions for entities that are reporting such emissions from their electric power purchases under the California Climate Action Registry, the Climate Registry, and the Local Governments for Sustainability (ICLEI). Under this methodology, year-to-year changes in electric power purchases resulting from EERE technologies will be calculated as the difference between the emissions in successive years based on the eGRID system average emission rates. As a result, this methodology will understate the emission reduction benefits of EERE technologies (as discussed in Section 5).

Figure 1: Map of the US EPA eGRID Sub-Regions.



4.2 EPA eGRID Non-Baseload Average Emission Rate

The eGRID non-baseload average emission rates also are provided by the U.S. EPA at its website and in its summary reports. They also are reported for eGRID regions and sub-regions. The non-baseload average is calculated from the average emission rates of those generating units that have variable generation that follows the regional load. This includes generation at units that are usually classified as intermediate load and peak load plants. These non-baseload average emission rates will not include baseload units, such as nuclear power plants and some coal-fired units. The non-baseload emission rate is higher than the system average rate because it excludes zero-emission nuclear power units. EPA eGRID also provides a fossil fuel output emission rate for each sub-region but this data is not suitable for estimating avoided air emissions.

4.3 Time Matched Marginal Emission Rate

Over the course of several years, Resource Systems Group (RSG) has developed a methodology for estimating air emissions avoided from the implementation of EERE technologies. The analysis is based on the following steps:

a. Estimating the hourly electric power generation for every fossil fuel-fired unit in a specific power market area based on using the EPA hourly CEM data for CO2 and the average CO2 emission rate (lbs/MWh) for each unit. The CO2 emission rate is used to estimate the generation at each hour.

b. Identifying the marginal fossil fuel-fired units at each hour by using the hourly generation to identify units that track the total load at each hour. The fuel type data also is tabulated to see if the identification of marginal units is economically reasonable. Based on this information, RSG estimates average emission rates of the marginal units based on their incremental contribution to the load.

c. Creating a profile of the energy savings or energy generation on an hourly basis over the 8760 hours of the years. This profile is prepared for a particular technology (e.g., wind power, high efficiency commercial air conditioning) and for a particular region.

d. The “time-matching” occurs when the load profile is matched for a specific technology on an hourly basis against the marginal emissions profile on an hourly basis.

e. The total hourly, monthly, and annual emissions are used to produce summary charts, including hourly avoided emission rates.

f. The avoided emission rates can be used to produce a calculator in Microsoft Excel format, and this calculator provides total avoided emissions from annual generation or savings using either project-specific profiles or default regional profiles. These calculators also can be used to estimate avoided emissions on a monthly or seasonal basis.

5.0 Findings from Recent Comparison of Three Avoided Emissions Methodologies Conducted by RSG

Resource Systems Group has conducted an analysis of results from the three different avoided emissions methodologies. The analysis focused on five EERE technologies as follows: high efficiency commercial lighting, high efficiency commercial air conditioning, LED traffic lights, solar photovoltaic energy, and wind energy. In each case, RSG compared the avoided emissions from a specific technology using its TMM methodology, the eGRID system average methodology, and the eGRID non-baseload methodology. Comparisons were made in both the PJM Interconnection power market area and the Upstate New York area.

The findings are as follows:

- Avoided air emission benefits for the five EERE technologies for carbon dioxide, sulfur dioxide, and nitrogen oxide are from 65% to 120% higher using the TMM methodology when compared to eGRID system average method;
- Avoided air emissions benefits for the five EERE technologies for carbon dioxide are from 5% to 25% higher using the TMM methodology when compared to eGrid non-baseload methodology. Avoided emission rates for sulfur dioxide and nitrogen oxide can be both higher and lower within a range of 5% to 30%;
- Within the two power market areas that were studies, the emission benefits associated with the five different EERE technologies varied by only up to 3% . The variability is mainly associated with the degree of seasonal variation in electricity savings or additional renewable energy generation.
- In all cases, the results for nitrogen oxides and sulfur dioxide are more complicated and more variable than the results for carbon dioxide. These complications are related to the highly variable emission rates for these two pollutants resulting from large differences in the efficiency of pollution control technologies for NOx and SO2. In comparison, there are no pollution controls for CO2 on the units studied.

The following example highlights the problems faced by state and local governments in preparing GHG inventories and conducting other GHG accounting because of the inconsistency in avoided emission methodologies. [1] For example, a municipality in Upstate near Lake Erie in western New York is tracking its GHG emissions and reporting under the Climate Registry protocols -- using system average emission rates for its purchase of electricity. Assume that the municipality decided to reduce its GHG emissions to meet a target in its Climate Action Plan and decided to install a municipal wind farm to power its own facilities and generate 10,000 MWh per year.

Under this example, the municipality's wind power initiative would result in a decrease in reported GHG emissions to the Climate Registry of approximately 4,100 tons per year. On the other hand, the municipality might decide to purchase renewable energy certificates (RECs) for 10,000 MWh generated by a commercial wind farm. Both the RECs and the carbon reductions are certified by the Center for Resource Solutions (CRS). Using the CRS carbon protocol (that is based on the eGRID non-baseload emission rates), the emission reduction claimed would be 8,500 tons of CO2. However, the amount reported under the CRS protocol could not be reported under the Climate Registry Protocol. Moreover, using an hourly marginal emissions analysis, such as the TMM method, a more accurate estimate of the avoided emissions benefits of a municipal purchase of a 10,000 MWh of wind power or wind power RECs would be about 9,160 tons of CO2.

[1] In this example (and for simplicity), we only have considered avoided emissions from operational changes in generation in the near-term. In other words, we have not considered the additional complexity that changes in generation may have on reducing the need to build new electric generating capacity.

This example illustrates the need to provide state and local governments with the tools to measure GHG reductions more accurately and consistently.

ADDITIONAL INFORMATION

This background paper was prepared by Debra Jacobson of DJ Consulting LLC and Colin High of Resource Systems Group, Inc. with funding support from the Clean Energy/Air Quality Integration Initiative of the U.S. DOE's Office of Energy Efficiency and Renewable Energy. Ms. Jacobson and Dr. High can be contacted at djconsultingllc@gmail.com and chigh@rsginc.com, respectively.