

Measuring Greenhouse Gas Benefits of Efficiency Programs

by

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World Resource Institute Guidelines

- In the Fall of 2007, the World Resource Institute (WRI) and the World Business Council for Sustainable Development published “Guidelines for quantifying GHG Reductions from Grid-Connected Electricity Projects.”
- The guidelines were developed to supplement the Greenhouse Gas Protocol for Project Accounting, published in December 2005.

World Resource Institute Guidelines

- The guidelines explain how to quantify reductions in greenhouse gas emissions (referred to as “GHG reductions”) resulting from projects that either generate or reduce the consumption of electricity transmitted over power grids.
- This presentation specifically describes the various calculation methods identified by the WRI report used for quantifying the avoided greenhouse gas (GHG) emission benefit of energy efficiency programs.

Electricity Reduction Project Activities

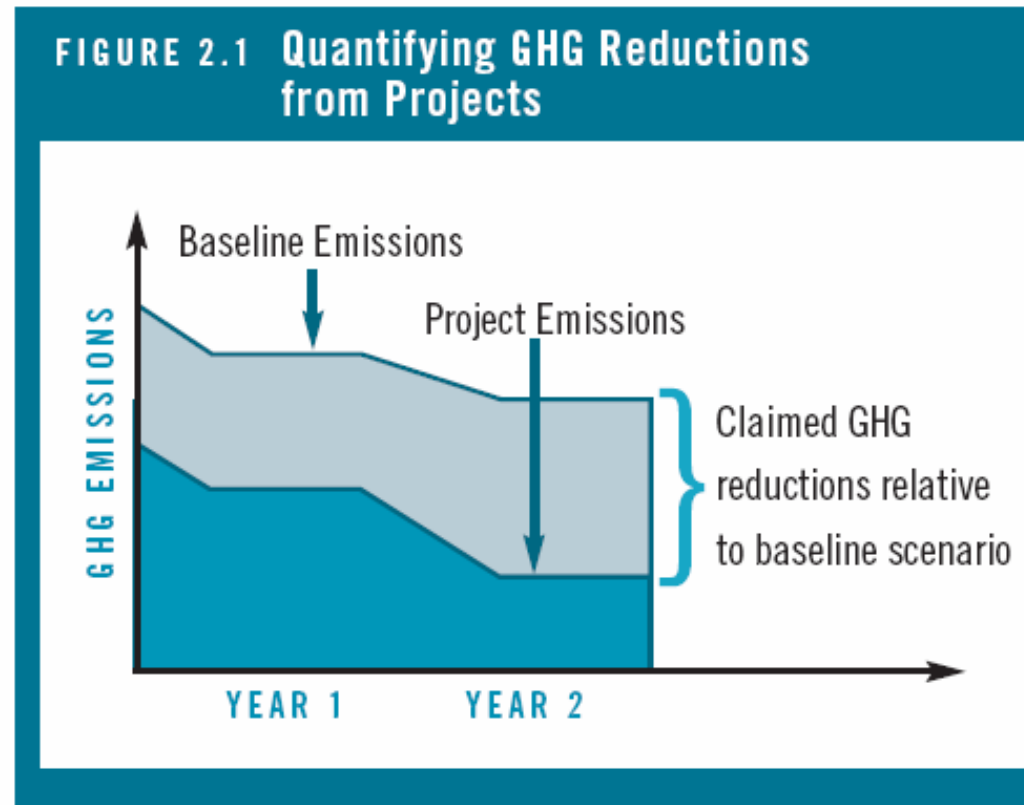
- Chapter 3 of the WRI guidelines concerns electricity reduction project activities. Electricity reduction project activities reduce GHG emissions by avoiding grid-based generation.
- These project activities involve either: (1) improving the efficiency with which grid electricity is used for a particular application; or (2) generating electricity onsite so that supply from the grid is unnecessary.

Efficiency Project Savings

- In terms of accounting for GHG reductions, electricity reduction and generation project activities can be treated analogously.
- The difference is that *the amount of avoided generation is used to determine baseline emissions* instead of the amount of generation.
- Whereas project activity generation can be metered and measured, avoided generation must be inferred from an estimate of the *project activity's electricity savings*.

Baseline vs. Actual Emissions

- Fully accounting for GHG reductions requires assessing both the intended change caused by a project activity (i.e., its “primary effect”) and any unintended changes (i.e., “secondary effects”).



Adjusted Consumption Baseline

- Well-developed standards exist for determining the adjusted consumption baseline for individual end-user activities.
- The Efficiency Valuation Organization's *International Performance Measurement and Verification Protocol (IPMVP)*, for example, contains extensive guidance for this purpose, including detailed descriptions of computation methodologies and monitoring methods.
- Another industry guideline is the American Society of Heating, Refrigerating, and Air-Conditioning Engineers' (ASHRAE) *Guideline 14-2002*. Available at <http://resourcecenter.ashrae.org/store/ashrae/>.

Adjusted Consumption Baseline

- Efficiency Valuation Organization, 2007. International Performance Measurement and Verification Protocol (IPMVP), Volumes I and III. San Francisco, USA. Volume I covers concepts and methodological options for determining electricity savings from retrofits to existing facilities.
- Volume III covers concepts and options for determining energy savings in new construction, as well as special considerations for electricity generation projects installed on the end-user side of the utility meter. Both volumes are available online at <http://www.evo-world.org>.

Adjusted Consumption Baseline

- For the purpose of GHG reduction accounting a full analysis should be conducted to demonstrate that the baseline scenario would not involve an alternative new technology or practice (changes in consumption not related to the efficiency program), and would not involve the project activity itself (in which case the project activity would not be additional).
- For example, some project activities may replace obsolete equipment with a currently available, standard equivalent. For the project activity to produce quantifiable GHG reductions, it would have to involve a more energy efficient model than current “standard” equipment.

Savings to Avoided Generation

- In order to estimate grid GHG reductions, electricity savings must be converted to a corresponding amount of avoided grid generation.

$$GENproj_t = \frac{S_t}{(1 - L)}$$

Where:

- $GENproj_t$ is total grid generation avoided by the project activity for time period t .
- S_t is total electricity savings for time period t ,
- L is the average fraction of generated power that is lost within the grid where the project activity is located. This fraction can generally be obtained from local grid operators.
- The magnitude of line losses can change over time as a grid develops. Thus, the quantity used for L may be monitored and updated over time as appropriate.

Estimating Claimed Emissions (BE)

- Estimating baseline and claimed emissions for electricity reduction project activities is done by multiplying **avoided generation** ($GEN_{proj,t}$) by an appropriate **baseline emission rate**.

$$BE_t = ER_{baseline,t} \cdot GEN_{proj,t}$$

Where:

- BE_t is the total baseline emissions for time period t ,
- $ER_{baseline,t}$ is the baseline emission rate for time period t ,
- $GEN_{proj,t}$ is the electricity generated or avoided by the project activity over time period t .

Build Margin and Operating Margin

- A key assumption of the guidelines is that a project activity can displace or avoid the operation of existing grid-connected power plants and/or the construction and operation of new power plants.
- Generation displaced from existing power plants is referred to as the “**Operating Margin**” (OM).
Generation from potential new capacity, whose construction is avoided due to the project activity, is referred to as the “**Build Margin**” (BM).

Baseline Emission Rate (*ER*)

- In deriving a baseline emission rate, the same types of considerations that apply to generation project activities also apply to electricity reduction project activities.
- The baseline emission rate can have both a Building Margin (BM) and Operating Margin (OM) component, and the same methods can be used to estimate BM and OM emission factors.

Baseline Emission Rate (ER)

- The formula for the baseline emission rate is:

$$ER_{baseline_t} = wBM + (1 - w)OM_t$$

Where:

- $ER_{baseline_t}$ is the baseline emission rate (e.g., tons of CO₂-equivalent per MWh) for time period, t (e.g., one year);
- BM is the build margin emission factor. The BM emission factor is calculated only once and does not vary by time period;
- OM_t is the operating margin emission factor for time period, t .
- w is the weight (between 0 and 1) assigned to the build margin.

Assessing the Capacity Value

- The capacity value of electricity reduction project activities can be determined in an analogous fashion to electricity generation project activities, by considering whether their operation is **predictable** or **unpredictable**.
- Capacity value will be largely determined by the minimum **predictable** load reduction caused by the project activity.

Assessing the Capacity Value

- Where precise values for predictable and variable load reductions are difficult to determine, estimate capacity value by assessing the timing of the project's operation and its **firm** and **non-firm** characteristics.
- Many (if not most) electricity reduction project activities will involve elements of predictability and unpredictability, analogous to both firm and non-firm power generation.

Assessing the Capacity Value

- For example, suppose a utility demand side management program affects electricity demand in a way that varies from hour to hour from 5 to 20 MW, with an average reduction of 10 MW.
- The “rated capacity” of the program would be equivalent to 20 MW, but the program’s capacity value would be the minimum predictable level of reduction, i.e., 5 MW.
- Analogously, its “capacity factor” would be 50 percent (10 MW / 20 MW). **The appropriate value for w** would therefore be $[5 \text{ MW} / (20 \text{ MW} \times 0.5)] = 0.5$.

Assessing the Capacity Value

- Many individual end-user project activities are small in scale, and are often implemented for reasons wholly unrelated to grid capacity requirements. These types of project activities will have little or no effect on the BM.
- For larger end-user project activities and for wide-area programs, a key consideration will be quantifying their effects on grid electricity consumption and translating these effects into estimates of their “capacity value” and “rated capacity.”

The Build Margin (BM)

- **Build margin emissions** are estimated from the GHG emission rates of recent capacity additions, or in some cases, planned and under-construction capacity. BM emission factor is calculated as follows:

$$BM = \frac{EM_t}{GEN_t}$$

Where:

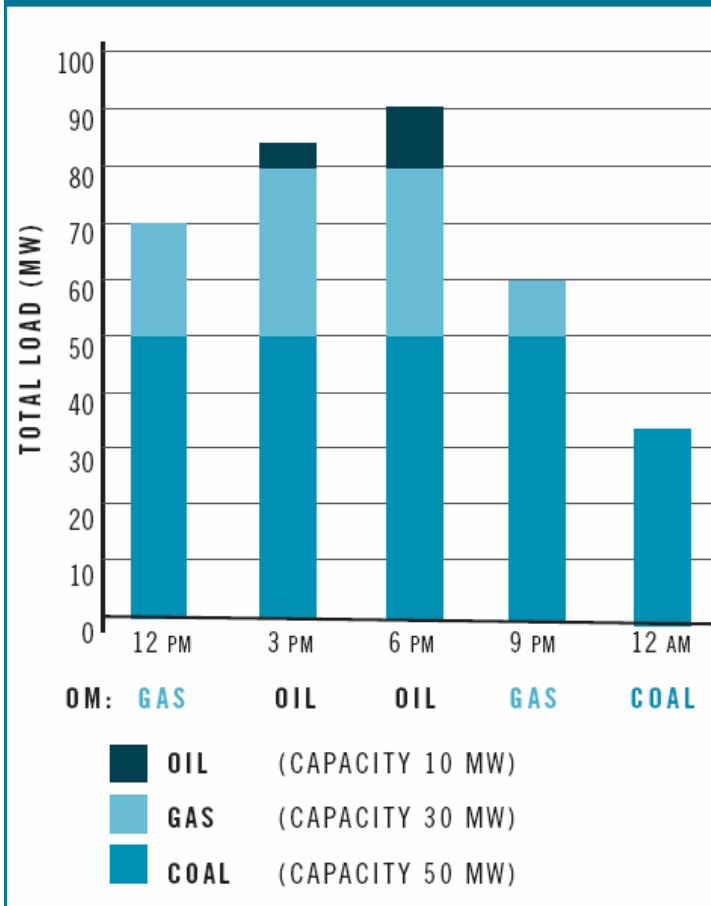
- *BM* is the build margin emission factor (e.g., expressed as **tons CO₂-equivalent per MWh**);
- *EM_t* is the total GHG emissions from the identified baseline candidate power plant over time period *t*.
- *GEN_t* is the total generation from the identified baseline candidate power plant over time period *t*.

The Operating Margin (OM)

- **OM emissions** are estimated using methods that attempt to approximate the emissions from the specific power plants whose operation is displaced.
- In theory, this estimation requires identifying which power plants are providing electricity at the margin (i.e., the last to be switched on-line or first to be switched off-line) during times when the project activity is operating.
- OM emissions can vary considerably over time depending on load levels, the types of power plants on the grid, and the order in which they are dispatched to meet load.

The Operating Margin (OM)

FIGURE 2.2 Simplified Example of Changes in the Operating Margin Over a Typical Day



- In this simplified example three different power plants are dispatched: a 50 MW coal plant (dispatched first); a 30 MW natural gas plant (dispatched second); and a 10 MW oil-fired plant (dispatched only to meet peak loads).
- The last resource to be dispatched in each hour is at the OM.

OM Calculation Methods

1. **Average load-following.** Calculates the average annual emissions of load-following power plants.
 2. **Average marginal.** Uses a load-duration curve analysis to calculate weighted average emissions of resource types that are on the margin for specific time periods.
 3. **Marginal historic.** Uses an analysis of historical data (i.e., a dispatch decrement analysis) to determine a marginal emission rate for each hour the project activity operates.
 4. **Marginal modeled.** Uses dispatch modeling to determine marginal emissions for each hour the project activity operates.
- Another method, not presented here, is to calculate a simple average grid emission rate (e.g., total GHG emissions divided by total MWh of generation for a given time period). An average emission rate is easy to calculate, but it provides only a rough approximation of marginal displaced emissions.

OM Calculation Methods

- To calculate an annual OM emission factor, weight each sub-annual emission factor by the project activity's output during that time period. Use the following general formula:

$$OM_y = \frac{\sum (EG_{t,y} \cdot OM_{t,y})}{EG_y}$$

Where:

- OM_y is the OM emission factor specific to the project activity for year, y , in tonnes of CO₂-equivalent per megawatt-hour (t CO₂eq/MWh).
- $EG_{t,y}$ is the project activity's output in MWh over sub-annual time period, t (e.g., hour, day, week, month, or season) for year, y .
- $OM_{t,y}$ is the OM emission factor (expressed as t CO₂eq/MWh) calculated for sub-annual time period, t , in year, y , using one of the methods described in this chapter.
- EG_y is the project activity's total output in MWh over the year, y .

Method 1: Average Load Following

- This type of method calculates the average annual emissions of power plants that are not baseload or must-run.
- The advantage of this method is that it is easy to perform and requires minimal amounts of data.
- However, the result is an average emission rate of load-following plants, which may or may not accurately reflect the emission rates of power plants that are actually on the margin.

Method 1: Average Load Following

- There are two specific methods for calculating an “average load-following” emission factor.
- Method 1A is preferred; Method 1B should be used only if obtaining the data for Method 1A would be difficult.

DATA REQUIREMENTS

METHOD 1A

- Total generation, by power plant
- Total emissions or total fuel consumption, by power plant
- A list of identified baseload, must-run, and intermittent power plants

METHOD 1B

- Total generation, by fuel type
- Total installed capacity or average fuel cost, by fuel type
- Total fuel consumption or GHG emissions, by fuel type

Method 2: Average Marginal Emissions

- This method calculates an OM emission factor by averaging the emission rates of different types of power resources, weighted according to the length of time these resources actually provide power on the margin.
- The length of time on the margin is determined through a “load duration curve” analysis, which reveals the types of resources that were required to meet peak system loads over a specific time period.
- The level of detail required for this analysis can vary, as can some of the specifics for determining marginal resources.

Method 2: Average Marginal Emissions

DATA REQUIREMENTS

- Total system loads (power demand, in MW), by hour, for specific time periods
- Total generation, by fuel or resource type, for specific time periods
- Total emissions or total fuel consumption, by fuel or resource type, for specific time periods
- Optional: Fuel and/or operating costs, by fuel or resource type

Method 3: Marginal Historic Emissions

- This type of method involves an analysis of historical data to determine which power plants were in the dispatch order for the grid during each hour of a year.
- The project activity's generation (or avoided consumption) can then be matched to the marginal generation mix in each hour to calculate an OM emissions rate.
- Ideally, this analysis is done with historical data derived from the same time period over which the project activity operates (*ex post*), although it can also be done using prior year data matched to project activity generation in the current year (*ex ante*).

Method 3: Marginal Historic Emissions

DATA REQUIREMENTS

- **Total generation from each power plant on the grid, by hour.**
- **GHG emissions or fuel consumption for each power plant on the grid, by hour.**
- **The system dispatch order of operation for each power plant on the grid.**

Method 4: Marginal Modeled Emissions

- This type of method uses a model of the grid electricity system to simulate the dispatch of power sources under typical operating conditions.
- Globally, a number of models are available for this purpose and they can be used and applied in different ways.
- There are two basic approaches, however, to this type of dispatch modeling:

Method 4: Marginal Modeled Emissions

1. Use a “generic” modeling run for the grid to calculate a typical OM emission factor for each hour in which the project activity generates.
 - This approach is analogous to the marginal historic method (Method #3), but relies on modeled rather than historical dispatch and emissions data.
 - In principle, hourly marginal GHG emissions can be estimated and applied to the output from any project activity that displaces the OM.

Method 4: Marginal Modeled Emissions

2. Conduct separate modeling runs that simulate grid operation under identical circumstances with and without the project activity.
 - OM emissions displaced by the project activity are estimated by comparing the results of the modeling runs.
 - This approach requires more effort and produces project-specific results, so it generally makes sense only for large project activities.

DSMore's Emission Monitoring

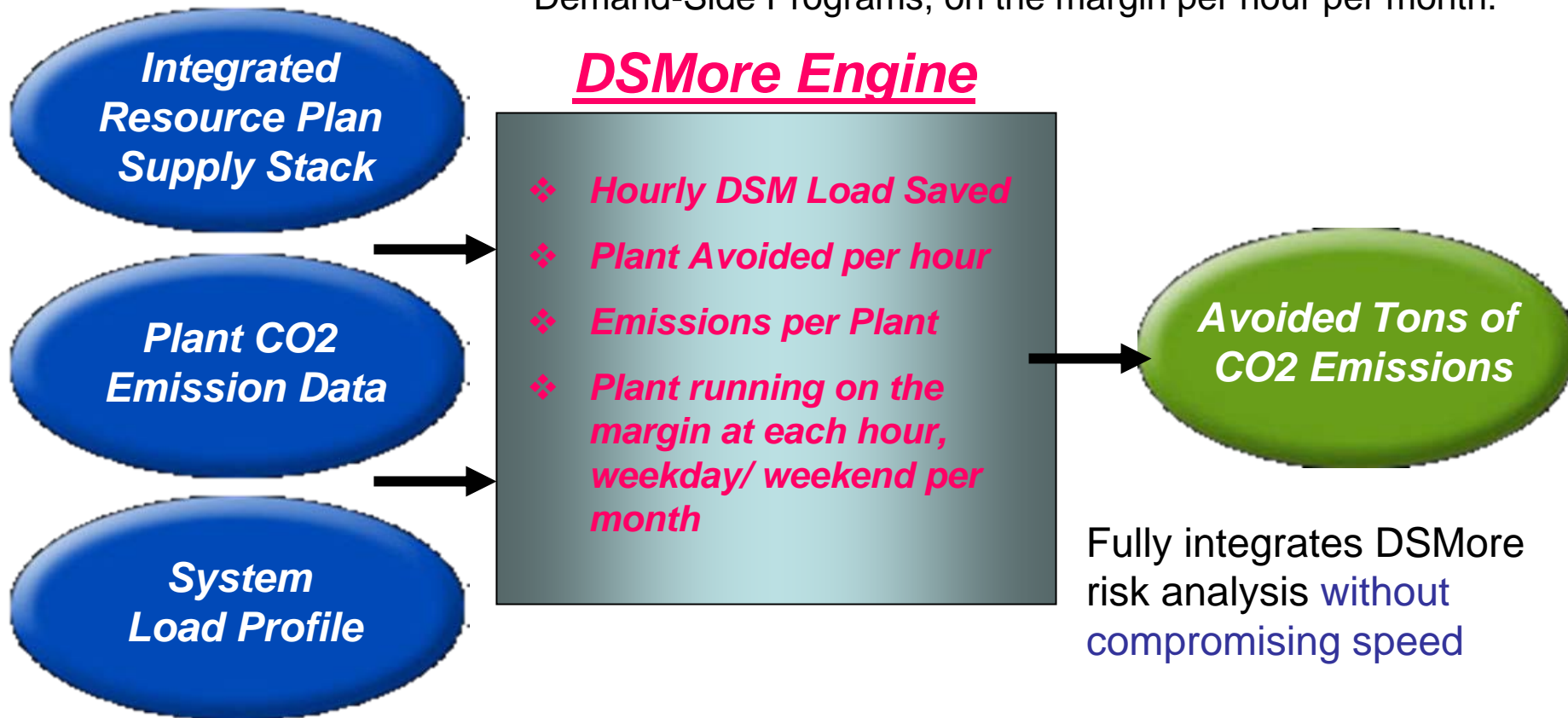
- **DSMore's approach to valuing avoided carbon emission ?**
 - A Greenhouse Gas Emission (GHG) worksheet is embedded inside the standard DSMORE calculation engine. Carbon emission results can be valued at the same time as normal DSM valuations.
 - Additional user set up is required, related to supply stack importing and review of default carbon emissions per plant or region.
 - Compatible with recognized GHG protocols (GHG Protocol Corporate Accounting and Reporting Standard and the GHG Protocol for Project Accounting).

DSMore's Emission Monitoring

- Explicitly addresses **varied emissions** savings due to weather uncertainty, load savings variability and variable plant dispatch decisions throughout the year.
- Relies on utility integrated planning estimates (IRP or other) to match supply-side resources with proposed demand-side activity.
- Values GHG emissions from recognized sources including traded markets and avoided emissions compliance technologies.

DSMore Emission Monitoring

- The IA GHG Model Aligns Supply-Side Resources with Demand-Side Programs, on the margin per hour per month.



Recognized Emissions and Avoided Value

- Combines recognized GHG emission data with plant specific performance information to generate avoided CO2 estimates

Estimates of CO₂ Emissions from Generation Technologies

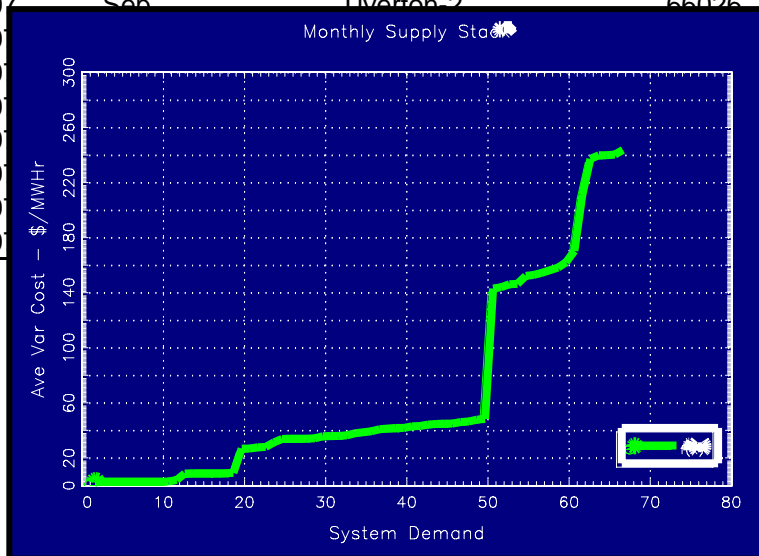
<u>Type of Unit</u>	<u>Tons CO₂/MWh</u> (New Units)*	<u>LBS CO₂/kWh</u> (New Units)*
Pulverized Coal	0.92	2.02768
Pulverized Coal w/ Carbon Capture	0.092	0.202768
IGCC	0.81	1.78524
IGCC w/Carbon Capture	0.081	0.178524
Supercritical Pulverized Coal	0.86	1.89544
Supercritical Pulverized Coal w/Carbon Capture		
Supercritical Pulverized Coal w/ Oxyfuel		
Natural Gas Combined Cycle		
NGCC w/Carbon Capture		
Nuclear/Hydro/Non-Fossil		

<u>Unit</u>	<u>Fuel</u>	<u>LBS CO₂/kWh</u>	<u>\$/Ton CO₂</u>	<u>\$/MWh CO₂</u>
Dan-River-CT	NG	1.115	\$ 24.00	\$ 12.14
Riverbend-CT	NG	1.115	\$ 24.00	\$ 12.14
BuzRst-GE-CT	NG	1.115	\$ 24.00	\$ 12.14
Custerd-CT-Fut	NG	0.74936	\$ 24.00	\$ 8.16
Buckside-3	COAL	2.02768	\$ 24.00	\$ 22.08
Buckside-4	COAL	2.02768	\$ 24.00	\$ 22.08
Cliffs-2	COAL	2.02768	\$ 24.00	\$ 22.08
Cliffs-3	COAL	2.02768	\$ 24.00	\$ 22.08
Cliffs-4	COAL	2.02768	\$ 24.00	\$ 22.08

Aligning Supply with Demand

- Aligns utility-specific supply-stack with hourly system demand profiles to accurately forecast plants on the margin, on which to measure avoided CO2 emissions

Year	Month	Unit	Monthly Generation MWhr	Ave Var Cost \$/MWhr	Fuel	LBS CO2/kWh	\$/MWh CO2
2007	Sep	Morro-1	19405	93	NG	0.82	\$ 12.04
2007	Sep	Morro-2	25452	85	NG	0.91	\$ 12.27
2007	Sep	Fort Drum	51068	43	NG	1.96	\$ 22.50
2007	Sep	Madison-3	52312	43	COAL	2.09	\$ 22.34
2007	Sep	Madison-4	54275	42	COAL	2.12	\$ 22.54
2007	Sep	Tiverton-2	66026	42	COAL	2.00	\$ 21.58
2007				39	COAL	2.23	\$ 21.59
2007				39	COAL	2.15	\$ 21.88
2007				39	COAL	1.85	\$ 22.54
2007				38	COAL	2.11	\$ 21.85
2007				0	NON	0	
2007				0	NON	0	
2007				0	NON	0	



- The intersection of monthly capacity factor and fractional **hourly** demand determines marginal avoided value

DSMore GHG Reports

Total Greenhouse Gas Impacts	
Total Per Participant Savings (Lbs)	160,997
Total Cumulative Savings (Lbs)	7,896,433
Total Per Participant Savings (\$)	\$1,753.14
Total Cumulative Savings (\$)	\$85,986.61
Total Cumulative NPV Savings (\$)	\$50,336.72

Greenhouse Gas Impacts by Year			
Year	Cumulative Participants	LBs CO2	\$ CO2
1	12	109,203	1,189
2	25	220,589	2,402
3	37	334,160	3,639
4	50	448,822	4,887
5	63	564,031	6,142
6	63	564,031	6,142
7	63	564,031	6,142
8	63	564,031	6,142
9	63	564,031	6,142
10	63	564,031	6,142

- DSMore Reports Total Program Greenhouse Gas Impacts:
 - Total Per Participant Savings (Lbs)
 - Total Cumulative Savings (Lbs)
 - Total Per Participant Savings (\$)
 - Total Cumulative Savings (\$)
 - Total Cumulative NPV Savings (\$)
- Greenhouse Gas Impacts by Year
 - Cumulative Participants
 - LBs CO2
 - \$ CO2

For more information about



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