Executive Summary

Estimating the Environmental Benefits of Renewable Energy and Energy Efficiency in North America: Experience and Methods

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For the Commission for Environmental Cooperation

When a new power plant operates in a regional electric system, the plant affects the system in a number of ways. Assuming that regional loads remain the same, the new plant will probably reduce the operation of another generating unit (or units) in the same system. Alternatively, all plants in the system might continue to operate at the same level, causing increased exports to (or decreased imports from) neighboring systems. New energy efficiency equipment has a similar effect: as demand is reduced, either generating units within the local system operate less or transactions with neighboring systems change. The result of either a new generating unit or reduced demand is likely to be a net change in air emissions across the interconnected systems.

Over the past decade there has been increasing interest across North America in understanding the net emissions impacts of specific resources that could be added (or have been added) to regional electric systems. However, estimating these emissions impacts in a comprehensive and accurate way is a complex process. The Commission for Environmental Cooperation (CEC) is interested in promoting a comparable methodology for estimating displaced emissions from renewable energy and energy efficiency across North America, in order to facilitate both trade and the development of these technologies. While many different policies and market-based mechanisms exist that have the potential to support these technologies, their potential is limited to some extent by the challenge of quantifying environmental benefits. Thus, credible and comparable methods to quantify these benefits can help to ensure that the policies and mechanisms, as well as the technologies which they are designed to support, can reach their potential. In addition, comparable methods of measuring and displaying these benefits, facilitate public awareness by showing in a consistent way the contribution these technologies can make to quality of life.

This paper explores the important methodological issues related to estimating the net air impacts of new resources in electric systems. In addition, we review fourteen projects undertaken across North America in which the emissions impacts of specific resources – both renewable projects and efficiency programs – have been estimated. Finally, we briefly explore different views of the principles that should underlie this kind of work.

There are two tasks involved in estimating the emissions impacts of specific generating resources and energy efficiency programs. These tasks are:

- Quantifying the (expected) electrical energy generated or saved, and
- Predicting how the regional electricity system(s) will react (or did react) to the energy saved or generated.

A variety of methods and analytic tools can be used for each of these tasks. The specific methods and tools selected for a given project are primarily dependent upon the resources available and

the purpose for which the avoided emissions are being calculated, and thereby the degree of certainty in estimates that are required. Generally, estimates with greater certainty also require a greater investment of resources.

The first step in predicting avoided emissions is to quantify how much energy the resource in question will produce, when and where the energy will be produced, and whether there will be air emissions associated with it. When assessing a potential new resource, one must predict how the generator or efficiency equipment will operate within the regional electric system. When assessing an existing resource, one must understand how the asset operated – when it produced energy and how much. Usually, estimating the impacts of an existing resource is easier than a new resource, because the energy generated or saved by the resource is known and does not have to be predicted.

The simplest way to predict the performance of a new asset is to estimate operation of the asset based on the typical operation of that resource type. More complex approaches include (a) using hourly production data from an existing project similar to potential new resource and (b) modeling the operation of the asset within the regional power system. The latter two approaches are more resource-intensive, but they provide results with a higher level of certainty than an analysis based on a rough estimate of production from the resource in question.

In addition to predicting the performance of the new asset, one must capture any air emissions that will come from the asset to calculate its net air impacts. Some renewable resources, such as biomass and landfill gas projects, will have air emissions. Information on the emission rates of these types of resources is available from federal agencies in Canada, Mexico and the US and from renewable energy trade associations.

The second step in the process is understanding how the resource in question will affect (or did affect) the regional system. Three methods are commonly used to do this.

1. **Displaced emissions analysis and time-specific marginal emission rates**. Computer simulation models can be used to predict displaced emissions by simulating the operation of the new resource within the regional system. These models can also be used to derive marginal emission rates for different time periods, which can then be used to estimate displaced emissions from a variety of policies and projects.
2. **Plant addition/retirement emission factors**. Displaced emission rates can be developed based on the emission rates of the new plants projected to be added to the system over the long term (from five to twenty-five years out) and the old plants projected to be retired.
3. **System average emission factors**. These rates are calculated simply by dividing total system emissions by total system generation. The emission factor is then applied to the output of the specific project to estimate displaced emissions.

When deciding which of these methods to use, a key consideration is whether the analysis will focus on the near term, the long term or both. For near term analyses (up to roughly five years into the future), marginal emission factors provide the estimates with the highest level of certainty. For these analyses, the task is to understand how the resource in question will affect the *existing* electric system. Because dispatch models can simulate the operation of the system in detail, holding other factors constant, they provide the most credible assessments of how specific resources affect system operation. To assess a specific resource with a dispatch model, one simulates system operation with and without the resource and compares the two scenarios. One can then identify which specific plants operated less with the new resource. However, dispatch modeling is labor intensive and can be costly. For projects that do not require a high level of certainty, one might be able to use system marginal emission rates derived with a dispatch model, rather than modeling each specific resource separately. To date, system marginal emission rates have been developed for several regions of the US. Where system marginal emission rates are not available, an estimate of system marginal emission rates should be used. Such an estimate should be based on the type of generating units operating on the margin in the local electric system during different time periods.

In projects where an estimate of system emission rates is used rather than dispatch modeling, it is important to use an estimate of system *marginal* emissions rather than system *average* emissions. The use of system average emission factors can provide highly misleading results, as these factors include the emissions of many plants (such as baseload resources) that are rarely affected by new generation or load reductions. For example, in many regions hydro and nuclear units – with very low air emissions – provide much of the baseload energy. If a weighted system average is calculated, these units' extremely low air emission rates have a very large impact on the result. Since most new assets have virtually no affect on these units' operation, this is clearly an inappropriate emission rate to use for assessing the air impacts of new assets.

For long-term analyses, the key question is: how will the new resource added today affect plant retirements and additions. Over the long term, decisions made by power plant owners and new plant developers will take into account many of the changes in the regional system that took place during the near term. The increase in supply provided by a new plant has two important effects. First, it decreases demand for new plants, and second, it decreases market prices, putting economic pressure on the least competitive plants in the region. Through the latter dynamic, a new plant effectively pushes the least competitive plants toward retirement. In light of these dynamics, the question of what kind of generating units will be added and retired is extremely important to predicting displaced emissions over the long term.

Thus, the second of the methods listed above – plant addition/retirement emission factors – is best for assessing long-term air impacts. Using this method, one would predict the type of plants likely to be added to the system and retired from the system and develop emission factors reflecting those plant types. One can predict plant additions and retirements either with an energy forecasting model or based on informed judgment.

Finally, for a study focusing on both the near-term and the long-term impacts of a given resource, one should ideally use system marginal emission factors for the near-term years and plant addition/retirement emission factors for the long term years. This approach provides the most accurate representation of how the resource in question will affect the system over time. Note that there is likely to be more certainty around estimates of displaced emissions in the near term, because the plants in the existing system are known, while plant addition/retirement rates are based on a prediction of plant additions and retirements.

A wide range of work is underway, both in North America and outside of it, which will likely increase the accuracy and credibility of emission reduction estimates over the coming years. We review fourteen projects here in which net air impacts have been estimated. Many of these calculations are based on system average emission rates, because other information was not available to the analysts. Some calculations are based on system marginal emission rates, either estimated or developed via dispatch modeling. In none of the projects reviewed here have the impacts of a specific resource been assessed with a dispatch model.

In addition, several projects are underway focused on developing principles to guide emission reduction estimates and producing standardized methods for making these estimates.