Quantifying Air and GHG Emission Reductions from Clean Energy Measures

4.2.2 QUANTIFY AIR AND GHG EMISSION REDUCTIONS FROM CLEAN ENERGY MEASURES

Once states have developed their baseline emission estimate or business as usual forecast, they can estimate the emissions that are avoided when implementing clean energy measures. Although an emission reduction estimation can be performed independently from a baseline emissions forecast, aligning many of the assumptions in the baseline case and the clean energy measures case is a desirable exercise. Table 4.2.4 shows that states can use either basic or sophisticated approaches to quantify air emission reductions from clean energy measures.

Basic approaches typically include spreadsheet-based analyses that use emissions factor relationships or other assumptions to estimate reductions. Sophisticated approaches are usually more complex and involve dynamic electricity or energy system representations that predict energy generation responses to policies and calculate the effects on emissions.*

TABLE 4.2.4 COMPARISON OF BASIC AND SOPHISTICATED APPROACHES FOR QUANTIFYING AIR POLLUTANT AND GHG EMISSION EFFECTS OF CLEAN ENERGY INITIATIVES

Tools	Advantages	Disadvantages	When to Use this Method
Basic Approaches			
▪ eCalc ▪ OTC Workbook[a] ▪ CACPS	▪ Transparent. ▪ Modest level of time, technical expertise, and labor required. ▪ Inexpensive.	▪ May be imprecise. ▪ May be inflexible. ▪ May have embedded assumptions that have large impacts on outputs.	▪ Preliminary studies for short-term resource planning. ▪ Designing new programs and evaluating existing ones. ▪ Regulatory compliance and energy plans.
Sophisticated Approaches			
▪ ENERGY 2020 ▪ NEMS ▪ IPM ▪ MARKAL ▪ PROSYM ▪ GE MAPS ▪ PROMOD	▪ More rigorous than basic modeling methods. ▪ May be perceived as more credible than basic modeling methods. ▪ Allows for sensitivity analysis. ▪ May explicitly account for and quantify leakage.	▪ Less transparent than spreadsheet methods. ▪ Labor- and time- intensive. ▪ Often high software licensing costs. ▪ Requires assumptions that have large impact on outputs. ▪ May require significant technical experience.	▪ State Implementation Plans. ▪ Late-stage resource planning. ▪ Rate cases. ▪ Project financing. ▪ Regulatory compliance and energy plans.

[a] *The OTC workbook is a spreadsheet tool that was developed from specific results of the PROSYM model.*

**This document is an excerpt from the EPA guide, "Assessing the Multiple Benefits of Clean Energy." To see the whole guide, go to http://www.epa.gov/statelocalclimate/resources/benefits.html*

Key Considerations for Selecting an Approach for Quantifying Emission Reductions from Clean Energy

As summarized in Table 4.2.4, there are advantages and disadvantages to each approach for quantifying emission reductions. States can use this information as guidance in determining the most appropriate approach for their particular goals. It is important for states to:

- Consider the cost of each potential approach and/or tool and the resources required;
- Determine whether the tools or methods can be used to estimate the pollutants and emissions of interest;[1] and
- Decide between a complex, detailed approach and a simple, transparent screening-level approach based on their pros and cons and relative importance of each.

Basic and sophisticated approaches, including associated uncertainties and limitations, are described in greater detail below.

Basic Approaches to Quantifying Emission Reductions

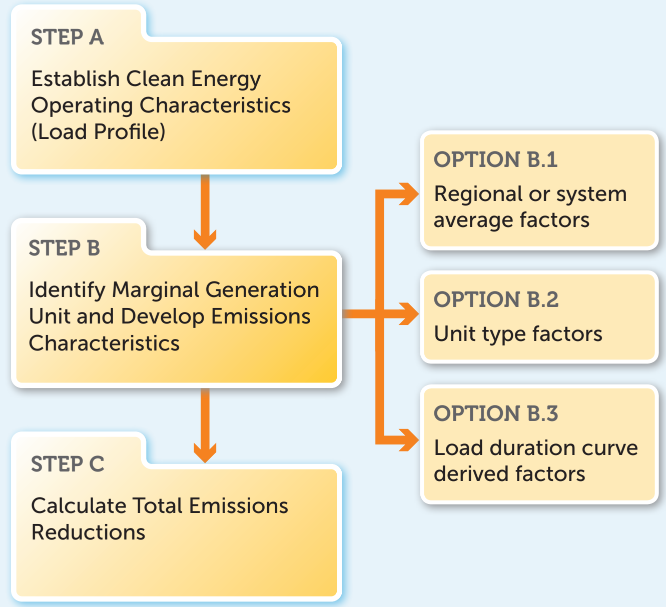
Basic, screening-level, approaches involve: 1) establishing the operating characteristics of the clean energy resource, also known as its load profile; 2) identifying the marginal generation unit and developing avoided emissions factors; and 3) calculating the total emissions reductions by multiplying the avoided emissions factor by the avoided electricity generation (i.e., as calculated in Chapter 2, *Assessing the Potential Energy Impacts of Clean Energy Initiatives*). These procedures are illustrated in the flowchart in Figure 4.2.1 and described in greater detail below.

Step A: Establish Clean Energy Operating Characteristics (Load Profile)

As previously discussed in Chapter 2, *Assessing the Potential Energy Impacts of Clean Energy Initiatives*, the first step when applying a basic modeling approach is to determine the specific ways that the clean energy initiative will affect either demand for electricity or available supply. This involves considering the

[1] *The Model Energy Efficiency Program Impact Evaluation Guide, which was developed as part of the National Action Plan for Energy Efficiency (NAPEE), provides further guidance on how to quantify emissions reductions (NAPEE, 2007).*

FIGURE 4.2.1 BASIC APPROACHES FOR QUANTIFYING AIR AND GREENHOUSE GAS REDUCTIONS FROM CLEAN ENERGY



following issues related to the operating characteristics, or load profile, of the clean energy measures:

- How much energy will the clean energy measure generate or save? (See Chapter 2 for more information)
- When and where will the electricity generation offset occur (e.g., season of year, time of day)? In the case of energy efficiency measure, load impact profiles describe the hourly changes in end use demand resulting from the program or measure. In the case of energy resources, the generation profiles (for wind or PV, for example) are required. (See Chapter 3)
- What, if any, are the emissions characteristics of the clean energy resource (e.g., emissions characteristics of using renewable fuels such as digester gas)?

Step B: Identify the Marginal Generation Unit and Develop Emissions Characteristics

Next, identify the marginal generation source and its associated emissions characteristics. The marginal generating source, as described earlier, is the last generating unit to be dispatched in any hour, based on least-cost dispatch (thus it is the most expensive on a variable cost basis). The emissions characteristics of this unit can be

TABLE 4.2.5 COMPARISON OF METHODS TO IDENTIFY MARGINAL UNIT AND ASSOCIATED EMISSIONS FACTOR

Method	Advantages	Disadvantages	When to Use this Method
Regional or system average based on historical year	▪ Computationally simple. ▪ Less labor and data required than for unit type or dispatch curve analysis.	▪ Insensitive to dispatch process. ▪ Neglects power transfers between areas. ▪ History may not be good indicator of future.	▪ Rough estimates of clean energy benefits for displacing emissions.
Based on unit type (capacity factor rule)	▪ Simpler and less labor required than dispatch curve analysis. ▪ Considers generation resource characteristics.	▪ Somewhat insensitive to dispatch process. ▪ Inaccurate for baseload clean energy resources.	▪ Preliminary planning and evaluation of clean energy resources, especially those that operate during peak times.
Derived from dispatch curve analyses	▪ More sensitive to dispatch process than regional or system average and unit type methods.	▪ Higher data requirements than regional or system average and unit type methods.	▪ Planning and regulatory studies.

expressed as an emissions factor for each pollutant, and are expressed in pounds per MWh. These factors represent the reduction in emissions per pound of energy generation avoided due to energy efficiency or due to clean energy resources supplied to the system.

There are several different approaches that can be used to characterize the marginal generation source and its associated emissions factor. As described in Chapter 3, these include (1) system average, (2) factors based on unit type or other characteristic that correlates with likelihood of displacement (e.g., capacity factor), and (3) factors derived from dispatch curve analyses. Information about the advantages, disadvantages, and when to use each method is summarized in Table 4.2.5, *Comparison of Methods to Identify Marginal Unit and Associated Emissions Factor*. Each method is described in more detail below.

- *Regional or system average emissions factors*. This approach typically involves taking an average of the annual emissions of all electricity generating units in a region or system over the total energy output of those units. Data on emission rates averaged by utility, state, and region are available from EPA's eGRID database. For example, using eGRID, states can locate emissions factors by eGRID subregion, state, or by specific boiler, generator, or plant.

WHAT ENERGY SOURCE IS DISPLACED?

It is important to note that only a small number of generating plants are affected by a clean energy measure. Power systems are generally dispatched based on economics, with the lowest-cost resource dispatched first and the highest-cost resource dispatched last. The lowest-cost units (known as baseload units) operate at all times and are often fueled by coal. Higher-cost units such as gas- and oil-fired units are brought online during peak use times. These are the units that will be displaced by a clean energy measure. This helps identify where the GHG and air pollutant benefits are likely to occur (See Section 3.1, *How Clean Energy Can Achieve Electric System Benefits*, and Section 3.2, *How States Can Estimate the Electric System Benefits of Clean Energy*, for a more detailed explanation of how generation resources are dispatched).

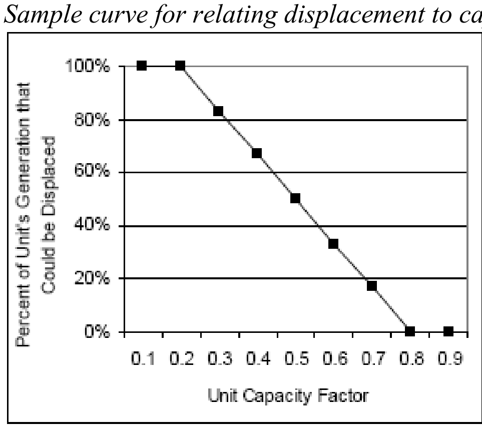
While easy to apply, this method ignores the fact that some units (such as baseload electricity generating units) are extremely unlikely to be displaced by clean energy resources (see text box *What Energy Source is Displaced?*). Baseload units and other units with low variable operating costs (e.g., hydro and renewables) can be excluded from the regional or system average to partially address this shortcoming. Some approaches, therefore, take a fossil-only average.

FIGURE 4.2.2 CAPACITY FACTORS AND UNIT DISPLACEMENT FOR BASELOAD AND LOAD-FOLLOWING PLANTS

In general, baseload plants operate all of the time throughout the year because their operating costs are low and because they are typically not suitable for responding to the many fluctuations in load that occur throughout the day. Thus, their capacity factors are generally very high (e.g., greater than 0.8) and they are unlikely to be affected by short-term fluctuations in load. In contrast, *load-following* plants that can quickly change output have much lower capacity factors (e.g., less than 0.3) and are more likely to be displaced.

The capacity factor of a plant can be used as a proxy for how likely the plant is to be displaced by a clean energy measure. The following graph shows an example of a displacement curve, or a rule for relating the likelihood that a unit's output would be displaced to its capacity factor. Baseload plants on the right side of the curve, such as nuclear units, are assumed to be very unlikely to be displaced; peak load plants on the left, such as combustion turbines, are much more likely to be displaced.

Sample curve for relating displacement to capacity factor



Source: Keith and Biewald, 2005.

Other methods for identifying the marginal unit and its emissions factors attempt to recognize that what is on the margin is a function of the time that clean energy load impacts (or energy generation) occurs. The most complete of these time-dependent methods would analyze the impact of changes in load for the 8,760 hours in a year using dispatch models. Basic methods try to approximate this using proxies, including unit type and capacity factor, as described further below.

- *Displaced unit and emissions factors identification based on type of unit.* As described above, system or regional average emissions factors do not take into account the fact that some electricity generating units are more likely to be displaced by clean energy resources than others. (See Section 3.1, *How Clean Energy Can Achieve Electric System Benefits* and Section 3.2, *How States Can Estimate the Electric System Benefits of Clean Energy*, for a more detailed explanation of how generation resources are dispatched.) The unit type approach for estimating emissions factors takes into account that some classes of units are more likely to be displaced than others by the operation of clean energy measures. For example, assume coal, nuclear, and hydro plants provide baseload power for an electricity grid. Higher-cost units will operate in a cyclic manner, increasing their output during peak daytime hours. A more efficient new gas-fired unit may be counted on to increase output during the day and decrease output at night, while older, less efficient and more expensive gas and oil units or combustion turbines are only dispatched during the peak output periods. This method can be made more representative by disaggregating the unit types as much as possible (e.g., by unit type, heat rate, and controls).

  Estimating emissions factors based on unit type involves the following steps.

  1. *Estimate the percentage of total hours each type of unit (e.g., coal-fired steam, oil-fired steam, gas combined-cycle, gas turbine, etc.) is likely to be on the margin* (the highest-cost unit dispatched at any point in time is said to be "on the margin" and is known as the "marginal unit") and thus to have its output displaced given the load profile of the new clean energy resource. This is discussed further in Chapter 3.

  2. *Determine the average emission rate for each unit type* (in pounds of emissions per MWh output). This can be determined based on public data sources such as EPA's eGRID database or standard unit type emissions factors from EPA AP-42, an available resource for estimated emissions factors.[2]

  3. *Calculate an emissions-contribution rate for each unit type* by multiplying the unit type

2 *Note that AP-42 does not provide GHG emissions factors; for GHGs, use fuel-specific emissions factors from EPA's Inventory of U.S. Greenhouse Gas Emissions and SInks. Also note that AP-42 factors are dependent on the air pollution controls that have been installed, and this information would be needed to accurately estimate emission rates. EPA AP-42 is available at* ***http://www.epa.gov/ttn/chief/ap42/index.html***

average emissions (lbs/MWh) by the fraction of hours that the unit type is likely to be displaced.

Using average emissions to approximate displaced emissions involves significant simplifications of electric system operations. For example, the emission rates for each existing generating unit may vary considerably. Similarly, plants of a certain type may have different operating costs and load-following capabilities.[3] For example, baseload units operate virtually all the time, load-following units are routinely turned off at night and used most days to meet the higher daytime electricity demand, and peaking units only operate during the highest demand periods (such as hot summer afternoons). Due to the operating characteristics of many types of clean energy projects, the electricity produced or saved is likely to displace electricity from load-following and peaking units in the short term, rather than from baseload units.[4] Generalizations must also be made about the type of generating unit that is on the margin, which may vary considerably across different control areas and time periods.

A limitation of this approach is that it misses important system-level dynamics. For example, reducing emissions of a regulated pollutant may result in shifts in other dispatch decisions in the short and long term. This is particularly true if those emission reductions have a market value (as in cap and trade system). For example, if an energy efficiency option allows for reduced output from a high-emitting oil/gas steam unit during the shoulder period (i.e., that period when demand falls below peak levels but above minimum, base load levels), it may allow increased operation of a coal plant (one not running at full utilization already) at an increased capacity factor. This may reduce system costs all while maintaining emissions at capped levels. In other words, the clean energy option has allowed the operator to reduce emissions compliance costs through dispatch changes. Over the longer term these impacts may include changes in retrofit or build decisions.

As an alternative to estimating the fraction of the time each unit type is on the margin, some analyses estimate the likelihood that a unit type could be displaced using a displacement curve based on capacity factors, shown in Figure 4.2.2, *Capacity Factors and Unit Displacement for Baseload and Load-Following Plants*. The capacity factor is the ratio of how much electricity a plant produces to how much it could produce, running at full capacity, over a given time period. Historical data on, or estimates of, capacity factors for individual plants are available from EPA's eGRID database.

Displacement rules do not capture some aspects of electric system operations. For example, an extended outage at a baseload unit (for scheduled maintenance or unanticipated repairs) would increase the use of load-following and peaking units, affecting the change in net emissions from the clean energy project. According to a displacement rule, this plant would be more likely to be displaced even though it would rarely if ever be on the margin. Nevertheless, adding this level of detail when estimating emissions factors will generally produce a more credible and accurate estimate of displaced emissions than relying simply on an unweighted system average emissions rate.

- *Emissions Factors Derived from Dispatch Curve Analyses* Load curve analysis is a method for determining tons of emissions avoided by a clean energy resource for a period of time in the past. In general, generating units are dispatched in a predictable order that reflects the cost and operational characteristics of each unit. These plant data can be assembled into a generation "stack," with lowest marginal cost units on the bottom and highest on the top. A dispatch curve analysis matches each load level with the corresponding marginal supply (or type of marginal supply). Table 4.2.6, *Hypothetical Load for One-Week Period on Margin and Emission Rate* and Figure 4.2.3, *A hypothetical dispatch curve representing 168 hours by generation unit, ranked by load level*, provide a combined example of a dispatch curve that represents 168 hours (a one-week period) during which a hypothetical clean energy resource would be operating.

Table 4.2.6 illustrates this process for a one-week period. There are ten generating units in this hypothetical power system, labeled 1 through 10. Column [3] shows the number of hours that each unit is on the margin, and column [4] shows the

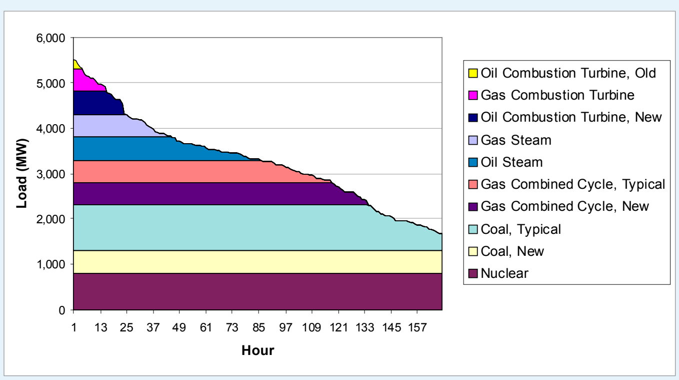
[3] *"Load-following" refers to those generating resources that are dispatched in addition to baseload generating resources to meet increased electricity demand, such as during daytime hours.*

[4] *In the longer term, the electricity saved from EE or produced from CE projects not specific to time of day (e.g., CHP, geothermal, not solar) can displace electricity from baseload resources.*

TABLE 4.2.6 HYPOTHETICAL LOAD FOR ONE-WEEK PERIOD: HOURS ON MARGIN AND EMISSION RATE

[1]	[2]	[3]	[4]
Unit	Unit name	Hours on margin	SO_2 emission rate (lb/MWh)
1	Oil Combustion Turbine, Old	5	1.00
2	Gas Combustion Turbine	10	0.00
3	Oil Combustion Turbine, New	9	1.00
4	Gas Steam	21	0.10
5	Oil Steam	40	12.00
6	Gas Combined Cycle, Typical	32	0.01
7	Gas Combined Cycle, New	17	0.01
8	Coal, Typical	34	13.00
9	Coal, New	0	1.00
10	Nuclear	0	0.00
Weighted average, SO_2 emissions (lbs/MWh):		*5.59*	

FIGURE 4.2.3 A HYPOTHETICAL LOAD DURATION/DISPATCH CURVE REPRESENTING 168 HOURS (SHOWN IN HALF-DAY INCREMENTS) BY GENERATION UNIT, RANKED BY LOAD LEVEL



Source: Developed by Synapse Energy, unpublished, 2007.

unit's SO_2 emission rate. The weighted average SO_2 emission rate for these units is 5.59 lb/MWh.

In many cases, dispatch curves are available from the local power authorities and load balancing authorities (e.g., a regional Independent System Operator (ISO)). If this information is not available, states can attempt to construct their own analysis.

Constructing a dispatch curve requires data on:

1. Historical utilization of all generating units in the region of interest;
2. Operating characteristics, including costs and emissions rates of the specific generating units, for each season;
3. Energy transfers between the control areas of the region and outside the region of interest in order to address leakage issues (see text box *Clean Energy and Leakage* earlier in this chapter); and
4. Hourly regional electricity demand (or loads).

Data on operating cost, historical utilization, and generator-specific emission rates can typically be obtained from the EIA (*http://www.eia.doe.gov/cneaf/electricity/page/data.html*), or the local load balancing authority. When generator cost data are not available, capacity factors (from the eGRID database, for example) for traditional generating units can be used to approximate the relative cost of the unit (those with the highest capacity factors are assumed to have the lowest cost). As an exception, variable power resources such as wind and hydropower are assumed to have lower costs than fossil fuel or nuclear units.

If unit-level cost data are available, calculating the weighted average of each unit's emission rate, as shown in Table 4.2.6, is preferable to aggregating plants, especially when there is considerable variation in the emission rates within each unit type.

Operational data (or simplifying assumptions) regarding energy transfers between the control areas of the region and hourly regional loads can be obtained from the ISO or other load balancing authority within the state's region.

Load duration curve analysis is commonly used in planning and regulatory studies. It has the advantage of incorporating elements of how generation is actually dispatched while retaining the simplicity and transparency associated with basic modeling methods. However, this method can become labor-intensive relative to other basic modeling methods for estimating displaced emissions if data for constructing the dispatch curve are not readily available. Another disadvantage is that it is based on the assumption that only one unit will be on the margin at any given time; this is not generally true in most regions.

- *Summary of Emissions Factor Methods*. In general, for each of the three methods—regional or system emissions factors, factors based on unit type, and factors derived from load duration/dispatch curve analyses—the more detailed the analysis, the more accurate the results, but the more involved it is to make the calculations. The accuracy of the analysis can be improved by calculating separate emissions factors for a number of different time periods during which load and unit operations are known to vary (e.g., peak and off-peak times in the winter and summer months). Ideally, several years of historical emissions and generation data would be used in calculating the average emission rate. For the latter two methods (i.e., emissions factors based on unit types and derived from load duration/dispatch curve analyses), the number of hours that the unit type is on the margin would also be incorporated into the calculation.

Step C: Calculate Total Emissions Reductions

Total emission reductions are calculated by applying the emissions factor developed during Step B *Identify the Marginal Generation Unit and Develop Emissions Characteristics* to the clean energy resource's level of activity, determined during Step A *Establish Clean Energy Operating Characteristics*.

In the final analysis of net emission impacts, it is also important to consider any GHG or criteria air pollution emissions that a clean energy initiative might produce during the production or generation of renewable fuels (e.g., landfill gas, biomass generation). For example, biomass generation releases about the same amount of CO_2 as burning fossil fuels. However, because biomass is a fuel derived from organic matter, including, but not limited to, wood and paper products, agricultural waste, or methane (e.g., from landfills), these materials are part of the natural carbon cycle and therefore do not contribute to global warming. Thus, all biomass CO_2 emissions (including those from renewable methane) are assigned a value of zero because these organic materials would otherwise release CO_2 (or other greenhouse gases) through decomposition.

USING LOAD DISPATCH CURVE EMISSIONS FACTORS TO ANALYZE THE EMISSIONS IMPACT OF WISCONSIN'S ENERGY EFFICIENCY PROGRAMS

In 2004, the Wisconsin Department of Administration (DOA) released an analysis of the air emission impacts of its Focus on Energy efficiency program. The DOA's evaluation team used a load dispatch curve analysis to estimate which generating plants were "on the margin" during different time periods. Using EPA's CEM data on historical plant operations and emissions reported to EPA, emissions factors were developed for the marginal generating units for different time periods (e.g., peak and off-peak hours during winter and summer) for NO_X, SO_2, and CO_2). These factors were then used to analyze the effects of different energy efficiency programs.

The study found that the marginal units' emission rates tend to be higher during off-peak hours (particularly in winter) than on-peak hours. The study suggests that energy efficiency programs that cut energy consumption in Wisconsin when system demands (and power supply costs) are low may produce the greatest reductions in emissions. For more information on Wisconsin's Focus on Energy program, see Section 4.3.2, Wisconsin - Focus on Energy Program.

Source: Erickson et al., 2004.

Tools

Several tools that take a basic modeling approach to estimating emissions reductions are available to states:

- *The Clean Air and Climate Protection Software* (CACPS) tool can be used to estimate emissions reductions in addition to the functions already mentioned above. ICLEI updated and re-released this software in April 2009. Web site: ***http://www.icleiusa.org/main-page/home-page-sections/cacp-software-2009-released***

- *The OTC Workbook*: The OTC Workbook is a free tool developed for the Ozone Transport Commission to help local governments prioritize clean energy actions. The Workbook uses a detailed Microsoft Excel spreadsheet format based on electric power plant dispatch and on the energy savings of various measures to determine the air quality benefits of various actions taken in the OTC Region. This tool

ELECTRIC ENERGY EFFICIENCY AND RENEWABLE ENERGY IN NEW ENGLAND: THE OTC WORKBOOK

An analysis conducted by the Regulatory Assistance Project (RAP) explains how energy efficiency and renewable energy have led to many positive effects on the general economy, the environment, and energy security in New England while also quantifying these effects in several new ways. The report assesses the air quality effects of efficiency and renewable investments using the OTC Workbook tool. The analysis finds that there is clear progress in reducing CO_2 emissions from the deployment of energy efficiency and renewable energy. The projections by the OTC Workbook indicate that due to current energy efficiency programs, 22.5 million tons of CO_2 emissions are avoided from 2000–2010.

Source: The Regulatory Assistance Project. *http://www.raponline.org*

A RESOURCE FOR CALCULATED AVOIDED EMISSIONS: THE MODEL ENERGY EFFICIENCY PROGRAM IMPACT EVALUATION GUIDE

The Model Energy Efficiency Program Impact Evaluation Guide provides guidance on model approaches for calculating energy, demand, and emissions savings resulting from energy efficiency programs. The Guide is provided to assist in the implementation of the National Action Plan for Energy Efficiency's five key policy recommendations and its Vision of achieving all cost-effective energy efficiency by 2025. Chapter 6 of the report presents several methods for calculating both direct onsite avoided emissions and reductions from grid-connected electric generating units. The chapter also discusses considerations for selecting a calculation approach (NAPEE, 2007).

is simple, quick, and appropriate for scenario analysis. It can calculate predicted emission reductions from energy efficiency, renewables, energy portfolio standards (EPSs), and multi-pollutant proposals. The tool contains two kinds of default emission rate: system average (for assessing EPSs) and marginal (for assessing displacement policies). Users can also input their own data. ***http://www.otcair.org***

- *Power Profiler*: The Power Profiler is a Web-based tool that allows users to evaluate the air pollution and GHG impact of their electricity choices. The tool is particularly useful with the advent of electric customer choice, which allows many electricity customers to choose the source of their power. ***http://www.epa.gov/cleanenergy/powerprofiler.htm***

- *eCalc*: eCalc is an online tool that identifies emission reductions from energy efficiency and renewable energy measures in the Electric Reliability Council of Texas (ERCOT) region. The eCalc tool incorporates both energy modeling (assessing the energy saved by a given measure) and emissions modeling (determining the emissions avoided by those energy savings). The energy modeling capability is extremely robust and detailed, accounting for a wide array of load types with weather normalization. It also includes energy production profiles for wind and solar power. Several states have approached the Energy Systems Laboratory (ESL) at Texas A&M University about developing other versions of eCalc. While the underlying code can be transferred, states will need to customize data such as weather, geography, building standards, emissions regulations, grid characteristics, and other factors. ***http://ecalc.tamu.edu/***

Note that many of these spreadsheet-based and other tools rely on models to estimate the underlying emission rates. For example, the OTC Workbook relied on runs of the PROSYM model to establish the emission rates, and eCalc integrates several legacy models depending on the user's desired analysis type. These tools thus have the same underlying concerns as those raised earlier, such as being dependent on key driving assumptions; to the extent that these tools and their inputs are not regularly updated, these key assumptions may no longer be applicable and relevant.

Limitations of Basic Approaches

Basic approaches for quantifying displaced emissions are analytically simple and the data are readily available. However, they involve a less rigorous approach than sophisticated modeling approaches; policy-making and regulatory decisions typically require more rigorous analysis. Basic approaches:

- *Are best suited for estimating potential emission reduction benefits for a relatively short time frame* (e.g., one to three years). Longer-term analyses would require emissions factors that account for impacts on the addition and retirement of energy sources over time and changes in market conditions including environmental requirements.

- *Do not typically account for imported power*, which may be from generating units with very different emissions characteristics than the units within the region or system. These methods also do not account for future changes in electricity import/export patterns, which may change the marginal energy sources during operation of the clean energy measure.

- *Do not account for the myriad factors that influence generating unit dispatch on a local scale.* For example, the emissions impacts of a clean energy resource within a load pocket (an area that is served by local generators when the existing electric system is not able to provide service, typically due to transmission constraints) would affect unit dispatch very differently than measures in an unconstrained region. Higher-cost units must be dispatched in a load pocket because energy cannot be imported from lower-cost units outside of the area.

For these reasons, use of basic approaches is often limited to providing preliminary estimates of emission reductions and reporting approximate program impacts data for annual project reports and program evaluations that do not involve regulatory compliance. Nevertheless, when using basic approaches it is important to remember that the more detailed the representation of the study area, the more precise and reliable the emissions estimates.

Sophisticated Approaches to Quantifying Emissions Benefits

Sophisticated modeling approaches, such as electric dispatch and capacity planning models, can be used to compare baseline energy and emissions forecasts with scenarios based on implementation of clean energy measures. Using sophisticated models to estimate emissions that are displaced as a result of clean energy measures generally results in more accurate estimation of emission impacts than using the basic approaches, but can be more resource-intensive.

Many of the models used to characterize or project changes in electricity supply and demand also provide estimates of the air pollution and GHG impacts associated with clean energy policies. Thus, by comparing clean energy policy scenarios with the BAU case, they facilitate quantification of emissions benefits. Two key types of models used to estimate emissions are electric dispatch models and capacity expansion (also referred to as system planning or planning) models. An electric dispatch model typically answers the question: how will this clean energy measure affect the operations of existing power plants? In other words, the model quantifies the emission reductions that occur in the short term. A capacity expansion model answers the question: how will this clean energy measure affect the composition of the fleet of plants in the future? A capacity model typically takes a long-term view and can estimate emission reductions from changes to the electricity grid, rather than changes in how a set of individual power plants is dispatched.

Some capacity expansion models include dispatch modeling capability, although typically on a more aggregate time scale than dedicated hourly dispatch models. Models that address dispatch and capacity expansion handle both the short and long term. These models are summarized in Table 4.2.7, *Comparison of Sophisticated Modeling Approaches for Quantifying Air and GHG Emission Effects of Clean Energy Initiatives*, and are described in more detail in Chapters 2 and 3).

For More Information

- *Estimating Seasonal and Peak Environmental Emission Factors – Final Report.* Prepared by PA Government Services for the Wisconsin DOA. May 2004. ***http://www.doa.state.wi.us/docs_view2.asp?docid=2404***
- *Focus on Energy Public Benefits Evaluation – Semiannual Summary Report.* Prepared by PA Government Services for the Wisconsin DOA. September 14, 2005. ***http://www.doa.state.wi.us/docs_view2.asp?docid=5237***
- *Focus on Energy Public Benefits Evaluation – Semiannual Summary Report.* Prepared by PA Government Services for the Wisconsin DOA. September 27, 2006. ***http://www.focusonenergy.com/files/Document_Management_System/Evaluation/semiannualyearendfy06_evaluationreport.pdf***
- *Focus on Energy Program* ***http://www.focusonenergy.com***