

# **Quantification of Environmental Benefits For Wisconsin's Focus on Energy Pilot Program**

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## **ABSTRACT**

This paper presents a summary of the interim evaluation results for the quantification of environmental benefits in the Wisconsin Focus on Energy Pilot. The Wisconsin Department of Administration's (DOA) Division of Energy sponsors this 10-program pilot.

A key objective of the evaluation is therefore to affirm the environmental benefits associated with the energy impacts of DOA's statewide Focus on Energy programs. Prior to the pilot, these benefits were initially projected by DOA using spreadsheet algorithms to convert energy impacts (by fuel type) to reductions in the tropospheric air pollutants NO<sub>x</sub>, CO, and SO<sub>2</sub>. Program energy impacts can also be expected to reduce emission of CO<sub>2</sub>, an anthropogenic green house gas, and DOA is further interested in quantifying reductions in mercury, and other particulates). The environmental benefits quantification analysis must be based on defensible energy impacts. Thus, a prerequisite for the environmental analysis is documentation by the evaluation contractor of sound research design, measurement, and analysis at the program-specific level in producing estimates of energy impacts.

This paper describes: (1) an Excel-based approach developed at Lawrence Berkeley National Laboratory (LBNL) for calculating emission factors; and, (2) the methods used to document energy savings from the Focus on Energy Pilot programs. Following presentation of the results to date for this approach, planned future enhancements are discussed in the context of Wisconsin's statewide public benefits efforts.

## **The Environmental Benefits Quantification Analysis**

This analysis approach is designed to:

- Provide the DOA with a tool that will support estimation of various environmental benefits associated with the energy impacts of the Focus on Energy pilot programs.
- Provide the DOA with appropriate Emissions Factors for NO<sub>x</sub>, SO<sub>2</sub>, and CO<sub>2</sub> based on plant-specific data for power plants that supply Wisconsin.

## **Approach**

Estimation of the emissions that are avoided by programs that reduce electricity demand through efficiency improvement requires an emissions rate or factor that represents what would have happened if not for the program. Such estimation hinges upon finding the type of power plants whose use would be avoided by the programs, and the emissions avoided by their reduced operation.

The approach described here allows estimation of the power plants that are expected to be the marginal source during a given period. It provides a reasonable estimate of which sources are likely to be curtailed in response to the load reduction from programs.<sup>1</sup>

The load of an electricity generation system during a given period can be represented in a diagram that plots system power output as a function of time. In order to clarify the respective roles of different power sources in meeting the load, chronological load data can be converted into a load duration curve. A load duration curve is a reordering of chronological load data into the form of *Figure 1*, in which the x-axis shows how many hours the load was equal to or greater than the power level shown on the y-axis. For each hour in the period, there is a particular cost-minimizing dispatch of power sources to meet the demand. The basic goal of the method is to approximate this dispatch, by filling in the area underneath the load duration curve. In so doing, one can estimate which sources operate at the margin and for how long (see Figure 2).

## Geographic Area Selected

The State of Wisconsin is primarily supplied by power plants in the MAIN region, though parts of the state are supplied by plants in the MAPP region. In the near future, these two regions will be combined into one. Thus, for this project we considered all plants in both of these regions. The approach could also be used if one elects to choose a subset of power plants.

## Discussion of Data

**Power plant operation.** The database consists of all power plants in the MAIN and MAPP regions, as given in the plant.dat file of EIA's National Energy Modeling System (NEMS) input files. The NEMS files include a large number of variables for each plant. We selected those relevant to the task of estimating EFs. NEMS files are the source of data for the following variables:

- Nameplate Capacity
- Summer Capacity
- Winter Capacity
- Average Capacity Factor
- January Capacity Factor<sup>2</sup>
- July Capacity Factor
- Average Heat Rate (Btu/kWh)
- Fuel Type<sup>3</sup>
- Variable O&M Cost
- Fixed O&M Cost
- NOx Emission Rate (lbs./MMBtu)
- Scrubber Efficiency (%) in Removing SO<sub>2</sub>

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<sup>1</sup> The method used in this work is primarily intended for small-to-medium size projects that affect operation at the margin. However, the basic approach could also be used to model substitution of a large project power plant for a planned power plant that would otherwise be part of the system.

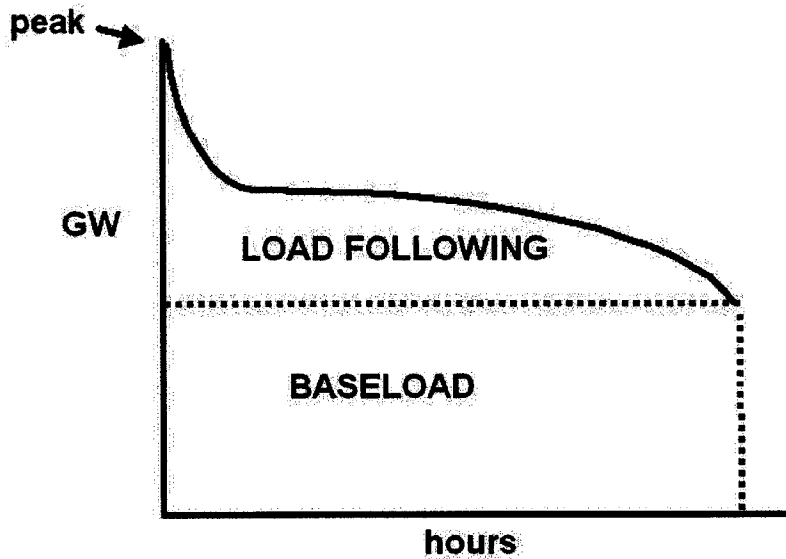
<sup>2</sup> January and July capacity factors were not used in the calculations, but they could be used if one wished to derive separate emissions factors for the winter and summer seasons.

<sup>3</sup> NEMS lists seven different fuel types for coal-fired plants and two types for oil-fired plants.

# Load Duration Curve

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load duration curve is a reordering of loads from highest to lowest



only generators in the load following section are affected by conservation

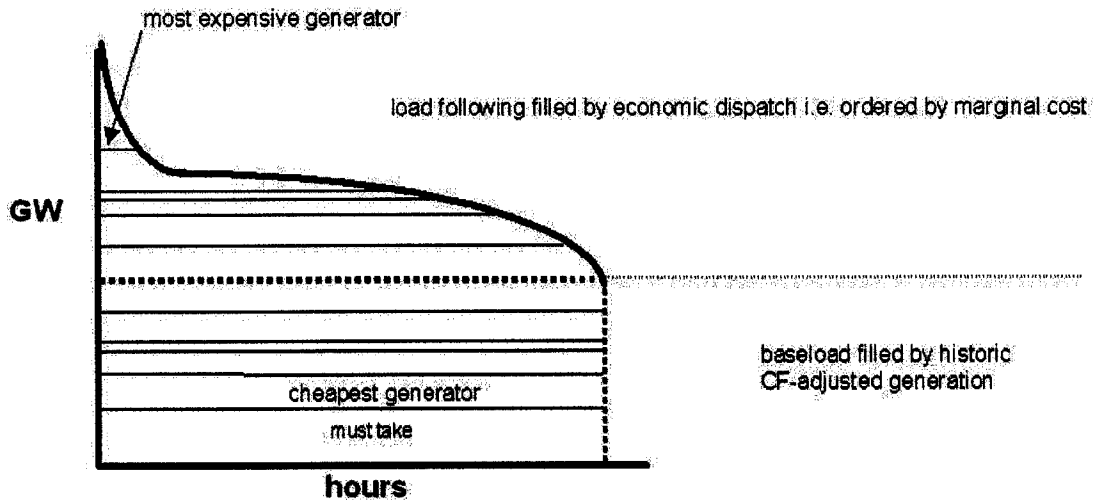
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**Figure 1.** Load Duration Curve

**Fuel data.** We estimated a fuel price in cents per million Btu for each of the 17 fuel types (the values used and the sources are documented in an Excel file). The sulfur content of different coal and oil types was based on EIA data. Values used were (in lbs. sulfur per million Btu) 0.3 for low-sulfur coal, 1.3 for medium-sulfur and scrubbed coal, 2.0 for high-sulfur coal, 0.15 for low-sulfur heavy oil, 0.2 for high-sulfur heavy oil, and 0.01 for fuel oil. We based the carbon content of different fossil fuels on data from the Intergovernmental Panel on Climate Change.

# Assume Economic Dispatch

load duration curve is filled from cheapest to most expensive generators  
(except for must take generation - hydro, wood, and CHP)



**Figure 2.** Assume Economic Dispatch

**Load data.** The load data for MAPP and MAIN are hourly data for 1999 from NERC. Figure 3 depicts the load duration curve that was constructed.

**Derived data.** We used the above data to calculate the variables necessary to derive the various EFs for each plant, including:

Average Capacity = The average of Summer Capacity and Winter Capacity

Annual Generation (MWh) = Average Capacity \* Average Capacity Factor \* 8760 hours

NO<sub>x</sub> Emission Rate (lbs./MWh) = NO<sub>x</sub> Emission Rate (lbs./MMBTU) \* Heat Rate (BTU/kWh)/1000

SO<sub>2</sub> Emission Rate (lbs./MWh) = Fuel Sulfur Content (lbs./MMBTU) \* Heat Rate (BTU/kWh)/1000 \* scrubber efficiency

CO<sub>2</sub> Emission Rate (lbs./MWh) = Fuel Carbon Content (lbs./MMBTU) \* Heat Rate (BTU/kWh)/1000 \* 3.667

Marginal Cost (\$/MWh) = Heat Rate (BTU/kWh)/1000 \* Fuel Cost (\$/MMBTU) + Variable O&M (\$/MWh) + Fixed O&M (\$/MWh)

# Actual LDC Used

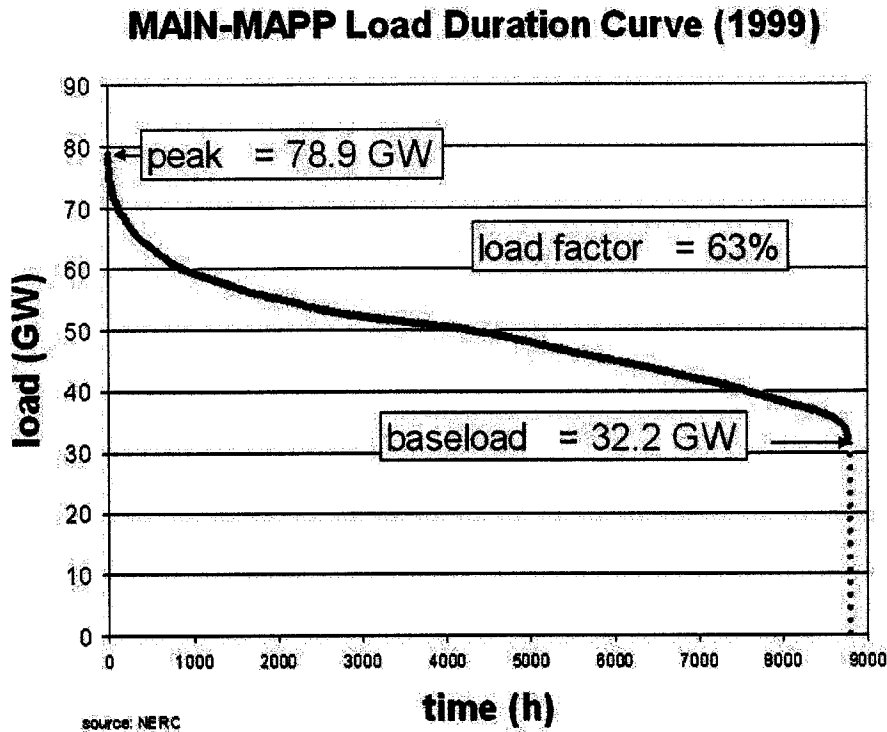
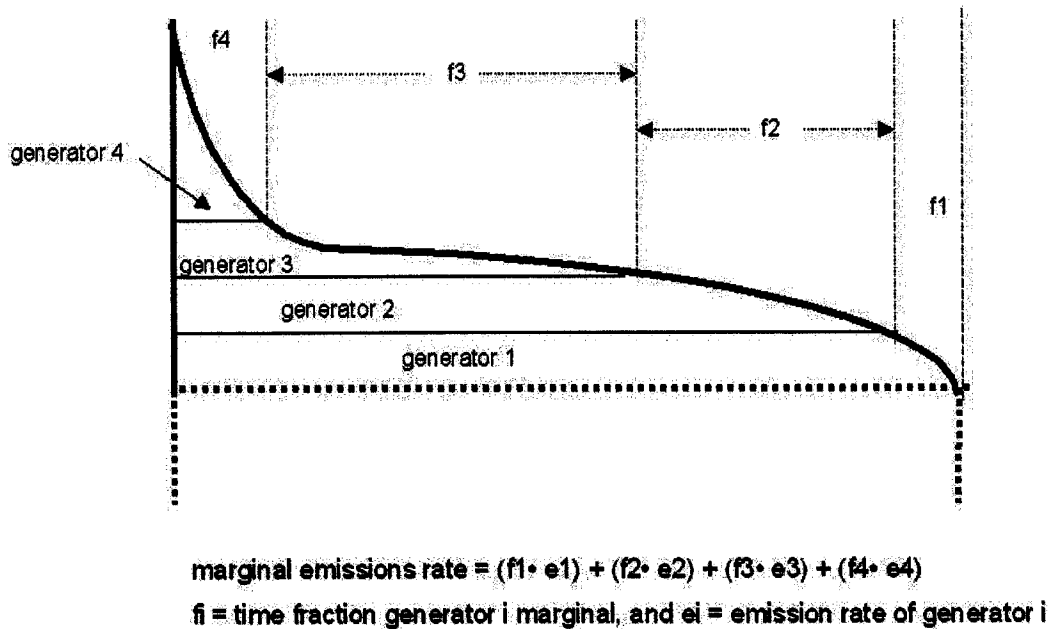


Figure 3. Actual LDC Used

## Marginal Emissions Rates

The marginal emissions rate for a given pollutant is calculated as the average of the respective emission factors for each source, weighted by the percentage of hours in the period for which each source is marginal (see Figure 4).

# Calculation of Marginal Emissions



**Figure 4.** Calculation of Marginal Emissions

The calculated emissions rates, based on ranking plants by marginal cost, are as follows:

	<b>Emissions rate (lbs./MWh)</b>
NO <sub>x</sub>	6.4
SO <sub>2</sub>	10.8
CO <sub>2</sub>	2400

The EFs vary slightly depending on whether one ranks the plants by marginal cost or by capacity factor (Figure 5). It is noteworthy that the marginal emission factors are very close to the average emission factors for all fossil fuel plants. The reason for this result is that the MAIN/MAPP system is dominated by fossil fuel (mainly coal-fired) generation (62% of the total), and the nuclear generation (30%) provides base load. This result suggests that using the average emission factors for all fossil fuel plants may be adequate - and simpler than deriving marginal emission factors - as a method.

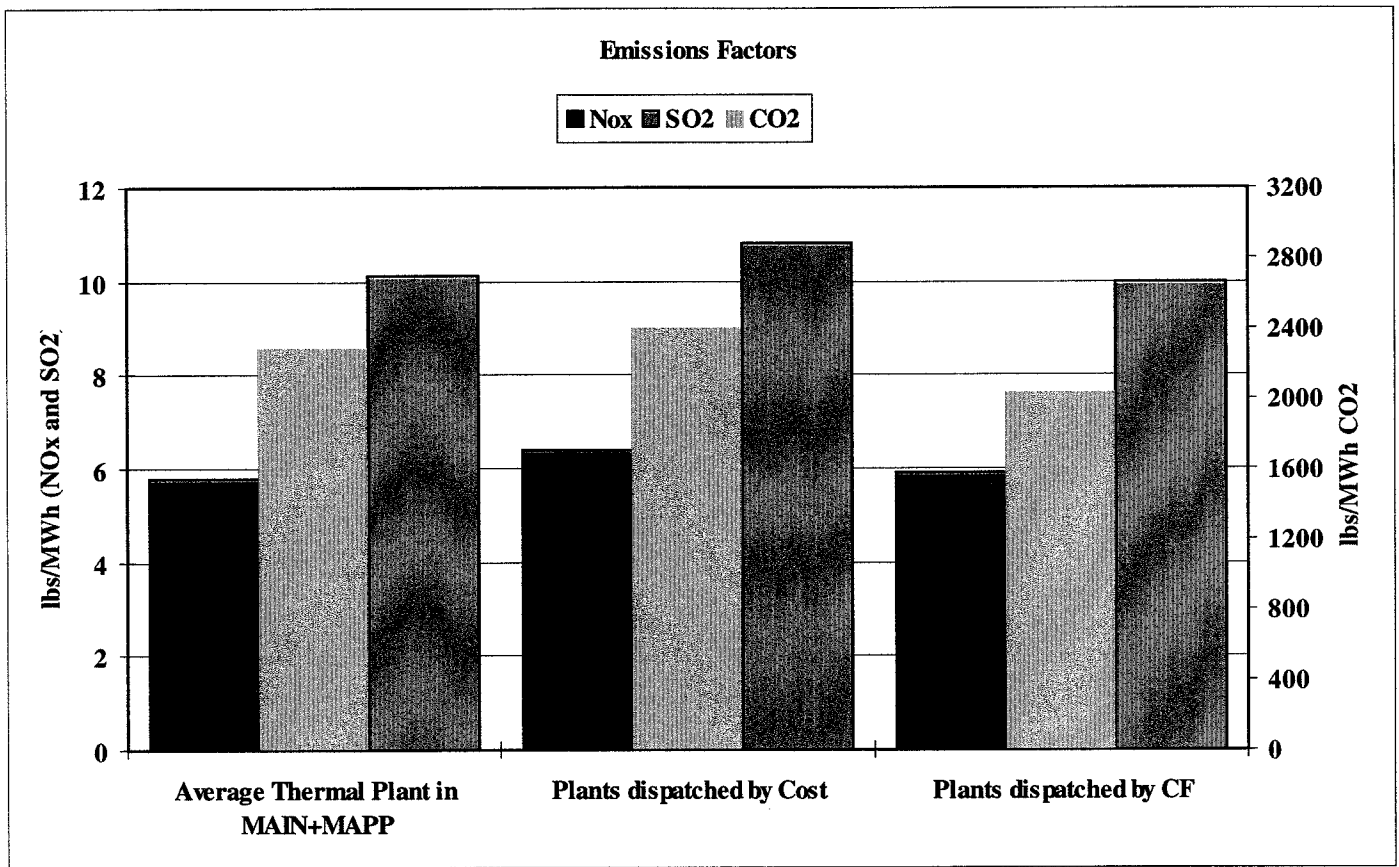


Figure 5. Results

## Methods and Results for Documenting Energy Savings for the Focus on Energy Pilot Programs

### Background

As program implementation plans and objectives evolved for the Focus on Energy pilot programs (in 1999), there was some redefinition of goals for several programs. This redefinition primarily consisted of *greater* emphasis on market preparation goals, and *lesser* emphasis on near-term capture of energy savings (i.e., kWh and therms). The pilot programs that have retained important near-term energy savings objectives (and associated evaluation objectives) include: the Commercial and Industrial programs; the Water Heater Conversion program; and, the Energy Efficiency Performance program (EEP). Given the pace and level of activity of program implementation, it is the Commercial and Industrial programs that are currently receiving the most evaluation effort toward documenting energy savings. Thus, the estimated net energy savings for these programs will produce the earliest results for the Focus on Energy environmental analysis. As participation in the other programs increases, their evaluated energy savings estimates will also be brought into the environmental analyses. The following summarizes the approach to documenting energy savings and provides the evaluated (net) energy savings and corresponding avoided emissions for NO<sub>x</sub>, SO<sub>2</sub>, and CO<sub>2</sub> employing the emissions factors estimated for the Focus on Energy pilot program.

## Overview

**Program implementation.** Commercial and Industrial program implementation staff initiate customer participation with either abbreviated or detailed audits of customer sites. They then develop recommendations for improving energy efficiency. Implementation staff typically prepare a written report to the customer detailing the recommended changes and the estimated savings that would be achieved from those savings.

**Evaluation approach.** The evaluation team estimated total direct electricity savings for the C&I Program of 20,715 MWh for the first year and 25,604 MWh cumulative total for year 3 (Table 1). In addition, estimated natural gas savings were estimated to be 3,311,715 therms in the first year and 3,292,890 by year 3. The majority of energy savings that have materialized (or will) are from the Industrial Program because of a few very large participants with enormous opportunities for energy efficiency improvement. Both the Commercial Program and the Industrial Program have been successful at achieving their participation goals and realizing actual energy savings.

Customers who have participated in the C&I Program through March 2001 will save \$1,175,569 in electricity costs next year, for savings that materialized within the first year. This is based on an average cost of electricity of 6.58 cents per kWh.

**Table 1: Summary of Program Energy Impacts**

	KWH Savings		Therm Savings	
	Year 1	Year 3	Year 1	Year 3
<b>Commercial Program</b>	2,007,443	2,877,547	241,831	250,806
<b>Industrial Program</b>	18,707,443	22,726,221	3,069,884	3,042,084
<b>Combined C&amp;I Program</b>	20,714,555	25,603,768	3,311,715	3,292,890

**Summary of avoided emissions based on the KWh energy savings.** Using the marginal emissions rates developed for the Focus on Energy pilot (as described above), the following environmental benefits are estimated for both Year 1 and Year 3 estimated energy impacts for the combined C&I programs.

**Table 2: Summary of Avoided Emissions Based on the KWh Energy Savings**

	Emissions rate (lbs./MWh)	Avoided Emissions (lbs.)	
		Year 1	Year 2
<b>NO<sub>x</sub></b>	6.4	132,573	163,864
<b>SO<sub>2</sub></b>	10.8	223,717	276,521
<b>CO<sub>2</sub></b>	2400	49,714,932	61,449,043

## Analysis Steps

Energy savings for the C&I Program were estimated by the evaluation team using seven steps, described below. Each step corresponds to a column in Table 2 below. .



**Table 3: C&I Program Energy Savings**

Analysis Element	Implementer Estimates (1)	Correction Factor (2)	Revised Estimates (3)	Year 1 Realization Rate (4)	Year 3 Realization Rate (5)	Year 1 Savings (6)	Year 3 Savings (7)
<b>COMMERCIAL PROGRAM</b>							
<b>KWHs</b>	4,471,196	88.61%	3,961,927	50.66%	72.63%	2,007,112	2,877,547
<b>Therms</b>	486,598	81.97%	398,864	60.63%	62.88%	241,831	250,806
<b>INDUSTRIAL PROGRAM</b>							
<b>KWH</b>	26,208,688	121.89%	31,945,770	58.56%	71.14%	18,707,443	22,726,221
<b>Therms</b>	3,331,340	105.63%	3,518,894	87.24%	86.45%	3,069,884	3,042,084
<b>COMBINED C&amp;I PROGRAM</b>							
<b>KWH</b>	30,679,884		35,907,697			20,714,555	25,603,768
<b>Therms</b>	3,817,938		3,917,759			3,311,715	3,292,890

**Implementation savings estimates.** The starting point of this analysis was estimates of program savings provided by the implementation team (March 2001). These estimates reflect the total kWh and therm savings the implementers expect if all of the measures recommended in the technical assessments were actually installed by participating customers (Table 3). This is considered a maximum potential that can be realized from the program.

**Table 4: Implementer Estimates of Potential Program Savings**

	Commercial	Industrial	Combined C&I Program
<b>Therm Savings</b>			
<b>Total Savings</b>	275,539	946,107	1,221,646
<b>Percent of Total</b>	22.55%	77.45%	100.00%
<b>KWH Savings</b>			
<b>Total Savings</b>	2,345,400	9,091,972	11,437,372
<b>Percent of Total</b>	20.51%	79.49%	100.00%

**Estimate correction factor.** The evaluation team derived a correction factor to adjust the implementer estimates based on an independent, detailed engineering analysis of selected projects. A total of 42 case studies were conducted to develop revised estimates of potential kWh and therm savings (Table 4).<sup>4</sup> These estimates were divided by the implementer estimates of potential savings for the same group of participants to compute a correction factor. Correction factors were calculated separately

<sup>4</sup> PA Consulting subcontractor Michaels Engineering performed the engineering analysis of 21 Commercial Program projects and SBW Consulting performed a parallel analysis of 21 Industrial Program projects.

for the Commercial Program and the Industrial Program. Within each program, correction factors for estimates of kWh and therm savings were calculated.<sup>5</sup>

**Table 5:** Evaluator Estimate of Potential Program Savings

	Commercial	Industrial	Combined C&I Program
	<b>Therm Savings</b>		
<b>Total Savings</b>	225,867	999,383	1,225,250
<b>Percent of Total</b>	18.43%	81.57%	100.00%
	<b>KWH Savings</b>		
<b>Total Savings</b>	2,078,305	11,082,566	13,160,871
<b>Percent of Total</b>	15.79%	84.21%	100.00%

**Revise estimate of potential savings.** The next step was to revise the estimates of program-wide potential kWh and therm savings developed by the implementation contractor to reflect the learnings from the detailed case studies. The correction factor was multiplied by the implementer estimates of program-wide savings described in step 1 above.

**Calculate realization rate for year 1.** The evaluation team developed realization rates for potential savings in the first year. This is defined as the ratio of savings from measures that have *actually* been installed (or highly likely) to estimates of potential savings. The first step was to tabulate survey data from participants regarding the actual (or planned) installation of recommended measures. In addition, the case studies looked for evidence that measure had already been installed or were in progress. Customer responses were assigned likelihood percentages to compute savings, as shown in Table 5 below.

**Table 6:** Expected Timing of Recommended Measures

Survey response (by measure)	Assigned likelihood of Installation within 1 year
Already installed	100%
Installation in progress	100%
Definitely plan to install	100%
Probably install	75%
Might install	50%
Probably won't install	25%
Definitely won't install	0%

Realized saving were calculated using a formula that multiplies potential savings for each project by the percentage (reflects likelihood of installation within year) that is assigned based on customer

<sup>5</sup> There was insufficient data to support the estimation of correction factors on a measure-by-measure basis. A total of 11 energy-efficiency measure groups were analyzed in the 42 case studies. Because many participants did not have certain measures recommended, the ratios were somewhat unstable.

survey responses (Table 6). The estimates of realized savings are then divided by the revised estimate of potential savings from column #3 above. This percentage is the Year 1 realization rate.

**Calculate realization rate for year 3.** The next step was to calculate realization rates for three years out. This is necessary since some of the savings will not occur in the first year. Therefore, the evaluators made assumptions about the remaining savings that were not realized in year 1 that could be expected by year 3.

**Calculate program-wide savings for year 1.** The evaluators used the realization rates for year 1 described in step 4 above to extrapolate the findings from the analysis group to the overall program. In other words, the realization rates were multiplied by revised estimates of potential savings for estimates of realized savings for the overall program through March 2001.

**Calculate program-wide savings for year 3.** The realization rates for year 3 described in step #5 above were applied to the estimate of overall potential program savings through March 2001. This is a cumulative estimate of realized savings expected from the program.

### **Planned Enhancements to the Quantification of Environmental Benefits Approach for Focus on Energy**

Enhancements to the environmental benefits quantification approach are underway in three areas: (1) development of multiple load duration curves (LDCs); (2) additional plant-specific data for heat rates and Nox curves; and (3) a more refined approach for defining control area dispatch. Each of these types of enhancements is summarized below.

**Multiple load duration curves.** The approach described in this paper is designed to provide factors for avoided emissions that are simple for the evaluation team to use. Creating more realism and complexity by deriving different EFs that are appropriate for different periods (on a seasonal and/or daily basis) in turn requires the evaluation to collect data on the electricity production or savings from a project in greater detail, corresponding to system-specific utility data for different service territories in Wisconsin. DOA has determined that disaggregating the single load duration curve is preferred, and would also like more work devoted toward identifying the marginal generators during these different periods.

In a system for which separate EFs have been derived for peak and off-peak periods during different seasons, the evaluation team will need to know or estimate the annual electricity generation or savings that took place during the peak and off-peak periods in each season. It is possible that providing this level of detail could be seen as demanding too much from project sponsors (customers), but the initial success in recruiting for the evaluation M&V is promising. In a system with numerous power sources and considerable variation in operation such detail could be important for accurately characterizing avoided emissions. One possible approach would be to require a higher level of detail for the largest ECM projects.

**Additional plant-specific data for heat rates and NOx curves.** NOx conditions vary greatly depending on specific generator plant operating conditions. Using data available from the Wisconsin Department of Natural Resources, the evaluation team plans to refine emissions factor data by plant.

**A more refined approach for defining control area dispatch.** As described above, the initial approach considered all plants in both the MAIN and MAPP regions. This method could be tailored to a subset of power plants that more closely models only Wisconsin generation sources.