Estimating Avoided Emissions Achieved Through Renewable Electricity

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Facilities that generate power from renewable resources (e.g., wind, solar, biomass, geothermal, hydro) create more than just electricity. For every megawatt-hour (MWh) of electricity from a renewable power facility that is connected to the regional electric system, there is one less MWh from conventional sources. If the displaced electricity would have been generated by coal, oil, or natural gas, then the renewable power plant avoids emissions of carbon dioxide, particulate matter, and other pollutants that the fossil-fired power plant would have emitted.

There has been increasing interest across North America to understand and quantify this emissions impact of grid-connected renewable power facilities. Over the past several years, the Commission for Environmental Cooperation (CEC, at <www.cec.org>), in collaboration with the U.S. Environmental Protection Agency (<www.epa.gov>) and the World Resources Institute (<www.wri.org>), has led a multi-stakeholder dialogue with government agencies, power sector experts, non-governmental organizations, and renewable power buyers and suppliers to explore this issue and evaluate methodologies for quantifying avoided emissions.

The following summarizes the results of this dialogue. It explains why developing an avoided emissions calculation methodology is important, discusses several types of methodologies, and assesses them against common parameters. It then outlines which of these methodologies are gaining preference in Canada, Mexico, and the United States.

WHY IMPORTANT?

Quantifying the amount of airborne emissions that are avoided when electricity is generated by renewable resources instead of by fossil fuels is important to policymakers, renewable electricity suppliers, and renewable power buyers.

- ***Policymakers:*** Federal, state, and provincial policymakers increasingly want to quantify and monitor the environmental improvements caused by public policies that support renewable power including renewable portfolio standards and economic incentives. In addition, some lawmakers are considering incorporating renewable energy into tradable pollution permit systems (also called "cap-and-trade programs") and air quality improvement regulations.
- ***Renewable electricity suppliers:*** Renewable electricity generators and suppliers are seeking clarity about the emissions benefits created by their facilities, want to make credible claims or statements regarding the emissions impact of the products they are selling, and are starting to request access to allowance set-asides in cap-and-trade programs such as US state nitrogen dioxide (NO_x) and carbon dioxide (CO_2) programs.
- ***Renewable power buyers:*** Corporate, institutional, and government buyers of green power and renewable energy certificates (RECs) often want to quantify avoided emissions associated with their purchases. Many buyers have established organizational greenhouse gas emissions inventories, record their greenhouse gas emissions in sustainability reports, and include statements about the emissions impact of green power purchases in press releases.

Establishing a commonly accepted avoided emissions calculation methodology (or methodologies) would meet the various needs of these stakeholders. In particular, a common approach would:

- Dispel uncertainty about the amount of emissions avoided when electricity is generated by renewable resources;
- Ensure the integrity of public claims about emissions reductions;
- Enable buyers of renewable power and RECs to estimate the cost of the avoided emissions associated with their purchases;
- Build the business case for purchases of renewable power and RECs; and
- Establish a foundation for including renewable power generation in cap-and-trade programs.

TYPES OF METHODOLOGIES

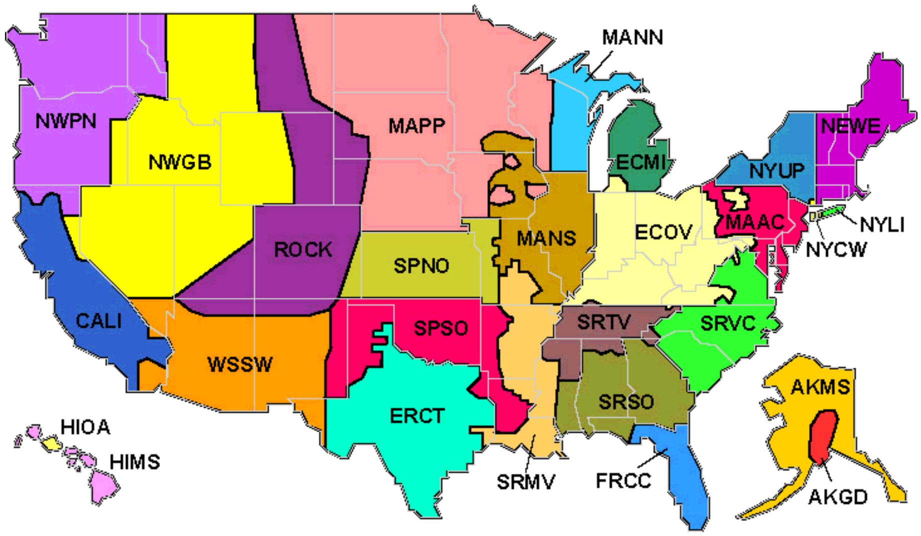
Quantifying the emissions that are avoided by a renewable power facility essentially entails determining the facility's impact on the future operation and composition of the power grid. To accomplish this, any methodology must incorporate at least three dimensions: geographic scope, temporal scale, and emission rates for both operation and composition effects.

Geographic scope

To calculate avoided emissions, one must determine the geographic region in which power plants (and therefore emissions) are impacted by a particular renewable generator. A spectrum of possible geographic scopes exists including a specific locale, a state or province, a regional power pool, or the entire nation.

Figure 1 illustrates the range of options. Consider a wind power project located in the US state of Maine (northeast corner of the United States). When the wind turbine is operating, it could reduce the need for a nearby natural gas-fired power plant to generate electricity or it could displace generation across the state. Alternatively, it could displace conventional power generation in the New England regional power pool (NEWE) given that power generation units are interconnected and managed on a regional basis. Or, it could impact power generation across the nation given that transmission lines link the New England power pool to other nearby power pools.

Figure 1. U.S. electricity power pool subregions (E-GRID)



Source: U.S. Environmental Protection Agency (2004)

Temporal scale

One also must determine the time period during which avoided emissions should be calculated. Temporal scales usually considered include:

- ***Annual:*** Reflects the average avoided emissions rate (e.g., kg/MWh) over the course of a year
- ***Seasonal:*** Provides average avoided emissions rate per season (e.g., winter, summer) since some power facilities may be more active during certain seasons.
- ***On/off peak:*** Provides an average avoided emissions rate for on-peak periods (e.g., daytime) and another for off-peak periods (e.g., nighttime).
- ***Hourly:*** Provides average avoided emissions rates for hourly increments.

The estimated amount of avoided emissions per MWh will likely differ depending on the temporal scale chosen. This is due to the fact that the set of conventional power plants in operation may differ between seasons and time of day. Likewise, many renewable power facilities do not operate at a consistent rate during the course of a year. Land-based wind turbines, for instance, often generate more power during the winter and evenings than they do at other times.

Another facet of the temporal scale is whether the data are retrospective or prospective. One could use data based on historical emissions figures or, alternatively, employ models to project future emissions.

Emissions rates

For a given geographic and temporal scale, a methodology also must utilize certain emissions rates or "emission factors" to estimate avoided emissions. There are three basic "types" of emission factors corresponding to the different effects a renewable energy facility may have on the grid:

1. ***Operating margin*** emission factors are intended to reflect the emissions avoided from existing plants on a grid whose operation is curtailed due to the renewable energy facility's generation. A number of methods have been proposed to estimate operating margin emissions, which differ in their accuracy and complexity.

   The simplest approach to calculating operating margin emissions is to approximate them using a ***system average*** emission factor. This is the emissions rate (such as tons/MWh) of all power generators within a specified geographic region and time period. It is calculated simply by dividing the total emissions from power plants in a specific geographic region and time period by the total amount of electricity generation from the same set of plants over the same time period. This emissions factor implies that all generators within a particular geographic scope are impacted by a MWh of renewable power

   A slightly more accurate, yet relatively easy method is to calculate the ***weighted average emissions of all existing load-following plants*** (e.g., power plants that operate less than 70% of the time over the course of a year) serving the grid.[1] This will be somewhat more accurate because it leaves out baseload plants whose generation is unlikely to be backed down due to another power plant's operation.

   The most accurate, yet difficult approach to estimating operating margin emissions is to use ***computer simulation models***. These models estimate operating margin emission factors by simulating the operation of a renewable power facility within the electricity network and predicting precisely which units will be backed down in response to its generation. These models can be used to derive marginal emissions rates for different time periods, which can then be used to estimate avoided emissions from a variety of renewable energy policies and projects. A dispatch model reflects the fact that regional electric grids in North America operate in complex and integrated ways. A credible prediction of how a system will respond to increased generation by a renewable power facility must be based on the ability to simulate these changes. Dispatch models require extensive information about the electricity generating units within the region of interest, as well as the regional transmission system and regional electricity loads, which can make them difficult and costly to use.

2. A ***build margin*** emission factor is the emissions rate of those future power plants whose planned installations are delayed or cancelled by a renewable power facility. Build margins also can reflect the emissions rate of those existing power plants whose retirement is accelerated due to the installation of a new renewable power facility. This type of emissions factor is used when it is assumed that a renewable power facility

[1] Sathaye, J., S. Murtishaw, L. Price, M. LeFranc, J. Roy, H. Winkler, and R. Spalding-Fecher. 2003. *Multi-project Baselines for Evaluation of Electric Power Projects.*

impacts the planned construction or retirement of other power plants This is a crucial distinction in assessing avoided emissions. Over the short term, new resources displace existing units—primarily the marginal unit—in the existing electric system. Over the long term, a resource added today will displace other new resources competing for market entry and/or cause retirements of existing capacity. When considering the effects of a specific resource over both the short term and long term, one must usually factor in both of these dynamics. That is, the short-term effects on the existing system give way to the long term effects on other plants competing for market entry.[2]

One approach for determining a region's build margin is to calculate the ***average emissions rates of recently built plants*** or of those under construction.[3] An alternative approach is to use ***integrated system planning models,*** which are typically broader in scope than dispatch models. These forecasting models project the evolution of electricity grids (e.g., plant additions and retirement) by simulating the interaction of fuel prices, economic growth, electricity supply, and power demand, optimizing the system using complex mathematical formulae. Some models operate iteratively, converging on a stable solution after a number of runs. Others use linear programming to identify electricity system expansion plans to satisfy an objective function such as least total cost.[4] To estimate build margin emissions, these models can be used to predict the types of power plants whose construction is deferred or avoided, or whose retirement is accelerated, by the installation of a renewable energy project at a certain point in time. The build margin is a weighted average of plants that do not get built ("avoided new entrants") and retired, existing plants.[5]

A final, much simpler method to estimate build margin emissions is to assume the emissions of a "proxy plant," i.e., the emissions from a certain type of plant that a renewable energy facility is likely to displace. Often, the proxy plant is conservatively assumed to be a highly efficient (combined-cycle) natural gas turbine.

3. Finally, a ***combined margin*** emission factor is often used to simulate both the operating margin and build margin effects of a particular renewable energy facility. A combined margin is simply a weighted average of both an operating margin and a build margin. The combined margin assumes that a renewable electricity project will impact both existing operational power plants in the short term and planned power plant construction in the long term. The proper weighting reflects the expected length of time that either marginal effect is likely to prevail. For example, if avoided emissions are calculated over 10 years, and a facility is expected to have an impact on the build margin starting in year 5, then the appropriate weight would be 50% operating margin (years 1-5) and 50% build margin (years 6-10).

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[2] *ibid.*
[3] Sathaye, J., S. Murtishaw, L. Price, M. LeFranc, J. Roy, H. Winkler, and R. Spalding-Fecher. 2003. *Multi-Project Baselines for Evaluation of Electric Power Projects.*
[4] Biewald, B., G. Keith, A. Sommer, P. Henn, and M. Breceda. 2003. *Estimating the Environmental Benefits of Renewable Energy and Energy Efficiency in North America: Experience and Methods.*
[5] ibid.

ASSESSING THE METHODOLOGIES

As the previous section highlights, there are a number of options among geographic scales, temporal scales, and types of emissions rates. Which combination is the most appropriate for calculating avoided emissions from renewable power facilities? One can evaluate the merits of each option against several parameters including:

- ***Accuracy.*** How accurate is the calculation relative to the real emissions impact?
- ***Practicality and feasibility.*** How readily available are the data required for the calculations (e.g., are they publicly available or proprietary)? Is acquiring the data and conducting the calculations expensive? How easy is it to conduct the calculations?
- ***Transparency.*** Are the data, underlying assumptions, and calculation methodology clear and open to examination? Are they easily replicable by others, thus enabling peer review?
- ***Conservativeness.*** Does the methodology err on the side of under-estimating the amount of avoided emissions?
- ***International congruency.*** Does the methodology align with avoided emissions calculation approaches that are emerging elsewhere and gaining institutional support (e.g., Clean Development Mechanism)?

The relative weighting of these parameters—and therefore the attractiveness of one methodology over another—will depend in part on the purpose or goal of measuring avoided emissions from renewable power facilities. The relative weighting may, in fact, differ between end users of these calculations or between countries. Not all end users will require the same degree of accuracy, for instance, which may be less important for a press release than for participation in greenhouse gas emissions. Therefore, it is not necessarily the case that governments and other stakeholders will agree on one "optimal" avoided emissions calculation methodology.

Table 1 provides a summary assessment of the methodological options against three of the most commonly used parameters. This assessment is based on outcomes of the multi-stakeholder dialogue supported by the CEC from 2003 to 2005.

Table 1. Assessment of methodology options

	Option	Precision	Practicality*	Transparency*
Geographic scale	State/province	Low	High	High
	Regional power pool	High	High	High
	Nation	Low	High	High
Temporal scale	Annual	Low	High	High
	Seasonal	Medium	Low	Low/Medium
	On/off peak	Medium	Low	Low/Medium
	Hourly	High	Low	Low/Medium
Type of emissions rate	System average	Low	High	High
	Operating margin	High**	Low	Low/Medium
	Build margin	High***	Medium	Low/Medium
	Combined margin	High	Low/Medium	Low/Medium

* Assessment may differ by country. Dependent upon availability of data
** For avoided emissions in the short-term, but less precise for long-term impacts
*** For avoided emissions in the long-term, but less precise for short-term impacts

As Table 1 highlights, most methodological options score well against some, but not all, of the assessment parameters. The typical trade-off is between accuracy and practicality. Arriving at more accurate avoided emissions estimates often requires large volumes of data and complex modeling of regional electricity networks, driving up costs. As an illustration, Box 1 discusses this trade-off for the systems average emissions rate.

Box 1. System average emissions factors: Precision versus practicality

System average emission factors are often used to estimate avoided emissions from renewable power facilities primarily because they are relatively easy, quick, and inexpensive to calculate. System averages, however, can provide estimated avoided emissions that are inaccurate.

A renewable power facility would affect marginal generating units more than it would other units in an electricity system. Marginal generators differ from units providing consistent, baseload electricity. For example, in the United States, hydroelectric and nuclear power units provide much of the baseload power in several regions. A system average emissions factor would include the very low emissions rates of hydro and nuclear units. However, a renewable power facility is highly unlikely to displace generation from these types of generators.

Despite its potential imprecision, the system average emission factor is popular, in part because it is easier and less resource-intensive to calculate than predicting plant additions (and retirements) or building a dispatch model. A system average emission rate often can be calculated at the cost of several hours of labor if data on a region's power plants are readily available. On the other hand, calculating an operating or build margin emissions factor can cost US$10,000 or more, given the expenses of licensing fees, modeling, and intensive labor-hours.

Source: Biewald, B., G. Keith, A. Sommer, P. Henn, and M. Breceda. 2003. *Estimating the Environmental Benefits of Renewable Energy and Energy Efficiency in North America: Experience and Methods.*

WHAT ARE NAFTA COUNTRIES CONSIDERING?

Each methodology has its advantages and disadvantages. In light of this mixed landscape, what avoided emissions calculation methodologies are being considered by policymakers and stakeholders in Canada, Mexico, and the United States? Recent developments indicate the emergence of certain methodologies in these NAFTA markets, primarily with regard to the impact of renewable power facilities on carbon dioxide emissions. However, the emerging approaches differ by country.

Canada

When designing its Climate Change Plan, the Canadian government proposed a greenhouse gas offset credit system. Offset credits could be bundled with green power and/or RECs to create certified renewable energy products. To determine the amount of avoided carbon dioxide equivalent (CO_2e) associated with each MWh of certified renewable energy, the government opted to establish a standard national intensity factor (NIF). Although the value is yet to be finalized, it will likely be between 200 kg of CO_2e per MWh (approximately the Canadian national system average emissions factor) and 400 kg CO_2e per MWh (the emissions factor of a new combined cycle natural gas power plant). Thus, the government's methodology reflects a national geographic scope, an annual temporal scale (the NIF applies regardless the time of day or season the renewable power facility operates), and either a system average or build margin emissions factor.

Mexico

An avoided emissions calculation methodology that is gaining ground in Mexico is a combined margin emissions factor for each of the nation's four regional electricity power pools (Baja California, Baja California Sur, Noroeste, and Interconectado). Fifty percent of the combined margin is comprised of the emissions rate of all fossil-fueled generators in the region and the other fifty percent is comprised of the emissions rate of the most recent five new power plants. The combined margin is capable of being recalculated each year. Table 2 summarizes the historical estimated avoided emissions per power pool as calculated by ATPAE (*Asociación de Técnicos y Profesionistas en Aplicación Energética*).

Table 2. Emissions factors recommended by ATPAE (historical 1995-2001)

Combined margin: 50% emissions factor of all existing fossil-fired generators + 50% emissions factor of five most recently built plants (tCO_2 eq./ MWh)					
Year	Interconnected System	Northeast System	Baja California System	Baja California Sur System	Complete National System
1995	0,6341	0,6911	0,6673	0,781	0,6273
1997	0,6317	0,6171	0,681	0,7877	0,6263
1998	0,6401	0,6029	0,6913	0,8228	0,6332
1999	0,6378	0,6247	0,7029	0,8172	0,6301
2000	0,638	0,6244	0,6627	0,8232	0,6612
2001	0,6521	0,6157	0,6029	0,8085	0,6539

Source : ATPAE, 2004.

One rationale for utilizing this methodology is that it is recognized by the Clean Development Mechanism (CDM) of the Kyoto Protocol as an approach for estimating the emissions impact of eligible CDM electricity sector projects. This is an important consideration, given that Mexico is a candidate site for CDM projects.

United States

Several avoided emissions calculation methodologies are gaining ground in the United States. Although most of these use the power pool geographic scope, programs differ regarding temporal scales and type of emissions rate. For example, an annual system average emissions rate per power pool is emerging as the methodology for RECs being sold in the voluntary US renewable energy market. Likewise, the Greenhouse Gas Protocol Initiative <www.ghgprotocol.org> and the US Environmental Protection Agency's Climate Leaders Program <www.epa.gov/climateleaders> recommend this avoided emissions calculation approach when corporations and institutions record their REC purchases in their greenhouse gas emissions inventories.

Several states, however, are opting to use an operating margin emissions factor. In Maryland, for instance, qualifying renewable power facilities can apply to receive NO_x emissions allowances from the state's "set-aside" pool of permits. The amount of allowances received per MWh is determined by modeling the operating margin impact of the renewable facility on power plants in its region, an approach approved by the state and US regulators (see <http://www.ert.net/release_5_13_2004.html> and <http://www.nrel.gov/docs/fy05osti/38071.pdf#search='Maryland%20Montgomery%20county%20wind%20emissions%20ERT> for more details on this approach). The operator of the electricity grid system in New England uses a model and historical data to calculate an operating margin emissions factor for SO_2, NO_x, and CO_2 for the entire six-state region. Its models provide annual emissions rates as well as rates for on-peak and off-peak ozone and non-ozone seasons (see <http://www.iso-ne.com/genrtion_resrcs/reports/emission> for more details).

Do differences between countries matter?
Canada, Mexico, and the United States are each migrating toward different avoided emissions calculation methodologies. However, this development should not hinder the emergence of robust markets for renewable energy. Most green power and REC transactions currently are made within national borders; therefore, different approaches between countries do not matter.

Different approaches should not matter, either, for cross-border transactions as long as both the buyer and seller clearly understand that the appropriate avoided emissions methodology is the one used by the country in which the renewable power facility is located. For instance, suppose a wind farm in the United States sells RECs to a corporate customer in Canada. The appropriate avoided CO_2 emissions calculation methodology is the one used by the United States for voluntary REC purchases (annual system average of the power pool in which the wind power facility is located). In other words, any avoided emissions claims being made should be based upon the generator country's methodology. What matters in terms of emissions impact is where the generator is located, not where the buyer is located.

TYPES OF ENVIRONMENTAL BENEFITS ADDRESSED

To date, the type of avoided emissions in which policymakers, renewable energy suppliers, and renewable energy buyers have mostly been interested calculating is carbon dioxide (CO_2). For Canadian stakeholders, CO_2 is of primary interest because Canada is obligated to reduce its national greenhouse gas emissions, having ratified the Kyoto Protocol. CO_2 is of interest to Mexican stakeholders since renewable energy projects in Mexico are candidates for being supported by the Kyoto Protocol's Clean Development Mechanism. US stakeholders are interested in CO_2 in light of emerging greenhouse gas markets such as the Regional Greenhouse Gas Initiative and the Chicago Climate Exchange as well as voluntary greenhouse emissions reduction initiatives being pursued by major corporations and other institutions.

Methodologies applicable for estimating avoided CO_2 emissions due to renewable power projects are also applicable for estimating other avoided emissions such as nitrogen oxides, sulfur dioxide, and particulate matter. The fact that a MWh of renewable power displaces a MWh of conventional power entails that these other emissions are avoided at the same time as the CO_2 emissions are. Thus, stakeholders interested in quantifying other avoided emissions can use the same calculation methodology.

However, analysts should be careful when attempting to calculate avoided emissions of a pollutant that is capped in an emissions cap-and-trade program (e.g., SO_2 in the US Acid Rain Program). In such a program, a government determines the total amount of emissions that can legally be released by setting a cap. Near-term emissions reductions due to renewable power facilities therefore will likely be "traded away" until the cap level is reached, thus the reductions are only temporary. In such situations a renewable power facility cannot be said to ultimately "avoid emissions" over the long-term, unless emissions allowances are retired when the renewable generators create power.

Renewable power facilities can generate environmental benefits other than avoided emissions. For instance, most renewable resources consume less water than do conventional power generators and do not leave permanent landscape scars as does strip-mining for coal. The broader suite of environmental benefits of renewable energy, however, is a topic for future research and analysis.

FURTHER READING

For presentations and discussion documents from CEC/USEPA/WRI multi-stakeholder dialogue workshops on estimating avoided emissions from renewable power facilities, see <http://www.cec.org/pubs_docs/scope/index.cfm?varlan=english&ID=14>

For further discussion about types of methodologies, see Synapse Energy Economics at <www.synapse-energy.com> and Environmental Resources Trust at <www.ert.net>

For a discussion about calculating the avoided emissions from renewable power facilities, see *Corporate Greenhouse Gas Emissions Inventories: Accounting for the Climate Benefits of Green Power*, by Craig Hanson and Janet Ranganathan, World Resources Institute, available at <http://pubs.wri.org/corporateguide03-pub-3817.html>

For more about the Greenhouse Gas Protocol rules for accounting for greenhouse gas emissions and emissions reductions, see <www.ghgprotocol.org>