ENERGY STAR Portfolio Manager
Methodology for Greenhouse Gas Inventory and Tracking Calculations

Introduction

Energy use in commercial and industrial buildings in the United States contribute 45 percent of national emissions of the greenhouse gases linked to global climate change.[1] Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are the principal greenhouse gases emitted to the atmosphere from the burning of fossil fuels to produce heat and power for buildings. Electricity consumption in these buildings is responsible for roughly three-quarters of these greenhouse gases (GHG), with the remainder resulting from burning natural gas and petroleum products. Of these three GHGs, CO_2 represents more than 99% of the total greenhouse gas emissions from fuels combusted by commercial, industrial, and electricity production sources, with CH_4 and N_2O together representing less than 1% from the same sources.[2]

The greenhouse gas accounting and tracking function in ENERGY STAR's Portfolio Manager was designed to provide users with the ability to record, track, and communicate the GHG emissions associated with the energy use of their buildings. The methodology for calculating GHG emissions in Portfolio Manager was designed to be consistent with the Greenhouse Gas Protocol[3] developed by the World Resources Institute and World Business Council for Sustainable Development, and as such is compatible with the accounting, inventory and reporting requirements of Environmental Protection Agency's (EPA) Climate Leaders program, as well as other state and NGO registry and reporting programs.

Methodology for Calculating a Building's Total Greenhouse Gas Footprint

The Portfolio Manager methodology to determine a building's total GHG emissions accounts for all CO_2, CH_4, and N_2O emissions associated with the building's energy use. This inventory includes GHG emissions from both fossil fuel consumed on-site (referred to as direct emissions), as well as GHG emissions generated off-site at power plants that deliver heat, cooling or electricity to the building (referred to as indirect emissions). To determine the direct emissions from on-site combusted fuels, Portfolio Manager utilizes a default fuel analysis approach. This simplifies calculation for the user by providing fuel-specific factors for heating value, carbon content, and carbon oxidation factor. Indirect emissions from district energy consumption (heating and cooling) use a similar approach. Indirect emissions from electricity consumption are determined through direct measurement by utility owners and operators, who report continuous emissions monitoring system data to EPA under several regulatory programs. This

[1] Table 2-16: U.S. Greenhouse Gas Emissions by Economic Sector and Gas with Electricity-Related Emissions, from *Inventory of U.S. Greenhouse Gas and Sinks: 1990-2005*. "USEPA #430-R-07-002, April 2007.
[2] Tables 3-3, 3-14, & 3-15, from *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*.
[3] World Resources Institute and the World Business Council for Sustainable Development, *The Greenhouse Gas Protocol; A Corporate Accounting and Reporting Standard*. Revised Edition. http://www.ghgprotocol.org/DocRoot/7e9ttsv1gVKekh7BFhqo/ghg-protocol-revised.pdf

information is available in U.S. EPA's Emissions & Generation Resource Integrated Database (eGRID)[4].

While a default fuel analysis approach provides a straightforward estimation of direct CO_2 emissions, estimating direct emissions of CH_4, and N_2O is much more complicated. Unlike CO_2 emissions, CH_4, and N_2O emissions depend not only upon fuel characteristics, but also on combustion technology (size, vintage, maintenance, and operation), combustion characteristics, usage of pollution control equipment, and ambient environmental conditions. Fortunately, as these direct emissions comprise a small percentage of the total GHG footprint of a building, fuel-specific, commercial sector factors are considered adequate to estimate CH_4, and N_2O emissions associated with on-site fuel consumption.

To provide consistency in reporting total GHG emissions, the quantity of each GHG is multiplied by its global warming potential, and expressed in CO_2-equivalents (CO_2e)[5]. A building's total GHG emissions are associated with the fuel consumption at the building only; any precombustion emissions associated with the energy used to extract, process, or deliver fuel to the building are not included.

Calculating Direct GHG Emissions

For ***direct*** greenhouse gas emissions in CO_2e, each fuel is assigned a heating content, carbon content, a carbon oxidation factor, and a standard carbon to CO_2 ratio to arrive at an emissions factor expressed in mass of CO_2 per unit of fuel energy. CH_4 and N_2O emissions factors are estimates derived for each fuel type using commercial end-use sector combustion technology, characteristics, and controls. Measured (billed or metered) site energy consumption is then multiplied by the following factors shown in **Table 1**.

[4] U.S. EPA's Emissions & Generation Resource Integrated Database (eGRID). eGRID2007 Version 1 contains the complete release of year 2005 data. The data are organized to reflect the owner, operator and electric grid configuration as of October 1, 2007. www.epa.gov/cleanenergy/egrid

[5] The 100 year global warming potential (GWP) of each greenhouse gas (CO_2=1, CH_4=21, and N_2O= 310) compares the radiative forcing ability of each gas relative to CO_2, which serves as the reference gas. Intergovernmental Panel on Climate Change, Climate Change 1995: The Science of Climate Change (Cambridge, UK; Cambridge University Press, 1995), http://www.ipcc.ch/ipccreports/assessments-reports.htm

Table 1 Direct Greenhouse Gas Emission Factors[6]				
Fuel Type	**kg CO_2/MBtu[7]**	**kg CH_4/Mbtu**	**kg N_2O/MBtu**	**kg CO_2e /MBtu**
Natural Gas	53.0567	0.0052709	0.0001054	53.200036
Fuel Oil (No. 2)	73.1500	0.0105419	0.0006325	73.567457
Wood	93.8667	0.3162555	0.0042167	101.815222
Propane	63.0667	0.0105419	0.0006325	63.484124
Liquid Propane	63.1620	0.0105419	0.0006325	63.579457
Kerosene	72.3067	0.0105419	0.0006325	72.724124
Fuel Oil (No. 1)	73.1500	0.0105419	0.0006325	73.567457
Fuel Oil (No. 5 & No. 6)	78.7967	0.0105419	0.0006325	79.214124
Coal (anthracite)	103.6200	0.0105419	0.0015813	104.331575
Coal (bituminous)	93.4633	0.0105419	0.0015813	94.174908
Coke	113.6667	0.0105419	0.0015813	114.378242
Fuel Oil (No. 4)	73.1500	0.0105419	0.0006325	73.567457
Diesel	73.1500	0.0105419	0.0006325	73.567457

Calculating Indirect GHG Emissions

Similar to the calculations for direct emissions, Portfolio Manager uses default emission factor values to determine ***indirect*** GHG emissions from purchased district energy. For purchased district steam and district hot water, use of a default emissions factor does not require the user to obtain boiler efficiency, fuel mix, or fuel emissions factor values from their energy supplier. For purchased district chilled water, the user should obtain the chilled water production method from their energy supplier. If this is not specified, no emissions results will be calculated for the building. For indirect emissions resulting from the consumption of district energy, measured site energy consumption is multiplied by the following factors shown in **Table 2**.

Table 2 Indirect Greenhouse Gas Emission Factors (District Energy)[8]	
Fuel Type	**kg CO_2e /MBtu**
District Steam	78.95
District Hot Water	78.95
District Chilled Water – Electric Driven Chiller	0.238095*eGRID Subregion Rate
District Chilled Water – Absorption Chiller using Natural Gas	66.50
District Chilled Water - Engine-Driven Chiller using Natural Gas	44.33

[6] U.S. Environmental Protection Agency, Climate Leaders Program, Direct Emissions from Stationary Combustion Sources, Appendix B, May 2008.
http://www.epa.gov/climateleaders/documents/resources/stationarycombustionguidance.pdf

[7] MBtu represents million Btu.

[8] Instructions for Form EIA-1605, Voluntary Reporting of Greenhouse Gases, Energy Information Administration, Department of Energy. October 15, 2007. Appendix N; Emissions Benchmarks for Purchased Steam and Chilled/Hot Water. Values do not include transmission losses.
http://www.eia.doe.gov/oiaf/1605/pdf/EIA1605_Instructions_10-23-07.pdf

For indirect emissions resulting from the consumption of grid-based electricity purchased from a utility, site electricity consumption is multiplied by the average electricity production output emission rates of the electricity grid serving the building, according to its eGRID subregion. These factors represent the average emissions from the all grid connected electricity generation units (baseload, intermediate, and peaking), and are appropriate for developing a carbon footprint or emissions inventory. The annual output emissions rate factors are shown in **Table 3** and the location of these eGRID subregions are shown in **Figure 1** below.

Table 3
Indirect Greenhouse Gas Emission Factors - Purchased Electricity [9]

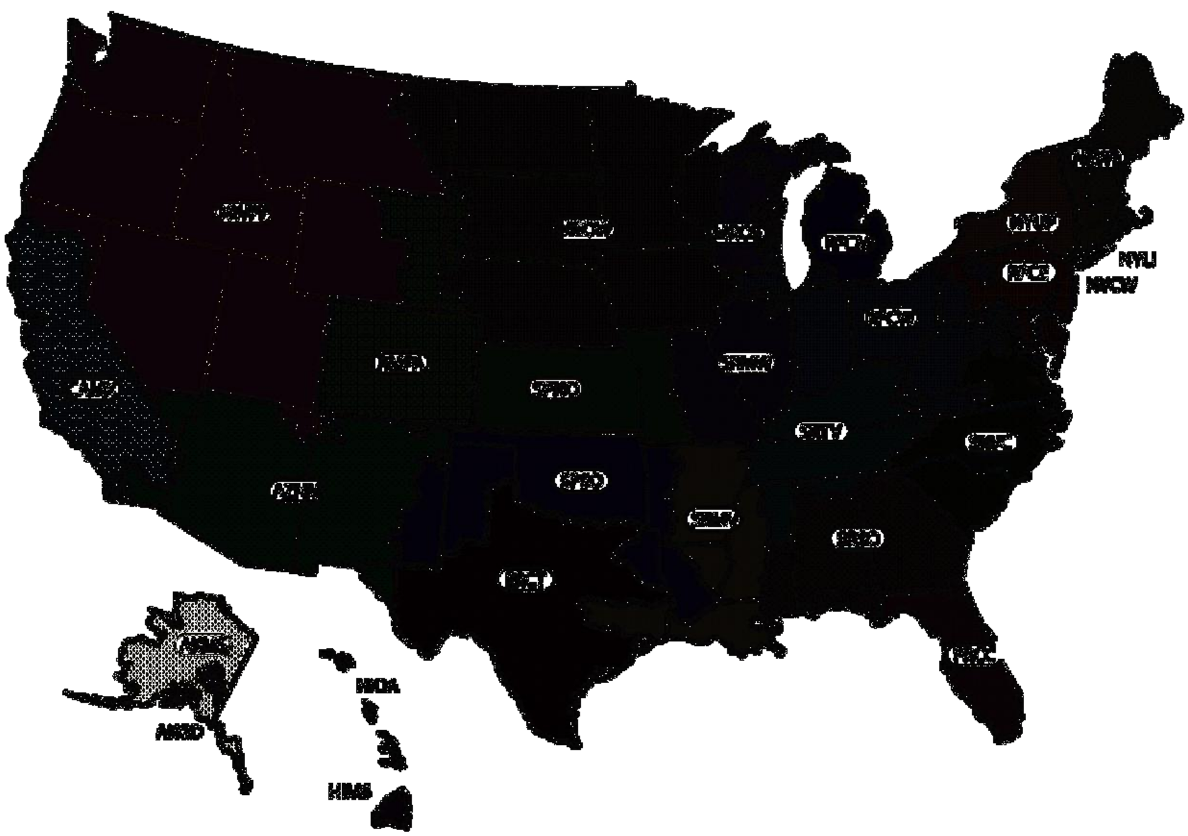
Electricity Grid by eGRID Subregion	kg CO_2/MBtu	kg CH_4/Mbtu	kg N_2O/MBtu	kg CO_2e /MBtu
AKGD (ASCC Alaska Grid)	170.78	0.0036	0.0010	171.1663
AKMS (ASCC Miscellaneous)	71.22	0.0030	0.0006	71.4645
AZNM (WECC Southwest)	166.52	0.0025	0.0022	167.2509
CAMX (WECC California)	90.53	0.0038	0.0008	90.8653
ERCT (ERCOT All)	166.51	0.0024	0.0019	167.1357
FRCC (FRCC All)	162.20	0.0055	0.0020	162.9387
HIMS (HICC Miscellaneous)	178.64	0.0180	0.0029	179.9127
HIOA (HICC Oahu)	215.46	0.0121	0.0028	216.5705
MORE (MRO East)	224.97	0.0038	0.0039	226.2458
MROW (MRO West)	229.00	0.0039	0.0039	230.2868
NEWE (NPCC New England)	110.06	0.0102	0.0020	110.9050
NWPP (WECC Northwest)	114.16	0.0022	0.0018	114.7709
NYCW (NPCC NYC/Westchester)	93.69	0.0035	0.0004	93.9041
NYLI (NPCC Long Island)	188.60	0.0120	0.0017	189.3924
NYUP (NPCC Upstate NY)	90.83	0.0023	0.0013	91.2872
RFCE (RFC East)	140.82	0.0036	0.0023	141.5987
RFCM (RFC Michigan)	219.49	0.0043	0.0037	220.7267
RFCW (RFC West)	206.25	0.0024	0.0034	207.3702
RMPA (WECC Rockies)	253.38	0.0031	0.0038	254.6387
SPNO (SPP North)	239.11	0.0028	0.0039	240.3732
SPSO (SPP South)	215.89	0.0033	0.0030	216.8818
SRMV (SERC Mississippi Valley)	133.48	0.0029	0.0015	133.9995
SRMW (SERC Midwest)	236.53	0.0027	0.0039	237.8043
SRSO (SERC South)	198.80	0.0031	0.0033	199.8789
SRTV (SERC Tennessee Valley)	204.83	0.0026	0.0034	205.9380
SRVC (SERC Virginia/Carolina)	148.68	0.0030	0.0025	149.5233
National Average	***171.89***	***0.0033***	***0.0026***	***172.7702***

As there are no emissions resulting from the consumption of renewable electricity produced from on-site solar photovoltaic or wind generation resources, site electricity consumption is multiplied by an emissions factor of zero (0) kg CO_2/MBtu. Hence, *a building that operates entirely using a on-site solar photovoltaic array will have no carbon emissions*.

[9] U.S. EPA's Emissions & Generation Resource Integrated Database (eGRID). eGRID2010 Version 1 contains the complete release of year 2007 data. The data are organized to reflect the operator, parent company, owner, and electric grid configuration as of December 31, 2010. www.epa.gov/cleanenergy/egrid

However, note that when renewable energy is generated, the environmental attributes (avoided emissions and social benefit) can be separated from the electricity (kWh). These environmental attributes can be sold as a Renewable Energy Certificate (REC). If the REC associated with on-site generation has been sold, then the owner of the solar panel *does not own* the environmental benefit. In these situations, although an on-site system is used at the building, the eGRID emissions factors presented in Table 3 will be applied.

Figure 1. Electricity Grid by eGRID Subregions



Mapping a Building to an eGRID Subregion

Given the interconnected nature of the electric transmission and distribution system and the resulting inability to identify the generation source for the electricity used, eGRID subregions were selected as a practical resolution of electricity origin to determine electricity emissions factors. An eGRID subregion, as defined by the U.S. EPA's Emissions & Generation Resource Integrated Database (eGRID), represents a portion of the U.S. power grid that is contained within a single North America Electric Reliability Council (NERC) region, which have similar emissions and resource mix characteristics, and may be partially isolated by transmission constraints. A building is located inside an eGRID subregion by mapping its zip code to its eGRID subregion. In many cases, a zip code is not confined within one eGRID subregion. In these instances, the user is asked to identify his/her electric distribution utility in order to locate that building within an eGRID subregion.[10] When a building has been mapped to an eGRID subregion, Portfolio Manager will also compare the grid fuel mix and the emissions factors for that building against the national averages. Finally, the user may also specify an individual power generation plant when the building is making a direct purchase of electricity from that plant. In some instances, a user may have a direct purchasing agreement or contract with a specific electric utility plant. The power purchase agreement specifies the terms and conditions under which electric power will be generated and purchased.

Computing Avoided Emissions from Green Power Purchases

As part of a corporate greenhouse gas reduction strategy, an organization may seek to purchase green power. The environmental attributes associated with green power purchase are quantified with Renewable Energy Certificates (RECs)[11]. A REC represents the environmental, social, and other non-power qualities associated with a unit of renewable electricity. A REC can be purchased whether or not a specific building has on-site renewable energy. An organization may choose to purchase RECs at either a corporate level or a building level and they typically apply to renewable energy for a specific time period (e.g. first quarter 2009). Portfolio Manager allows tracking of REC purchases at the building level, for all buildings in a portfolio. RECs can be combined across all buildings as part of an organization's greenhouse gas emissions inventory.

When RECs are purchased, they have an associated quantity of avoided emissions. This is the amount of emissions they offset, that would otherwise be generated from traditional means of power generation. When a REC is input into Portfolio Manager, the total amount of avoided emissions can be quantified. Portfolio Manager will sum all REC purchases within a specified time period to present the total avoided emissions from RECs.

To compute the avoided emissions, the eGRID database described above is employed. However, different emissions factor are required. To compute the emissions associated with a grid purchase, system average factors are used (as shown in **Table 3**). In order to compute avoided emissions, non-baseload (or, marginal) factors are used. These factors are presented in **Table 4**. A marginal factor captures the emissions associated with the last pieces of equipment that go into service. For example, a given utility may have a general boiler or furnace that it burns to create electricity. At peak demand they may have a secondary unit they will need to turn on. In this case, if the demand is reduced (e.g. through green power), then the emissions that are avoided are those emissions associated with the secondary unit, a marginal emissions rate would reflect this

[10] Zip code mapping accomplished through the Ventyx Velocity Suite software product, also utilized by EPA's Power Profiler. Buildings located outside the continental United States are assigned the US national average emission factor.
[11] To learn more about green power, visit the website for EPA's Green Power Partnership: http://www.epa.gov/grnpower.

unit. Applying this concept to the full electric grid, the marginal rates reported by eGRID best capture the emissions avoided through a reduction of demand associated with a green power purchase[12].

Finally, to compute the avoided emissions it is necessary to use emissions factors for the eGRID region *where the energy associated with the REC was generated*. For example, a building in Ohio may purchase a REC from a wind farm in Texas. In this case, it is the emissions in Texas that are avoided. Thus, the marginal emissions factor eGRID region in Texas would be applied to compute avoided emissions.

Table 4
Indirect Greenhouse Gas Emission Factors - Onsite Renewable Electricity and RECs

Electricity Grid by eGRID Subregion	kg CO_2/MBtu	kg CH_4/MBtu	kg N_2O/MBtu	kg CO_2e /MBtu
AKGD (ASCC Alaska Grid)	181.22	0.0047	0.0009	181.5991
AKMS (ASCC Miscellaneous)	194.39	0.0082	0.0016	195.0642
AZNM (WECC Southwest)	161.10	0.0027	0.0012	161.5360
CAMX (WECC California)	138.96	0.0052	0.0006	139.2623
ERCT (ERCOT All)	145.72	0.0026	0.0007	146.0084
FRCC (FRCC All)	171.01	0.0058	0.0015	171.6040
HIMS (HICC Miscellaneous)	218.75	0.0163	0.0028	219.9762
HIOA (HICC Oahu)	216.80	0.0141	0.0025	217.8616
MORE (MRO East)	253.26	0.0047	0.0040	254.5982
MROW (MRO West)	264.37	0.0071	0.0044	265.8752
NEWE (NPCC New England)	160.17	0.0081	0.0018	160.8959
NWPP (WECC Northwest)	170.10	0.0058	0.0021	170.8703
NYCW (NPCC NYC/Westchester)	164.05	0.0050	0.0006	164.3553
NYLI (NPCC Long Island)	185.82	0.0059	0.0009	186.2279
NYUP (NPCC Upstate NY)	183.25	0.0042	0.0022	184.0102
RFCE (RFC East)	222.26	0.0044	0.0030	223.2698
RFCM (RFC Michigan)	239.77	0.0043	0.0036	240.9817
RFCW (RFC West)	263.48	0.0032	0.0042	264.8489
RMPA (WECC Rockies)	206.63	0.0031	0.0022	207.3740
SPNO (SPP North)	260.32	0.0034	0.0037	261.5302
SPSO (SPP South)	190.79	0.0033	0.0017	191.4049
SRMV (SERC Mississippi Valley)	155.67	0.0038	0.0009	156.0369
SRMW (SERC Midwest)	258.65	0.0032	0.0039	259.9365
SRSO (SERC South)	206.19	0.0038	0.0029	207.1624
SRTV (SERC Tennessee Valley)	254.87	0.0035	0.0040	256.1800
SRVC (SERC Virginia/Carolina)	220.82	0.0051	0.0033	221.9351
National Average	**202.08**	**0.0043**	**0.00245**	**202.9242**

[12] U.S. Environmental Protection Agency, Climate Leaders Greenhouse Gas Inventory Protocol Optional Modules Methodology for Project Type: Green Power and Renewable Energy Certificates (RECs), Version 1.1, November 2008. http://www.epa.gov/stateply/documents/greenpower_guidance.pdf