Full-Fuel-Cycle Energy and Emission Factors for Building Energy Consumption – 2013 Update

Prepared for

American Gas Association
400 N. Capitol St., NW
Washington, DC 20001

Prepared by

Neil Leslie
Gas Technology Institute
Des Plaines, Illinois

January 2014 Rev.1

American Gas Association
400 North Capitol Street, NW
Washington, DC 20001

Disclaimer

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Executive Summary

This report provides updated full-fuel-cycle (FFC) energy and pollutant emission factors based on current public domain information for use by AGA and other stakeholders. It also includes new CO_2e emissions factors (including carbon dioxide, methane, and nitrous oxide), as well as non-baseload (marginal) FFC energy and emission factors. The definition of FFC energy used throughout this report is as follows:

> **Full-fuel-cycle energy is the energy consumed by an appliance, system, or building as measured at the building site plus the energy consumed in the extraction, processing, and transport of primary fuels such as coal, oil, and natural gas; energy losses in thermal combustion in power-generation plants; and energy losses in transmission and distribution to the building site.**

The factors for calculating FFC energy consumption and related emissions were developed at the state, eGRID sub-region, NERC region, and U.S. average level for electricity for all power plants. Factors for non-baseload power plants were developed at the eGRID sub-region and U.S. average levels. Factors for fossil fuels were developed at the U.S. average level.

National average FFC energy factors for electricity generated with different fuel types and for fossil fuels are shown below.

Energy Type	Process energy efficiency (percent)						
	Extraction	Processing	Transportation	Conversion	Distribution	Cumulative Efficiency	FFC Energy Conversion Factor
Electricity							
Coal	98.0	98.6	99.0	32.9	93.5	29.4	3.40
Oil	96.3	93.8	98.8	32.0	93.5	26.7	3.75
Natural Gas	96.2	97.0	99.3	43.2	93.5	37.4	2.67
Nuclear	99.0	96.2	99.9	32.6	93.5	29.0	3.45
Hydro	100.0	100.0	100.0	90.0	93.5	84.2	1.19
Biomass	99.4	95.0	97.5	24.4	93.5	21.0	4.76
Wind	100.0	100.0	100.0	26.0	93.5	24.3	4.11
Solar	100.0	100.0	100.0	12.0	93.5	11.2	8.91
Geothermal	100.0	100.0	100.0	16.0	93.5	15.0	6.68
U.S. Average	98.0	97.8	99.3	35.7	93.5	31.8	3.15
Fossil Fuels Used in Buildings							
Natural Gas	96.2	97.0	99.0	100.0	99.0	91.5	1.09
Heating Oil	94.9	89.1	99.7	100.0	99.6	84.0	1.19
Propane/LPG	94.6	93.6	99.2	100.0	99.2	87.1	1.15

1 Introduction and Overview

The American Gas Association (AGA) has recognized the importance of full-fuel-cycle (FFC) energy efficiency and pollutant emissions as a basis for setting appropriate public policy for decades. AGA has advocated FFC energy in numerous rulemakings and standards developments. AGA also has published key information on FFC energy efficiency and carbon dioxide emissions from buildings for more than 20 years, including “EA 1990-5, A comparison of Carbon Dioxide Emissions Attributable to New Natural Gas and All-Electric Homes,” published in 1990, EA 1999-04, "Energy Efficiency, Economic, and Environmental Comparison of Natural Gas, Electric, and Oil Services in Residences," published in 1999, “Source Energy and Emission Factors for Residential Energy Consumption,” published in 2000, and “Source Energy and Emission Factors for Building Energy Consumption,” published in 2009. This report provides updated FFC energy and pollutant emission factors based on more current information for use by AGA and other stakeholders. It also includes new CO_2e emissions factors (including carbon dioxide, methane, and nitrous oxide), as well as non-baseload (marginal) FFC energy and emission factors.

Sample calculations in this report compare the performance of residential gas and electric storage water heaters for average and marginal generation mixes – including FFC energy consumption and CO_2e emissions by eGRID sub-region and the US. The methodologies used in the water heater example can be applied to a full spectrum of end use equipment and appliances, providing a comprehensive understanding of energy efficiency and environmental impact associated with building energy use.

1.1 National Energy and Emissions Data and Future Trends

A comparison of national energy use for natural gas and electricity in the buildings sector illustrates the need for technically defensible FFC energy factors. According to the Energy Information Administration (EIA), buildings consumed over 40 percent of the primary energy resources and 74 percent of the electricity generated in the United States in 2011. Buildings were also responsible for 39 percent of CO_2 emissions during that year. According to EIA, site use of natural gas and electricity in buildings in 2011 totaled 8.06 and 9.36 quadrillion Btu’s (Quads) respectively – a sum of 17.42 Quads. However, losses associated with electricity production and delivery were 19.65 quads of energy – an amount greater than the total site energy demand. As shown in Figure 1, these electricity losses are expected to continue to dominate building primary energy consumption through 2040.

A recent shift in the power generation mix is worth examining to determine if EIA views it as the start of a new long-term trend or a response to short-term market forces. Figure 2 shows the shift from 2009 through 2012 in the power generation mix from coal to natural gas and, to a much smaller extent, wind power generation. The increase in natural gas power generation reflected the impact of a significant reduction in natural gas prices starting in 2008 associated with new shale gas production. EIA expects the recent shift from coal-fired power generation to natural gas generation to stabilize in the next few years as natural gas prices resume a modest upward trend. As shown in Figure 3, coal-fired power generation is projected to fall from 42 percent of total generation in 2011 to 35 percent in 2040. At the same time, the nuclear power generation fraction (with near zero full-fuel-cycle CO_2 emissions) is projected to fall from 19 percent in 2011 to 17 percent in 2040.

Projected increases in wind and solar power generation are not expected to change the aggregate power generation efficiency significantly through 2040. Overall growth in electric power demand will limit the impact of growth in renewable power generation, which is projected to increase from 13 percent of total generation in 2011 to 16 percent in 2040. Figure 4 shows the resulting bulk power generation efficiency delivered to buildings projected by EIA, including transmission and distribution losses. The generation efficiency is projected to increase slowly from 32.2 percent in 2011 to 34.4 percent in 2040.

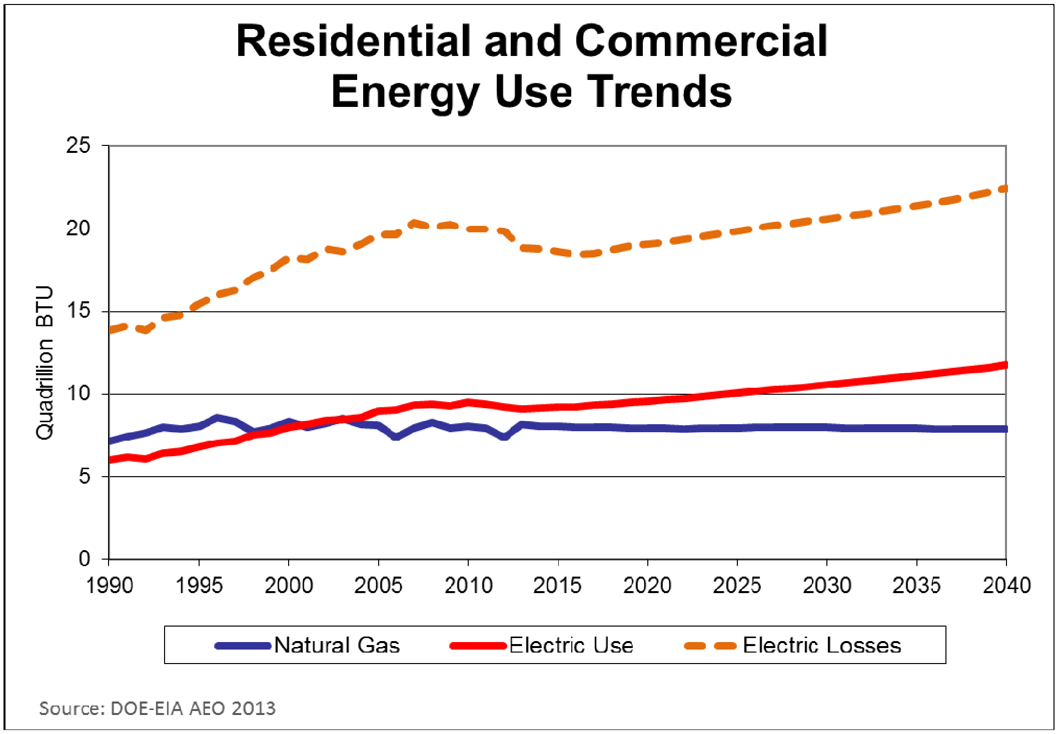


Figure 1 Residential and Commercial Building Energy Usage Trends

Source: EIA Annual Energy Review 2011, Annual Energy Outlook 2013

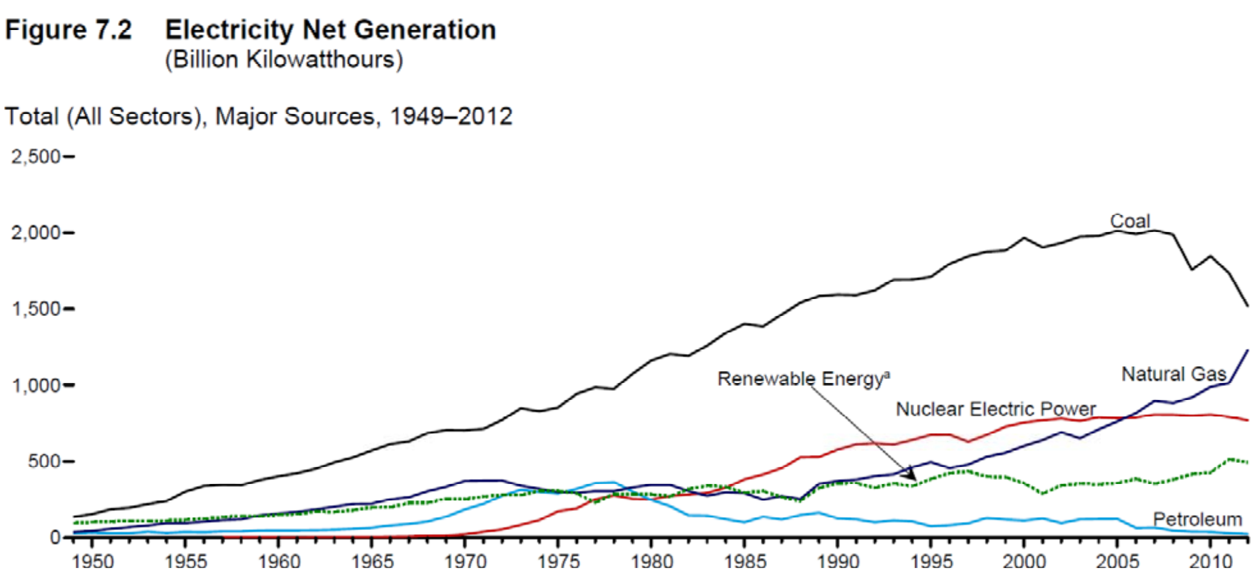


Figure 2 U.S. Power Generation Trends 1949 – 2011

Source: EIA Monthly Energy Review September 2013

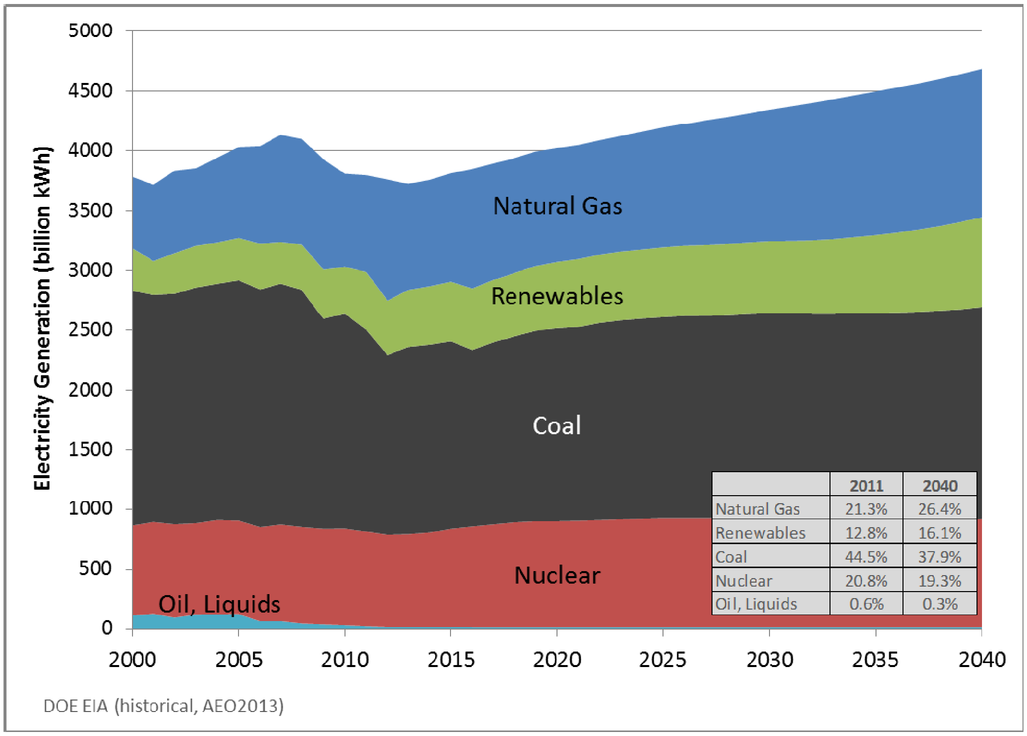


Figure 3 U.S. Power Generation Fuel Mix Trends and Projections through 2040

Source: EIA Annual Energy Review 2011, Annual Energy Outlook 2013

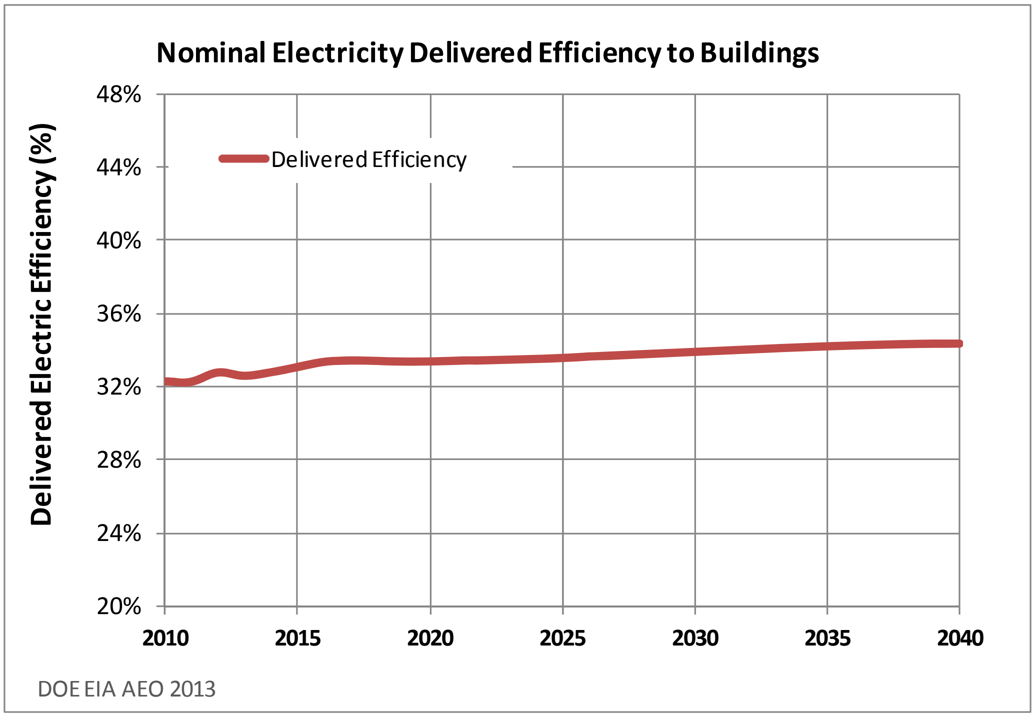


Figure 4 Power Generation Efficiency Delivered to Buildings through 2040

Source: EIA Annual Energy Outlook 2013

Homes and commercial businesses have also been growing contributors to CO_2 emissions, especially from 1990 through 2010. As shown in Figure 5, the increasing CO_2 emissions of residential and commercial buildings during that period were driven by growing consumption of electricity, including emissions associated with power generation as well as increased electricity consumption per building. Much of the increased carbon impact from residential and commercial electricity use comes from power plants and the relatively inefficient "full-fuel-cycle" of production and delivery of electricity to the buildings. The remainder comes from increased end uses of electricity for cooling and processes.

While the shift from coal to natural gas between 2010 and 2012 did not materially affect the FFC energy efficiency of electricity generation, it did impact the CO_2 emissions shown in Figure 5 because natural gas power generation emits less CO_2 per megawatt-hour than coal-fired generation. The downward trend in CO_2 emissions is projected to continue for the next 4 years primarily due to coal plant retirements. After 2016, power plant emission factors are projected to stabilize, with increased electricity demand causing an overall increase in the amount electricity CO_2 emissions through 2040.

Emissions from direct use of natural gas in buildings reflect a combination of improved end use efficiency over time and the continued growth in number of residential and commercial customers. Aggregate CO_2 emissions from natural gas consumption in U.S. buildings are currently at 1990 levels, and are projected to remain stable through 2040 despite projected growth in the number of gas customers.

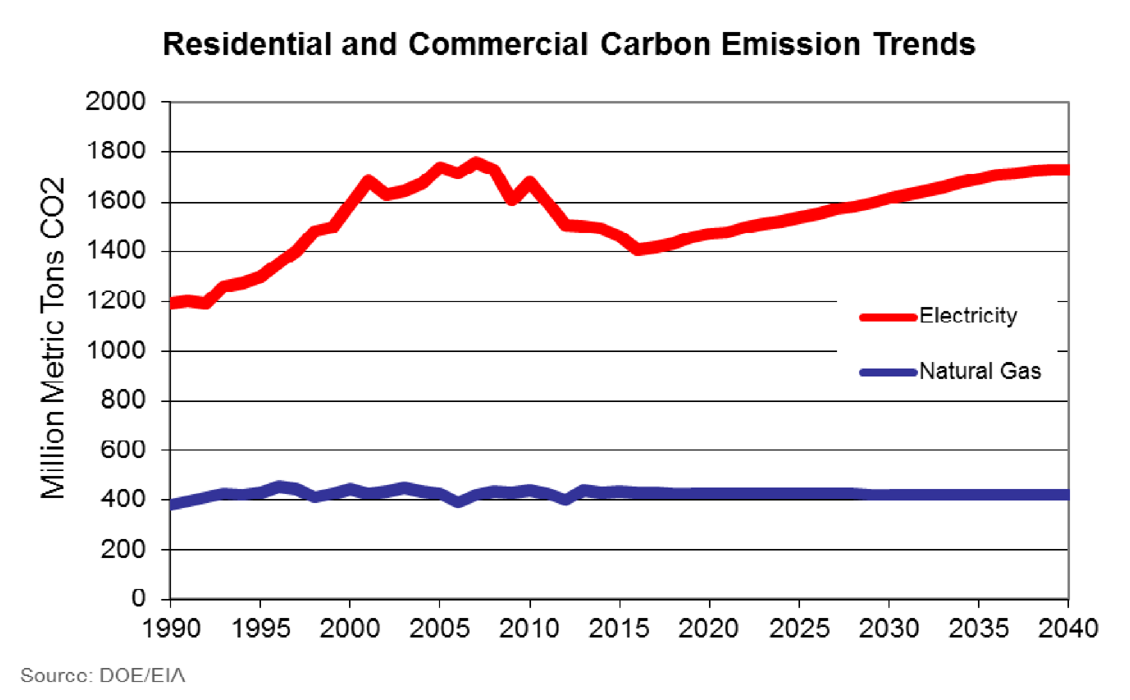


Figure 5 Gas and Electric CO_2 Emission Trends in Residential and Commercial Buildings

Source: EIA Annual Energy Outlook 2013

2 Analysis Framework

2.1 Boundary Conditions

Analysis of the impact of building and appliance energy consumption on primary energy consumption and associated GHG emissions requires definition of one or more equitable boundary conditions based on the objectives of the analysis. Figure 6 compares the "full-fuel-cycle" boundary condition with the site energy and DOE primary energy boundary condition. The definition of FFC energy used throughout this report is as follows:

> **Full-fuel-cycle energy is the energy consumed by an appliance, system, or building as measured at the building site plus the energy consumed in the extraction, processing, and transport of primary fuels such as coal, oil, and natural gas; energy losses in thermal combustion in power-generation plants; and energy losses in transmission and distribution to the building site.**

Other stakeholders use and define different boundary conditions for their purposes. For instance, the boundary condition for DOE appliance rulemaking is legislatively mandated at the appliance point of use, which is defined as the energy by energy form consumed to operate the appliance. DOE energy factors such as the water heater EF are based on point-of-use energy. Of interest are situations in which the DOE energy factors do not account for all of the energy consumed by the appliance. An example is the Annual Fuel Utilization Efficiency (AFUE) for a gas furnace, or the EF of a condensing gas water heater. These point-of-use energy factors are misleading in that they only account for gas consumption, and do not include the electric energy consumed by the furnace or water heater.

The next level boundary condition is "building energy", which is defined by ASHRAE as the sum of all point-of-use energy by energy form used in the building, however that energy is supplied (ASHRAE Standard 105r Public Review Draft 2012). This boundary condition is most useful when on site renewable energy is supplying energy to the building appliances.

The "site energy" boundary condition aligns closely with utility metered energy, and is defined by ASHRAE as the energy by energy form crossing the building site boundary (ASHRAE Standard 105r Public Review Draft 2012). It would likely be less than "building energy" whenever on site renewable energy is produced to meet the "building energy" requirements. Site energy could also approach zero over the course of a year if there is sufficient on site renewable energy to meet the annual building energy requirements. However, depending on the energy form displaced by the on site renewable production and net metering provisions, net zero site energy consumption may not result in net zero FFC energy consumption, especially for mixed fuel buildings.

Source energy currently has different boundary conditions as defined by DOE and EPA, which can cause confusion in the marketplace. For instance, in the EPA Portfolio Manager methodology, "source energy" incorporates transmission, delivery, and production losses, but it does not include extraction or processing losses, and is therefore not the same as full-fuel-cycle energy.

Three alternative boundary conditions for source energy, none of which are FFC, have been defined by DOE and EPA as follows:

"Primary" energy (DOE): energy consumed on-site, plus energy losses that occur in the generation, transmission, and distribution of electricity, as illustrated in Figure 6. Extraction, processing, and transportation energy is not included in the DOE primary energy definition (Federal Register /Vol. 76, No. 160 /Thursday, August 18, 2011 / Proposed Rules 51283).

"Source" energy (DOE): "the amount of fossil and renewable fuels consumed for the four end-use sectors, plus the electricity used by these end-use sectors (electricity sales). In addition, the losses associated with the production of electricity by the utility sector (i.e., losses that occur in the generation, transmission, and distribution) are also allocated to the end-use sectors. The sum of source energy for four end-use sectors (transportation, industrial, residential buildings, and commercial buildings) is equal to the sum of all primary energy consumed by the four sectors plus energy consumed by the electricity producing sector. "Source energy" is equivalent to the term "total energy" as used by EIA in the AER. For this Web site, the use of the term "source" was judged to be more precise, particularly in discussions involving subsectors and aggregations of subsectors where the team total energy may be ambiguous." http://www1.eere.energy.gov/analysis/eii_trend_definitions.html.

"Source" energy (EPA): the total primary fuel needed to deliver heat and electricity to the building site. Generally, this means the methodology should perform the following adjustments for energy consumed on site:

- Primary Energy (e.g., natural gas, fuel oil) – Account for losses that occur in the distribution, storage, and dispensing of the primary fuel.

- Secondary Energy (e.g., electricity, district steam) – Account for conversion losses at the plant in addition to losses incurred during transmission and distribution of secondary energy to the building. https://portfoliomanager.energystar.gov/pdf/reference/Source%20Energy.pdf?3d47-8bc4

"Full-fuel-cycle" energy (DOE): point-of-use energy, the energy losses associated with generation, transmission, and distribution of electricity, and the energy consumed in extracting, processing, and transporting or distributing primary fuels (Federal Register /Vol. 76, No. 160 /Thursday, August 18, 2011 / Proposed Rules 51282). This definition is consistent with the "full-fuel-cycle energy" definition used in this report.

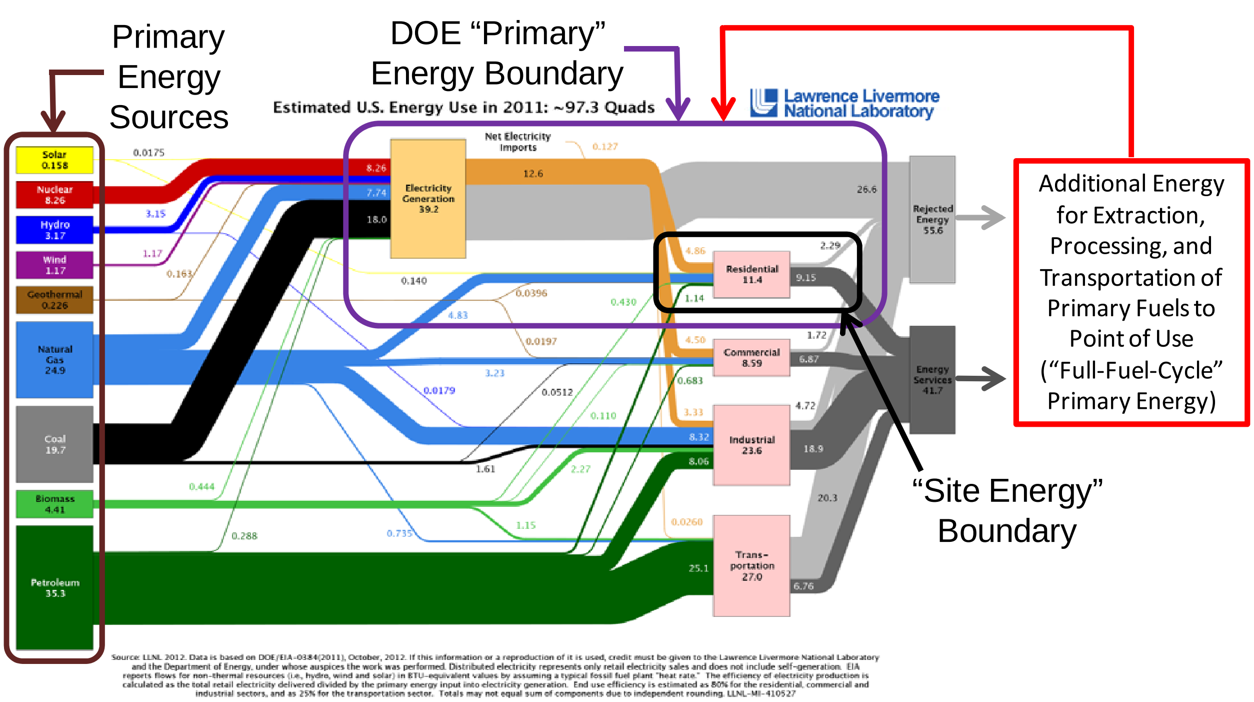


Figure 6 2011 U.S. Energy Use Profile with Different Boundary Conditions

Energy Flow Chart Source: Lawrence Livermore National Laboratory 2012

2.2 FFC Energy Implementation Strategies

Reducing or avoiding building electricity consumption is an important strategy to achieve meaningful reductions in primary energy use and greenhouse gas emissions. In this regard, strategies and programs that encourage the direct use of efficient natural gas technologies in buildings can often provide the least-cost option for major reductions in primary energy consumption and greenhouse gas emissions compared to electric equipment when compared on a full-fuel-cycle basis. To achieve this societal benefit, it is essential to shift the focus from site energy to FFC energy methodologies when rating or benchmarking performance and when making policy or investment decisions.

As shown in Figure 7, the choice of metric depends on the objective of the analysis. Building energy loads are satisfied at the point of use based on technology choices. Point-of-use energy is aggregated to site energy by energy form. Site energy by energy form is needed for measuring and monitoring, and is the essential starting point for converting each energy form to energy costs, FFC energy, and pollutant emissions attributable to design options or building operation. Energy cost is the preferred metric where the focus is on defined economic objectives. FFC energy is the preferred metric where the focus is on natural resources, the environment, or other societal impacts of energy use. Environmental impacts need FFC energy-based metrics using factors that convert site energy to FFC energy and associated GHG emissions or other impacts.

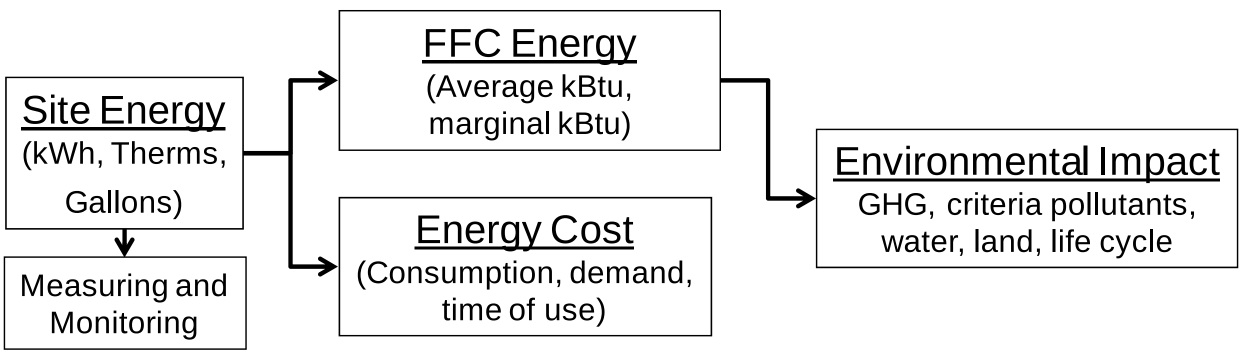


Figure 7 Different Metrics Needed Depending on Analysis Objectives

Site energy is a necessary starting point for all calculations because it is the only thing that can be measured and verified directly at the energy-consuming appliance. That is its only legitimate role. For site energy to become useful, it must always be converted into another meaningful metric such as energy cost, primary energy, or GHG emissions. Site energy cannot serve as the basis of any program, regulation, policy, or investment decision whose goal is to reduce consumption of primary energy resources attributable to operation of the appliance, system, or building.

Site measurement methods—a calculation of the energy consumed by an appliance at the end-use point (in the building)—do not properly or equitably account for the total energy consumed when more than one energy source is used in an appliance (such as a gas furnace) or when comparing the consumption of different fuels that can be used for the same application (such as water heating or combined heat and power). In addition, site measurement does not account for the energy lost and emissions created throughout the extraction, processing, transportation, conversion, and distribution of energy to the building. On the other hand, full-fuel-cycle measurement of the energy consumption of appliances and the overall home from the point of extraction to the point of use does account for energy losses that occur (e.g., in the production of natural gas or in the generation of electricity).

Site energy would be a sufficient metric only if the energy at the meter were the only parameter of concern. However, energy required for generating and delivering electricity does not originate at the meter, but at one of the primary energy sources (solar, nuclear, hydro, wind, geothermal, natural gas, coal, biomass, and petroleum). To ignore the original source of the energy leads to the unsupportable argument that energy is created at the meter, and upstream energy losses are not relevant to the building. Using that argument, 1 Btu of electricity would be considered the same as 1 Btu of natural gas. This would be fine if each energy form were equivalent. But they are not equivalent. Electricity is considered a high value energy form because of its versatility and ability to convert directly to mechanical energy, light, and heat through devices such as motors, semiconductors, lights, and resistance heating elements. Primary energy sources such as natural gas, petroleum, nuclear, and coal, are much more limited in their direct conversion capability, typically burned or split to convert chemical or nuclear energy to heat. Electricity's versatility is valued by consumers, who are willing to pay a much higher price per Btu delivered at the meter for electricity than for other forms of energy such as natural gas.

A good example of the problem with site energy is the comparison of conventional electric and gas storage water heaters for a home. An electric resistance water heater with a site energy factor (EF) of 0.91 will reduce site energy consumption by 33 percent compared to a gas storage water heater with a site EF of 0.59. This is clearly a misleading statistic for comparing the performance of the competing technology options because it does not account for the energy cost differences or impact on primary energy consumption or GHG emissions. More importantly, the electric water heater will have a much higher full-fuel-cycle energy consumption and GHG emissions. According to the U.S. Environmental Protection Agency (EPA), the electric resistance water heater will consume twice as much source energy and have over twice as high CO_2 emissions as the gas water heater based on national average generation mix values as shown in Figure 8.

Given the magnitude of source-to-site energy impacts, it is important for energy efficiency and environmental initiatives to account accurately for total national primary energy use and associated GHG emissions. Specifically, there is a need for a defensible and easily implemented methodology for calculating building or appliance energy efficiency based on FFC energy factors for electricity and fossil fuels like natural gas or petroleum. Fortunately, other stakeholders continue to make progress implementing FFC energy metrics in various initiatives. For instance, California recognized the need to account for primary energy use in their building energy codes when they developed the initial Title 24 standards in 1978. California Title 24 Energy Efficiency Standards for Residential and Nonresidential Buildings incorporate FFC energy efficiency supplemented by Time Dependent Valuation in their current building energy budget methodology.

Further underscoring the importance of FFC energy considerations, a 2009 report by the National Research Council (NRC)'s Board on Energy and Environmental Systems to the U.S. Department of Energy recommended shifting toward a full-fuel-cycle energy basis for appliance standards calculations. The NRC report stated "using that metric could provide the public with more comprehensive information on the impacts of energy consumption on the environment." In addition, the report notes that "the current use by DOE/EERE of site energy consumption is effective for setting standards for the operational efficiency of single-fueled appliances within the same class and should be continued without change. However, DOE/EERE's current use of site energy consumption does not account for the total consumption of energy when more than one fuel is used in an appliance or when more than one fuel can be used for the same application. For these appliances, measuring full-fuel-cycle energy consumption would provide a more complete picture of energy used, allowing comparison across many different appliances as well as an improved assessment of impacts such as effects on energy security and the environment." Those recommendations may have significant impact on future federal appliance energy efficiency rulemaking and standards if DOE chooses to implement them.

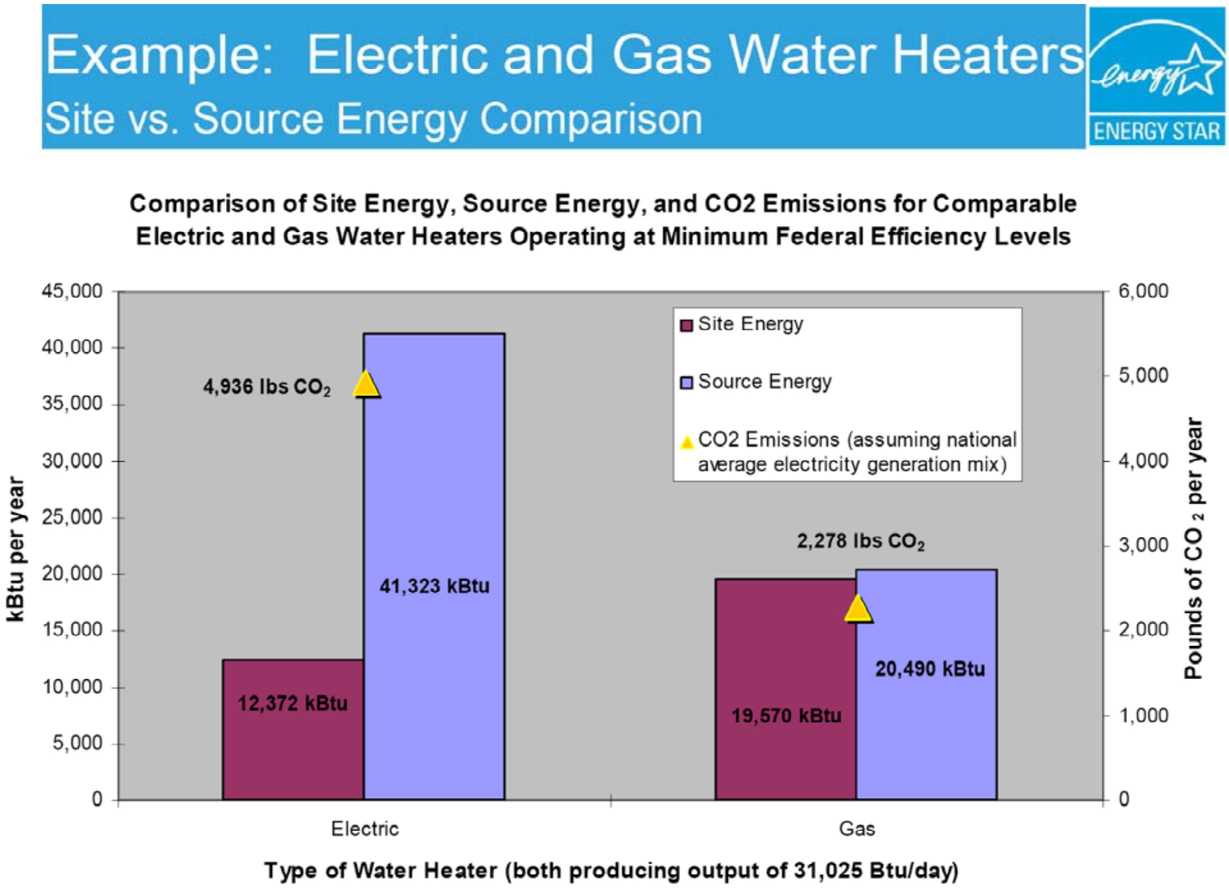


Figure 8 Site Energy, Source Energy, and CO_2 Emissions for Comparable Water Heaters

Source: EPA Presentation to National Academy of Sciences February 2008

2.3 Average Electricity Conversion Factors

For electricity, it is important to distinguish between conversion factors for inventory purposes and conversion factors for investment purposes. Although average energy and emissions calculations may be suitable for inventory and benchmarking purposes, they do not necessarily provide accurate information when making competitive energy efficiency design or investment decisions.

FFC energy and GHG emissions inventory and benchmarking initiatives may use national average electric power generation mix data for their calculations. National average data provides simple FFC energy and emissions conversion factors. The consistency provided by use of national average factors also sends a strong signal regarding FFC energy efficiency and its impact on pollutant emissions, and does not reward or penalize a building based on its location. However, a national average calculation may distort the actual FFC energy or pollutant emissions associated with electricity consumption in specific buildings in different regions.

Use of regional values has the potential to reflect more accurately the actual FFC energy use and environmental impact of the building stock for inventory or benchmarking due to the regional nature of the power grid. Some stakeholders may consider a regional average FFC methodology useful when comparing the impact of a new building or a new electrically-driven technology on two distinct geographic regions, but do not want to reward or penalize investment choices (i.e., new building design options or existing building efficiency improvement investments) compared to the existing level of performance in the building stock. Regional average factors do not reflect the impact of investment and energy consumption decisions on incremental FFC energy consumption or pollutant emissions and can be even more misleading than national average factors in some situations such as power exported or imported from one region to another. This is especially true for regions that have large fractions of hydropower or nuclear power.

2.4 Marginal Electricity Conversion Factors

As noted by EPA in chapters 3 and 4 of its evaluation of benefits of clean energy initiatives (http://www.epa.gov/statelocalclimate/resources/benefits.html), marginal calculation methodologies are more accurate than either national or regional average calculations for evaluating the impacts of changes in electricity consumption, such as comparing new building energy efficiency design options or evaluating competing retrofit measures. EPA's interest in marginal methodologies arose from its understanding that clean energy policies and energy efficiency improvements reduce emissions at the marginal or non-baseload electric generating units. Average electricity generation emission factors can be used appropriately to determine carbon footprint or GHG inventory. However, average emission rates typically under-predict the emission reduction when used for energy savings through efficiency improvements because these averages include baseload generation such as nuclear or hydropower, which would not be affected by the efficiency improvement.

Marginal generation represents the next generation plant used, built, or avoided with that particular fuel type and heat rate, and can be complicated to determine precisely. Marginal generation may be location specific, or it may be generated from the local or regional power pool. In other cases it may involve determining the location of the ultimate power plant avoided or built within or across power pools, and may even cross international boundaries that are grid-connected. Marginal and average FFC energy and CO_2e emission results can be significantly different, especially in regions dominated by hydropower generation. In addition, displacing coal plants has a higher impact on CO_2e emissions and FFC energy use than displacing natural gas plants.

Marginal generation methodologies are typically based on some form of economic dispatch model. Based on the plant's marginal generation cost, economic dispatch of electricity typically brings on plants in the following order: renewable and hydro first, then nuclear, followed by coal, and finally gas and oil plants. Based on economic dispatch, marginal changes in electricity (saved or consumed) would likely be from either a gas or oil plant during peak periods. During baseload periods (evenings, weekends), the marginal plant would likely be either gas or coal. It is unlikely that low marginal cost hydropower, wind, or nuclear plants would be affected by the marginal changes in power. Rather, they would continue to operate and sell their power at a profit to another portion of the grid to offset more expensive coal or gas power somewhere along the interconnected grid. This key aspect of marginal generation will have a significant impact on the actual FFC energy and pollutant emissions associated with new investment decisions to use an electric appliance rather than a gas appliance. It also highlights the importance of selecting the correct boundary condition for a marginal generation analysis.

EPA recognizes several valid and established approaches to quantify emission reductions using the non-baseload electricity mix. Non-baseload CO_2emission factors are published by the EPA to facilitate the calculation of emissions reduction due to energy efficiency improvements. The use of eGRID sub-region non-baseload emission factors is recommended by the EPA as a simple, low-cost method to estimate emission reduction potential, to explain emission benefits to the general public, or to determine annual emission reductions or regional or national estimates. EPA's non-baseload emission rates and methodology are currently used in several tools, including EPA's Greenhouse Gas Equivalencies Calculator (http://epa.gov/cleanenergy/energy-resources/calculator.html) and Green Power Partnership's Green Power Equivalency Calculator (http://www.epa.gov/greenpower/pubs/calculator.htm).

EPA's non-baseload emission rate methodology also provides a convenient way to determine the primary energy factor associated with marginal non-baseload power plants for each eGRID sub-region.

The emission factors can be correlated with the associated generation mix of oil, natural gas, and coal. Knowing this mix, the aggregate primary energy conversion factor can be calculated based on marginal power plant efficiency levels for each fuel type. In the absence of marginal power plant efficiency level information, average power plant efficiency levels may provide an acceptable substitute.

Different marginal generation mix methodologies provided by EPA were reviewed to identify one or more that were considered acceptably precise and accurate for inclusion in this report. The non-baseload capacity factor methodology described in more detail in Appendix A was selected for marginal factors in this report based on its simplicity and use of the eGRID 2012 non-baseload generation database.

2.5 Public Domain Data Sources

A number of relevant data sources, listed in the bibliography, were analyzed in preparation of this report. From this list, five sources provided most of the data compiled for this report. These sources were selected because they were public domain, periodically updated, and provided useful information in calculating FFC energy and emission conversion factors for electricity and fossil fuels typically used in buildings. The five primary sources of data include:

- EPA
- EIA
- Argonne National Laboratory (ANL)
- National Renewable Energy Laboratory (NREL)
- National Hydropower Association

Appendix B provides a more detailed description and application of information and data collected from these sources in developing the FFC energy and pollutant emission factors in this report.

3 Full-Fuel-Cycle Energy Conversion Factors

Site energy methods are often used over a FFC energy-based approach due to perceived lack of reliable information on source-to-site energy conversion factors. This is argued especially with electricity, which is generated from thousands of plants around the U.S. Fortunately, due to the increasing importance of environmental and energy efficiency reporting requirements, there are a number of publicly available and regularly updated sources of data allowing accurate calculation of FFC energy conversion factors for electricity and fossil fuels. Among these are information databases and reports from the EPA, EIA, ANL, NREL, National Hydropower Association, California Energy Commission, and AGA. Protocols for mapping site to full-fuel-cycle energy have been developed by these and other organizations. Details differ in these protocols, but there is reasonable precision, accuracy, flexibility, and stability to permit rational comparisons.

In 1990, AGA published a report that included FFC energy conversion factors that formed the basis of AGA estimates of FFC energy efficiency for residential applications. Table 1 extracted from that report shows the FFC energy efficiencies for electricity, natural gas, and oil, including the cumulative impact of extraction, processing, transportation, generation, transmission, and distribution losses on overall efficiency. Conversion efficiency is the net generation efficiency at the power plant. Cumulative efficiency is the full-fuel-cycle efficiency for residential applications, including all losses from extraction through distribution to the site. The FFC energy conversion factor is the inverse of the cumulative efficiency. Table 6 and Table 13 in this report update the 1990 factors shown in Table 1 using more recent data.

Table 1 FFC Energy Efficiency Factors from AGA 1990 Report

Source Energy Type	Process energy efficiency (percent)						Source Energy Conversion Factor
	Extraction	Processing	Transportation	Conversion	Distribution	Cumulative Efficiency	
Electricity							
Coal based	99.4	90.0	97.5	33.4	92.0	26.8	3.7
Natural Gas Based	96.8	97.6	97.3	31.8	92.0	26.9	3.7
Oil based	96.8	90.2	98.4	32.5	92.0	25.7	3.9
Fossil Fuels Used in Buildings							
Natural Gas	96.8	97.6	97.3	100	98.4	90.5	1.1
Oil	96.8	90.2	98.4	100	99.8	85.7	1.2

Source: AGA report EA 1990-05, "A comparison of Carbon Dioxide Emissions Attributable to New Natural Gas and All-Electric Homes." American Gas Association, October 31, 1990.

The following sections provide a review and compilation of the latest available data for calculations of source-to-site energy efficiency and emission factors as well as overall FFC energy conversion factors for electricity and fossil fuels used in U.S. buildings. This includes detailed information on national, regional, and state-level electricity factors as well as national fossil fuel factors.

3.1 Electricity Generation Fuel Mix

The EPA eGRID2012 version 1.0 database provides data for the year 2009 on U.S. electric power plant generation output and percentage of power supplied by coal, oil, natural gas, hydro, nuclear, and other renewable sources. Table 2 shows the eGRID2012 electricity generation resource mix by NERC Region shown in Figure 9 as well as the U.S. composite resource mix. Table 3 shows the generation resource mix by eGRID Sub-region shown in Figure 10. Table 4 shows state level data. The generation mix data shown in these tables is useful to calculate FFC energy conversion factors for electricity at state, regional, and national levels.

Table 2 Electricity Generation Resource Mix by NERC Region and U.S. (%)

NERC Region	Generation resouce mix (percent)										
	Coal	Oil	Gas	Other Fossil	Biomass	Hydro	Nuclear	Wind	Solar	Geo-thermal	Other
ASCC Alaska Systems Coordinating Council	9.4	17.3	53.4	-	0.1	19.8	-	0.1	-	-	-
FRCC Florida Reliability Coordinating Council	23.7	4.4	54.8	0.6	1.7	0.0	14.0	-	0.0	-	0.7
HICC Hawaiian Islands Coordinating Council	13.6	75.5	-	3.6	2.5	1.0	-	2.3	0.0	1.5	-
MRO Midwest Reliability Organization	69.1	0.4	2.7	0.2	1.5	4.1	14.1	7.8	-	-	0.1
NPCC Northeast Power Coordinating Council	10.5	1.8	37.6	1.1	3.6	13.7	30.7	1.0	-	-	0.0
RFC Reliability First Corporation	60.2	0.5	8.0	0.5	0.9	0.8	28.3	0.7	0.0	-	0.0
SERC SERC Reliability Corporation	50.0	0.7	16.8	0.2	1.7	3.8	26.5	0.0	0.0	-	0.1
SPP Southwest Power Pool	61.1	0.2	25.6	0.2	0.8	3.8	4.3	4.0	-	-	0.0
TRE Texas Regional Entity	33.0	1.1	47.8	0.1	0.1	0.2	12.3	5.3	-	-	0.1
WECC Western Electricity Coordinating Council	28.7	0.5	32.1	0.1	1.3	22.8	9.5	2.8	0.1	2.0	0.1
U.S.	**44.5**	**1.1**	**23.3**	**0.3**	**1.4**	**6.8**	**20.2**	**1.9**	**0.0**	**0.4**	**0.1**

Source: EPA eGRID 2012 Version 1.0

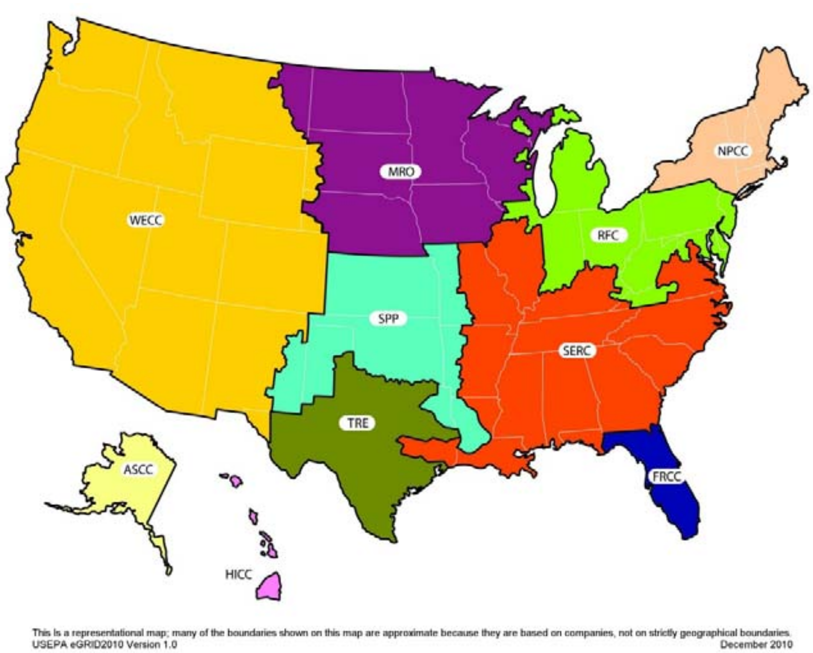


Figure 9 NERC Regions

Source: EPA eGRID 2012 Version 1.0

Table 3 Electricity Generation Average Resource Mix by eGRID Sub-Region (%)

eGRID 2012 Sub-region Acronym	eGRID 2012 Sub-region Name	Generation Mix										
		Coal	Oil	Gas	Other fossil	Biomass	Hydro	Nuclear	Wind	Solar	Geo-thermal	Other unknown /purchased fuel
AKGD	ASCC Alaska Grid	11.8	13.7	66.0	-	-	8.5	-	-	-	-	-
AKMS	ASCC Miscellaneous	-	31.3	3.9	-	0.5	63.9	-	0.5	-	-	-
ERCT	ERCOT All	38.6	0.1	35.7	0.0	0.3	6.1	16.5	0.5	0.1	2.2	-
FRCC	FRCC All	7.3	1.4	53.0	0.2	2.7	12.7	14.9	2.8	0.3	4.4	0.3
HIMS	HICC Miscellaneous	33.0	1.1	47.8	0.1	0.1	0.2	12.3	5.3	-	-	0.1
HIOA	HICC Oahu	23.7	4.4	54.8	0.6	1.7	0.0	14.0	-	0.0	-	0.7
MROE	MRO East	2.0	69.9	-	7.1	3.3	3.7	-	8.3	0.0	5.6	-
MROW	MRO West	18.0	77.6	-	2.2	2.2	-	-	-	-	-	-
NYLI	NPCC Long Island	68.9	2.4	5.0	0.1	3.2	2.7	15.3	2.3	-	-	0.1
NEWE	NPCC New England	69.1	0.2	2.4	0.2	1.2	4.4	13.9	8.7	-	-	0.1
NYCW	NPCC NYC/Westchester	11.9	1.5	42.0	1.6	5.9	7.0	29.8	0.3	-	-	0.0
NYUP	NPCC Upstate NY	29.8	0.3	15.2	0.1	1.1	46.5	2.5	3.8	-	0.6	0.1
RFCE	RFC East	-	1.8	55.9	0.5	0.5	0.0	40.8	0.5	-	-	-
RFCM	RFC Michigan	-	13.0	77.3	4.6	5.1	-	-	-	-	-	-
RFCW	RFC West	14.5	0.9	18.9	0.4	1.6	30.8	30.6	2.4	-	-	-
SRMW	SERC Midwest	35.4	0.7	17.1	0.8	1.3	1.2	43.0	0.4	0.0	-	0.0
SRMV	SERC Mississippi Valley	72.0	0.4	9.5	0.6	1.9	-	15.3	0.3	-	-	-
SRSO	SERC South	69.9	0.4	3.5	0.4	0.5	0.8	23.6	0.9	-	-	0.1
SRTV	SERC Tennessee Valley	67.8	0.0	22.6	-	0.1	4.3	-	5.1	0.0	-	0.1
SRVC	SERC Virginia/Carolina	73.8	0.3	7.8	0.0	0.0	0.1	13.5	4.4	-	-	-
SPNO	SPP North	55.2	0.2	33.9	0.2	1.2	5.5	-	3.8	-	-	0.0
SPSO	SPP South	22.7	1.5	45.1	0.9	1.9	1.7	26.0	-	-	-	0.2
CAMX	WECC California	79.8	0.1	1.0	0.0	0.1	1.8	17.1	0.1	-	-	-
NWPP	WECC Northwest	52.2	0.3	22.3	0.1	2.9	4.1	18.1	-	-	-	0.0
RMPA	WECC Rockies	58.8	0.9	8.6	0.0	0.8	8.6	22.1	0.2	-	-	-
AZNM	WECC Southwest	45.1	0.6	9.0	0.2	2.0	1.6	41.3	-	0.0	-	0.1

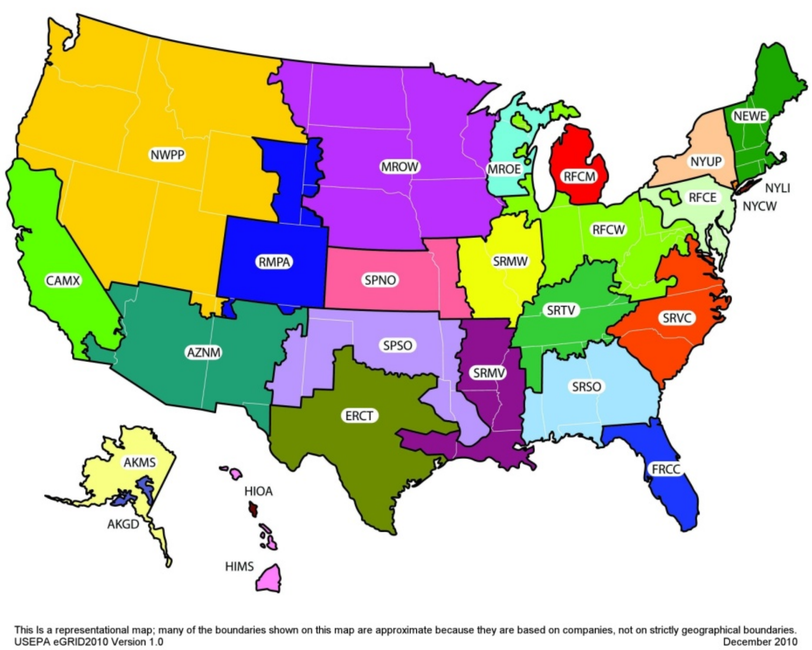


Figure 10 eGRID Sub-Regions

Source: EPA eGRID 2012 Version 1.0

Table 4 Electricity Generation Average Resource Mix by State (%)

State	Coal	Oil	Gas	Other fossil	Biomass	Hydro	Nuclear	Wind	Solar	Geo-thermal	Other unknown/ purchased fuel
AK	9.4	17.3	53.4	-	0.1	19.8	-	0.1	-	-	-
AL	38.8	0.2	22.1	0.1	2.4	8.7	27.7	-	-	-	-
AR	43.6	0.2	19.5	0.0	2.8	7.5	26.4	-	-	-	-
AZ	35.5	0.1	31.0	-	0.1	5.9	27.4	0.0	0.0	-	-
CA	1.0	1.4	55.4	0.2	3.0	13.7	15.5	2.9	0.3	6.3	0.3
CO	62.6	0.0	27.6	-	0.1	3.5	-	5.9	0.1	-	0.1
CT	7.9	1.0	31.4	2.4	2.3	1.7	53.4	-	-	-	0.0
DC	-	100.0	-	-	-	-	-	-	-	-	-
DE	58.8	5.3	28.4	4.7	2.6	-	-	-	-	-	0.1
FL	24.8	4.2	54.3	0.6	1.9	0.1	13.3	-	0.0	-	0.7
GA	54.0	0.5	15.9	0.0	2.2	2.7	24.6	-	-	-	-
HI	13.6	75.5	-	3.6	2.5	1.0	-	2.3	0.0	1.5	-
IA	72.0	0.2	2.3	0.0	0.3	1.9	9.0	14.3	-	-	-
ID	0.6	0.0	12.5	-	3.6	79.6	-	2.4	-	0.6	0.6
IL	46.4	0.1	2.3	0.0	0.4	0.1	49.2	1.5	-	-	0.0
IN	92.8	0.4	3.3	1.3	0.3	0.4	-	1.2	-	-	0.3
KS	69.1	0.3	5.7	-	-	0.0	18.8	6.1	-	-	-
KY	92.7	2.2	1.0	0.0	0.4	3.7	-	-	-	-	-
LA	25.4	2.0	48.4	1.4	2.6	1.4	18.4	-	-	-	0.4
MA	23.1	2.3	53.9	2.1	3.0	1.7	13.8	0.0	0.0	-	-
MD	55.2	0.8	4.0	1.2	1.2	4.3	33.2	-	-	-	-
ME	0.4	2.7	45.0	2.2	22.2	25.8	-	1.8	-	-	-
MI	66.0	0.4	8.4	0.6	2.3	0.5	21.6	0.3	-	-	-
MN	56.4	0.1	5.5	0.5	3.3	1.6	23.8	8.7	-	-	0.1
MO	81.1	0.1	3.9	0.0	0.1	2.7	11.6	0.6	-	-	-
MS	26.6	0.1	47.8	0.0	2.9	-	22.6	-	-	-	0.0
MT	58.4	1.8	0.3	-	0.4	35.6	-	3.1	-	-	0.4
NC	55.2	0.3	3.7	0.0	1.6	4.4	34.6	-	0.0	-	0.2
ND	86.6	0.3	0.0	-	0.0	4.3	-	8.8	-	-	-
NE	67.5	0.1	0.9	-	0.2	2.9	27.3	1.1	-	-	-
NH	14.3	0.9	26.5	0.3	5.6	8.3	43.7	0.3	-	-	-
NJ	8.2	0.7	33.3	0.9	1.4	-	55.4	0.0	0.0	-	-
NM	73.4	0.1	21.8	-	0.1	0.7	-	3.9	-	-	-
NV	20.0	0.0	68.6	0.0	0.0	6.5	-	-	0.5	4.3	-
NY	9.6	2.0	31.4	0.7	1.6	20.4	32.7	1.7	-	-	-
OH	83.6	1.0	3.4	0.0	0.5	0.4	11.2	0.0	-	-	-
OK	45.4	0.0	46.2	-	0.3	4.6	-	3.6	-	-	-
OR	5.6	0.0	28.5	0.1	1.4	58.3	-	6.1	-	-	0.0
PA	48.0	0.5	13.3	0.6	1.0	0.9	35.2	0.5	0.0	-	-
RI	-	0.2	97.8	-	1.9	0.1	-	-	-	-	-
SC	34.4	0.5	9.8	0.1	1.7	1.4	52.1	-	-	-	-
SD	39.6	0.1	1.0	0.4	0.1	47.4	-	11.5	-	-	-
TN	52.2	0.2	0.5	0.0	1.1	12.0	33.8	0.1	-	-	-
TX	35.2	1.1	47.5	0.2	0.3	0.3	10.4	5.0	-	-	0.1
UT	81.7	0.1	14.8	0.0	0.1	1.9	-	0.2	-	0.6	0.4
VA	36.5	1.6	17.4	0.6	3.4	0.2	40.3	-	-	-	0.0
VT	-	0.0	0.1	-	5.7	20.4	73.6	0.2	-	-	-
WA	7.2	0.3	11.5	0.1	1.4	69.9	6.4	3.4	-	-	-
WI	62.3	1.2	9.1	0.1	2.1	2.3	21.1	1.7	-	-	0.1
WV	96.2	0.2	0.2	0.1	-	2.3	-	1.0	-	-	0.0
WY	91.1	0.1	1.1	0.6	-	2.1	-	4.8	-	-	0.1

Source: EPA eGRID 2012 Version 1.0

3.2 Electricity Generation FFC Energy Conversion Factors

FFC energy factors due to electricity and fossil fuel consumption were derived from government and public databases using GTI's Source Energy and Emissions Analysis Tool (SEEAT) as described in more detail in Appendix B. National, regional, and state level electricity FFC emission factors were derived based on full-fuel-cycle calculations.

FFC energy factors were derived only at the national level for fossil fuels based on full-fuel-cycle calculations. Unlike factors for electricity, average and marginal natural gas factors are very similar. Minor variations in marginal and average natural gas factors are attributable mainly to transmission distance and type of production (e.g., conventional vs. shale gas wells). Published data on such variations is limited, and the calculated impact on the results is small enough to ignore for the purposes of this report.

Since the eGRID2012 database does not provide details on the type of coal used, a supplemental set of data was compiled from DOE/EIA Form 923, Power Plant Operations Report, for 2011. Table 5 shows the percentage of each coal type (bituminous, subbituminous, and lignite) used in the overall coal fuel mix for electric power generation by state and the composite for the U.S. This information was used in SEEAT for calculating FFC energy conversion factors for electricity generated using coal at state, regional, and national levels.

Table 6 through Table 9 show national, regional, and state average FFC energy factors for electricity generated with different fuel types calculated using SEEAT.

Table 10 shows aggregate average U.S. electric power generation heat rates and the corresponding plant energy conversion factors based on data provided in the EIA 2011 Annual Energy Review. The net conversion efficiency values are very close to those provided in Table 6 for all fuel types except hydropower generation. Modern hydropower plant conversion efficiency is actually much higher (state of the art plants are over 90% efficient) than the 35.0% conversion efficiency used by EIA.

Table 11 shows non-baseload FFC energy factors for electricity generated with different fuel types for each eGRID sub-region calculated using SEEAT. Table 12 summarizes non-baseload and average FFC energy factors for electricity for each eGRID sub-region and the U.S.

Table 5 Electricity Generation Coal Type Mix by State

State	Percent of total coal-based generation		
	Bituminous	Subbituminous	Lignite
AK	-	100	-
AL	64	36	-
AR	0	100	-
AZ	40	60	-
CA	100	-	-
CO	27	73	-
CT	9	91	-
DC	-	-	-
DE	100	-	-
FL	100	-	-
GA	65	35	-
HI	100	-	-
IA	2	98	-
ID	77	23	-
IL	7	93	-
IN	70	30	-
KS	1	99	-
KY	99	1	-
LA	2	79	19
MA	100	-	-
MD	96	4	-
ME	100	-	-
MI	21	79	-
MN	0	100	-
MO	3	97	-
MS	62	12	25
MT	-	98	2
NC	100	-	-
ND	-	7	93
NE	-	100	-
NH	100	-	-
NJ	98	2	-
NM	47	53	-
NV	56	44	-
NY	64	36	-
OH	87	13	-
OK	5	95	-
OR	-	100	-
PA	99	1	-
RI	-	-	-
SC	100	-	-
SD	-	100	-
TN	59	41	-
TX	-	66	34
UT	98	2	-
VA	100	-	-
VT	-	-	-
WA	-	100	-
WI	16	84	-
WV	98	2	-
WY	1	99	-
U.S.	**49**	**46**	**5**

Source: EIA Form 923 for 2011

Table 6 U.S. Average Electricity Generation FFC Energy Factors by Fuel Type

Energy Type	Process energy efficiency (percent)						
	Extraction	Processing	Transportation	Conversion	Distribution	Cumulative Efficiency	FFC Energy Conversion Factor
Electricity							
Coal	98.0	98.6	99.0	32.9	93.5	29.4	3.40
Oil	96.3	93.8	98.8	32.0	93.5	26.7	3.75
Natural Gas	96.2	97.0	99.3	43.2	93.5	37.4	2.67
Nuclear	99.0	96.2	99.9	32.6	93.5	29.0	3.45
Hydro	100.0	100.0	100.0	90.0	93.5	84.2	1.19
Biomass	99.4	95.0	97.5	24.4	93.5	21.0	4.76
Wind	100.0	100.0	100.0	26.0	93.5	24.3	4.11
Solar	100.0	100.0	100.0	12.0	93.5	11.2	8.91
Geothermal	100.0	100.0	100.0	16.0	93.5	15.0	6.68
U.S. Average	98.0	97.8	99.3	35.7	93.5	31.8	3.15

Source: SEEAT Version 6.0

Table 7 Electricity Generation Average FFC Energy Factors by NERC Region and U.S.

NERC Region	NERC name	Process energy efficiency (percent)						
		Extraction	Processing	Transportation	Conversion	Distribution	Cumulative Efficiency	FFC Energy Conversion Factor
ASCC	Alaska Systems Coordinating Council	97.2	97.2	99.2	38.0	94.2	33.6	2.98
FRCC	Florida Reliability Coordinating Council	97.4	97.4	99.0	36.5	94.2	32.3	3.10
HICC	Hawaiian Islands Coordinating Council	97.0	95.1	98.7	34.1	92.2	28.6	3.49
MRO	Midwest Reliability Organization	98.9	99.0	97.7	32.1	94.1	28.9	3.46
NPCC	Northeast Power Coordinating Council	98.1	97.3	99.4	39.0	94.2	34.9	2.87
RFC	Reliability First Corporation	99.0	98.3	98.6	33.8	94.2	30.5	3.27
SERC	SERC Reliability Corporation	98.6	98.2	98.7	34.8	94.1	31.3	3.19
SPP	Southwest Power Pool	98.3	98.8	98.0	33.5	93.7	29.9	3.35
TRE	Texas Regional Entity	97.6	97.9	98.4	36.9	92.0	31.9	3.14
WECC	Western Electricity Coordinating Council	98.4	98.4	99.0	40.1	91.8	35.3	2.83
U.S.		98.0	97.8	99.3	35.7	93.5	31.8	3.15

Source: SEEAT Version 6.0

Table 8 Electricity Generation Average FFC Energy Factors by eGRID Sub-Region

eGRID 2012 Sub-region	eGRID 2012 Sub-region Name	Process energy efficiency (percent)						FFC Energy Conversion
		Extraction	Processing	Transportation	Conversion	Distribution	Cumulative	
AKGD	ASCC Alaska Grid	96.8	97.1	99.0	35.0	94.2	30.7	3.27
AKMS	ASCC Miscellaneous	98.7	97.9	99.6	58.7	94.2	53.2	1.93
ERCT	ERCOT All	97.6	97.9	98.4	37.1	92.0	32.1	3.11
FRCC	FRCC All	97.5	97.4	99.0	35.6	94.2	31.5	3.17
HIMS	HICC Miscellaneous	97.3	95.0	98.8	31.3	92.2	26.3	3.78
HIOA	HICC Oahu	96.9	94.9	98.5	36.4	92.2	30.4	3.29
MROE	MRO East	98.9	98.7	98.0	33.8	94.2	30.5	3.28
MROW	MRO West	98.9	99.0	97.6	31.9	94.1	28.7	3.49
NYLI	NPCC Long Island	96.5	96.7	99.1	33.7	94.2	29.3	3.41
NEWE	NPCC New England	97.9	97.0	99.2	38.3	94.2	34.0	2.94
NYCW	NPCC NYC/Westchester	97.4	96.7	99.5	36.7	94.2	32.4	3.09
NYUP	NPCC Upstate NY	98.8	98.0	99.5	43.6	94.2	39.5	2.55
RFCE	RFC East	98.6	97.5	99.0	34.5	94.2	30.9	3.23
RFCM	RFC Michigan	98.2	98.1	97.5	33.6	93.6	29.6	3.30
RFCW	RFC West	99.1	98.6	98.4	33.7	94.2	30.5	3.27
SRMW	SERC Midwest	99.0	99.0	97.9	33.3	94.2	30.1	3.33
SRMV	SERC Mississippi Valley	97.7	97.3	98.9	36.2	93.9	31.9	3.13
SRSO	SERC South	98.5	98.2	98.6	36.4	94.2	32.7	3.06
SRTV	SERC Tennessee Valley	99.0	98.6	98.6	35.6	94.2	32.3	3.10
SRVC	SERC Virginia/Carolina	98.9	97.8	98.9	34.4	94.2	31.0	3.23
SPNO	SPP North	98.8	99.0	97.9	31.0	94.2	27.9	3.58
SPSO	SPP South	98.2	98.7	97.9	35.0	93.5	31.0	3.22
CAMX	WECC California	97.7	97.6	99.4	39.2	91.8	34.1	2.93
NWPP	WECC Northwest	99.1	99.2	99.1	47.8	91.8	42.7	2.36
RMPA	WECC Rockies	98.5	99.0	98.1	32.7	91.8	28.7	3.48
AZNM	WECC Southwest	98.1	98.1	98.8	36.0	91.8	31.4	3.18

Source: SEEAT Version 6.0

Table 9 Electricity Generation FFC Energy Factors by State

State	Process energy efficiency (percent)						
	Extraction	Processing	Transportation	Conversion	Distribution	Cumulative Efficiency	FFC Energy Conversion Factor
AK	97.2	97.2	99.2	38.0	94.2	33.6	2.98
AL	98.5	98.0	98.9	37.7	94.2	33.9	2.95
AR	98.5	98.1	98.6	36.9	94.2	33.1	3.02
AZ	98.2	97.9	98.9	36.4	91.8	31.8	3.14
CA	97.6	97.5	99.5	38.3	91.8	33.2	3.01
CO	98.3	98.9	98.3	33.1	91.8	29.1	3.44
CT	98.1	96.7	99.4	35.4	94.2	31.5	3.18
DC	96.3	93.8	98.8	22.3	94.2	18.7	5.33
DE	98.2	98.2	98.4	30.7	94.2	27.4	3.64
FL	97.4	97.4	99.0	35.5	94.2	31.4	3.19
GA	98.7	98.2	98.6	35.6	94.2	32.1	3.12
HI	97.0	94.9	98.6	34.9	92.2	29.2	3.43
IA	99.0	99.3	98.1	31.7	94.2	28.8	3.47
ID	99.5	99.4	99.8	71.2	91.8	64.5	1.55
IL	98.9	97.8	98.7	32.3	94.2	29.1	3.44
IN	99.1	99.4	97.9	33.4	94.2	30.3	3.30
KS	98.8	98.8	98.0	30.8	94.2	27.8	3.60
KY	99.2	99.4	98.1	33.3	94.2	30.4	3.29
LA	97.6	97.4	98.7	36.3	94.2	32.1	3.12
MA	97.5	97.3	99.0	38.4	94.2	34.0	2.94
MD	99.1	98.2	98.8	34.4	94.2	31.1	3.21
ME	98.0	97.2	99.0	47.3	94.2	42.0	2.38
MI	98.8	98.5	98.3	33.6	94.2	30.3	3.30
MN	98.9	98.5	98.1	31.2	94.2	28.0	3.57
MO	98.8	99.1	97.8	33.6	94.2	30.4	3.29
MS	97.7	97.4	98.9	34.9	94.2	30.9	3.23
MT	99.3	99.6	98.4	39.2	91.8	35.0	2.86
NC	99.1	98.2	98.8	35.0	94.2	31.7	3.15
ND	98.6	99.6	95.2	31.7	94.2	27.9	3.59
NE	98.9	98.6	98.1	31.6	94.2	28.5	3.51
NH	98.4	97.1	99.3	35.5	94.2	31.7	3.15
NJ	98.1	96.7	99.5	35.5	94.2	31.5	3.17
NM	98.4	99.0	97.9	33.7	91.8	29.5	3.39
NV	97.2	97.8	99.1	39.6	91.8	34.3	2.92
NY	98.3	97.5	99.5	40.0	94.2	35.9	2.78
OH	99.1	99.0	98.3	34.1	94.2	31.0	3.23
OK	97.8	98.4	98.5	36.1	94.2	32.3	3.10
OR	98.8	99.0	99.6	59.2	91.8	53.0	1.89
PA	98.8	97.9	98.9	34.5	94.2	31.1	3.22
RI	96.3	97.0	99.3	44.0	94.2	38.4	2.61
SC	98.8	97.4	99.1	34.0	94.2	30.6	3.27
SD	99.5	99.4	98.9	44.1	94.2	40.7	2.46
TN	99.3	98.4	98.8	36.8	94.2	33.4	2.99
TX	97.6	97.9	98.3	36.5	92.0	31.5	3.17
UT	98.8	99.2	98.3	34.8	91.8	30.8	3.25
VA	98.6	97.5	99.0	34.4	94.2	30.8	3.24
VT	99.2	96.9	99.8	36.7	94.2	33.1	3.02
WA	99.4	99.3	99.7	60.8	91.8	54.9	1.82
WI	98.8	98.5	98.2	33.2	94.2	29.8	3.35
WV	99.3	99.6	98.1	34.5	94.2	31.5	3.18
WY	98.9	99.6	97.5	31.4	91.8	27.7	3.61

Source: SEEAT Version 6.0

Table 10 EIA Electricity Generation Heat Rates by Fuel Type

Fuel Type	Annual Heat Input (MMBTu)	Net Generation (MWh)	Plant Heat Rate (Btu/kWh)	Net Conversion Efficiency (%)	Energy Conversion Factor
Coal	1.920E+10	1.847E+09	10,392	32.8%	3.05
Natural Gas	7.853E+09	9.877E+08	7,950	42.9%	2.33
Fuel Oil	3.859E+08	3.706E+07	10,412	32.8%	3.05
Nuclear	8.434E+09	8.070E+08	10,452	32.6%	3.06
Hydro*	2.539E+09	2.602E+08	9,756	35.0%	2.86
Biomass	6.303E+08	5.609E+07	11,237	30.4%	3.29

* The heat input for hydro is intended to estimate how much fossil fuel is replaced rather than the actual heat input or efficiency
Source: EIA Annual Energy Review 2012 (2010 data), tables 8.2a and 8.4a

Table 11 Electricity Generation Non-Baseload FFC Energy Factors by eGRID Sub-Region

eGRID 2012 Sub-region	eGRID 2012 Sub-region Name	Process energy efficiency (percent)						FFC Energy Conversion
		Extraction	Processing	Transportation	Conversion	Distribution	Cumulative	
AKGD	ASCC Alaska Grid	96.4	96.4	99.0	33.9	94.2	29.4	3.40
AKMS	ASCC Miscellaneous	96.3	94.1	98.8	36.2	94.2	30.5	3.27
ERCT	ERCOT All	96.6	97.4	98.8	40.4	92.0	34.5	2.89
FRCC	FRCC All	96.9	97.2	99.0	38.0	94.2	33.4	2.99
HIMS	HICC Miscellaneous	96.5	94.0	98.7	33.6	92.2	27.7	3.61
HIOA	HICC Oahu	96.4	93.8	98.8	34.4	92.2	28.3	3.53
MROE	MRO East	98.4	98.7	97.8	34.8	94.2	31.1	3.21
MROW	MRO West	98.4	99.0	97.1	30.8	94.1	27.4	3.64
NYLI	NPCC Long Island	96.2	96.5	99.2	32.3	94.2	28.0	3.57
NEWE	NPCC New England	96.9	97.2	98.9	40.6	94.2	35.6	2.80
NYCW	NPCC NYC/Westchester	96.2	96.8	99.3	37.0	94.2	32.2	3.10
NYUP	NPCC Upstate NY	97.4	97.8	98.7	40.0	94.2	35.4	2.82
RFCE	RFC East	97.9	98.3	98.5	35.9	94.2	32.1	3.11
RFCM	RFC Michigan	98.4	98.8	98.0	35.0	94.2	31.4	3.18
RFCW	RFC West	98.9	99.2	98.1	33.8	94.2	30.7	3.26
SRMW	SERC Midwest	98.9	99.5	97.5	32.0	94.2	28.9	3.46
SRMV	SERC Mississippi Valley	96.5	97.2	99.0	36.6	93.9	31.9	3.13
SRSO	SERC South	98.0	98.4	98.4	36.6	94.2	32.8	3.04
SRTV	SERC Tennessee Valley	98.7	99.0	98.1	34.2	94.2	30.9	3.23
SRVC	SERC Virginia/Carolina	98.2	98.5	98.4	35.5	94.2	31.8	3.14
SPNO	SPP North	98.3	99.0	97.8	30.3	94.2	27.1	3.68
SPSO	SPP South	97.2	97.9	98.4	34.5	93.5	30.2	3.31
CAMX	WECC California	96.3	96.9	99.2	39.4	91.8	33.5	2.99
NWPP	WECC Northwest	97.4	97.8	98.5	38.0	91.8	32.7	3.04
RMPA	WECC Rockies	97.7	98.4	98.3	33.7	91.8	29.2	3.41
AZNM	WECC Southwest	96.8	97.5	99.0	40.3	91.8	34.6	2.89

Source: SEEAT Version 6.0

Table 12 Non-Baseload and Average Electricity FFC Energy Factors by eGRID Sub-Region

eGRID 2012 Sub-region Acronym	eGRID 2012 Sub-region Name	Non-Baseload FFC Energy Conversion Factor	Average FFC Energy Conversion Factor
AKGD	ASCC Alaska Grid	3.41	3.27
AKMS	ASCC Miscellaneous	3.27	1.93
ERCT	ERCOT All	2.89	3.11
FRCC	FRCC All	2.99	3.17
HIMS	HICC Miscellaneous	3.61	3.78
HIOA	HICC Oahu	3.53	3.29
MROE	MRO East	3.21	3.28
MROW	MRO West	3.63	3.49
NYLI	NPCC Long Island	3.57	3.41
NEWE	NPCC New England	2.80	2.94
NYCW	NPCC NYC/Westchester	3.10	3.09
NYUP	NPCC Upstate NY	2.82	2.55
RFCE	RFC East	3.11	3.23
RFCM	RFC Michigan	3.18	3.29
RFCW	RFC West	3.26	3.27
SRMW	SERC Midwest	3.46	3.33
SRMV	SERC Mississippi Valley	3.15	3.13
SRSO	SERC South	3.05	3.06
SRTV	SERC Tennessee Valley	3.23	3.10
SRVC	SERC Virginia/Carolina	3.14	3.23
SPNO	SPP North	3.69	3.58
SPSO	SPP South	3.31	3.22
CAMX	WECC California	2.99	2.93
NWPP	WECC Northwest	3.05	2.36
RMPA	WECC Rockies	3.41	3.48
AZNM	WECC Southwest	2.89	3.18
US Average		**3.13**	**3.15**

Source: SEEAT Version 6.0

3.3 Fossil Fuel FFC Energy Conversion Factors

Table 13 lists the total FFC energy conversion factor for natural gas, heating oil, and propane, the most common fossil fuels used in buildings. Process energy efficiency is included as percentage of energy of fuel leaving each stage to the total energy entering each stage including energy of other fuels spent in the process. Efficiency of end-use conversion to useful work inside the building was not included in this table as it varies depending on specific equipment efficiency.

Table 13 U.S. Average Building Fuels FFC Energy Factors by Fuel Type

Energy Type	Process energy efficiency (percent)						
	Extraction	Processing	Transportation	Conversion	Distribution	Cumulative Efficiency	FFC Energy Conversion Factor
Fossil Fuels Used in Buildings							
Natural Gas	96.2	97.0	99.0	100.0	99.0	91.5	1.09
Heating Oil	94.9	89.1	99.7	100.0	99.6	84.0	1.19
Propane/LPG	94.6	93.6	99.2	100.0	99.2	87.1	1.15

Source: SEEAT Version 6.0

4 FFC Pollutant and GHG Emission Factors

FFC emission factors due to electricity and fossil fuel consumption were derived from government and public databases using SEEAT as described in Appendix B. Emission factors include CO_2, NO_x, SO_2, Hg, CH_4, N_2O, and CO_2e emissions based on the FFC energy consumption associated with each type of power generation. National, regional, and state level electricity emission factors were derived based on FFC calculations. Emission factors were derived only at the national level for fossil fuels based on FFC calculations. Constituent factors are tabulated below, along with the aggregated FFC emission factors associated with building energy consumption. This allows quick calculations and comparisons of the FFC emissions associated with buildings, systems, or appliances based on their point-of-use or site consumption by energy form.

4.1 Electric Power Plant Emission Factors

The eGRID2012 Version 1.0 database provides information on pollutant emissions associated with U.S. electric power plants. The latest data are for year 2009 and are reported for nearly all U.S. power plants and aggregated at several levels including state, eGRID sub-region, NERC region, and national level. Table 14 shows CO_2, NOx, SO_2, Hg, CH_4, and N_2O emissions in pounds of pollutant per unit of generated electricity (MWh or GWh) by NERC Region and U.S. average. Table 15 and Table 16 show similar data at the eGRID sub-region and state level. The emission factors shown in Table 14 through Table 16 are based on electricity output and include the total fuel mix used by power plants, while factors shown in Table 17 through Table 19 include power plant emissions related only to fossil fuel input.

Table 14 Power Plant Emission Rate by NERC Region and U.S. - All Fuels

NERC region	NERC name	NO_x output emission rate (lb/MWh)	SO_2 output emission rate (lb/MWh)	CO_2 output emission rate (lb/MWh)	CH_4 output emission rate (lb/GWh)	N_2O output emission rate (lb/GWh)	Hg output emission rate (lb/GWh)*	CO_2e output emission rate (lb/MWh)
ASCC	Alaska Systems Coordinating Council	3.50	1.16	1,126	26.52	7.0	0.002	1,129
FRCC	Florida Reliability Coordinating Council	0.98	1.89	1,177	39.24	13.5	0.009	1,182
HICC	Hawaiian Islands Coordinating Council	3.31	4.93	1,527	93.70	19.7	0.012	1,535
MRO	Midwest Reliability Organization	2.21	4.30	1,624	28.15	27.7	0.039	1,633
NPCC	Northeast Power Coordinating Council	0.46	1.05	654	48.10	9.7	0.011	658
RFC	Reliability First Corporation	1.21	5.55	1,370	21.91	22.5	0.042	1,377
SERC	SERC Reliability Corporation	0.94	3.29	1,247	20.22	19.4	0.028	1,254
SPP	Southwest Power Pool	1.95	3.10	1,668	22.54	24.0	0.034	1,676
TRE	Texas Regional Entity	0.72	2.24	1,182	16.70	13.1	0.025	1,186
WECC	Western Electricity Coordinating Council	1.12	0.76	953	20.84	12.7	0.014	957
US		**1.12**	**3.08**	**1,216**	**24.03**	**18.1**	**0.027**	**1,222**

* Hg emissions are from EPA eGRID 2007
Source: EPA eGRID 2012 Version 1.0

Table 15 Power Plant Emission Rate by eGRID Sub-Region - All Fuels

eGRID 2012 Sub-region Acronym	eGRID 2012 Sub-region Name	NO_x output emission rate (lb/MWh)	SO_2 output emission rate (lb/MWh)	CO_2 output emission rate (lb/MWh)	CH_4 output emission rate (lb/GWh)	N_2O output emission rate (lb/GWh)	Hg output emission rate (lb/GWh)*	CO_2e output emission rate (lb/MWh)
AKGD	ASCC Alaska Grid	2.58	0.92	1,281	27.7	7.7	0.002	1,284
AKMS	ASCC Miscellaneous	7.09	2.07	521	21.8	4.3	N/A	523
ERCT	ERCOT All	0.72	2.24	1,182	16.7	13.1	0.029	1,186
FRCC	FRCC All	0.98	1.89	1,177	39.2	13.5	0.011	1,182
HIMS	HICC Miscellaneous	5.84	5.60	1,352	72.4	13.8	N/A	1,357
HIOA	HICC Oahu	2.36	4.67	1,593	101.7	22.0	0.016	1,602
MROE	MRO East	1.48	5.13	1,592	24.0	27.0	0.032	1,601
MROW	MRO West	2.32	4.18	1,629	28.8	27.8	0.052	1,638
NYLI	NPCC Long Island	1.13	1.00	1,348	96.9	12.4	0.006	1,354
NEWE	NPCC New England	0.52	1.42	728	75.7	13.9	0.015	734
NYCW	NPCC NYC/Westchester	0.28	0.10	611	23.8	2.8	0.011	612
NYUP	NPCC Upstate NY	0.40	0.98	498	15.9	6.8	0.030	500
RFCE	RFC East	0.81	4.60	947	26.8	15.0	0.064	953
RFCM	RFC Michigan	1.78	6.14	1,659	31.4	27.9	0.044	1,669
RFCW	RFC West	1.31	5.90	1,521	18.1	25.1	0.058	1,529
SRMW	SERC Midwest	1.01	5.47	1,750	19.6	29.0	0.052	1,759
SRMV	SERC Mississippi Valley	1.05	1.57	1,002	19.4	10.7	0.014	1,006
SRSO	SERC South	1.06	4.85	1,326	22.3	20.8	0.045	1,333
SRTV	SERC Tennessee Valley	1.02	3.22	1,358	17.3	22.1	0.039	1,365
SRVC	SERC Virginia/Carolina	0.68	2.12	1,036	21.5	17.4	0.037	1,042
SPNO	SPP North	2.05	3.05	1,816	21.0	28.9	0.049	1,825
SPSO	SPP South	1.90	3.13	1,599	23.2	21.8	0.033	1,606
CAMX	WECC California	0.42	0.18	659	28.9	6.2	0.007	661
NWPP	WECC Northwest	1.04	1.05	819	15.3	12.5	0.029	823
RMPA	WECC Rockies	2.59	1.93	1,825	22.2	27.2	0.020	1,833
AZNM	WECC Southwest	1.52	0.62	1,191	19.1	15.6	0.032	1,197

* Hg emissions are from EPA eGRID 2007
Source: EPA eGRID 2012 Version 1.0

Table 16 Power Plant Emission Rate by State - All Fuels

State abbreviation	NO_x output emission rate (lb/MWh)	SO_2 output emission rate (lb/MWh)	CO_2 output emission rate (lb/MWh)	CH_4 output emission rate (lb/GWh)	N_2O output emission rate (lb/GWh)	Hg output emission rate (lb/GWh)*	CO_2e output emission rate (lb/MWh)
AK	3.50	1.16	1,126	26.5	7.0	0.002	1,129
AL	0.74	3.95	1,041	18.9	15.8	0.040	1,046
AR	1.24	2.52	1,113	19.6	17.4	0.021	1,118
AZ	1.19	0.65	1,085	15.5	14.3	0.015	1,089
CA	0.20	0.14	556	31.0	4.5	0.002	558
CO	2.53	1.90	1,737	21.7	25.1	0.016	1,745
CT	0.36	0.38	577	62.0	10.5	0.016	581
DC	4.59	18.56	2,485	106.7	21.3	N/A	2,494
DE	2.05	7.18	1,795	26.2	23.3	0.040	1,803
FL	1.02	2.19	1,192	39.2	14.0	0.010	1,197
GA	0.95	4.30	1,286	19.1	20.5	0.027	1,293
HI	3.31	4.93	1,527	93.7	19.7	0.012	1,535
IA	1.62	3.75	1,625	18.5	26.7	0.051	1,634
ID	0.11	0.17	120	10.7	2.1	N/A	121
IL	0.76	2.48	1,068	12.2	17.4	0.043	1,073
IN	1.96	7.18	2,034	23.8	33.7	0.045	2,045
KS	2.11	2.21	1,674	19.3	26.7	0.044	1,683
KY	1.74	5.57	2,046	23.6	34.6	0.038	2,057
LA	1.21	1.89	1,128	22.6	12.2	0.013	1,133
MA	0.80	2.06	1,114	73.7	16.8	0.015	1,121
MD	0.90	9.32	1,232	30.6	21.7	0.039	1,239
ME	0.57	0.63	500	148.9	21.1	0.003	510
MI	1.71	5.61	1,524	30.5	26.0	0.031	1,533
MN	1.69	2.12	1,397	48.4	26.4	0.029	1,406
MO	1.29	5.72	1,808	20.4	29.5	0.043	1,817
MS	1.14	1.75	1,103	20.9	13.0	0.013	1,107
MT	1.63	2.59	1,439	17.1	24.1	0.036	1,446
NC	0.73	1.97	1,157	17.7	19.7	0.027	1,163
ND	3.69	7.68	2,058	22.2	33.0	0.072	2,068
NE	2.71	4.39	1,598	17.8	26.4	0.022	1,606
NH	0.48	3.47	601	71.7	14.4	0.003	607
NJ	0.32	0.48	550	22.6	5.8	0.013	552
NM	3.37	0.97	1,821	22.3	27.3	0.064	1,830
NV	0.82	0.43	1,061	17.0	8.6	0.015	1,064
NY	0.42	0.75	583	24.1	6.2	0.011	585
OH	1.48	9.11	1,781	21.1	29.5	0.048	1,790
OK	2.09	2.66	1,495	21.5	18.2	0.028	1,501
OR	0.31	0.41	364	15.1	3.7	0.004	365
PA	1.11	5.79	1,140	24.4	18.6	0.049	1,147
RI	0.17	0.01	895	17.6	1.8	N/A	896
SC	0.50	2.11	825	14.5	13.4	0.012	829
SD	3.08	2.98	914	10.3	15.0	0.014	919
TN	0.74	2.75	1,072	13.6	18.3	0.028	1,078
TX	0.82	2.29	1,243	17.8	14.0	0.025	1,248
UT	2.94	1.15	1,854	22.3	29.6	0.008	1,864
VA	0.92	2.80	994	37.3	17.1	0.016	1,000
VT	0.10	0.01	2	53.2	7.1	N/A	5
WA	0.25	0.09	286	10.4	4.3	0.007	288
WI	1.21	3.74	1,514	24.4	24.9	0.037	1,522
WV	1.06	5.03	2,011	22.5	33.7	0.054	2,021
WY	3.01	3.37	2,116	23.6	35.0	0.041	2,128

* Hg emissions are from EPA eGRID 2007
Source: EPA eGRID 2012 Version 1.0

Table 17 Power Plant Emission Rate by NERC Region and U.S. - Fossil Fuels

NERC region	NERC name	NO_x output emission rate (lb/MWh)	SO_2 output emission rate (lb/MWh)	CO_2 output emission rate (lb/MWh)	Hg output emission rate (lb/GWh)*
ASCC	Alaska Systems Coordinating Council	4.36	1.44	1,405	0.002
FRCC	Florida Reliability Coordinating Council	1.07	1.95	1,366	0.007
HICC	Hawaiian Islands Coordinating Council	3.37	5.25	1,603	0.002
MRO	Midwest Reliability Organization	2.97	5.90	2,231	0.049
NPCC	Northeast Power Coordinating Council	0.63	1.86	1,183	0.010
RFC	Reliability First Corporation	1.72	7.98	1,963	0.054
SERC	SERC Reliability Corporation	1.35	4.78	1,840	0.039
SPP	Southwest Power Pool	2.22	3.54	1,912	0.038
TRE	Texas Regional Entity	0.88	2.73	1,441	0.029
WECC	Western Electricity Coordinating Council	1.78	1.22	1,541	0.021
US		**1.57**	**4.38**	**1,743**	**0.036**

* Hg emissions are from EPA eGRID 2007
Source: EPA eGRID 2012 Version 1.0

Table 18 Power Plant Emission Rate by eGRID Sub-Region - Fossil Fuels

eGRID 2012 Sub-region Acronym	eGRID 2012 Sub-region Name	NO_x output emission rate (lb/MWh)	SO_2 output emission rate (lb/MWh)	CO_2 output emission rate (lb/MWh)	CH_4 combustion output emission rate	N_2O combustion output emission rate	Hg output emission rate (lb/GWh)*
AKGD	ASCC Alaska Grid	2.82	1.01	1,400	30.3	8.4	0.002
AKMS	ASCC Miscellaneous	19.91	5.81	1,463	61.1	12.0	N/A
ERCT	ERCOT All	0.88	2.73	1,441	20.3	15.9	0.029
FRCC	FRCC All	1.07	1.95	1,366	45.6	15.7	0.007
HIMS	HICC Miscellaneous	7.40	7.15	1,725	87.9	16.8	N/A
HIOA	HICC Oahu	2.15	4.68	1,567	101.7	22.0	0.002
MROE	MRO East	1.84	6.58	2,078	30.1	33.9	0.033
MROW	MRO West	3.16	5.78	2,257	39.4	38.0	0.052
NYLI	NPCC Long Island	1.01	0.94	1,260	96.9	12.4	N/A
NEWE	NPCC New England	0.47	2.18	1,137	120.3	22.0	0.007
NYCW	NPCC NYC/Westchester	0.39	0.08	1,001	40.5	4.8	N/A
NYUP	NPCC Upstate NY	1.05	2.76	1,404	43.9	18.7	0.024
RFCE	RFC East	1.40	8.39	1,688	48.5	27.0	0.053
RFCM	RFC Michigan	2.11	7.40	2,002	37.1	32.9	0.040
RFCW	RFC West	1.76	7.95	2,048	24.3	33.6	0.057
SRMW	SERC Midwest	1.24	6.76	2,162	24.1	35.8	0.053
SRMV	SERC Mississippi Valley	1.46	2.10	1,432	26.9	14.7	0.014
SRSO	SERC South	1.36	6.39	1,776	28.6	26.7	0.047
SRTV	SERC Tennessee Valley	1.48	4.69	1,988	25.0	31.9	0.039
SRVC	SERC Virginia/Carolina	1.16	3.77	1,877	37.7	30.6	0.037
SPNO	SPP North	2.50	3.72	2,215	25.6	35.2	0.049
SPSO	SPP South	2.10	3.46	1,784	25.6	24.0	0.033
CAMX	WECC California	0.62	0.27	1,043	44.6	9.5	0.004
NWPP	WECC Northwest	2.25	2.26	1,793	32.8	26.8	0.029
RMPA	WECC Rockies	2.87	2.13	2,018	24.6	30.0	0.020
AZNM	WECC Southwest	2.04	0.82	1,601	25.6	20.9	0.032

* Hg emissions are from EPA eGRID 2007
Source: EPA eGRID 2012 Version 1.0

Table 19 Power Plant Emission Rate by State - Fossil Fuels

State	NO_x output emission rate (lb/MWh)	SO_2 output emission rate (lb/MWh)	CO_2 output emission rate (lb/MWh)	Hg output emission rate (lb/GWh)*
AK	4.36	1.44	1,405	0.002
AL	1.17	6.22	1,709	0.060
AR	1.88	3.81	1,763	0.035
AZ	1.78	0.98	1,630	0.022
CA	0.33	0.23	934	0.000
CO	2.80	2.10	1,924	0.017
CT	0.81	0.84	1,119	0.015
DC	4.59	18.56	2,485	N/A
DE	2.05	7.18	1,811	0.040
FL	1.18	2.53	1,379	0.009
GA	1.31	5.92	1,832	0.038
HI	3.48	5.18	1,603	0.002
IA	2.17	5.01	2,179	0.061
ID	0.64	0.97	912	N/A
IL	1.54	5.03	2,186	0.083
IN	1.99	7.29	2,078	0.045
KS	2.81	2.94	2,230	0.056
KY	1.81	5.78	2,133	0.039
LA	1.51	2.36	1,458	0.016
MA	0.95	2.44	1,228	0.008
MD	1.44	14.92	1,948	0.051
ME	0.79	0.87	830	N/A
MI	2.20	7.23	2,022	0.040
MN	2.56	3.21	2,200	0.039
MO	1.51	6.72	2,124	0.048
MS	1.47	2.27	1,484	0.018
MT	2.66	4.22	2,375	0.055
NC	1.19	3.23	1,949	0.043
ND	4.25	8.83	2,368	0.075
NE	3.95	6.40	2,333	0.032
NH	1.01	7.29	1,328	0.004
NJ	0.72	1.06	1,176	0.006
NM	3.53	1.02	1,911	0.066
NV	0.93	0.48	1,195	0.016
NY	0.93	1.67	1,274	0.013
OH	1.68	10.30	2,020	0.054
OK	2.27	2.89	1,635	0.029
OR	0.88	1.15	1,043	0.010
PA	1.74	9.13	1,791	0.075
RI	0.17	0.01	913	N/A
SC	1.08	4.54	1,846	0.023
SD	7.49	7.23	2,222	0.028
TN	1.36	5.09	2,024	0.046
TX	0.97	2.72	1,480	0.028
UT	3.03	1.18	1,909	0.008
VA	1.55	4.71	1,729	0.026
VT	1.75	0.17	2,817	N/A
WA	1.24	0.45	1,492	0.033
WI	1.62	5.00	2,066	0.040
WV	1.09	5.21	2,081	0.054
WY	3.24	3.63	2,277	0.042

* Hg emissions are from EPA eGRID 2007
Source: EPA eGRID 2012 Version 1.0

4.2 Electricity Generation Pre-combustion and Plant Input Emission Factors

GREET Model v1 2012 rev2 and US EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks, draft Feb 11, 2013 were sources of information on pre-combustion air emissions associated with U.S. electric power generation. These factors are applied only to the pre-combustion energy for extraction, processing, and transportation to the power plant. Emission factors were calculated using HHV of all fuels involved in pre-combustion stages of preparing a specific fuel for combustion at the power plant. Table 20 provides U.S. average pre-combustion emission factors associated with electricity generation by fuel type. Table 21 shows similar data for power plant combustion emissions based on the consumption of each type of fuel in the power plant.

Table 20 U.S. Average Electricity Generation Pre-combustion Emission Factors

	Pre-Combustion					
Electricity Source	CO_2 (lb/MMBtu)	SO_2 (lb/MMBtu)	NO_x (lb/MMBtu)	CH_4 (lb/MMBtu)	N_2O (lb/MMBtu)	CO_2e (lb/MMBtu)
Coal	70.3	0.348	0.593	7.189	0.001	250.32
Oil	169.5	0.357	0.754	2.011	0.003	220.67
Natural Gas	127.6	0.305	0.584	6.161	0.002	282.22
Nuclear	152.7	0.258	0.282	0.371	0.003	162.87
Hydro	-	-	-	-	-	-
Biomass	161.4	0.061	0.722	0.233	0.003	168.12
Wind	-	-	-	-	-	-
Solar	-	-	-	-	-	-
Geothermal	-	-	-	-	-	-
Other	-	-	-	-	-	-

Source: GREET Model v1 2012 rev2; US EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks, draft Feb 11, 2013

Table 21 U.S. Average Power Plant Input Emission Factors by Fuel Type

Conversion						
Electricity Source	**CO_2 (lb/MMBtu)**	**SO_2 (lb/MMBtu)**	**NO_x (lb/MMBtu)**	**CH_4 (lb/MMBtu)**	**N_2O (lb/MMBtu)**	**CO_2e (lb/MMBtu)**
Coal	205.8	0.622	0.201	0.002	0.003	206.7
Oil	175.5	0.614	0.289	0.005	0.002	176.2
Natural Gas	120.4	0.020	0.061	0.002	-	120.5
Nuclear	-	-	-	-	-	-
Hydro	-	-	-	-	-	-
Biomass	-	0.319	0.208	0.044	0.006	2.9
Wind	-	-	-	-	-	-
Solar	-	-	-	-	-	-
Geothermal	-	-	-	-	-	-
Other	56.7	0.001	0.029	0.001	-	56.7

Source: EPA eGRID 2012 Version 1.0

4.3 Fossil Fuel Pre-combustion and Stationary Combustion Emission Factors

Table 22 lists U.S. average fossil fuel pre-combustion emissions factors, including fuel used for extraction, processing, transmission, and distribution to the building based on information provided in GREET. Emission factors were calculated using HHV of all fuels involved in pre-combustion stages of preparing a specific fuel for combustion. Table 23 lists fossil fuel stationary combustion emissions data derived from GREET. In combination with the pre-combustion emission factors provided in Table 22, the data are useful in evaluating total emissions from fossil fuel consumption in buildings. Table 24 lists LHV and HHV as well as specific density for several fossil fuels.

Table 22 Fossil Fuel Pre-combustion Emission Factors

Pre-Combustion						
Fuel	**CO_2 (lb/MMBtu)**	**SO_2 (lb/MMBtu)**	**NO_x (lb/MMBtu)**	**CH_4 (lb/MMBtu)**	**N_2O (lb/MMBtu)**	**CO_2e (lb/MMBtu)**
Natural Gas	127.8	0.302	0.594	6.947	0.002	302.1
Fuel Oil	166.6	0.272	0.500	1.387	0.002	201.9
Propane	166.5	0.273	0.522	1.375	0.002	201.5

Source: GREET Model v1 2012 rev2; US EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks, draft Feb 11, 2013

Table 23 Fossil Fuel Stationary Combustion Emission Factors

Conversion						
Fuel	**CO_2 (lb/MMBtu)**	**SO_2 (lb/MMBtu)**	**NO_x (lb/MMBtu)**	**CH_4 (lb/MMBtu)**	**N_2O (lb/MMBtu)**	**CO_2e (lb/MMBtu)**
Natural Gas	118.3	0.001	0.117	0.002	0.002	118.9
Fuel Oil	160.0	0.004	1.117	0.009	0.004	161.4
Propane	139.4	-	0.158	0.002	0.011	142.7

Source: GREET Model v1 2012 rev2; US EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks, draft Feb 11, 2013

Table 24 Heating Value and Density of Fossil Fuels

Fuel	Heating Value		Density
	LHV	HHV	
Liquid Fuels:	**Btu/gal**	**Btu/gal**	**lb/gal**
Crude oil	129,670	138,350	7.0670
Distillate oil	128,450	137,380	6.9832
Residual oil	140,353	150,110	8.2732
Conventional gasoline	116,090	124,340	6.2159
Liquefied petroleum gas (LPG)	84,950	91,410	4.2402
Liquefied natural gas (LNG)	74,720	84,820	3.5743
Gaseous Fuels (at 60°F and 14.7 psia):	**Btu/ft3**	**Btu/ft3**	**lb/ft3**
Natural gas	930	1,029	0.04584
Solid Fuels:	**Btu/ton**	**Btu/ton**	
Coal	19,546,300	20,608,570	

Source: ANL GREET model v1 2012 rev2

4.4 FFC Pollutant Emission Factors Associated with Building Consumption

The emission factor components shown above can be combined with the FFC energy loss factors for electricity and fossil fuels to calculate FFC emission factors associated with building energy consumption for each energy form. Table 25 through Table 28 show national, regional, and state average FFC pollutant emission factors for electricity calculated using SEEAT. Table 29 shows non-baseload FFC pollutant emission factors for electricity for each eGRID sub-region calculated using SEEAT. Table 30 summarizes non-baseload and average FFC CO_2e emission factors for electricity for each eGRID sub-region and the U.S.

Table 25 U.S. Average Electricity and Fossil Fuel Pollutant Emission Factors

	CO_2 emission rate	SO_2 emission rate	NO_x emission rate	CH_4 emission rate	N_2O emission rate	Hg emission rate*	CO_2e emission rate
Electricity (lb/MWh)	1,346	3.38	1.45	2.67	0.02	0.03	1,419
Natural Gas (lb/MMBtu)	130	0.03	0.17	0.65	0.00	-	147
Fuel Oil (lb/MMBtu)	192	0.06	1.21	0.27	-	-	200
Propane (lb/MMBtu)	164	0.04	0.23	0.21	0.01	-	172

Source: SEEAT Version 6.0

Table 26 Average Electricity Pollutant Emission Factors by NERC Region

NERC region	NERC name	CO_2 emission rate (lb/MWh)	SO_2 emission rate (lb/MWh)	NO_x emission rate (lb/MWh)	CH_4 emission rate (lb/MWh)	NO_2 emission rate (lb/MWh)	Hg emission rate (lb/MWh)*	CO_2e emission rate (lb/MWh)
ASCC	Alaska Systems Coordinating Council	1,292	1.45	4.14	3.68	0.01	-	1,387
FRCC	Florida Reliability Coordinating Council	1,240	1.99	1.35	3.11	0.02	0.01	1,322
HICC	Hawaiian Islands Coordinating Council	1,722	5.70	4.38	2.39	0.02	-	1,789
MRO	Midwest Reliability Organization	1,761	4.73	2.63	3.04	0.03	0.04	1,846
NPCC	Northeast Power Coordinating Council	701	1.26	0.76	1.98	0.01	0.01	754
RFC	Reliability First Corporation	1,485	6.03	1.50	1.95	0.02	0.04	1,541
SERC	SERC Reliability Corporation	1,371	3.61	1.23	2.17	0.02	0.03	1,432
SPP	Southwest Power Pool	1,828	3.49	2.39	3.53	0.03	0.04	1,924
TRE	Texas Regional Entity	1,352	2.63	1.12	3.53	0.02	0.03	1,445
WECC	Western Electricity Coordinating Council	1,080	0.95	1.45	2.29	0.01	0.01	1,142

Source: SEEAT Version 6.0

Table 27 Average Electricity Pollutant Emission Factors by eGRID Sub-Region

eGRID 2012 Sub-region Acronym	eGRID 2012 Sub-region Name	CO_2 emission rate (lb/MWh)	SO_2 emission rate (lb/MWh)	NO_x emission rate (lb/MWh)	CH_4 emission rate (lb/MWh)	NO_2 emission rate (lb/MWh)	Hg emission rate (lb/MWh)*	CO_2e emission rate (lb/MWh)
AKGD	ASCC Alaska Grid	1,465	1.24	3.23	4.36	0.01	-	1,577
AKMS	ASCC Miscellaneous	613	2.30	7.71	0.96	0.01	-	639
ERCT	ERCOT All	1,352	2.63	1.12	3.53	0.02	0.03	1,445
FRCC	FRCC All	1,240	1.99	1.35	3.11	0.02	0.01	1,322
HIMS	HICC Miscellaneous	1,509	6.45	7.15	2.06	0.02	-	1,566
HIOA	HICC Oahu	1,802	5.43	3.34	2.51	0.03	-	1,873
MROE	MRO East	1,740	5.55	1.82	2.58	0.03	0.03	1,813
MROW	MRO West	1,764	4.61	2.75	3.10	0.03	0.04	1,851
NYLI	NPCC Long Island	1,324	1.31	1.73	4.75	0.02	-	1,447
NEWE	NPCC New England	755	1.65	0.86	2.12	0.02	-	813
NYCW	NPCC NYC/Westchester	702	0.29	0.61	2.59	-	-	768
NYUP	NPCC Upstate NY	558	1.15	0.59	1.19	0.01	0.01	590
RFCE	RFC East	1,018	5.03	1.09	1.69	0.02	0.04	1,065
RFCM	RFC Michigan	1,800	6.67	2.15	2.62	0.03	0.04	1,874
RFCW	RFC West	1,653	6.39	1.60	2.00	0.03	0.05	1,711
SRMW	SERC Midwest	1,899	5.96	1.32	2.71	0.03	0.05	1,976
SRMV	SERC Mississippi Valley	1,143	1.87	1.45	2.98	0.01	0.01	1,221
SRSO	SERC South	1,453	5.30	1.37	2.38	0.02	0.04	1,519
SRTV	SERC Tennessee Valley	1,482	3.54	1.28	1.95	0.02	0.03	1,538
SRVC	SERC Virginia/Carolina	1,134	2.29	0.91	1.59	0.02	0.02	1,180
SPNO	SPP North	1,973	3.40	2.46	3.17	0.03	0.04	2,062
SPSO	SPP South	1,759	3.53	2.36	3.74	0.02	0.03	1,860
CAMX	WECC California	772	0.34	0.74	2.43	0.01	-	835
NWPP	WECC Northwest	914	1.22	1.29	1.65	0.01	0.01	959
RMPA	WECC Rockies	2,036	2.27	3.12	3.45	0.03	0.02	2,131
AZNM	WECC Southwest	1,354	0.83	1.93	2.76	0.02	0.03	1,428

Source: SEEAT Version 6.0

Table 28 Average Electricity Pollutant Emission Factors by State

State abbreviation	CO_2 emission rate (lb/MWh)	SO_2 emission rate (lb/MWh)	NO_x emission rate (lb/MWh)	CH_4 emission rate (lb/MWh)	NO_2 emission rate (lb/MWh)	Hg emission rate (lb/MWh)*	CO_2e emission rate (lb/MWh)
AK	1,292	1.45	4.14	3.68	0.01	-	1,387
AL	1,151	4.33	1.02	1.89	0.02	0.04	1,204
AR	1,234	2.83	1.59	2.31	0.02	0.02	1,298
AZ	1,243	0.87	1.55	2.45	0.02	0.02	1,309
CA	660	0.29	0.50	2.37	0.01	-	721
CO	1,943	2.24	3.05	3.34	0.03	0.02	2,035
CT	560	0.56	0.66	1.63	0.01	0.01	605
DC	2,969	20.41	6.35	4.05	0.03	-	3,079
DE	1,723	7.80	2.55	3.26	0.03	0.04	1,812
FL	1,258	2.32	1.39	3.05	0.02	0.01	1,339
GA	1,420	4.72	1.25	2.16	0.02	0.03	1,481
HI	1,724	5.71	4.39	2.39	0.02	-	1,791
IA	1,759	4.11	1.95	2.60	0.03	0.05	1,833
ID	147	0.21	0.21	0.53	-	-	161
IL	1,194	2.78	1.02	1.74	0.02	0.05	1,243
IN	2,183	7.78	2.32	2.72	0.04	0.05	2,262
KS	1,825	2.51	2.51	2.92	0.03	0.05	1,906
KY	2,197	6.03	2.06	2.46	0.04	0.04	2,269
LA	1,275	2.22	1.66	3.36	0.01	0.01	1,363
MA	1,110	2.35	1.18	2.81	0.02	0.01	1,186
MD	1,303	10.02	1.15	1.61	0.02	0.04	1,350
ME	537	0.76	1.01	2.01	0.02	-	595
MI	1,659	6.10	2.07	2.42	0.03	0.04	1,728
MN	1,501	2.38	2.05	2.40	0.03	0.03	1,570
MO	1,959	6.23	1.62	2.92	0.03	0.05	2,041
MS	1,249	2.04	1.54	2.99	0.02	0.01	1,329
MT	1,600	2.95	1.99	2.35	0.03	0.04	1,667
NC	1,280	2.20	0.96	1.60	0.02	0.03	1,326
ND	2,241	8.43	4.39	5.78	0.04	0.08	2,396
NE	1,745	4.83	3.13	2.63	0.03	0.02	1,819
NH	685	3.83	0.77	1.67	0.02	-	732
NJ	608	0.67	0.60	1.70	0.01	0.01	653
NM	2,031	1.24	3.98	3.64	0.03	0.07	2,131
NV	1,216	0.62	1.20	3.30	0.01	0.02	1,302
NY	645	0.94	0.68	1.79	0.01	0.01	693
OH	1,921	9.77	1.78	2.22	0.03	0.05	1,986
OK	1,641	2.99	2.53	3.54	0.02	0.03	1,736
OR	416	0.51	0.47	1.30	-	-	450
PA	1,234	6.28	1.39	1.80	0.02	0.05	1,285
RI	1,035	0.20	0.57	3.92	-	-	1,134
SC	911	2.12	0.70	1.38	0.02	0.01	950
SD	986	3.23	3.39	1.49	0.02	0.02	1,028
TN	1,181	3.04	0.96	1.40	0.02	0.03	1,222
TX	1,419	2.69	1.24	3.68	0.02	0.03	1,516
UT	2,051	1.35	3.44	2.69	0.03	0.01	2,128
VA	1,068	3.11	1.23	1.74	0.02	0.02	1,177
VT	77	0.12	0.28	0.23	0.01	-	85
WA	326	0.15	0.37	0.77	0.01	0.01	347
WI	1,655	4.07	1.53	2.56	0.03	0.04	1,727
WV	2,157	5.46	1.32	2.37	0.04	0.06	2,227
WY	2,343	3.85	3.57	3.48	0.04	0.04	2,441

Source: SEEAT Version 6.0

Table 29 Non-Baseload Electricity Pollutant Emission Factors by eGRID Sub-Region

eGRID 2012 Sub-region Name	CO_2 emission rate (lb/MWh)	SO_2 emission rate (lb/MWh)	NO_x emission rate (lb/MWh)	CH_4 emission rate (lb/MWh)	NO_2 emission rate (lb/MWh)	Hg emission rate (lb/MWh)*	CO_2e emission rate (lb/MWh)
ASCC Alaska Grid	1,529	1.38	3.23	4.62	0.01	-	1,648
ASCC Miscellaneous	1,754	6.52	22.05	2.70	0.02	-	1,826
ERCOT All	1,339	0.98	1.07	4.32	0.01	0.03	1,450
FRCC All	1,480	2.07	1.57	3.81	0.01	0.01	1,579
HICC Miscellaneous	1,972	5.94	10.23	2.71	0.02	-	2,046
HICC Oahu	1,974	4.84	3.98	2.57	0.02	-	2,045
MRO East	2,043	6.25	2.50	3.27	0.03	0.03	2,135
MRO West	2,315	6.36	3.85	4.30	0.04	0.04	2,434
NPCC Long Island	1,653	1.49	1.85	4.98	0.01	-	1,679
NPCC New England	1,311	2.45	1.09	3.43	0.02	-	1,402
NPCC NYC/Westchester	1,291	0.40	1.12	4.67	-	-	1,409
NPCC Upstate NY	1,497	3.21	1.41	3.27	0.02	0.01	1,584
RFC East	1,787	8.99	1.81	3.19	0.02	0.04	1,874
RFC Michigan	1,993	7.20	2.35	3.21	0.03	0.04	2,083
RFC West	2,163	10.13	2.41	2.79	0.03	0.05	2,243
SERC Midwest	2,364	7.76	1.84	3.46	0.04	0.05	2,462
SERC Mississippi Valley	1,382	1.24	1.83	4.57	0.01	0.01	1,499
SERC South	1,774	7.74	2.00	3.25	0.03	0.04	1,863
SERC Tennessee Valley	2,079	6.21	1.95	2.86	0.03	0.03	2,160
SERC Virginia/Carolina	1,837	5.52	1.69	3.06	0.03	0.02	1,922
SPP North	2,335	4.22	2.93	4.19	0.03	0.04	2,460
SPP South	1,699	2.40	2.45	4.57	0.02	0.03	1,819
WECC California	1,182	0.26	0.80	4.42	0.01	-	1,294
WECC Northwest	1,559	1.45	1.99	3.71	0.02	0.01	1,698
WECC Rockies	1,979	2.20	3.18	4.07	0.03	0.02	2,088
WECC Southwest	1,370	0.62	1.28	4.00	0.01	0.03	1,474

Source: SEEAT Version 6.0

Table 30 Non-Baseload and Average Electricity CO_2e Emission Factors by eGRID Sub-Region

eGRID 2012 Sub-region Acronym	eGRID 2012 Sub-region Name	Non-Baseload CO_2e Emission Factor Including T&D Losses (lb/MWH)	Average CO_2e Emission Factor Including T&D Losses (lb/MWH)
AKGD	ASCC Alaska Grid	1,648	1,577
AKMS	ASCC Miscellaneous	1,826	639
ERCT	ERCOT All	1,450	1,445
FRCC	FRCC All	1,579	1,322
HIMS	HICC Miscellaneous	2,046	1,566
HIOA	HICC Oahu	2,045	1,873
MROE	MRO East	2,135	1,813
MROW	MRO West	2,434	1,851
NYLI	NPCC Long Island	1,679	1,447
NEWE	NPCC New England	1,402	813
NYCW	NPCC NYC/Westchester	1,409	768
NYUP	NPCC Upstate NY	1,584	590
RFCE	RFC East	1,874	1,065
RFCM	RFC Michigan	2,083	1,874
RFCW	RFC West	2,243	1,711
SRMW	SERC Midwest	2,462	1,976
SRMV	SERC Mississippi Valley	1,499	1,221
SRSO	SERC South	1,863	1,519
SRTV	SERC Tennessee Valley	2,160	1,538
SRVC	SERC Virginia/Carolina	1,922	1,180
SPNO	SPP North	2,460	2,062
SPSO	SPP South	1,819	1,860
CAMX	WECC California	1,294	835
NWPP	WECC Northwest	1,698	959
RMPA	WECC Rockies	2,088	2,131
AZNM	WECC Southwest	1,474	1,428
US Average		**1,826**	**1,426**

Source: SEEAT Version 6.0

5 FFC Energy and Emissions Sample Calculations

Site energy consumption by fuel type for each energy consuming device and for the whole building forms the basis of the FFC energy and emissions calculation methodology in SEEAT that accounts for primary energy consumption and related emissions for the full-fuel-cycle of extraction, processing, transportation, conversion, distribution, and consumption. The methodology permits aggregate average FFC energy and emission calculations as well as marginal analysis of incremental changes in consumption by fuel type.

The following sample calculations illustrate the application of the methodology to compare the FFC energy and pollutant emissions of an electric water heater with an energy factor (EF) of 0.95 and a natural gas water heater with an EF of 0.62 for a fixed annual hot water load of 10.8 MMBtu. FFC energy consumption and associated emissions are presented for eGRID sub-regions and U.S. using average and non-baseload factors for electricity and average factors for natural gas.

The sample calculations illustrate the societal benefit of optimizing the use of the nation's primary energy sources associated with building operation. While there is no single best choice for the entire country, it is possible to demonstrate the societal value of decisions that increase site energy consumption but reduce the nation's primary energy consumption as well as GHG and other pollutant emissions.

5.1 Average and Marginal (Non-Baseload) FFC Energy Calculations

Table 31 shows the FFC energy consumption comparison based on electricity and natural gas site energy consumption, calculated using eGRID sub- region and U.S. average FFC energy factors for all power plants. Table 32 shows similar calculations for non-baseload power plants

The results of the regional and national comparison indicate that the FFC energy consumption of the gas water heater was always less than the electric water heater, but the savings varied significantly depending on the electricity generation mix in the eGRID sub-region, and whether the analysis used average generation mix or non-baseload (marginal) generation data.

Based on all power plants (average overall generation mix), the savings from the gas water heater ranged from 13 to 56 percent in the eGRID sub-regions, while for the U.S. average generation mix, the difference was 47 percent. The variability in regional average savings is primarily due to the impact of hydropower, which has high FFC energy efficiency.

Based on non-baseload power plants (marginal generation mix), the FFC energy savings from the gas water heater were always significant, ranging from 42 to 55 percent across the eGRID sub-regions. The variability in savings was much less than the average generation mix case because the non-baseload power will nearly always be fossil fuel.

5.2 Average and Marginal (Non-Baseload) Pollutant Emission Calculations

Table 33 compares corresponding pollutant emissions using eGRID sub- region and U.S. average FFC energy factors for all power plants. Table 34 shows similar calculations for non-baseload power plants. Table 35 summarizes the pollutant emission savings of the natural gas water heater compared to the electric water heater using eGRID sub- region and U.S. average FFC energy factors for all power plants. Table 36 shows similar savings calculations for non-baseload power plants.

Based on all power plants (average overall generation mix), CO_2e emissions from the gas water heater were also lower than the electric water heater for the U.S. average and in all but two eGRID sub-regions dominated by hydropower generation. The variability was wider than the FFC energy consumption, ranging from a 30 percent increase to 64 percent reduction across eGRID sub-regions, with the U.S. average reduction of 46 percent. SO_2 and NOx emission reductions varied from 48 percent to 98 percent reduction for SO_2 and an 51 percent increase to 88 percent reduction for NOx across eGRID sub-regions. The U.S. average reduction was 46 percent for SO_2 and 88 percent for NOx. The variability in regional average CO_2e savings is primarily due to the impact of hydropower and nuclear power, both of which have essentially no pollutant emissions. The variability in average NOx emissions illustrates the impact of regional criteria pollutant emission reduction initiatives in the electric industry.

Based on marginal (non-baseload) power plants, pollutant emissions from the gas water heater were significantly lower than the electric water heater in all 26 eGRID sub-regions. CO_2e emissions savings ranged from -41 percent to 69 percent across the eGRID sub-regions. The variability in savings was much less than the average generation mix case because the non-baseload power will nearly always be fossil fuel with significant CO_2e emissions. Corresponding SO_2 and NOx emission reductions ranged from 42 to 99 percent for SO_2 and an 11percent increase to 96 percent reduction for NOx across eGRID sub-regions, illustrating the impact of regional NOx emission reduction initiatives in non-baseload power plants.

6 Summary

Within this report, an extensive set of data were compiled using publicly available sources to support calculation of the full-fuel-cycle energy consumption and associated pollutant emissions for electricity generation and fossil fuel energy use. The factors for calculating FFC energy consumption and related emissions for the full-fuel-cycle of extraction, processing, transportation, conversion, distribution, and consumption were developed at the state, eGRID sub-region, NERC region, and U.S. average level for electricity for all power plants. Factors for non-baseload power plants were developed at the eGRID sub-region and U.S. average levels. Factors for fossil fuels were developed at the U.S. average level.

Comparison of the U.S. average FFC energy factors in the AGA report published in 2009 with the corresponding new datasets shows modest FFC energy efficiency changes. The fossil fuels FFC emission factors compiled in this report are similar to those provided in the 2009 AGA report. CO_2e emission factors are provided for calculation of total greenhouse gas emissions.

The sample calculations of residential electric and natural gas water heaters provide examples of the application of the tabulated FFC energy and emissions factors to evaluate impacts of energy choice on FFC energy consumption and pollutant emissions, including CO_2e emissions. The sample calculations illustrate the importance of selecting the appropriate energy and fuel type as well as geographical conversion factors when evaluating benefits of optimizing energy use in buildings.

Table 31 FFC Energy Comparison, eGRID Sub-Regions and U.S., All Power Plants

eGRID 2012 Sub-region	eGRID 2012 Sub-region Name	FFC Energy		FFC Energy Savings	
		Electric WH (MMBtu)	Gas WH (MMBtu)	Gas WH savings (MMBtu)	Gas WH savings (%)
AKGD	ASCC Alaska Grid	37.2	19.0	18.2	49%
AKMS	ASCC Miscellaneous	21.9	19.0	3.0	13%
ERCT	ERCOT All	35.4	19.0	16.4	46%
FRCC	FRCC All	36.0	19.0	17.1	47%
HIMS	HICC Miscellaneous	43.0	19.0	24.0	56%
HIOA	HICC Oahu	37.4	19.0	18.4	49%
MROE	MRO East	37.3	19.0	18.3	49%
MROW	MRO West	39.7	19.0	20.7	52%
NYLI	NPCC Long Island	38.8	19.0	19.8	51%
NEWE	NPCC New England	33.4	19.0	14.4	43%
NYCW	NPCC NYC/Westchester	35.1	19.0	16.1	46%
NYUP	NPCC Upstate NY	29.0	19.0	10.0	35%
RFCE	RFC East	36.7	19.0	17.7	48%
RFCM	RFC Michigan	37.4	19.0	18.4	49%
RFCW	RFC West	37.2	19.0	18.2	49%
SRMW	SERC Midwest	37.9	19.0	18.9	50%
SRMV	SERC Mississippi Valley	35.6	19.0	16.6	47%
SRSO	SERC South	34.8	19.0	15.8	45%
SRTV	SERC Tennessee Valley	35.2	19.0	16.3	46%
SRVC	SERC Virginia/Carolina	36.7	19.0	17.7	48%
SPNO	SPP North	40.7	19.0	21.7	53%
SPSO	SPP South	36.6	19.0	17.6	48%
CAMX	WECC California	33.3	19.0	14.3	43%
NWPP	WECC Northwest	26.8	19.0	7.8	29%
RMPA	WECC Rockies	39.6	19.0	20.6	52%
AZNM	WECC Southwest	36.2	19.0	17.2	47%
US Average		**35.8**	**19.0**	**16.8**	**47%**

Source: SEEAT Version 6.0

Table 32 FFC Energy Comparison, eGRID Sub-Regions, Non-Baseload Power Plants

eGRID 2012 Sub-region	eGRID 2012 Sub-region Name	FFC Energy		FFC Energy Savings	
		Electric WH (MMBtu)	Gas WH (MMBtu)	Gas WH savings (MMBtu)	Gas WH savings (%)
AKGD	ASCC Alaska Grid	38.8	19.0	19.8	51%
AKMS	ASCC Miscellaneous	37.2	19.0	18.2	49%
ERCT	ERCOT All	32.9	19.0	13.9	42%
FRCC	FRCC All	34.0	19.0	15.0	44%
HIMS	HICC Miscellaneous	41.0	19.0	22.1	54%
HIOA	HICC Oahu	40.1	19.0	21.1	53%
MROE	MRO East	36.5	19.0	17.5	48%
MROW	MRO West	41.3	19.0	22.3	54%
NYLI	NPCC Long Island	40.6	19.0	21.6	53%
NEWE	NPCC New England	31.8	19.0	12.8	40%
NYCW	NPCC NYC/Westchester	35.2	19.0	16.3	46%
NYUP	NPCC Upstate NY	32.1	19.0	13.1	41%
RFCE	RFC East	35.4	19.0	16.4	46%
RFCM	RFC Michigan	36.2	19.0	17.2	47%
RFCW	RFC West	37.1	19.0	18.1	49%
SRMW	SERC Midwest	39.3	19.0	20.3	52%
SRMV	SERC Mississippi Valley	35.8	19.0	16.8	47%
SRSO	SERC South	34.7	19.0	15.7	45%
SRTV	SERC Tennessee Valley	36.7	19.0	17.7	48%
SRVC	SERC Virginia/Carolina	35.7	19.0	16.7	47%
SPNO	SPP North	41.9	19.0	23.0	55%
SPSO	SPP South	37.6	19.0	18.6	50%
CAMX	WECC California	34.0	19.0	15.0	44%
NWPP	WECC Northwest	34.7	19.0	15.7	45%
RMPA	WECC Rockies	38.8	19.0	19.8	51%
AZNM	WECC Southwest	32.9	19.0	13.9	42%

Source: SEEAT Version 6.0

Table 33 Pollutant Emissions Comparison, eGRID Sub-Regions and U.S., All Power Plants

	eGRID 2012 Sub-region Acronym	eGRID 2012 Sub-region Name	CO_2 emissions (lbs)	SO_2 emissions (lbs)	NO_x emissions (lbs)	CH_4 emissions (lbs)	NO_2 emissions (lbs)	Hg emissions (lbs)*	CO_2e emissions (lbs)
Electric Water Heater	AKGD	ASCC Alaska Grid	4,884	4.1	10.8	14.5	0.03	-	5,258
	AKMS	ASCC Miscellaneous	2,045	7.7	25.7	3.2	0.03	-	2,130
	ERCT	ERCOT All	4,507	8.8	3.7	11.8	0.07	0.10	4,817
	FRCC	FRCC All	4,133	6.6	4.5	10.4	0.07	0.03	4,407
	HIMS	HICC Miscellaneous	5,031	21.5	23.8	6.9	0.07	-	5,221
	HIOA	HICC Oahu	6,008	18.1	11.1	8.4	0.10	-	6,243
	MROE	MRO East	5,799	18.5	6.1	8.6	0.10	0.10	6,044
	MROW	MRO West	5,881	15.4	9.2	10.3	0.10	0.13	6,170
	NYLI	NPCC Long Island	4,414	4.4	5.8	15.8	0.07	-	4,825
	NEWE	NPCC New England	2,517	5.5	2.9	7.1	0.07	-	2,710
	NYCW	NPCC NYC/Westchester	2,340	1.0	2.0	8.6	-	-	2,561
	NYUP	NPCC Upstate NY	1,861	3.8	2.0	4.0	0.03	0.03	1,968
	RFCE	RFC East	3,393	16.8	3.6	5.6	0.07	0.13	3,551
	RFCM	RFC Michigan	6,000	22.2	7.2	8.7	0.10	0.13	6,249
	RFCW	RFC West	5,510	21.3	5.3	6.7	0.10	0.17	5,704
	SRMW	SERC Midwest	6,331	19.9	4.4	9.0	0.10	0.17	6,588
	SRMV	SERC Mississippi Valley	3,811	6.2	4.8	9.9	0.03	0.03	4,072
	SRSO	SERC South	4,844	17.7	4.6	7.9	0.07	0.13	5,066
	SRTV	SERC Tennessee Valley	4,942	11.8	4.3	6.5	0.07	0.10	5,129
	SRVC	SERC Virginia/Carolina	3,781	7.6	3.0	5.3	0.07	0.07	3,933
	SPNO	SPP North	6,579	11.3	8.2	10.6	0.10	0.13	6,874
	SPSO	SPP South	5,866	11.8	7.9	12.5	0.07	0.10	6,202
	CAMX	WECC California	2,572	1.1	2.5	8.1	0.03	-	2,783
	NWPP	WECC Northwest	3,046	4.1	4.3	5.5	0.03	0.03	3,197
	RMPA	WECC Rockies	6,788	7.6	10.4	11.5	0.10	0.07	7,106
	AZNM	WECC Southwest	4,514	2.8	6.4	9.2	0.07	0.10	4,762
	US Average		**4,488**	**11.3**	**4.8**	**8.9**	**0.07**	**0.10**	**4,731**
Gas Water Heater			**2,269**	**0.5**	**3.0**	**11.3**	**0.05**	**-**	**2,566**

Source: SEEAT Version 6.0

Table 34 Pollutant Emissions Comparison, eGRID Sub-Regions, Non-Baseload Power Plants

	eGRID 2012 Sub-region Acronym	eGRID 2012 Sub-region Name	CO_2 emissions (lbs)	SO_2 emissions (lbs)	NO_x emissions (lbs)	CH_4 emissions (lbs)	NO_2 emissions (lbs)	Hg emissions (lbs)*	CO_2e emissions (lbs)
Electric Water Heater	AKGD	ASCC Alaska Grid	5,099	4.6	10.8	15.4	0.03	-	5,493
	AKMS	ASCC Miscellaneous	5,846	21.7	73.5	9.0	0.07	-	6,087
	ERCT	ERCOT All	4,465	3.3	3.6	14.4	0.03	0.10	4,834
	FRCC	FRCC All	4,933	6.9	5.2	12.7	0.03	0.03	5,264
	HIMS	HICC Miscellaneous	6,574	19.8	34.1	9.0	0.07	-	6,821
	HIOA	HICC Oahu	6,581	16.1	13.3	8.6	0.07	-	6,819
	MROE	MRO East	6,811	20.8	8.3	10.9	0.10	0.10	7,117
	MROW	MRO West	7,717	21.2	12.8	14.3	0.13	0.13	8,116
	NYLI	NPCC Long Island	5,510	5.0	6.2	16.6	0.03	-	5,598
	NEWE	NPCC New England	4,371	8.2	3.6	11.4	0.07	-	4,673
	NYCW	NPCC NYC/Westchester	4,305	1.3	3.7	15.6	-	-	4,698
	NYUP	NPCC Upstate NY	4,990	10.7	4.7	10.9	0.07	0.03	5,281
	RFCE	RFC East	5,958	30.0	6.0	10.6	0.07	0.13	6,249
	RFCM	RFC Michigan	6,646	24.0	7.8	10.7	0.10	0.13	6,945
	RFCW	RFC West	7,210	33.8	8.0	9.3	0.10	0.17	7,478
	SRMW	SERC Midwest	7,883	25.9	6.1	11.5	0.13	0.17	8,210
	SRMV	SERC Mississippi Valley	4,606	4.1	6.1	15.2	0.03	0.03	4,997
	SRSO	SERC South	5,916	25.8	6.7	10.8	0.10	0.13	6,212
	SRTV	SERC Tennessee Valley	6,930	20.7	6.5	9.5	0.10	0.10	7,202
	SRVC	SERC Virginia/Carolina	6,126	18.4	5.6	10.2	0.10	0.07	6,409
	SPNO	SPP North	7,786	14.1	9.8	14.0	0.10	0.13	8,202
	SPSO	SPP South	5,666	8.0	8.2	15.2	0.07	0.10	6,064
	CAMX	WECC California	3,941	0.9	2.7	14.7	0.03	-	4,316
	NWPP	WECC Northwest	5,197	4.8	6.6	12.4	0.07	0.03	5,661
	RMPA	WECC Rockies	6,596	7.3	10.6	13.6	0.10	0.07	6,961
	AZNM	WECC Southwest	4,568	2.1	4.3	13.3	0.03	0.10	4,913
Gas Water Heater			**2,269**	**0.5**	**3.0**	**11.3**	**0.05**	**-**	**2,566**

Source: SEEAT Version 6.0

Table 35 Gas Water Heater Emissions Savings, eGRID Sub-Regions and U.S., All Power Plants

eGRID 2012 Sub-region Acronym	eGRID 2012 Sub-region Name	CO_2 emissions reduction		SO_2 emissions reduction		NO_x emissions reduction		CH_4 emissions reduction		NO_2 emissions reduction		Hg emissions reduction*		CO_2e emissions reduction	
		lbs	%	lbs	%	lbs	%	lbs	%	lbs	%	lbs	%	lbs	%
AKGD	ASCC Alaska Grid	2,616	54%	3.6	88%	7.8	73%	3.21	22%	(0.02)	-57%	-	-	2,692	51%
AKMS	ASCC Miscellaneous	(224)	-11%	7.2	93%	22.7	88%	(8.12)	-254%	(0.02)	-57%	-	-	(436)	-20%
ERCT	ERCOT All	2,238	50%	8.3	94%	0.8	21%	0.45	4%	0.01	22%	0.10	100%	2,250	47%
FRCC	FRCC All	1,864	45%	6.1	92%	1.5	34%	(0.95)	-9%	0.01	22%	0.03	100%	1,841	42%
HIMS	HICC Miscellaneous	2,763	55%	21.0	98%	20.9	88%	(4.45)	-65%	0.01	22%	-	-	2,655	51%
HIOA	HICC Oahu	3,739	62%	17.6	97%	8.2	73%	(2.95)	-35%	0.05	48%	-	-	3,677	59%
MROE	MRO East	3,531	61%	18.0	97%	3.1	51%	(2.72)	-32%	0.05	48%	0.10	100%	3,478	58%
MROW	MRO West	3,613	61%	14.9	97%	6.2	68%	(0.99)	-10%	0.05	48%	0.13	100%	3,604	58%
NYLI	NPCC Long Island	2,145	49%	3.9	88%	2.8	49%	4.51	29%	0.01	22%	-	-	2,259	47%
NEWE	NPCC New England	248	10%	5.0	91%	(0.1)	-3%	(4.25)	-60%	0.01	22%	-	-	144	5%
NYCW	NPCC NYC/Westchester	71	3%	0.5	48%	(0.9)	-46%	(2.69)	-31%	(0.05)	-	-	-	(5)	0%
NYUP	NPCC Upstate NY	(407)	-22%	3.3	87%	(1.0)	-51%	(7.36)	-185%	(0.02)	-57%	0.03	100%	(598)	-30%
RFCE	RFC East	1,124	33%	16.3	97%	0.7	19%	(5.69)	-101%	0.01	22%	0.13	100%	985	28%
RFCM	RFC Michigan	3,731	62%	21.7	98%	4.2	59%	(2.59)	-30%	0.05	48%	0.13	100%	3,683	59%
RFCW	RFC West	3,241	59%	20.8	98%	2.4	44%	(4.65)	-70%	0.05	48%	0.17	100%	3,138	55%
SRMW	SERC Midwest	4,062	64%	19.4	97%	1.4	33%	(2.29)	-25%	0.05	48%	0.17	100%	4,022	61%
SRMV	SERC Mississippi Valley	1,542	40%	5.7	92%	1.9	39%	(1.39)	-14%	(0.02)	-57%	0.03	100%	1,506	37%
SRSO	SERC South	2,576	53%	17.2	97%	1.6	35%	(3.39)	-43%	0.01	22%	0.13	100%	2,500	49%
SRTV	SERC Tennessee Valley	2,674	54%	11.3	96%	1.3	31%	(4.82)	-74%	0.01	22%	0.10	100%	2,563	50%
SRVC	SERC Virginia/Carolina	1,513	40%	7.1	93%	0.1	2%	(6.02)	-114%	0.01	22%	0.07	100%	1,367	35%
SPNO	SPP North	4,310	66%	10.8	96%	5.2	64%	(0.75)	-7%	0.05	48%	0.13	100%	4,308	63%
SPSO	SPP South	3,597	61%	11.3	96%	4.9	62%	1.15	9%	0.01	22%	0.10	100%	3,636	59%
CAMX	WECC California	303	12%	0.6	55%	(0.5)	-20%	(3.22)	-40%	(0.02)	-57%	-	-	217	8%
NWPP	WECC Northwest	777	26%	3.6	88%	1.3	31%	(5.82)	-106%	(0.02)	-57%	0.03	100%	631	20%
RMPA	WECC Rockies	4,520	67%	7.1	93%	7.4	72%	0.18	2%	0.05	48%	0.07	100%	4,540	64%
AZNM	WECC Southwest	2,246	50%	2.3	82%	3.5	54%	(2.12)	-23%	0.01	22%	0.10	100%	2,196	46%
US Average		**2,220**	**49%**	**10.8**	**96%**	**1.9**	**39%**	**(2.42)**	**-27%**	**0.01**	**22%**	**0.10**	**100%**	**2,165**	**46%**

Source: SEEAT Version 6.0

Table 36 Gas Water Heater Emissions Savings, eGRID Sub-Regions, Non-Baseload Power Plants

eGRID 2012 Sub-region Acronym	eGRID 2012 Sub-region Name	CO_2 emissions reduction		SO_2 emissions reduction		NO_x emissions reduction		CH_4 emissions reduction		NO_2 emissions reduction		Hg emissions reduction*		CO_2e emissions reduction	
		lbs	%	lbs	%	lbs	%	lbs	%	lbs	%	lbs	%	lbs	%
AKGD	ASCC Alaska Grid	2830	56%	4.1	89%	7.8	73%	4.1	26%	-0.02	-57%	0.00	-	2927	53%
AKMS	ASCC Miscellaneous	3578	61%	21.2	98%	70.6	96%	-2.3	-26%	0.07	100%	0.00	-	3521	58%
ERCT	ERCOT All	2196	49%	2.8	85%	0.6	17%	3.1	21%	0.03	100%	0.10	100%	2268	47%
FRCC	FRCC All	2664	54%	6.4	93%	2.3	43%	1.4	11%	0.03	100%	0.03	100%	2698	51%
HIMS	HICC Miscellaneous	4305	65%	19.3	97%	31.1	91%	-2.3	-25%	0.07	100%	0.00	-	4255	62%
HIOA	HICC Oahu	4313	66%	15.6	97%	10.3	78%	-2.8	-32%	0.07	100%	0.00	-	4253	62%
MROE	MRO East	4543	67%	20.3	98%	5.4	64%	-0.4	-4%	0.10	100%	0.10	100%	4551	64%
MROW	MRO West	5448	71%	20.7	98%	9.9	77%	3.0	21%	0.13	100%	0.13	100%	5550	68%
NYLI	NPCC Long Island	3241	59%	4.5	90%	3.2	52%	5.3	32%	0.03	100%	0.00	-	3032	54%
NEWE	NPCC New England	2102	48%	7.7	94%	0.7	19%	0.1	1%	0.07	100%	0.00	-	2107	45%
NYCW	NPCC NYC/Westchester	2036	47%	0.8	62%	0.8	21%	4.2	27%	0.00	-	0.00	-	2132	45%
NYUP	NPCC Upstate NY	2721	55%	10.2	95%	1.7	37%	-0.4	-4%	0.07	100%	0.03	100%	2715	51%
RFCE	RFC East	3689	62%	29.5	98%	3.1	51%	-0.7	-6%	0.07	100%	0.13	100%	3683	59%
RFCM	RFC Michigan	4377	66%	23.5	98%	4.9	62%	-0.6	-6%	0.10	100%	0.13	100%	4379	63%
RFCW	RFC West	4942	69%	33.3	99%	5.1	63%	-2.0	-22%	0.10	100%	0.17	100%	4912	66%
SRMW	SERC Midwest	5614	71%	25.4	98%	3.2	52%	0.2	2%	0.13	100%	0.17	100%	5644	69%
SRMV	SERC Mississippi Valley	2338	51%	3.6	88%	3.1	51%	3.9	26%	0.03	100%	0.03	100%	2431	49%
SRSO	SERC South	3647	62%	25.3	98%	3.7	56%	-0.5	-4%	0.10	100%	0.13	100%	3646	59%
SRTV	SERC Tennessee Valley	4661	67%	20.2	98%	3.5	54%	-1.8	-19%	0.10	100%	0.10	100%	4636	64%
SRVC	SERC Virginia/Carolina	3857	63%	17.9	97%	2.7	47%	-1.1	-11%	0.10	100%	0.07	100%	3843	60%
SPNO	SPP North	5517	71%	13.6	96%	6.8	70%	2.6	19%	0.10	100%	0.13	100%	5636	69%
SPSO	SPP South	3397	60%	7.5	94%	5.2	64%	3.9	26%	0.07	100%	0.10	100%	3498	58%
CAMX	WECC California	1672	42%	0.4	42%	-0.3	-11%	3.4	23%	0.03	100%	0.00	-	1750	41%
NWPP	WECC Northwest	2928	56%	4.3	90%	3.7	55%	1.0	8%	0.07	100%	0.03	100%	3095	55%
RMPA	WECC Rockies	4328	66%	6.8	93%	7.6	72%	2.2	17%	0.10	100%	0.07	100%	4395	63%
AZNM	WECC Southwest	2299	50%	1.6	76%	1.3	31%	2.0	15%	0.03	100%	0.10	100%	2347	48%

Source: SEEAT Version 6.0

7 References

AGA. 1990. A comparison of Carbon Dioxide Emissions Attributable to New Natural Gas and All-Electric Homes. Washington, D.C.: American Gas Association.

AGA. 1999. Energy Efficiency, Economic, and Environmental Comparison of Natural Gas, Electric, and Oil Services in Residences. Washington, D.C.: American Gas Association.

AGA. 2000. Source Energy and Emission Factors for Residential Energy Consumption. Washington, D.C.: American Gas Association.

AGA. 2009. Source Energy and Emission Factors for Building Energy Consumption (http://www.aga.org/SiteCollectionDocuments/KnowledgeCenter/OpsEng/CodesStandards/0008ENERGYEMISSIONFACTORSRESCONSUMPTION.pdf). Washington, D.C.: American Gas Association.

ANL. 2012. Greenhouse Gases, Regulated Emissions, and Energy use in Transportation Model. GREET 2012 rev2 (http://greet.es.anl.gov/). Argonne, IL.: Argonne National Laboratory.

ASHRAE. 2013. Building Energy Quotient, ASHRAE's Building Energy Labeling Program (http://www.buildingenergyquotient.org/). Atlanta: American Society of Heating, Refrigerating and Air-conditioning Engineers, Inc.

ASHRAE. 2013. ANSI/ASHRAE Standard 90.1-2013, Energy Standard for Buildings Except Low-Rise Residential Buildings. Atlanta: American Society of Heating, Refrigerating and Air-conditioning Engineers, Inc.

ASME Hydro Power Technical Committee. 1996. Hydropower Mechanical Design. HCI Publications.

BCS Inc. 2002. Energy and Environmental Profile of the U.S. Mining Industry http://www1.eere.energy.gov/manufacturing/resources/mining/pdfs/cover.pdf. Washington, D.C.: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy.

CEC. 2012. 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings (http://www.energy.ca.gov/2012publications/CEC-400-2012-004/CEC-400-2012-004-CMF-REV.pdf). CEC-400-2012-004-CMF-REV. Sacramento, CA: California Energy Commission.

CEC. 2012. Reference Appendices for the 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings (http://www.energy.ca.gov/title24/2013standards/rulemaking/documents/final_rulemaking_documents/44_Final_Express_Terms/2013_Reference_Appendices_JA_NA_RA_combined.pdf). CEC-400-2012-004-CMF-REV. Sacramento, CA: California Energy Commission.

DeLuchi, M.A. 1993. Emissions of Greenhouse Gases from Transportation Fuels and Electricity, Volume 2: Appendixes A-S, ANL/ESD/TM-22, Vol. 2, Argonne, IL.: Argonne National Laboratory.

Deru, M., and P. Torcellini. 2007 Source Energy and Emission Factors for Energy Use in Buildings (http://www.nrel.gov/docs/fy07osti/38617.pdf). NREL/TP-550-38617. Golden, CO: .National Renewable Energy Laboratory.

DeYoung, R. 2011. Quantification Methods using eGRID State and Local Examples, , March 31, 2011. (http://www.epa.gov/statelocalclimate/documents/pdf/DeYoung_presentation_3-31-11.pdf). Washington, D.C.: U.S. Environmental Protection Agency, State Climate and Energy Program.

DeYoung, R. 2012. Deciding an Approach for Quantifying Emission Impacts of Clean Energy Policies and Programs, January 30, 2012. (http://www.epa.gov/statelocalclimate/documents/pdf/DeYoung_presentation_1-30-2012.pdf). Washington, D.C.: U.S. Environmental Protection Agency, State Climate and Energy Program.

DOE. Upstream Emission Factors from Coal and natural Gas Production, Appendix K-3 (http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/k-3.pdf), Washington, D.C.: U.S. Department of Energy.

EIA. 2011. Emissions of Greenhouse Gases in the United States 2009 (http://www.eia.gov/environment/emissions/ghg_report/pdf/0573%282009%29.pdf). DOE/EIA-0573(2009). Washington, D.C.: U.S. Department of Energy, Energy Information Agency.

EIA. 2011. Form EIA-923 Power Plant Operations Report (http://www.eia.gov/electricity/data/eia923/). DOE/EIA-0923(2011). Washington, D.C.: U.S. Department of Energy, Energy Information Agency.

EIA. 2012. Annual Energy Review 2011 (http://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf). DOE/EIA-0384(2011). Washington, D.C.: U.S. Department of Energy, Energy Information Agency.

EIA. 2012. State Electricity Profiles 2010 (http://www.eia.gov/electricity/state/pdf/sep2010.pdf). DOE/EIA-0348(01)/2. Washington, D.C.: U.S. Department of Energy, Energy Information Agency.

EIA. 2013. Annual Energy Outlook 2013(http://www.eia.gov/forecasts/aeo/pdf/0383%282013%29.pdf). DOE/EIA-0383(2013). U.S. Department of Energy, Energy Information Agency, Washington, D.C.

EIA. 2013, EIA National Energy Review, EIA-906, EIA-920 and EIA-923 databases (http://www.eia.gov/electricity/data/eia923/). Washington, D.C.: U.S. Department of Energy, Energy Information Agency.

EIA. 2013. Voluntary Reporting of Greenhouse Gases Program - Electricity Factors - Fuel and Energy Source Codes and Emission Coefficients (http://www.eia.gov/oiaf/1605/coefficients.html). Washington, D.C.: U.S. Department of Energy, Energy Information Agency.

EPA. 1995. Compilation of Air Pollution Emission Factors AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources (http://www.epa.gov/ttn/chief/ap42/toc_kwrd.pdf). Washington, D.C.: U.S. Environmental Protection Agency.

EPA. 1998. Clearinghouse for Inventories & Emissions Factors AP 42, Fifth Edition (http://www.epa.gov/ttnchie1/ap42/). U.S. Environmental Protection Agency, Washington, D.C.

EPA. 2008, Compilation of Air Pollution Emission Factors AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources. Chapter 1: External Combustion Sources (http://www.epa.gov/ttn/chief/ap42/ch01/index.html). Washington, D.C.: U.S. Environmental Protection Agency.

EPA. 2008. Compilation of Air Pollution Emission Factors AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources. Chapter 3: Stationary Internal Combustion Sources (http://www.epa.gov/ttn/chief/ap42/ch03/index.html). Washington, D.C.: U.S. Environmental Protection Agency.

EPA. 2011, ENERGY STAR Performance Ratings Technical Methodology (http://www.energystar.gov/ia/business/evaluate_performance/General_Overview_tech_methodology.pdf). Washington, D.C.: U.S. Environmental Protection Agency.

EPA. 2011. Assessing the Multiple Benefits of Clean Energy a Resource for States http://www.epa.gov/statelocalclimate/resources/benefits.html. Washington, D.C.: U.S. Environmental Protection Agency.

EPA. 2012. EPA Emissions & Generation Resource Integrated Database eGRID2012 Version 1.0 (http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html). Washington, D.C.: U.S. Environmental Protection Agency.

EPA. 2013. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2011 (http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2013-Main-Text.pdf). EPA 430-R-13-001. Washington, D.C.: U.S. Environmental Protection Agency.

Exelon. 2008. Exelon 2020 a Low Carbon Roadmap (http://www.exeloncorp.com/assets/newsroom/downloads/docs/bro_Exelon2020.pdf). Chicago, IL: Exelon Corporation.

IPCC. 2007. Climate Change 2007 The Physical Science Basis (http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4_wg1_full_report.pdf), Geneva, Switzerland.

Jacobson, D. 2009. Flawed Methodologies in Calculating Avoided Emissions from Renewable Energy , The GW Solar Institute, October 24, 2009. (http://solar.gwu.edu/index_files/Resources_files/DJ_REILPresentation.pdf).

Jacobson, D. and Colin High. 2010. U.S. Policy Action Necessary to Ensure Accurate Assessment of the Air Emission Reduction Benefits of Increased Use of Energy Efficiency and Renewable Energy Technology, Journal of Energy and Environmental Law, Vol. 1:1, 2010. (http://gwujeel.files.wordpress.com/2013/07/1-1-jh.pdf). Washington, D.C.: George Washington University.

Jaramillo, P., W. Michael Griffin, and J. Scott Matthews. 2007. Comparative Life-Cycle Air Emissions of Coal, Domestic Natural Gas, LNG, and SNG for Electricity Generation. *Environmental Science and Technology* 41:6290-96.

Keith, G. and Bruce Biewald. 2005. Methods for Estimating Emissions Avoided by Renewable Energy and Energy Efficiency. Washington, D.C.: U.S. Environmental Protection Agency.

Leslie, N.P.; Czachorski; M, Yang; Y. and Ron Edelstein. 2010. .Methodology to Evaluate End Use Options to Reduce CO_2 Emissions from Buildings. ASHRAE Transactions, Vol. 116, pt. 1. Atlanta: American Society of Heating, Refrigerating and Air-conditioning Engineers, Inc.

Leslie, N. and Marek Czachorski. 2014. Options for Determining Marginal Primary Energy and Greenhouse Gas Emission Factors (NY-14-C057). ASHRAE Transactions, Vol. 120, pt. 1. Atlanta: American Society of Heating, Refrigerating and Air-conditioning Engineers, Inc.

NRC. 2009. Review of Site (Point-of-Use) and Full-Fuel-Cycle Measurement Approaches to DOE/EERE Building Appliance Energy-Efficiency Standards. Washington, D.C.: National Research Council.

NHP. http://www.hydro.org National Hydropower Association.

NREL. 2004. U.S. Life Cycle Inventory Database Project – User's Guide. NREL/BK-35854. (http://www.nrel.gov/lci/pdfs/users_guide.pdf) Golden, CO: National Renewable Energy Laboratory.

Ossberger. 2009. Ossberger Kaplan Turbine Technical Specifications, pp 5-6. Weissenberg, Germany.

Rittase R.A. 2007. Hydro Turbine Overview an Introduction. Waterpower XV, Chattanooga, TN.

Rothschild, S. and Art Diem. 2008. Total, Non-baseload, eGRID Sub-region, State? Guidance on the Use of eGRID Output Emission Rates. (http://www.epa.gov/ttn/chief/conference/ei18/session5/rothschild.pdf) Washington, D.C.: U.S. Environmental Protection Agency, Climate Protection Partnership Division.

Spath, Pamela L., Margaret K. Mann,. and Dawn R. Kerr. 1999. Life Cycle Assessment of Coal-fired Power Production (http://www.nrel.gov/docs/fy99osti/25119.pdf). Technical Report TP-570-25119. Golden, CO: National Renewable Energy Laboratory.

USGBC 2009, LEED Version 3. Washington, D.C.: U.S. Green Building Council.

Appendix A FFC Energy and Emissions Factors Algorithms

A-1. Average FFC Energy Factors

The FFC energy factor for electric power generation is given by:

$$s_t = \begin{bmatrix} m_1 \\ m_2 \\ \dots \\ m_n \end{bmatrix} \cdot \begin{bmatrix} s_1 \\ s_2 \\ \dots \\ s_n \end{bmatrix} \quad (1)$$

where, m_i is the fraction of the power generation from each type of fuel and s_i is the FFC energy factor of each type of fuel. The subscripts 1 through n for both the generation mix and the FFC energy factors specifically represent:

1	Coal
2	Oil
3	Natural Gas
4	Nuclear
5	Hydro
6	Biomass
7	Wind
8	Solar
9	Geothermal
10	Other

The mix fractions m_i are determined by analysis of the eGRID 2012 database. In the case of coal based generation, the fraction of lignite, bituminous, and sub-bituminous coals used are given by NREL/TP-550-38617.

For example, in the SPSO sub-region the aggregate average FFC energy factor is given by:

$$s_t = \begin{bmatrix} 0.5816 \\ 0.0007 \\ 0.3072 \\ 0.0000 \\ 0.0553 \\ 0.0175 \\ 0.0378 \\ 0.0000 \\ 0.0000 \\ 0.0000 \end{bmatrix} \cdot \begin{bmatrix} 3.48 \\ 3.43 \\ 3.06 \\ 3.45 \\ 1.19 \\ 1.97 \\ 4.11 \\ 8.91 \\ 6.68 \\ 5.27 \end{bmatrix} = 3.22 \quad (2)$$

The FFC energy factors s_i are calculated according to:

$$s_i = \frac{1}{e_1 \cdot e_2 \cdot \dots \cdot e_n} \quad (3)$$

where, e_n is the efficiency of each of the processes contributing to power generation. The subscripts 1 through n specifically represent:

1 Extraction
2 Processing
3 Transportation
4 Conversion
5 Distribution

In the SPSO sub-region for coal based generation this yields:

$$s_{coal} = \frac{1}{0.989 \cdot 0.996 \cdot 0.969 \cdot 0.322 \cdot 0.935} = 3.48 \quad (4)$$

which is the first FFC energy value used in Equation 2.

Using this procedure for each type of generation fuel gives the values shown in Table 37 below. The values that populate Table 37 cells use database information from published sources as shown in Table 38.

Table 37 FFC Energy Factors for SPSO Sub-region, All Plants

Fuel Type	Extraction	Processing	Transportation	Conversion	Distribution	Mix	FFC Factor
Coal	98.9	99.6	96.9	32.2	93.5	58.16	3.48
Oil	96.3	93.8	98.8	34.9	93.5	0.07	3.43
Natural Gas	96.2	97.0	99.3	37.7	93.5	30.72	3.06
Nuclear	99.0	96.2	99.9	32.6	93.5	0	3.45
Hydro	100.0	100.0	100.0	90.0	93.5	5.53	1.19
Biomass	99.4	95.0	97.5	59.0	93.5	1.75	1.97
Wind	100.0	100.0	100.0	26.0	93.5	3.78	4.11
Solar	100.0	100.0	100.0	12.0	93.5	0	8.91
Geothermal	100.0	100.0	100.0	16.0	93.5	0	6.68
Other	100.0	100.0	100.0	20.3	93.5	0	5.27
Total	**98.15**	**98.73**	**97.91**	**34.97**	**93.49**		**3.22**

Table 38 Sources for FFC Energy Factors

	Extraction	Processing	Transportation	Conversion	Distribution	Mix	Source
Coal	a	a	a	d	from eGRID 2012 V1.0 Database	Calculated from eGRID 2012 V1.0 Database	Calculated from Equation 3
Oil	b	b	b	d			
Natural Gas	b	b	b	d			
Nuclear	b	b	b	e			
Hydro	c	c	c	f			
Biomass	b	b	b	d			
Wind	c	c	c	g			
Solar	c	c	c	h			
Geothermal	c	c	c	i			
Other	c	c	c	d			
Total	k						j

a. Coal mix from NREL/TP-550-38617, efficiencies from NREL LCI database

b. From NREL LCI database

c. Assumed to be 100%

d. Calculated from eGRID 2012 V1.0 Database

e. DOE EIA Table 8.4a Consumption for Electricity Generation by Energy Souce: Total (All Sectors), http://www.eia.doe.gov/emeu/aer/txt/ptb0804a.html

f. Based on published estimates for the efficiency of larg-scale hydroelectric plants. See http://www.usbr.gov/power/edu/pamphlet.pdf.

g. Based on the average rated efficiency at rated wind speed for a sample of commercially available wind turbines. The rated wind speed is the minimum wind speed at which a turbine achieves its nameplate rated output under standard atmospheric conditions. Efficiency is calculated by dividing the nameplate rated power by the power available from the wind stream intercepted by the rotor disc at the rated wind speed.

h. Based on the average rated efficiency for a sample of commercially available modules. Rated efficiency is the conversion efficiency under standard test conditions which represents a fixed, controlled operating point for the equipment, efficiency can vary with temperature and the strength of incident sunlight. Rated efficiencies are based on the direct current output of the module; since grid-tied applications require alternating current output, efficiencies are adjusted to account for a 20% reduction in output when converting from DC to AC.

i. Estimated by EIA on the basis of an informal survey of relevant plants

j. Calculated from Equation 1

k. Total weighted average efficiencies for each process can be calculated according to, for example in the case of overall extraction efficiency $e_1^T = \frac{1}{\frac{m_1}{e_1}+\frac{m_2}{e_1}+\cdots+\frac{m_n}{e_1}}$

A-2. Marginal FFC Energy Factors

A public domain marginal analysis methodology is available from EPA to quantify the emission reduction due to energy efficiency measures or clean energy policies. EPA's interest in this methodology arose from its understanding that clean energy policies and energy efficiency improvements reduce emissions at the marginal or non-baseload electric generating units. Analysts and EPA staff have noted that emission reductions must be quantified using non-baseload emission factors rather than average emission factors[1 2 3] Average electricity generation emission factors can be used appropriately to determine carbon footprint or GHG inventory. However, average emission rates typically under-predict the emission reduction when used for energy savings through efficiency improvements because these averages include baseload generation such as nuclear or hydro power, which would not be affected by the efficiency improvement.[4]

EPA recognizes several valid and established approaches to quantify emission reductions using the non-baseload electricity mix.[5] Non-baseload CO_2emission factors are published by the EPA to facilitate the calculation of emissions reduction due to energy efficiency improvements. The use of eGRID sub-region non-baseload emission factors is recommended by the EPA as a simple, low-cost method to estimate emission reduction potential, to explain emission benefits to the general public, or to determine annual emission reductions or regional / national estimates.[6] EPA's non-baseload emission rates and methodology are currently used in several tools, including EPA's Greenhouse Gas Equivalencies Calculator (http://epa.gov/cleanenergy/energy-resources/calculator.html) and Green Power Partnership's Green Power Equivalency Calculator (http://www.epa.gov/greenpower/pubs/calculator.htm).[7]

EPA's non-baseload emission rate methodology also provides a convenient way to determine the primary energy factor associated with marginal non-baseload power plants for each eGRID sub-region. The emission factors can be correlated with the associated generation mix of oil, natural gas, and coal. Knowing this mix, the aggregate primary energy conversion factor can be calculated based on marginal power plant efficiency levels for each fuel type. In the absence of marginal power plant efficiency level information, average power plant efficiency levels may provide an acceptable substitute.

Keith and Biewald developed a methodology implemented by the EPA for calculating marginal (or non-baseload) power plant emission rates based on the capacity factor of each plant. The capacity factor methodology allows the user to determine marginal energy consumption and GHG emissions at any level of desired aggregation using historical or projected power plant values for any time period. It provides a simplified and reasonably accurate methodology compared to marginal dispatch models or hourly generation databases. The EPA implemented this methodology in the eGRID database to list the emissions of "non-baseload" power plants for application in marginal generation scenarios and analyses.

---

1 Jacobson, D. and High, C. , *U.S. Policy Action Necessary to Ensure Accurate Assessment of the Air Emission Reduction Benefits of Increased Use of Energy Efficiency and Renewable Energy Technology*, Journal of Energy and Environmental Law, Vol. 1:1, 2010. (http://www.rsginc.com/assets/Reports--Publications/RSG-Modeling-of-Air-Emission-Reduction-in-the-Electricity-Sector.pdf)
2 DeYoung, R., *Deciding an Approach for Quantifying Emission Impacts of Clean Energy Policies and Programs*, U.S. Environmental Protection Agency, State Climate and Energy Program, January 30, 2012. (http://www.epa.gov/statelocalclimate/documents/pdf/DeYoung_presentation_1-30-2012.pdf)
3 Rothschild, S. and Diam, A., *Total, Non-baseload, eGRID Sub-region, State? Guidance on the Use of eGRID Output Emission Rates*, Prepared for the U.S. Environmental Protection Agency, Climate Protection Partnership Division, Washington, DC, 2008. (http://www.epa.gov/ttn/chief/conference/ei18/session5/rothschild.pdf)
4 Jacobson, D., Flawed Methodologies in Calculating Avoided Emissions from Renewable Energy , The GW Solar Institute, October 24, 2009. (http://solar.gwu.edu/index_files/Resources_files/DJ_REILPresentation.pdf)
5 DeYoung, R., *Deciding an Approach for Quantifying Emission Impacts of Clean Energy Policies and Programs*, U.S. Environmental Protection Agency, State Climate and Energy Program, January 30, 2012. (http://www.epa.gov/statelocalclimate/documents/pdf/DeYoung_presentation_1-30-2012.pdf)
6 DeYoung, R., *Quantification Methods using eGRID State and Local Examples*, U.S. Environmental Protection Agency, State Climate and Energy Program, March 31, 2011. (http://www.epa.gov/statelocalclimate/documents/pdf/DeYoung_presentation_3-31-11.pdf)
7 Collison, B., *Green Power 101*, US EPA Green Power Partnership, Renewable Energy Markets Conference, Atlanta, GA, September 13, 2009 (http://www.renewableenergymarkets.com/docs/presentations/2010/Wed_RE%20101_Blaine%20Collison.pdf)

Using this approach, all plants with generation capacity factors less than 0.2 are considered non-baseload generation in the eGRID non-baseload generation database, and those with capacity factors greater than 0.8 are considered baseload generation as shown in Figure 11. For the SPSO sub-region this yields the results shown in Table 39. Note that the pre-combustion efficiencies remain the same but the conversion efficiencies and the generation mix change.

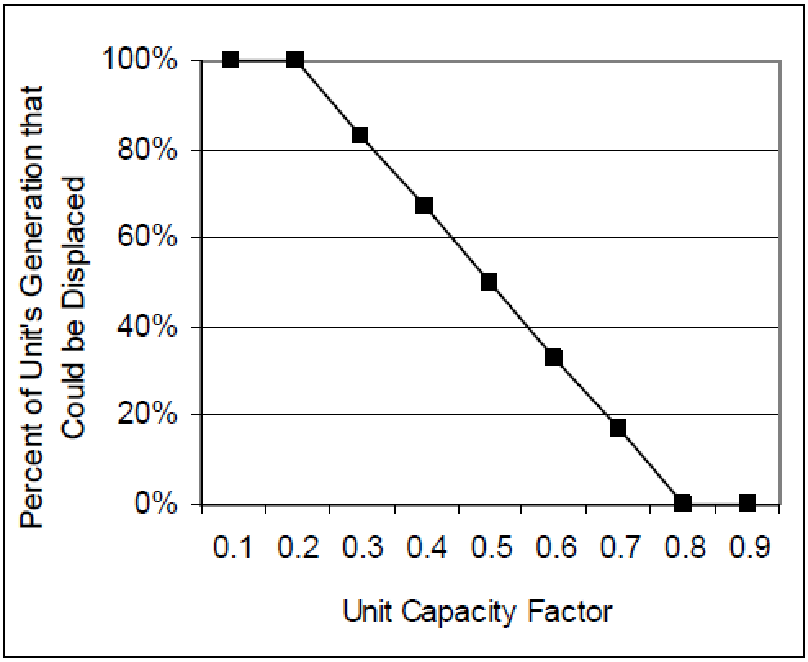


Figure 11 Keith and Biewald Capacity Factor Displacement Methodology

Table 39 FFC Energy Factors for SPSO Sub-region, Non-baseload.

Fuel Type	Extraction	Processing	Transportation	Conversion	Distribution	Mix	FFC Factor
Coal	98.9	99.6	96.9	32.6	93.5	35.99	3.44
Oil	96.3	93.8	98.8	30.1	93.5	0.21	3.98
Natural Gas	96.2	97.0	99.3	35.4	93.5	62.69	3.26
Nuclear	99.0	96.2	99.9	32.6	93.5	0	3.45
Hydro	100.0	100.0	100.0	90.0	93.5	0	1.19
Biomass	99.4	95.0	97.5	56.5	93.5	1.11	2.06
Wind	100.0	100.0	100.0	26.0	93.5	0	4.11
Solar	100.0	100.0	100.0	12.0	93.5	0	8.91
Geothermal	100.0	100.0	100.0	16.0	93.5	0	6.68
Other	100.0	100.0	100.0	20.3	93.5	0	5.27
Total	**97.19**	**97.89**	**98.40**	**34.46**	**93.50**		3.31

A-3. Pollutant Emission Factors

Emissions factors used in the calculation of FFC emissions come from several sources. Fossil fuels pre-combustion emissions factors are calculated using data from the GREET Model v1 2012 rev. 2 with natural gas CH_4 pre-combustion emissions adjusted to comply with latest U.S. EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks" draft document released February 11, 2013. (http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2011.pdf). The combustion emissions for conversion to electricity are calculated using eGRID2012 V1.0. Table 40 gives baseload conversion emissions factors and Table 43gives non-baseload conversion emissions factors for the SPSO sub-region. The emissions factors used for the SPSO sub-region for pre-combustion are given in Table 41. Note that in the case of pre-combustion processes the emissions factors apply to the energy consumed during the pre-combustion processes, not the energy used in electric generation.

The emissions factors, F_i, are used to calculate total emissions using the following procedure. The FFC energy required in units of MMBtu of FFC energy per MWh of electric generation is calculated according to:

$$E_{required}\left(\frac{MMBtu}{MWh}\right) = \frac{3.4121\frac{MMBtu}{MWh}}{e_{conversion} \cdot e_{distribution}} \quad (5)$$

where, $e_{conversion}$ and $e_{distribution}$ are the efficiencies of conversion and distribution given in Table 37. For coal in the SPSO baseload case this yields:

$$E_{required} = \frac{3.4121\frac{MMBtu}{MWh}}{0.322 \cdot 0.925} = 11.33\,\frac{MMBtu}{MWh} \quad (6)$$

Table 40 Emissions Factors for Conversion Processes in the SPSO Sub-region (Baseload)

	Conversion					
Fuel Type	**CO_2 (lb/Btu)**	**SO_2 (lb/MMBtu)**	**NO_x (lb/MMBtu)**	**CH_4 (lb/MMBtu)**	**N_2O (lb/MMBtu)**	**CO_2e (lb/MMBtu)**
Coal	205.0	0.501	0.247	0.002	0.003	205.944
Oil	146.7	0.052	2.112	0.002	0.003	147.644
Natural Gas	118.8	0.002	0.122	0.002	0.000	118.85
Nuclear	0.0	0.000	0.000	0.000	0.000	0
Hydro	0.0	0.000	0.000	0.000	0.000	0
Biomass	0.0	0.358	0.211	0.024	0.005	2.09
Wind	0.0	0.000	0.000	0.000	0.000	0
Solar	0.0	0.000	0.000	0.000	0.000	0
Geothermal	0.0	0.000	0.000	0.000	0.000	0
Other	64.0	0.001	0.066	0.001	0.000	64.025

Table 41 Emissions Factors for Pre-Combustion Processes in the SPSO Sub-region (Baseload)

	Pre-Combustion					
Fuel Type	**CO_2 (lb/Btu)**	**SO_2 (lb/MMBtu)**	**NO_x (lb/MMBtu)**	**CH_4 (lb/MMBtu)**	**N_2O (lb/MMBtu)**	**CO_2e (lb/MMBtu)**
Coal	70.3	0.348	0.593	7.189	0.001	250.323
Oil	169.5	0.357	0.754	2.011	0.003	220.669
Natural Gas	127.6	0.305	0.584	6.161	0.002	282.221
Nuclear	152.7	0.258	0.282	0.371	0.003	162.869
Hydro	0.0	0.000	0.000	0.000	0.000	0
Biomass	161.4	0.061	0.722	0.233	0.003	168.119
Wind	0.0	0.000	0.000	0.000	0.000	0
Solar	0.0	0.000	0.000	0.000	0.000	0
Geothermal	0.0	0.000	0.000	0.000	0.000	0
Other	0.0	0.000	0.000	0.000	0.000	0

Emissions due to conversion for each fuel type are then calculated using:

$$Emissions_{conversion} = E_{required} \cdot F_{conversion} \tag{7}$$

where, for the SPSO baseload case, the emissions factors are given in Table 40. For CO_2e from coal in the SPSO baseload case this gives:

$$Emissions_{conversion} = 11.33 \frac{MMBtu}{MWh} \cdot 205.944 \frac{lb}{MMBtu} = 2334.01 \frac{lb\ CO_2e}{MWh} \tag{8}$$

Pre-conversion emissions are calculated according to equation 9,

$$Emissions_{pre} = (1 - e_1 \cdot e_2 \cdot e_3) E_{required} e_1 \cdot e_2 \cdot e_3 F_{pre} \tag{9}$$

where, e_1, e_2, and e_3 are the efficiencies of extraction processing and transportation given in Table 37, $E_{required}$ is given by Equation 6, and the emissions factor is given in Table 41. For CO_2e from coal in the SPSO baseload case this gives:

$$Emissions_{pre} = \frac{(1-0.989 \cdot 0.996 \cdot 0.969) \cdot 11.33 \frac{MMBtu}{MWh}}{0.989 \cdot 0.996 \cdot 0.969} 250.323 \frac{lb\ CO_2e}{MMBtu} = 135.21 \frac{lb\ CO_2e}{MWh} \tag{10}$$

Emissions pre-conversion and conversion are then added to determine total emissions for each type of fuel. These are then summed using the generation mix ratios to determine the overall emissions according to:

$$Emissions_{total} = \begin{bmatrix} m_1 \\ m_2 \\ \dots \\ m_n \end{bmatrix} \cdot \begin{bmatrix} Emissions_1 \\ Emissions_2 \\ \dots \\ Emissions_n \end{bmatrix} \tag{11}$$

where , m_i is the fraction of the power generation from each type of fuel and the subscripts are the same as those given for Equation 1. For CO_2e emissions in the baseload generation case for the SPSO sub-region this procedure gives the results displayed in Table 42.

The same process is repeated for the case of non-baseload emissions but in this case emissions factors for energy conversion are updated as are the generation mix and FFC energy efficiencies. For the SPSO sub-region the emissions factors for conversion processes are given in Table 43. This yields the energy requirements and pre-conversion and conversion process emissions shown in Table 44.

Table 42 CO_2e Emissions for Each Fuel Type and Overall in the SPSO Sub-Region (Baseload)

Fuel Type	Required MMBtu/MWh	Pre-Conversion	Conversion	Total per source (lb/MWh)	Generation Mix	CO_2e for Each Fuel Type
Coal	11.33	135.21	2334.04	2469.25	58.16	1436.12
Oil	10.46	278.06	1543.85	1821.91	0.07	1.28
Natural Gas	9.68	216.38	1150.46	1366.84	30.72	419.89
Nuclear	11.19	93.08	0.00	93.08	0.00	0.00
Hydro	4.05	0.00	0.00	0.00	5.53	0.00
Biomass	6.19	89.57	12.93	102.50	1.75	1.79
Wind	14.04	0.00	0.00	0.00	3.78	0.00
Solar	30.41	0.00	0.00	0.00	0.00	0.00
Geothermal	22.81	0.00	0.00	0.00	0.00	0.00
Other	17.98	0.00	1150.98	1150.98	0.00	0.00
Total						1859.08

Table 43 Factors for Conversion Processes in the SPSO Sub-region (non-Baseload)

	Conversion					
Fuel Type	**CO_2 (lb/Btu)**	**SO_2 (lb/MMBtu)**	**NO_x (lb/MMBtu)**	**CH_4 (lb/MMBtu)**	**N_2O (lb/MMBtu)**	**CO_2e (lb/MMBtu)**
Coal	203.3	0.483	0.254	0.002	0.003	204.244
Oil	145.6	0.146	0.824	0.003	0.002	146.271
Natural Gas	122.9	0.031	0.151	0.002	0.000	122.95
Nuclear	0.0	0.000	0.000	0.000	0.000	0
Hydro	0.0	0.000	0.000	0.000	0.000	0
Biomass	34.1	0.369	0.217	0.028	0.005	36.29
Wind	0.0	0.000	0.000	0.000	0.000	0
Solar	0.0	0.000	0.000	0.000	0.000	0
Geothermal	0.0	0.000	0.000	0.000	0.000	0
Other	70.4	0.018	0.086	0.001	0.000	70.425

Table 44 CO_2e Emissions by Fuel Type and Overall in SPSO Sub-Region (non-Baseload)

Fuel Type	Required MMBtu/MWh	Pre-Conversion	Conversion	Total per source (lb/MWh)	Generation Mix	CO_2e for Each Fuel Type
Coal	11.19	135.21	2286.37	2421.59	35.99	871.53
Oil	12.12	278.06	1773.40	2051.46	0.21	4.31
Natural Gas	10.31	216.38	1267.48	1483.86	62.69	930.23
Nuclear	11.19	93.08	0.00	93.08	0.00	0.00
Hydro	4.05	0.00	0.00	0.00	0.00	0.00
Biomass	6.46	89.57	234.40	323.97	1.11	3.60
Wind	14.04	0.00	0.00	0.00	0.00	0.00
Solar	30.41	0.00	0.00	0.00	0.00	0.00
Geothermal	22.81	0.00	0.00	0.00	0.00	0.00
Other	17.98	0.00	1266.04	1266.04	0.00	0.00
Total						1809.66

Appendix B Source Energy and Emissions Analysis Tool Description

B-1. Overview

GTI's Source Energy and Emissions Analysis Tool (SEEAT) publicly available at www.cmictools.com was used to develop the full-fuel-cycle energy and pollutant emission factors tabulated in this report. SEEAT uses government published and publicly available data sources to determine FFC energy consumption and related greenhouse gas and other pollutant emissions for selected fossil fuels and electricity based on point-of-use energy consumed by an appliance, building, industrial application, or vehicle. Default values for most efficiency and emission parameters can be changed by the user. Users can evaluate electricity consumption using average or non-baseload (marginal) FFC energy and greenhouse gas emissions factors.

B-2. User Inputs

SEEAT is flexible and simple to use when choosing default input data for the analysis. It also provides the user the opportunity to change one or more inputs to tailor the analysis for a specific need. After selecting the relevant market for analysis (e.g., residential buildings) and the type of analysis desired (average or non-baseload), the user selects the desired region for electricity generation mix and optional building energy consumption calculations. Region options include state, eGRID subregion, NERC region, or U.S. average.

Then the user inputs the annual point-of-use or site energy consumption associated with the baseline and alternative configurations for one or more of the following energy forms: Electricity, natural gas, fuel oil, or propane. Energy estimation modules can be used to automatically enter annual site energy consumption if the user desires.

The user then chooses the version of the eGRID database for the analysis. SEEAT includes three versions of eGRID data:

- **eGRID2012 v1.0** database that provides detailed and aggregate data on electric power plant generation and emissions for the year 2009, or
- **eGRID2010 v1.1** database that uses year 2007 data, or
- **eGRID2007 v1.1** database that uses year 2005 data

Users also have the option of using the corresponding eGRID plant level database screened by GTI analysts to verify and align fuel plant classification with primary input fuel. This option addresses input errors identified in the eGRID aggregated databases that skew results in certain regions.

The user then selects the desired electricity generation mix and characteristics, either using the eGRID defaults for the selected region or user-defined generation mix and either default or user-defined efficiency factors. Similarly, the user can choose either defaults or enter user-defined efficiency factor values for fuels. Finally, the user can choose either the default emission factors or enter user-defined values for each energy form.

Selecting the non-baseload (marginal) calculation option for electricity limits the user geographical area selection to eGRID sub-regions and data source selection to eGRID2012 v1.0 database.

B-3. Calculations

Based on the user-defined and default inputs, SEEAT calculates FFC energy and emissions factors for the analysis. Based on annual site electric use input data, SEEAT calculates location-specific:

- Electric distribution efficiency and resulting power plant generation requirement,
- Power plant fuel mix,
- Conversion efficiency and corresponding primary energy and air emissions by fuel type,

- Primary energy required and corresponding air emissions by fuel type for extraction, processing, and transportation to the power plant
- FFC energy and composite emission factors

Based on annual natural gas, oil, and propane use input data, SEEAT calculates location-specific:

- Primary energy required and corresponding air emissions by fuel type for extraction, processing, transmission, and distribution to the building. Conversion (combustion) occurs in the building, so the "conversion efficiency" factor is not applicable for these fuels.
- FFC energy and composite emission factors

B-4. Reports

SEEAT output reports include tabular and graphic results for the baseline and alternative configurations as well as a comparison of baseline versus alternative for the following:

- **Annual Site Energy Consumption** by energy form in units delivered to the site
- **Annual FFC Energy Consumption** by energy form and total in units delivered to the site converted to FFC Btu's
- **FFC Energy Factors** for each energy form and composite factor
- **Annual Greenhouse Gas Emissions** (CO_2 and CO_2e) by energy form and total in units delivered to the site converted to FFC energy emissions in thousand pounds.
- **Annual Emissions - Other Pollutants**, including SO_2, NO_x, and Hg by energy form and total in pounds. However, Hg emission data are only available in the eGRID 2007 databases.
- **Efficiency Factors for Energy Delivered to Building**, including electricity and other energy forms
- **Emission Factors for Energy Delivered to Building**, including electricity and other energy forms
- **Electric Generation Resource Mix** for the region selected for analysis

B-5. Point-of-Use and Site Energy Consumption Estimation Modules

SEEAT also includes point-of-use and site energy consumption estimation modules to aid users in screening and comparing total annual energy consumption by energy form for baseline and alternative configurations. This information can be submitted to data input cells for the annual site energy consumption by energy form for use in FFC energy and emission calculations. Current modules provide location-specific consumption estimates for residential buildings and several types of commercial buildings, normalized energy consumption estimates for certain industrial applications, and comparative consumption estimates for various types of passenger vehicles.

The **Residential Buildings Module** includes Detached Single-Story, Detached Two-Story, Townhouse, and Multi-family configurations. Energy consumption is calculated for each appliance and the entire building based on modeled energy consumption of relatively energy efficient building configurations. The user selects the desired location, size, number of occupants, and appliances to include in the building, and the module provides an estimate of associated site energy consumption for each appliance and the whole building.

The **Commercial Buildings Module** includes Fast Food, Nursing Home, Retail Store, School, Small Office, and Supermarket configurations. Energy consumption calculations are similar to the residential buildings module.

The **Industrial Applications Module** includes annual industrial energy consumption data collected by the U.S. Energy Information Administration and by the U.S. Census Bureau linked to value-based measures of industrial output (Btu/$ produced) for 12 different major industrial classifications. This data is used by the tool to calculate the FFC energy and emissions per million dollars produced.

The **Passenger Vehicle Module** includes both conventional and low emission vehicles. All modeled vehicles are passenger cars with a Gross Vehicle Weight Rating (GVWR) less than 6,000 lbs. MPG (per gasoline equivalent gallon) is based on a gallon of 38/62% mix of conventional and reformulated gasoline with Higher Heating Value of 123,094.19 Btu. The module includes the following vehicle types:

- **Gasoline - 38/62 Conv. & Ref. Fuel**; Spark ignition gasoline vehicle fuelled with 38/62% mix of conventional and reformulated gasoline with a default fuel efficiency of 24.28 MPG
- **Compressed Natural Gas - Dedicated Vehicle**; Dedicated compressed natural gas vehicle with a default fuel efficiency of 24.62 MPG (per gasoline equivalent gallon)
- **Liquid Petroleum Gas - Dedicated Vehicle**; Dedicated liquid petroleum gas (propane) vehicle with a default fuel efficiency of 25.25 MPG (per gasoline equivalent gallon)
- **Diesel - Direct Injection Compression Ignition**; Diesel engine vehicle fueled with conventional diesel oil and a default fuel efficiency of 29.14 MPG (per gasoline equivalent gallon)
- **Electric Vehicle**; Electric vehicle with 85% efficient grid to battery charger efficiency. Default fuel efficiency of 76.88 MPG (per gasoline equivalent gallon)
- **Hybrid Electric - 38/62 Conv. & Ref. Gasoline**; Hybrid electric / spark ignition gasoline vehicle fueled with 38/62% mix of conventional and reformulated gasoline. Default fuel efficiency of 33.99 MPG (per gasoline equivalent gallon)
- **Plug-in Hybrid Electric - 38/62 Conv. & Ref. Gasoline**; Plug-in hybrid electric / spark ignition gasoline vehicle fueled with 38/62% mix of conventional and reformulated gasoline. Default fuel efficiency of 60.8 MPG (per gasoline equivalent gallon). Fully charged vehicle Operational All Electric Range (OAER) 20 miles. Percentage of miles driven in Charge Depletion (CD) mode 44.5%, balance of 55.5% driven in Charge Sustaining (CS) mode. 85% efficient grid to battery charger efficiency.

B-6. Data Sources

Default values for emission and FFC energy factors in SEEAT were derived from the following sources:

- **Greenhouse Gas and Criteria Pollutant Emission Factors**
  - Fossil fuels pre-combustion emissions are calculated using data from the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model version 1 2012 rev. 2 released by Argonne National Laboratory in December 2012 with the natural gas CH4 pre-combustion emissions adjusted to comply with latest US EPA "Inventory of U.S. Greenhouse Gas Emissions and Sinks" draft document released February 11, 2013. (http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2011.pdf) GREET references current US EIA and EPA data sources as well as a database of information developed by Argonne National Laboratory during the past 19 years. The GREET program, sponsored by the U.S. DOE Office of Energy Efficiency and Renewable Energy (EERE), is being used by DOE for modeling emissions and energy use in transportation. (http://www.transportation.anl.gov/modeling_simulation/GREET)
  - Fossil fuels on-site combustion emissions are calculated using GREET version 1 2012 rev. 2 data.
  - Fossil fuels combustion emissions for conversion to electricity are calculated using the EPA 2012 Emissions & Generation Resources Integrated Database (eGRID) database. eGRID2012 provides detailed and aggregate data on electric power plant generation and emissions for the year 2009. Data is available for nearly all U.S. power plants and aggregated at state, eGRID sub-region, National Electric Reliability Council (NERC) region, and national levels. Relevant emissions data includes CO_2, NO_x, SO_2, Hg, CH_4, N_2O, and CO_2e emissions. In addition, the database includes the percentage of power supplied by coal, oil,

natural gas, hydro, nuclear, and other renewable sources. This generation mix data is useful to estimate FFC energy conversion factors at state, regional, and national levels. Heat rates for electricity generation using fossil fuels like coal, natural gas, and oil as well as electricity transmission and distribution (T&D) losses are also available from eGRID2012 Version 1.0. (http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html)
- o CO2e emission factors are calculated using global warming potential values for three of the greenhouse gas contained in the IPCC 4th assessment: CO_2 = 1, CH_4 = 25, N_2O = 298. This differs from EPA inventory calculations that are based on IPCC SAR values of 21 and 310 for CH_4 and N_2O respectively, but is considered more current. (http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter2.pdf pg 212.)

- **FFC Energy Factors**
  - FFC energy factors for fossil fuels pre-combustion energy consumption are calculated using the National Renewable Energy laboratory (NREL) U.S. Life-Cycle Inventory (LCI) database and GREET 1 2012 rev. 2 data. The NREL LCI database provides data needed to calculate FFC energy conversion factors for the three major types of coal (bituminous, subbituminous, and lignite) used in U.S. power plants. Related supplemental data are provided in NREL report TP-550-38617 "Source Energy and Emission Factors for Energy Use in Buildings". (www.nrel.gov/docs/fy07osti/38617.pdf) That report also provides data needed to calculate the percentage of coal fuel mix 2 March 19, 2010 (bituminous, subbituminous, and lignite) used in electric power generation at state, regional, and national levels. (http://www.nrel.gov/lci/)
  - FFC energy factors for fossil fuels on-site combustion are assumed to be 100% (i.e., complete combustion).
  - FFC energy factors for fossil fuels combustion at power plants for conversion to electricity are calculated using EPA eGRID 2012 v1.0 data (with options to use eGRID2010 v1.1 or eGRID2007 v1.1 data).
  - Hydroelectric plant conversion efficiency is estimated at 90%.[8]
  - Solar power generation conversion efficiency is estimated at 12%.[9]
  - Wind power generation conversion efficiency is estimated at 26%.[10]
  - Nuclear power generation conversion efficiency is a national average value based on DOE EIA data.[11]
  - Biomass power generation conversion efficiency is based on eGRID 2012 v1.0 data (with options to use eGRID2010 v1.1 or eGRID2007 v1.1 data).

8 Page 66 of a hydropower presentation by Professor Stephen Lawrence of Leeds School of Business, University of Colorado, Boulder, CO estimates overall hydropower plant efficiency to be 75% to 95%. The default value of 90% efficiency in SEEAT is based on the trend to higher efficiency in newer and refurbished plants. http://leeds-faculty.colorado.edu/Lawrence/SYST6820/Lectures/Hydropower.ppt

9 CEC estimates typical <100 kW PV installations to have efficiency ranging from 5% to 15%. The default average value of 12% efficiency in SEEAT is the mid-range. (http://www.energy.ca.gov/distgen/equipment/photovoltaic/photovoltaic.html)

10 California Energy Commission (CEC) estimates peak wind turbine efficiency between 20% and 40% (http://www.energy.ca.gov/distgen/equipment/wind/wind.html). The Danish Wind Industry Association estimates typical efficiency to be "somewhat above 20%" with significant variations based on wind speed and turbine design. http://www.talentfactory.dk/en/tour/wres/cp.htm The default value of 26% efficiency in SEEAT is based on estimated seasonal efficiency including wind speed and direction impacts on peak efficiency levels.

11 The DOE Energy Information Administration (EIA) Table 8.4a Consumption for Electricity Generation by Energy Source: Total (All Sectors) (http://www.eia.doe.gov/emeu/aer/txt/ptb0804a.html)

B-7. Renewable Power Generation FFC Energy Conversion Options

SEEAT uses thermodynamic efficiency in its default calculations for all power generation energy forms. For example, wind power generation efficiency is determined by calculating how much of the available wind energy reaching the turbine is converted to electricity. Using thermodynamic efficiency allows a direct comparison with other renewable options such as solar thermal and photovoltaics, but does not value a renewable Btu differently than a conventional Btu such as nuclear energy or fossil fuels.

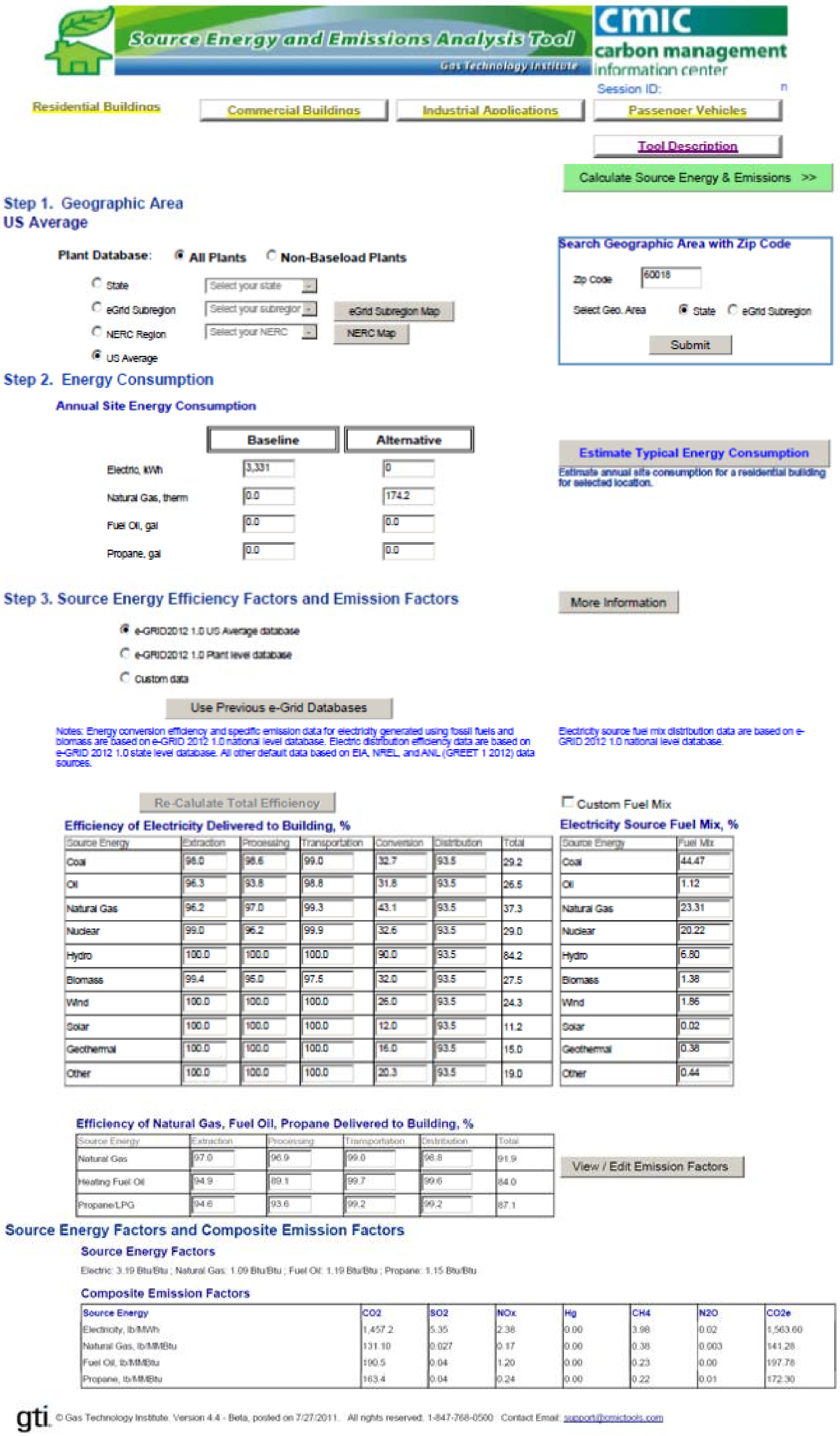
GHG emission factors account for the environmental benefits of renewable energy. However, renewable energy poses unique analytical challenges from a full-fuel-cycle energy efficiency perspective. The thermodynamic efficiency methodology compares all FFC energy efficiency equally irrespective of the energy form, including renewable energy. When comparing fuel types used to generate electricity, the energy consumption of renewable energy such as hydropower and wind power is not the same as depletable resource consumption (nuclear or fossil fuels) because the energy “consumed” is renewable and free when available. Full-fuel-cycle methodologies cannot address this issue except by substituting a policy-based conversion factor (e.g., 100% generation efficiency, or zero consumption for the power generated) that biases the energy efficiency analysis in favor of renewable energy based on its “non-depletable” benefit. SEEAT can accommodate that approach through user inputs, but the thermodynamic efficiency was selected as the basis of the default efficiency factor based on simple physics rather than nature of the energy form. Hydropower production in the US is not likely to increase much in the future. However, as wind power and solar thermal systems become more prevalent, this issue will need to be addressed equitably based on policy goals.

For full-fuel-cycle analysis based on current and projected power generation mix, renewable power does not impact the results meaningfully. Using 100% efficiency for all renewables (hydro, biomass, wind, solar, geothermal), the national average electricity FFC energy factor using eGRID 2012 data goes from 3.15 to 3.00. Using “zero energy” for non-combusted renewables (i.e., the energy from hydro, wind, solar, and geothermal is considered inexhaustible and should not be included in FFC energy consumption calculations for electricity), the FFC energy factor goes to 2.86.

Full-fuel-cycle pollutant emission factors attributable to site electricity consumption are not affected by changes in assumed renewable power efficiency since renewable energy emission factors are already zero.

Renewable power factors are irrelevant for marginal analysis because renewable power (a non-depletable intermittent power source) will never be displaced when available due to its low marginal cost of operation.

Sample Residential Building Input Screen



Sample Report Screen

Source Energy and Emissions Analysis Tool
Gas Technology Institute
cmic carbon management information center

Emission Report

Session ID: n

Geographic Area:

US Average

Baseline:

Annual Site Energy Consumption

Electric: 3,516 kWh   Natural Gas: 0 therm   Fuel Oil: 0 gal   Propane: 0 gal

Annual Source Energy Consumption

Electric: 38.2 MMBtu ; Natural Gas: 0.0 MMBtu ; Fuel Oil: 0.0 MMBtu ; Propane: 0.0 MMBtu ; Total: 38.2 MMBtu

Source Energy Factors

Electric: 3.19 Btu/Btu ; Natural Gas: n/a ; Fuel Oil: n/a ; Propane: n/a ; Site composite: 3.19 Btu/Btu

Annual Greenhouse Gas Emissions

Pollutant	Electric	Natural Gas	Fuel Oil	Propane	Total
CO2, 1000 lbs	5.12	0.00	0.00	0.00	5.12
CH4, lbs	14.00	0.00	0.00	0.00	14.00
N2O, lbs	0.08	0.00	0.00	0.00	0.08
CO2e*, 1000 lbs	5.50	0.00	0.00	0.00	5.50

Annual Emissions - Other Pollutants * Hg emission data are not available in eGRID 2010.

Pollutant	Electric	Natural Gas	Fuel Oil	Propane	Total
SO2, lbs	18.81	0.00	0.00	0.00	18.81
NOx, lbs	8.37	0.00	0.00	0.00	8.37
Hg, lbs	N/A	N/A	N/A	N/A	N/A

Alternative:

Annual Site Energy Consumption

Electric: 0 kWh   Natural Gas: 174 therm   Fuel Oil: 0 gal   Propane: 0 gal

Annual Source Energy Consumption

Electric: 0.0 MMBtu ; Natural Gas: 18.9 MMBtu ; Fuel Oil: 0.0 MMBtu ; Propane: 0.0 MMBtu ; Total: 18.9 MMBtu

Source Energy Factors

Electric: n/a ; Natural Gas: 1.09 Btu/Btu ; Fuel Oil: n/a ; Propane: n/a ; Site composite: 1.09 Btu/Btu

Annual Greenhouse Gas Emissions

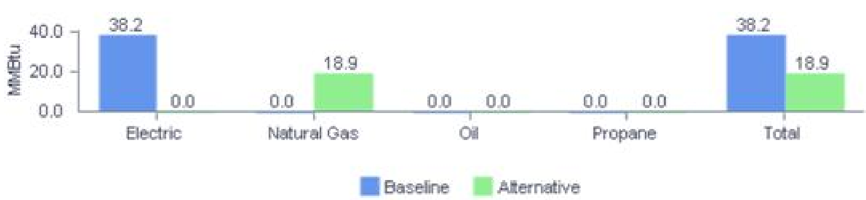
Pollutant	Electric	Natural Gas	Fuel Oil	Propane	Total
CO2, 1000 lbs	0.00	2.28	0.00	0.00	2.28
CH4, lbs	0.00	6.55	0.00	0.00	6.55
N2O, lbs	0.00	0.05	0.00	0.00	0.05
CO2e*, 1000 lbs	0.00	2.46	0.00	0.00	2.46

Annual Emissions - Other Pollutants * Hg emission data are not available in eGRID 2010.

Pollutant	Electric	Natural Gas	Fuel Oil	Propane	Total
SO2, lbs	0.00	0.48	0.00	0.00	0.48
NOx, lbs	0.00	2.89	0.00	0.00	2.89
Hg, lbs	N/A	N/A	N/A	N/A	N/A

Energy and Emission Comparison: Baseline vs. Alternative

Annual Source Energy Consumption by Fuel Type



Annual Greenhouse Gas Emission Reduction (Baseline - Alternative) by Fuel Type

Pollutant	Electric	Natural Gas	Fuel Oil	Propane	Total

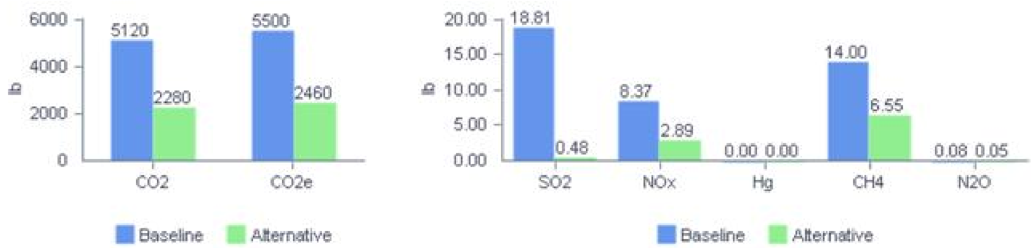
Sample Report Screen (Continued)

CO2, 1000 lbs	5.12	-2.28	0.00	0.00	2.84
CH4, lbs	14.00	-6.55	0.00	0.00	7.45
N2O, lbs	0.08	-0.05	0.00	0.00	0.03
CO2e*, 1000 lbs	5.50	-2.46	0.00	0.00	3.04

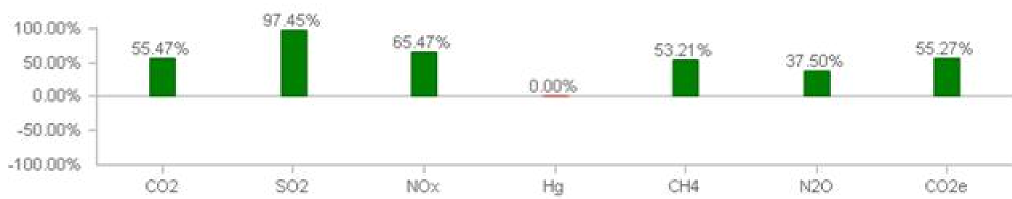
Annual Other Pollutant Emission Reduction (Baseline - Alternative) by Fuel Type

Pollutant	Electric	Natural Gas	Fuel Oil	Propane	Total
SO2, lbs	18.81	-0.48	0.00	0.00	18.33
NOx, lbs	8.37	-2.89	0.00	0.00	5.48
Hg, lbs	N/A	N/A	N/A	N/A	N/A

Annual Emission, Baseline vs. Alternative



Annual Emission Percent Reduction vs. Baseline



Efficiency Factors for Energy Delivered to Building:

Efficiency Factors for Electricity Delivered to Building, %

Source Energy	Extraction	Processing	Transportation	Conversion	Distribution	Total
Coal	98.0	98.6	99.0	32.4	93.8	29.1
Oil	96.3	93.8	98.8	31.8	93.8	26.6
Natural Gas	97.0	96.9	99.0	42.3	93.8	36.9
Nuclear	99.0	96.2	99.9	32.6	93.8	29.1
Hydro	100.0	100.0	100.0	85.0	93.8	79.7
Biomass	99.0	99.0	98.9	32.3	93.8	29.4
Wind	100.0	100.0	100.0	23.0	93.8	21.6
Solar	100.0	100.0	100.0	10.0	93.8	9.4
Geothermal	100.0	100.0	100.0	16.2	93.8	15.2
Other	100.0	100.0	100.0	12.8	93.8	12.0

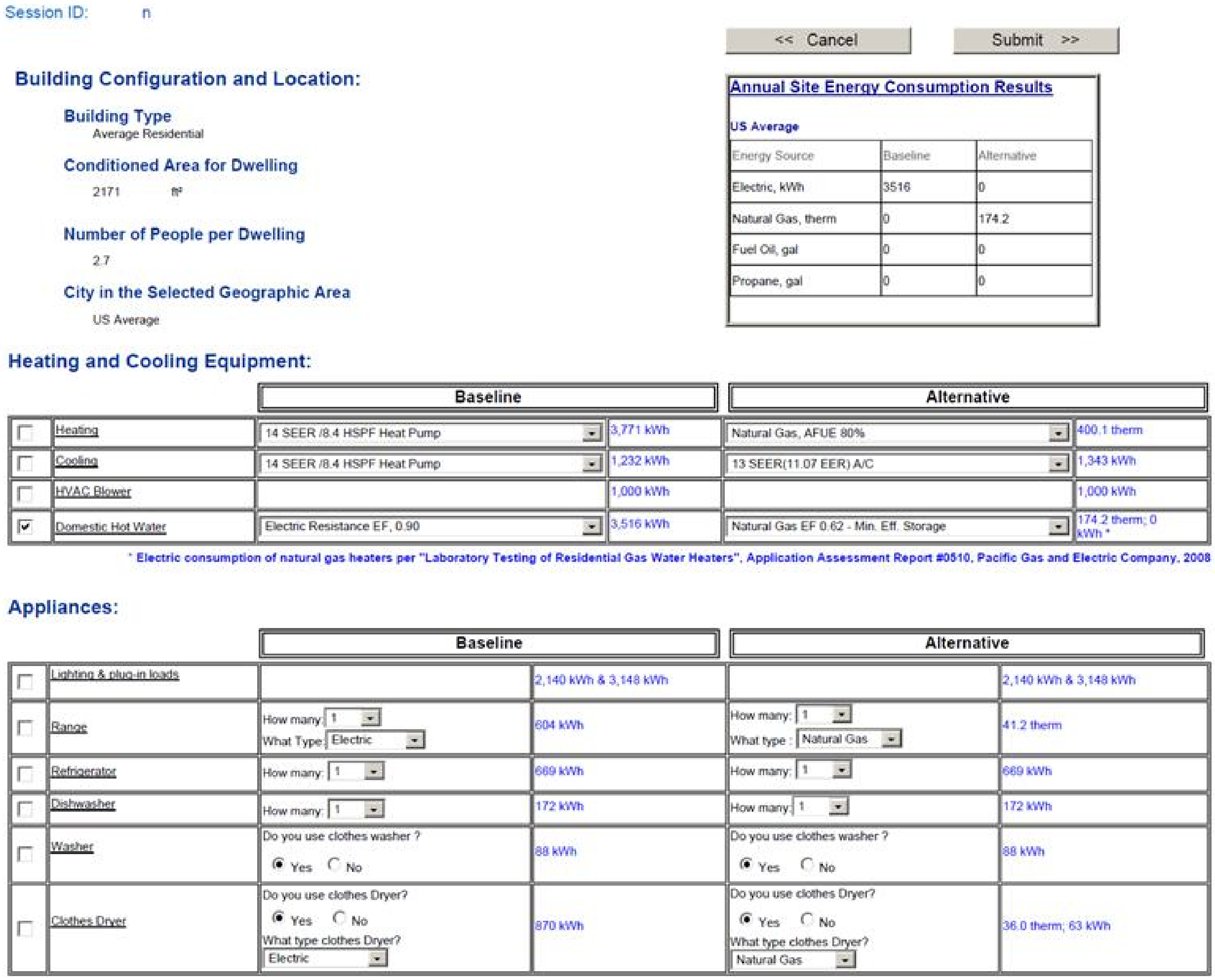
Efficiency Factors for Natural Gas, Fuel Oil, Propane Delivered to Building, %

Source Energy	Extraction	Processing	Transportation	Distribution	Total
Natural Gas	97.0	96.9	99.0	98.8	91.9
Heating Fuel Oil	94.9	89.1	99.7	99.6	84.0
Propane/LPG	94.6	93.6	99.2	99.2	87.1

Notes: Energy conversion efficiency and specific emissions data for electricity generated using fossil fuels and biomass are based on e-GRID 2010 1.1 Plant level database screened to verify primary fuel plant classification. Electric distribution efficiency data are based on e-GRID 2010 1.1 state level database. All other default data based on EIA, NREL, and ANL (GREET 1.8c) data sources.

* CO2e value represents cumulative Global Warming Potential (GWP) of emissions from consumed fuels during their precombustion and combustion/conversion processes. Calculations are based on GWP values for pollutants 100 years lifetime as per 2007 Intergovernmental Panel on Climate Change (AR4 p212): Carbon Dioxide (CO2) GWP = 1; Methane (CH4) GWP = 25 ; Nitrous Oxide (N2O) GWP = 298.

Residential Building Module Screen



Session ID: n

<< Cancel | Submit >>

Building Configuration and Location:

Building Type
Average Residential

Conditioned Area for Dwelling
2171 ft²

Number of People per Dwelling
2.7

City in the Selected Geographic Area
US Average

Annual Site Energy Consumption Results

US Average

Energy Source	Baseline	Alternative
Electric, kWh	3516	0
Natural Gas, therm	0	174.2
Fuel Oil, gal	0	0
Propane, gal	0	0

Heating and Cooling Equipment:

		Baseline		Alternative	
☐	Heating	14 SEER /8.4 HSPF Heat Pump	3,771 kWh	Natural Gas, AFUE 80%	400.1 therm
☐	Cooling	14 SEER /8.4 HSPF Heat Pump	1,232 kWh	13 SEER(11.07 EER) A/C	1,343 kWh
☐	HVAC Blower		1,000 kWh		1,000 kWh
☑	Domestic Hot Water	Electric Resistance EF, 0.90	3,516 kWh	Natural Gas EF 0.62 - Min. Eff. Storage	174.2 therm; 0 kWh *

* Electric consumption of natural gas heaters per "Laboratory Testing of Residential Gas Water Heaters", Application Assessment Report #0510, Pacific Gas and Electric Company, 2008

Appliances:

		Baseline		Alternative	
☐	Lighting & plug-in loads		2,140 kWh & 3,148 kWh		2,140 kWh & 3,148 kWh
☐	Range	How many: 1 What Type: Electric	604 kWh	How many: 1 What type : Natural Gas	41.2 therm
☐	Refrigerator	How many: 1	669 kWh	How many: 1	669 kWh
☐	Dishwasher	How many: 1	172 kWh	How many: 1	172 kWh
☐	Washer	Do you use clothes washer ? ◉ Yes ○ No	88 kWh	Do you use clothes washer ? ◉ Yes ○ No	88 kWh
☐	Clothes Dryer	Do you use clothes Dryer? ◉ Yes ○ No What type clothes Dryer? Electric	870 kWh	Do you use clothes Dryer? ◉ Yes ○ No What type clothes Dryer? Natural Gas	36.0 therm; 63 kWh

Commercial Building Module Screen

Session ID: n

<< Cancel Submit >>

Annual Site Energy Consumption Results

US Average

Energy Source	Baseline	Alternative
Electric, kWh	48,711	14,091
Natural Gas, therm	0	3,551
Fuel Oil, gal	0	0
Propane, gal	0	0

Building Configuration and Location:

Application Building Type

Small Office

Total Building Area

30000 ft²

Number of Floors

1

Geographic Area

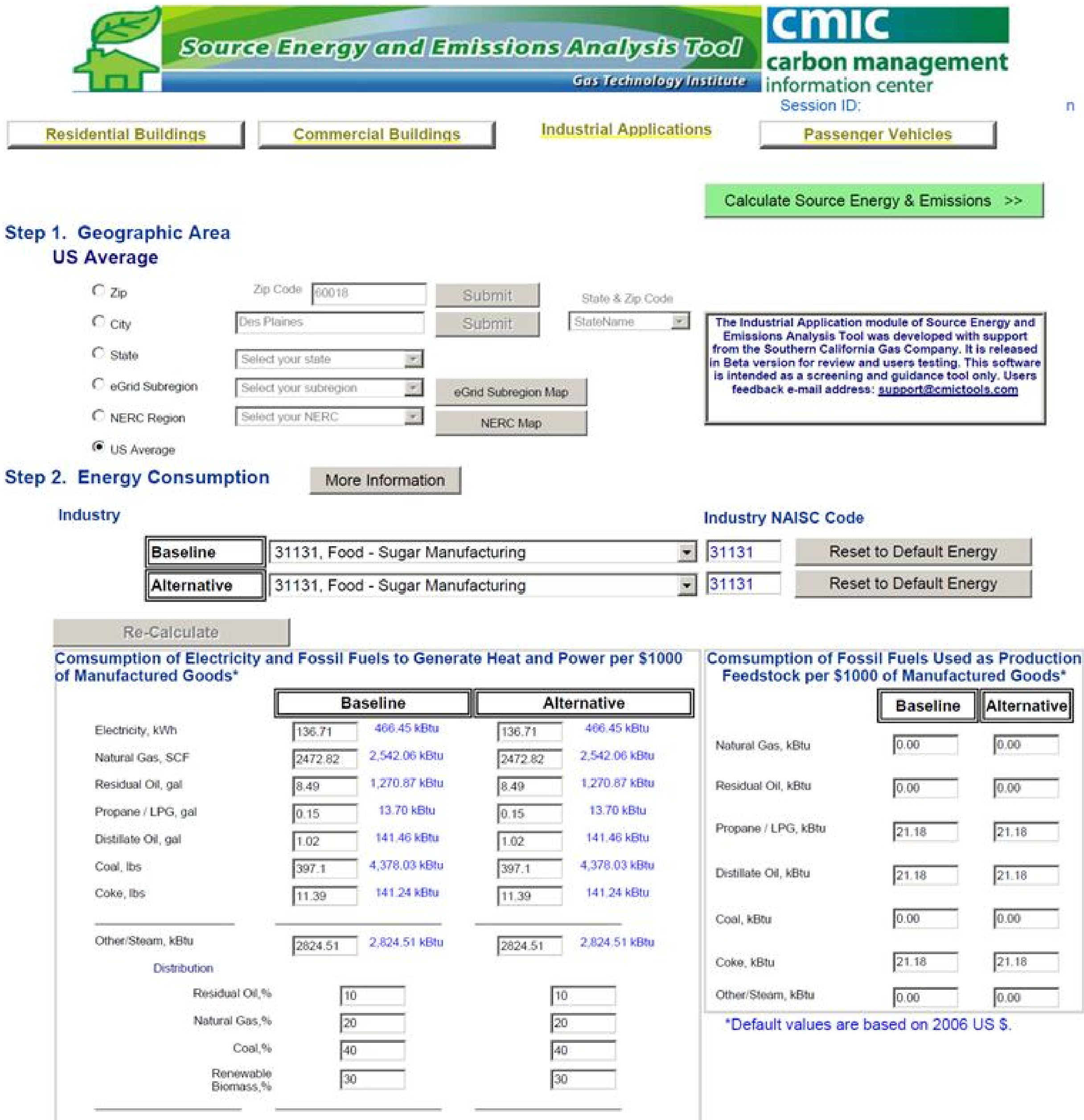
US Average

Re-Calculate

Energy Consumption:

		Baseline	Alternative
☑	Heating	Heat Pump - SEER 14 / HSPF 8.4 29,650 kWh	Natural Gas, Average AFUE 80% 3,288.0 therm
☐	Cooling	Heat Pump - SEER 14 / HSPF 8.4 30,667 kWh	Rooftop DX - High EER 13.0 27,177 kWh
☑	HVAC Blower	14,091 kWh	14,091 kWh
☑	Domestic Hot Water	Electric Resistance TE 92% - Storage 4,969 kWh	Natural Gas TE 80% - Min. Eff. Storage 263.1 therm; 0 kWh
☐	Lighting	107,124 kWh	107,124 kWh
☐	Heat Reject.	15,784 kWh	15,784 kWh
☐	Pumps & Misc.	79 kWh	79 kWh
☐	Misc. Equipment	90,645 kWh	90,645 kWh

Industrial Applications Input Screen



Passenger Vehicles Input Screen