ENERGY STAR® Portfolio Manager® Technical Reference

Source Energy

OVERVIEW

Commercial buildings use different mixes of energy including electricity, natural gas, fuel oil, district steam, and many others. To evaluate energy performance for these buildings, we have to express these different energy types in a single common unit. ***Source energy*** is the most equitable unit of evaluation, and enables a complete assessment of energy efficiency.

You may be familiar with ***site energy***, the amount of heat and electricity consumed by a building as reflected in utility bills. Site energy may be delivered to a facility in one of two forms. ***Primary energy*** is the *raw fuel* that is burned to create heat and electricity, such as natural gas or fuel oil. ***Secondary energy*** is the *energy product* created from a raw fuel, such as electricity purchased from the grid or heat received from a district steam system. A unit of primary energy and a unit of secondary energy consumed at the site are not directly comparable because one represents a raw fuel while the other represents a converted fuel. Ultimately, buildings require heat and electricity to operate, and there are always losses associated with generating and delivering this heat and electricity. ***Source energy*** traces the heat and electricity requirements of the building back to the raw fuel input, thereby accounting for any losses and enabling a complete thermodynamic assessment.

The figure below summarizes the ratios used in Portfolio Manager to convert to source energy. We use national average ratios for the conversion to source energy to ensure that no specific building will be credited (or penalized) for the relative efficiency of its energy provider(s).

Figure 1 – Source-Site Ratios for all Portfolio Manager Energy Meter Types

Energy Type	U.S. Ratio	Canadian Ratio
Electricity (Grid Purchase)	3.14	1.96
Electricity (on-Site Solar or Wind Installation)	1.00	1.00
Natural Gas	1.05	1.01
Fuel Oil (1,2,4,5,6,Diesel, Kerosene)	1.01	1.01
Propane & Liquid Propane	1.01	1.04
Steam	1.20	1.33
Hot Water	1.20	1.33
Chilled Water	1.00	0.57
Wood	1.00	1.00
Coal/Coke	1.00	1.00
Other	1.00	1.00

This document explains source energy and the details behind each factor in the following sections:

THE VALUE OF SOURCE ENERGY

The purpose of the conversion from site energy to source energy is to provide an equitable assessment of building-level energy efficiency. Because billed site energy use includes a combination of primary and secondary forms of energy, a comparison using site energy does not provide an equivalent thermodynamic assessment for buildings with different fuel mixes. In contrast, source energy incorporates all production, transmission, and delivery losses, which accounts for all primary fuel consumption and enables a complete assessment of energy efficiency in a building.

When source energy is used to evaluate energy performance, an individual building's performance does not receive either a credit or a penalty for using any particular fuel type. In contrast, use of a site energy metric would provide a credit for buildings that purchase energy produced offsite by a utility (such as electricity). You can see this neutrality in the following example scenarios with different heating systems and in a comparison of ENERGY STAR certified buildings to the national commercial building stock.

Source Energy in Different Heating Scenarios

Because most buildings use electricity for lighting and other equipment, the reason that fuel mix varies by building is usually due to the choice of heating system. Another way to understand the relationship between fuel choice, source energy, and energy performance is to consider six different scenarios for heating systems in buildings, which are included in the figure below. For each scenario, the building operation and thermal envelope are the same. Therefore, the heat load for each building is identical. The differences among the buildings are solely in the type of heating fuel and the equipment used for heating. As a result of these differences, the buildings have different site and source energy consumption, as shown in the figure below.

Figure 2 – Comparison of Alternate Heating Scenarios

	Building A	Building B	Building C	Building D	Building E	Building F
Heating Fuel	**Natural Gas**	**Natural Gas**	**District Steam**	**Electric**	**Electric**	**Electric**
Heating System	Gas-fired Boiler 90% combustion efficiency 80% system efficiency	District Steam 70% combustion efficiency 55% system efficiency	District Steam 95% system efficiency	Geothermal COP=4.0	Air Source Heat Pump COP = 2.5	Electric Resistance Heat
Heat to Space (MBtu)	1000	1000	1000	1000	1000	1000
Site Energy (MBtu)	1250	1818	1053	250	400	1000
Source Energy (MBtu)	**1313**	**1909**	**1264**	**785**	**1256**	**3140**

Note that the U.S. source-site ratios were applied:

- *Electricity: 1 unit site = 3.14 units source*
- *Natural Gas: 1 unit site = 1.05 units source*
- *Steam: 1 unit site = 1.20 units source*

The site and source energy values in ***Figure 2*** demonstrate the key differences between the two metrics and illustrate why source energy is the more equitable comparative metric. A comparison of these building scenarios using site energy fails to recognize efficiency losses from the off-site energy generation. In contrast, source energy provides an accurate and equitable comparison of these building scenarios, as described further in ***Figure 3*** below. The metrics in Portfolio Manager (e.g., the ENERGY STAR score, Source EUI) aim to evaluate energy performance based on whole-building energy use, independent of heating system, or building technology. Using source energy allows the heating system efficiency to be fairly represented in the whole-building energy use metrics.

Figure 3 – The Benefits of Source Energy

✓ Benefits of Source Energy

- ✓ Allows for a whole-building assessment that combines all fuels
- ✓ Evaluates all buildings fairly, regardless of heating system
- ✓ Fairly evaluates electric heating in relation to natural gas and steam systems
  - ✓ Identifies geothermal heating as most efficient
  - ✓ Evaluates air source heat pump systems as efficient, on par with natural gas boilers and district steam systems
  - ✓ Identifies electric resistance heating as least efficient
- ✓ Provides equitable comparison of steam systems with natural gas-fired systems
- ✓ Fairly compares natural gas boilers with different on-site efficiency levels

Electricity Consumption in Portfolio Manager and ENERGY STAR Certified Buildings

To understand how these heating scenarios work in the real world, we can evaluate the fuel mixes of buildings across the United States, as represented by the Commercial Building Energy Consumption Survey (CBECS), a nationally representative sample of buildings. We can then compare this with buildings that have earned ENERGY STAR certification in 2012.

Across all commercial buildings in the United States, electricity accounts for 62% of energy use. Among ENERGY STAR certified buildings, the average percent electricity is slightly higher, at 78%. In addition to the average percent electricity we can also evaluate the percent of buildings that are 100% electricity (i.e. heated and cooled with electricity). Here, we see that 30% of the buildings nationally are 100% electric, as compared with 26% among ENERGY STAR certified buildings. Taken together, these statistics show that buildings with a high percentage of electricity use are just as likely to earn ENERGY STAR certification as other types of buildings.

Figure 4 – Percent Electricity in U.S. Commercial Buildings

	CBECS	ENERGY STAR Certified (2012)
Number of Buildings Represented	4,319,931	8,287
Average % Electricity	62%	78%
Number of Buildings that are 100% Electric	1,276,441	2,143
Percent of Buildings that are 100% Electric	30%	26%

CBECS is conducted by the US Department of Energy's Energy Information Administration. Filters were applied to CBECS data for analysis purposes. ENERGY STAR Certified facilities include those that benchmarked in Portfolio Manager and earned certification in 2012.

METHODOLOGY

Ultimately, the goal of the conversion to source energy is to account for the total primary fuel needed to deliver heat and electricity to the site. Generally, this means the methodology should perform the following adjustments for energy consumed on site:

- **Primary Energy.** Account for losses that occur in the distribution, storage and dispensing of the primary fuel (e.g., natural gas, fuel oil).
- **Secondary Energy.** Account for conversion losses at the plant in addition to losses incurred during transmission and distribution of secondary energy to the building (e.g., electricity, district steam).

These adjustments quantify the total energy content of the primary fuel. In this assessment, the primary fuels are considered refined products such as coal, natural gas and oil. The analysis does not account for the energy that is consumed in mining, transporting, and refining crude products. While that type of analysis may provide an instructive look at the lifecycle impacts of energy use, it is beyond the scope of a building-level assessment. Specific details on the application of this methodology to each type of energy are provided in following sections of this document.

Use of National Average Source-Site Ratios

The efficiency of secondary energy (e.g., electricity) production depends on the types of primary fuels that are consumed and the specific equipment that is used. These characteristics are unique to specific power plants and differ by region. For example, some regions have a higher percentage of hydroelectric power, while others consume greater quantities of coal. The goal of the ENERGY STAR program is to provide comparisons of building energy efficiency relative to a national peer group, and therefore it is most equitable to employ national-level source-site ratios. Because Portfolio Manager is available in both the United States and Canada, country-specific source-site ratios are used. For each country, there is only one national source-site ratio for each of the primary and secondary fuels in Portfolio Manager, including grid purchases of electricity. Most of the factors are generally similar for the two countries, although the ratio for electricity is lower in Canada due to a higher percentage of hydroelectric power at the national level.

There are a few reasons why national source-site ratios provide the most equitable approach:

1. **Fixed Geography.** The geographic location is fixed for most buildings; there is no opportunity to relocate the building to a region with more efficient electrical production.
2. **Interconnected Grid.** For most buildings, it is not possible to trace each kWh of electricity back to a specific power plant. Across a given utility region, the grid is connected and the electric consumption of a specific building cannot be associated with any individual plant.
3. **Building Focus.** The key unit of analysis for Portfolio Manager is the building. It is the efficiency of the building, not the utility, which is evaluated. Two buildings with identical operation and energy efficiency will receive the same ENERGY STAR score regardless of their geographic location or utility company.[1]

The use of national source-site ratios ensures that no specific building will be credited (or penalized) for the relative efficiency of its utility provider.

[1] Note that two buildings with equivalent energy *efficiency* in two different regions may have different *absolute energy consumption* owing to weather conditions. The ENERGY STAR score accounts for climate differences in this situation, providing an equitable comparison for buildings in different climates. The use of source energy ensures that a building does not receive either a credit or a penalty based on its utility provider.

On-Site Fuel Conversion

The objective of the conversion to source energy is to quantify the total amount of energy, by accounting for conversion, transmission, and distribution losses. When energy conversion occurs on site, the losses (or gains) from this conversion are accounted for in site energy because the building is assessed based on the fuel that is purchased. Conversion of fuel on site can take a variety of forms. At a simple level, this could include combustion of natural gas in a boiler to generate heat. A more complex system may be a Combined Heat and Power (CHP) system, which converts natural gas into both heat and electricity. In the case of either a CHP system or a natural gas boiler, the required input for Portfolio Manager is the natural gas fuel purchase. The efficiency of the energy conversion (by the boiler or CHP system) is reflected in the quantity of natural gas purchased, and the source conversion factor for natural gas accounts for only the transmission and distribution losses.

If the boiler or CHP system produces heat and/or electricity more efficiently than these products can be produced by the utility, then the conversion loss on site is not as great as the conversion loss associated with purchasing those products from a utility. In this case, the building with the efficient CHP system or boiler would use less total energy than a building purchasing equivalent heat and electricity from a utility; hence, the building with the efficient CHP system or boiler will have lower (better) source energy. Sometimes the reverse can be true, and the on-site production will be less efficient. A building with production that is less efficient than the average utility will not score as well as a building purchasing those products from the utility. The efficiency of any specific equipment at a building will depend on proper installation, operation, and maintenance.

Offsite Renewable Electricity Generation

The electric grid includes a variety of renewable sources of electricity, including wind power, solar power, and low-impact hydroelectric power. These renewable sources of energy do not depend on the consumption of any fossil fuels; rather there is conversion of energy directly from sun, wind, or moving water. Although renewable energy is not subject to the same conversion losses as other fuels, an individual building is typically not able to trace each kWh of electricity to a specific power generation plant. Therefore, a building may be located in a utility region that includes multiple forms of electric generation including wind, hydroelectric, and coal but because the grid is interconnected, it is not possible to assign a specific production method to a specific building. Moreover, as noted above, individual buildings do not have control over the available power supply options in their geographic area. Therefore, Portfolio Manager uses national source-site ratios, which reflect the proportion of renewable electric generation on the national grid.

Source energy and the ENERGY STAR score are focused on energy consumption, not the energy supplier or resulting greenhouse gas emissions. The application of a single national electric factor ensures that no particular building is credited or penalized based on its utility provider. By focusing on the *building* rather than the energy supply, the score can help a building owner or manager optimize his or her energy efficiency. Efficiency is the first step to achieving a zero carbon building. Once a building is as energy efficient as possible, the purchase of green power, through either utility green pricing products or Renewable Energy Certificates (RECs), is an option for reducing indirect greenhouse gas emissions and reducing the overall carbon footprint. Portfolio Manager enables tracking of these green power purchases and the corresponding avoided emissions. It is recommended that these purchases be tracked alongside the building energy efficiency (i.e. score), to motivate superior, high performance buildings. Note that the purchase of green power does not make the building itself any more or less efficient in its energy consumption. Hence, green power does not impact the source energy or score calculations. For more information, refer to the Technical Reference on Green Power, at www.energystar.gov/GreenPower.

Onsite Renewable Energy Generation

When renewable energy is produced at a building through solar photovoltaic panels or wind turbines, the goal of the source energy factor is still to account for conversion, transmission, and distribution loses. In this case, there is not an analogous conversion loss because electricity is derived from the sun or the wind, which are not considered discrete organic fuels, such as fossil fuels. In addition, because the electricity is converted on-site, there is no transmission or distribution. Hence, the source-site ratio for on-site solar or wind electricity is 1.0. Because on-site solar and wind do not have the losses that are incurred when electricity is purchased from the grid, the application of these on-site technologies will be associated with lower source energy and higher ENERGY STAR scores.

Timeframe for Updating Source-Site Ratios

The most recent revision of all source-site ratios occurred in 2018. The revisions for Canadian source factors were released in February 2018; the U.S. revisions will be released in August 2018. The source-site ratios computed and applied in Portfolio Manager depend on several characteristics, including the quality of the fuels, the average efficiency of conversion from primary to secondary energy, and the distribution efficiency. Therefore, over time the ratios are expected to change as the national infrastructure and fuel mix evolve. Characteristics that impact the ratios do not change drastically from one year to the next, but may be expected to change over time. Therefore, the ratios for all fuels are reviewed every 3 to 5 years, and updated accordingly. Additionally, specific ratios may be updated as needed to reflect new information, methodologies, or program policies.

SOURCE-SITE RATIOS BY ENERGY TYPE IN THE U.S.

This section presents the specific reference documents and calculations used to derive the source-site ratios for the United States.

Electricity – Grid Purchased

Grid-purchased electricity is a secondary form of energy that is consumed at a building. It is generated through a variety of methods including the burning of fossil fuels (e.g., coal, natural gas, fuel oil), from nuclear plants, and from renewable sources including wind, hydropower, and biomass. The source-site ratio must reflect the losses incurred when these fuels are converted into electricity, and any losses that occur on the electric grid as the electricity is transported to specific buildings.

These values can be computed directly from the Electricity Flow Diagram, included in the Energy Information Administration's Annual Energy Review.[2] As shown in the diagram, the mix of electric production in the United States is approximately 66% fossil fuel, 21% nuclear, and 13% renewable (hydropower, biomass, solar, wind, geothermal). The source-site ratio is calculated as Primary Energy (i.e., the total primary energy involved in electricity generation) divided by Net Generation less Transmission and Distribution (T&D) Losses. This calculation is summarized in ***Figure 5***. As shown, the source-site ratio can be calculated separately for any given year, and varies slightly over time. Because a building in Portfolio Manager can have multiple years of data and buildings have energy data for different time periods, a five-year average is used. The source-site ratio for grid electricity is 3.14.

Figure 5 – U.S. Source-Site Ratio Calculations for Electricity

Year	Primary Energy Consumed for Generation	Net Generation	T&D Losses	Source-Site Ratio
2007	42.09	14.19	1.34	3.28
2008	40.67	14.02	1.04	3.13
2009	38.89	13.49	1.00	3.11
2010	40.26	14.06	1.04	3.09
2011	40.04	14.01	1.04	3.09
Average (2007-2011)				**3.14**

Sample Calculation for 2007: (42.09 / (14.19 – 1.34) = 3.28

Source: Electricity Flow (Figure 8.0) in the Annual Energy Review. Values in Quadrillion Btus (Quads). *http://www.eia.doe.gov/emeu/aer/contents.html*

[2] Every year, the Energy Information Administration publishes the Annual Energy Review at: http://www.eia.doe.gov/emeu/aer/contents.html. This web page also provides links to reports for previous years. Each report contains and Electric Flow Diagram: http://www.eia.gov/totalenergy/data/annual/pdf/sec8_3.pdf

Electricity - On-Site Solar or Wind Electricity

Renewable energy produced at a building through solar photovoltaic panels or wind turbines is a secondary form of energy. With these fuels, there is no conversion loss because electricity is derived from the sun or the wind, which are not considered discrete organic fuels, such as fossil fuels. In addition, because the electricity is converted on-site, there is no transmission or distribution. Hence, the source-site ratio for on-site solar or wind electricity is 1.0.

Natural Gas

Natural gas is a type of primary energy that is burned on-site to produce heat and/or electricity. The source-site ratio must account for losses incurred in pipeline transmission and distribution of natural gas from the provider to the customer. These values are obtained from the Natural Gas Annual, a regular publication of the Energy Information Administration. The source-site ratio can be computed directly from the information in Table 1 of the Natural Gas Annual, Summary Statistics for Natural Gas in the United States.[3] The source-site ratio is obtained first by computing the sum of the delivery to consumers, the pipeline and distribution use, and the plant use, and then dividing this total by the total delivery to consumers. This calculation indicates the total amount of gas that is used at the distribution plant or lost in transmission, for each unit of gas that is delivered to a consumer. As shown in ***Figure 6***, the source-site ratio for natural gas can be calculated separately for any given year, and varies slightly over time. Because a building in Portfolio Manager can have multiple years of data and buildings have energy data for different time periods, a five-year average is used. The source-site ratio for natural gas is 1.05.

Figure 6 – U.S. Source-Site Ratio Calculations for Natural Gas

Year	Sum of Pipeline and Distribution Use, Plant Fuel, and Delivery to Consumers	Sum of Pipeline and Distribution Use, Plant Fuel	Delivery to Consumers	Source-Site Ratio
2007	22,242,749	986,687	21,256,042	1.05
2008	22,412,895	1,003,546	21,409,349	1.05
2009	21,996,848	1,032,183	20,964,665	1.05
2010	23,170,000	1,042,954	22,127,046	1.05
2011	23,446,216	1,067,963	22,378,253	1.05
Average (2001-2005)				**1.05**

Sample Calculation for 2007: (986,687 + 21,256,042 = 22,242,749) / 21,256,042 = 1.05

Source: Table 1. Summary Statistics for Natural Gas in the United States, 2007-2011. Natural Gas Annual. Values in Million cubic feet. Excludes Lease Fuel to be consistent with the method for electricity.
http://www.eia.doe.gov/oil_gas/natural_gas/data_publications/natural_gas_annual/nga.html

[3] Every year the Energy Information Administration publishes the Natural Gas Annual at: http://www.eia.doe.gov/oil_gas/natural_gas/data_publications/natural_gas_annual/nga.html. This web page also provides links to reports for previous years. Each report contains a Table, *Summary Statistics for Natural Gas in the United States* http://www.eia.doe.gov/pub/oil_gas/natural_gas/data_publications/natural_gas_annual/current/pdf/table_001.pdf.

Fuel Oil

Refined petroleum products are a type of primary energy that is burned on-site to produce heat and/or electricity. These products include fuel oil (# 1, 2, 4, 5, 6), diesel, and kerosene. The source-site ratio must account for losses incurred in fuel distribution, storage, and dispensing. EIA does not produce an annual report that quantifies the losses associated with fuel oil distribution, storage and dispensing. However, several other detailed reports were reviewed to explore the lifecycle energy requirements for producing transportation fuels. The most suitable report for the desired estimate was determined to be A Lifecycle Emissions Study (LEM) conducted at the University of California, Davis.[4] From this study, estimates relating to the production and distribution of highway diesel fuel were determined to be the most analogous to the types of heating fuels found in commercial buildings.[5] The LEM study identifies the energy required for distribution and storage, and fuel dispensing, and the relative proportion of this energy use to the total end use. These figures are presented in ***Figure 7***. The proportion of diesel fuel that is used in distribution and storage and fuel dispensing is approximately 1% of the total delivery to customers. Therefore, the source-site ratio for fuel oil is 1.01.

Figure 7 – U.S. Summary of LEM Study Figures for Highway Diesel Fuel

Highway Diesel Fuel Lifecycle	Energy Required (Btu/mile)	Energy Proportion Relative to End Use
Fuel Distribution and Storage	189	0.8%
Fuel Dispensing	45	0.2%
End Use	24,600	100.0%
Total	**24,834**	**101.0%**

Source: Table 51B, LEM Study, p. 400. Excludes feedstock recovery, transmission, and refining to be consistent with the method used for electricity.

Propane

Propane is a fuel that can be generated either as a bi-product of petroleum-refining or natural gas processing. Once created, propane is considered a primary fuel that is burned on-site to produce heat and/or electricity. The source-site ratio must account for losses incurred in fuel distribution, storage, and dispensing. EIA does not produce an annual report that quantifies the losses associated with propane distribution, storage and dispensing. For propane, these losses are considered to be most analogous to those of fuel oil. Therefore, the source-site ratio for propane is 1.01.

District Steam

District steam is a type of secondary energy that is generated off-site and delivered to a facility. The source-site ratio must account for losses that occur when the primary fuel is converted into the secondary form of energy and any losses that occur when the secondary energy is distributed to the facility. District steam is generated using both conventional boiler technology and combined heat and power (CHP) technology. Both systems were incorporated into the source-site ratio to accurately reflect the steam market. Properties of district systems, including ranges for

[4] A Lifecycle Emissions Model (LEM): Lifecycle Emissions from Transportation Fuels, Motor Vehicles, Transportation Modes, Electricity Use, Heating and Cooking Fuels, and Materials, Mark DeLucchi, Institution of Transportation Studies, University of California, Davis, December 2003. Found at: http://repositories.cdlib.org/cgi/viewcontent.cgi?article=1064&context=itsdavis (LEM Study).

[5] Highway diesel fuel is a more refined product than fuel oil that may be used in buildings. However, the primary contributors to the source-site ratio (energy for distribution, storage, and dispensing of the fuel) are expected to be similar.

the production and distribution efficiencies are referenced in a report titled *District Energy Services: Commercial Data Analysis for EIA's National Energy Modeling System.*[6]

An analysis of conventional steam generation is included in ***Figure 8***. Typical boiler efficiencies range from 80% to 85% at full load (i.e. design) conditions. Efficiency at partial load is in the range of 90% to 97% of the design efficiency. To generate a source-site ratio for district steam, production was evaluated at the midpoint of the boiler efficiency range (82.5%) and the high end of the partial load efficiency range (97%), since district heating systems operate at relatively high annual load factors. Once steam is generated, there is heat loss of approximately 6% to 9% associated with distribution. The midpoint of this range (7.5%) was used for analysis. The resulting efficiency of conventional steam production is 74%. This translates to 1.35 kBtu of source energy required to provide 1 kBtu of energy to the building, and a source-site ratio for conventional district steam of 1.35.

Figure 8 – U.S. Source-Site Ratio for Conventional Steam Generation

Input Parameter	Value
Boiler Efficiency	82.5%
Part Load Adjustment	97.0%
Production Efficiency (Boiler Efficiency x Part Load Adjustment)	80.0%
Heating Distribution Losses	7.5%
Efficiency After Heat Loss Production Efficiency – (Distribution Losses * Production Efficiency)	74.0%
Source-Site Ratio for Conventional Steam (1 / Efficiency After Heat Loss)	**1.35**

A separate analysis was performed for CHP district systems, which is summarized in ***Figure 9***. In an average CHP district system, for every 100 units of input energy, 36.2 units of steam are produced and 27.6 units of electricity are produced.[7] This is equivalent to a system-wide conversion efficiency of 64%. It is necessary to isolate the production efficiency for the steam only, in order to determine a source-site factor for CHP district steam systems. To accomplish this, a CHP system can be compared with two traditional systems used to produce the same amount of steam and electricity. Assuming a conversion efficiency of 82.5% for traditional steam and 32% for traditional electricity, 43.9 units of input energy would be needed to produce the same amount of steam and 86.3 units of input energy would be needed to produce the same amount of electricity as the CHP system. The total input energy for the traditional systems would be 130.1. The percent breakdown in the input energy for the traditional systems can be used to equitably divide CHP input energy between the steam and electric products. The ratio of the steam input to total input for the traditional systems (43.9 units / 130.1 units) can be multiplied by the total CHP input energy of 100 units to get the input energy associated with steam generation for the CHP system of 33.7.

The effective production efficiency of steam in a CHP district system can then be expressed as 36.2 units output / 33.7 units input = 107.4%. The value over 100% occurs because of the efficiencies generated with CHP systems. As

[6] Energy and Environmental Analysis, Inc. and International District Energy Association. *District Energy Services: Commercial Data Analysis for EIA's National Energy Modeling System.* Submitted to: Decision Analysis Corporation and Energy Information Administration. August 2007.

[7] EPA and its contractor ICF International derived estimates for CHP efficiency and market share based on analysis of total steam delivery for 54 identified downtown district steam systems. This analysis was an extension and update of the 2007 district steam assessment completed for the Department of Energy's Energy Information Administration. This assessment was completed by the Energy and Environmental Analysis Inc. and the International District Energy Association.

with conventional steam systems, it is necessary to account for losses from the delivery of steam to the facility. The same 7.5% distribution loss can be applied. CHP steam production then delivers heat to a facility with an efficiency of 99.3%. Given this efficiency, it takes 1.01 kBtu of source energy to provide 1 kBtu of energy to the building, resulting in source-site ratio for CHP district steam of 1.01. The lower source-site ratio reflects the efficiency gains associated with using CHP.

Figure 9 – U.S. Source-Site Ratio for Steam Produced by CHP

Input Parameters	CHP Production	Traditional Systems
Total Input Energy	100	130.1
Steam Output	36.2	36.2
Electricity Output	27.6	27.6
Conversion Efficiency (Steam and Electricity Output/Total Input Energy)	64%	49%
Input for Steam (Traditional System = Steam Output/82.5%) (CHP Production based on ratio for Traditional System)	33.7	43.9
Input for Electricity (Traditional System = Electricity Output/32%) (CHP Production based on ratio for Traditional System)	66.3	86.3
Production Efficiency	107.4%	--
Heating Distribution Losses	7.5%	--
Efficiency After Heat Losses	99.3%	--
Source-site Ratio for CHP	**1.01**	**--**

To determine the national district steam source-site ratio, a weighted average of the CHP and non-CHP ratios was taken. CHP systems are growing in market share and now comprise about 43% of the district steam market in the United States. The CHP factor of 1.01 can be multiplied by 43%, and the conventional steam factor of 1.35 can be multiplied by 57%, to get the weighted average ratio. **The national source-site ratio for district steam is 1.20**.

District Hot Water

District hot water is a type of secondary energy that is generated off-site and delivered to a facility. The source-site ratio must account for losses that occur when the primary fuel is converted into the secondary form of energy and any losses that occur when the secondary energy is distributed to the facility. There are few systems in operation that are solely district hot water—most occur in conjunction with district steam systems. Similar to district steam, district hot water can be generated using both conventional boiler technology and CHP technology. An analysis similar to the district steam review was conducted to determine the source-site ratio for district hot water. Heating distribution losses are lower for district hot water systems than for district steam (2.5% vs. 7.5%), but these are offset by losses associated with pumping energy (on the order of 1% of total hot water costs), so on balance the system efficiencies are generally similar. Given the similar performance of steam and hot water, and the prevalence of combined steam and hot water systems, the source-site ratio of 1.20 for district steam is also used for district hot water.

District Chilled Water

District chilled water is a type of secondary energy that is generated off-site and delivered to a facility. The source-site ratio must account for losses that occur when the primary fuel is converted into the secondary form of energy and any losses that occur when the secondary energy is distributed to the facility. District chilled water generation is characterized by two main technologies: electric chillers and steam driven chillers. Both systems were incorporated into the source-site ratio to accurately reflect the market. Properties of district systems, including ranges for the production and distribution efficiencies are referenced in a report titled *District Energy Services: Commercial Data Analysis for EIA's National Energy Modeling System.*[8]

The efficiency of electric chillers can be described in terms of the Coefficient of Performance (COP), the number of units of output cooling to input energy. As illustrated in ***Figure 10***, COP values range from 2.9 to 4.4. Electric chillers will also be subject to a loss of up to 10% due to partial load operation. As such, the COP range is better stated as 2.6 to 4.0, which expresses the net production efficiency. The source-site ratio must also account for the distribution losses, which range from 2% to 3%. Subtracting this percent from the COP values yields a range of 2.5 to 3.9. The midpoint of this range is 3.2. For each kBtu of energy required by the electric chiller, approximately 3.2 kBtu of energy is delivered to the building. The net COP of 3.2 can be re-stated as 0.3125 kBtu of electricity required at the chiller in order to generate 1 kBtu of cooling at the buildings. However, it is important to recall that the Btu requirement to drive the chiller is electric, and electricity is a secondary form of energy. Therefore, in order to quantify the total energy requirement, the energy requirement of the chiller must be multiplied by the source-site ratio for electricity (which is 3.14). Thus for electric chillers, the source-site ratio is 0.98.

Figure 10 – U.S. Source-Site Ratio for Electric Chillers

Input Parameters	Low End	High End
Chiller COP	2.9	4.4
Part Load COP	2.6	4.0
COP Including Distribution Losses	2.5	3.9
Average COP	3.2	
Electricity Input to Chiller (kBtu) for 1 kBtu On-Site Cooling (1/COP)	0.3125	
Source Energy Input to Chiller (kBtu) for 1 kBtu On-Site Cooling (Electricity Input x Source-Site Ratio for Electricity)	0.98	
Source-Site Ratio for Electric Chillers	**0.98**	

Steam-driven chillers, often fired by natural gas, constitute a much smaller portion of total chilled water generation. As shown in ***Figure 11***, these chillers are typically characterized by COP values of 0.7 to 1.4, indicating that 0.7 to 1.4 Btu of energy is provided for every Btu of natural gas that is consumed. Actual operation is typically at partial load, which will reduce the production COP to 0.6 to 1.3. As with electric chillers, the distribution losses are estimated to be 2% to 3%. Subtracting these losses from the COP values yields a range of 0.6 to 1.2; the middle of this net range is 0.9, indicating that for each Btu of gas required by the chiller, 0.9 Btu are delivered to the building. The net COP of 0.9 can be restated as 1.11 kBtu of natural gas required at the chiller in order to generate 1 kBtu of cooling at

[8] Energy and Environmental Analysis, Inc. and International District Energy Association. *District Energy Services: Commercial Data Analysis for EIA's National Energy Modeling System.* Submitted to: Decision Analysis Corporation and Energy Information Administration. August 2007.

the buildings. Because natural gas is a form of primary energy, an additional source-site calculation is not required. This primary energy consumption occurs at the power plant and therefore is not subject to the same distribution losses as at a commercial building.

Figure 11 – U.S. Source-Site Ratio for Steam-Driven Chillers

Input Parameters	Low End	High End
Chiller COP	0.7	1.4
Part Load COP	0.6	1.3
COP Including Distribution Losses	0.6	1.2
Average COP	0.9	
Natural Gas Input to Chiller (kBtu) for 1 kBtu On-Site Cooling (1/COP)	1.11	
Source-Site Ratio for Steam-Driven Chillers	**1.11**	

Although the exact technology breakdown between steam-driven and electric chillers is not well documented by either EIA or IDEA, electric chillers are known to be the dominant technology. The electric chilled water source-site ratio is 0.98, while the natural gas chilled water source-site ratio is 1.11. Assuming as much as 10 to 20% of chilled water comes from natural gas; the average ratio across the two technologies is 1.0. Therefore, **the source-site ratio for district chilled water is 1.0.**

Wood

Wood is a type of primary energy that is combusted on site to produce heat and/or electricity. The source-site ratio must account for any losses that occur in the storage, transportation, and delivery of wood to the building. There are not considered to be any transmission or distribution losses associated with the delivery of wood to a site. Therefore, the source-site ratio for wood is 1.0.

Coal

Coal is a type of primary energy that is burned on-site to produce heat and/or electricity. The source-site ratio must account for any losses that occur in the storage, transportation and delivery of coal to a building. There is no direct quantifiable loss of coal that occurs when it is stored, transported, or delivered to a facility. Therefore, the source-site ratio for coal is 1.0.

Other

Portfolio Manager includes the capacity for many types of fuels, each of which falls into one of the preceding categories. In the event that a building using a different fuel on-site (e.g., waste biomass), then a user may select the "Other" category. In these situations, because the primary fuel source is not reported, it is not possible to quantify losses associated with conversion, transportation, or distribution. Hence, the source-site ratio is 1.0.

SOURCE-SITE RATIOS BY ENERGY TYPE IN CANADA

This section presents the specific reference documents and calculations used to derive the source-site ratios for Canada.

Electricity – Grid Purchased

Grid-purchased electricity is a secondary form of energy that is consumed at a building. It is generated through a variety of methods including the burning of fossil fuels (e.g., coal, natural gas, fuel oil), from nuclear plants, and from renewable sources including wind, hydropower, and biomass. The source-site ratio must reflect the losses incurred when these fuels are converted into electricity, and any losses that occur on the electric grid as the electricity is transported to specific buildings. These values are determined using data from Statistics Canada on electric power generation. The mix of electric production in Canada is approximately 18% fossil fuel, 16% nuclear, and 66% renewable (hydropower, biomass, solar, wind, geothermal). The source-site ratio is calculated as Fuel Consumed for Power Generation and Amount Generated with Renewables (i.e., the total primary energy involved in electricity generation) divided by Electricity Sold to Customers and Net Exports. This calculation is summarized in ***Figure 12***. As shown, the source-site ratio can be calculated separately for any given year, and varies slightly over time. Because a building in Portfolio Manager can have multiple years of data and buildings have energy data for different time periods, a five-year average is used. The source-site ratio for grid electricity in Canada is 1.96.

Figure 12 – Canadian Source-Site Ratio Calculations for Electricity

Year	Fuel Consumed for Power Generation + Amount Generated with Renewables	Electricity Sold to Customers + Net Export	Source-Site Ratio
2011	3,695,715	1,797,740	2.06
2012	3,613,467	1,843,690	1.96
2013	3,679,888	1,915,476	1.92
2014	3,693,315	1,906,819	1.94
2015	3,693,557	1,909,317	1.93
Average (2011-2015)			**1.96**

Sample Calculation for 2011: (3,695,715 / 11,797,740) = 2.06

Source: Statistics Canada, Table 127-0004, Table 127-0007, and Table 127-0008. Values displayed in Terajoules. http://www5.statcan.gc.ca/cansim

Electricity - On-Site Solar or Wind Electricity

Renewable energy produced at a building through solar photovoltaic panels or wind turbines is a secondary form of energy. With these fuels, there is no conversion loss because electricity is derived from the sun or the wind, which are not considered discrete organic fuels, such as fossil fuels. In addition, because the electricity is converted on-site, there is no transmission or distribution. Hence, the source-site ratio for on-site solar or wind electricity is 1.0.

Natural Gas

Natural gas is a type of primary energy that is burned on-site to produce heat and/or electricity. The source-site ratio must account for losses incurred in pipeline transmission and distribution of natural gas from the provider to the customer. These values are obtained using data from Statistics Canada on natural gas supply. The source-site ratio can be computed directly from the information in Table 131-0001, Supply and Disposition of Natural Gas, Monthly. The source-site ratio is obtained by dividing the total net disposition by the sum of deliveries, exports, and utility sales. As shown in ***Figure 13***, the source-site ratio for natural gas can be calculated separately for any given year, and varies slightly over time. Because a building in Portfolio Manager can have multiple years of data and buildings have energy data for different time periods, a five-year average is used. The source-site ratio for natural gas in Canada is 1.01.

Figure 13 – Canadian Source-Site Ratio Calculations for Natural Gas

Year	Net Disposition	Deliveries + Exports + Direct Sales + Utility Sales	Source-Site Ratio
2011	211,976	206,195	1.03
2012	207,016	203,793	1.02
2013	200,862	197,204	1.02
2014	194,386	193,699	1.00
2015	191,493	191,649	1.00
Average (2011-2015)			**1.01**

Sample Calculation for 2011: (211,976 / 206,196) = 1.03

Source: Statistics Canada, Table 131-0001. Values in Million cubic meters. http://www5.statcan.gc.ca/cansim

Fuel Oil

Refined petroleum products are a type of primary energy that is burned on-site to produce heat and/or electricity. These products include fuel oil (# 1, 2, 4, 5, 6), diesel, and kerosene. The source-site ratio must account for losses incurred in fuel distribution, storage, and dispensing. These values are obtained using data from Statistics Canada on fuel oil supply. The source-site ratio can be computed directly from the information in Table 134-0004, Supply and Disposition of Refined Petroleum Products, Monthly. The source-site ratio is obtained by dividing the total refinery production by the refinery production minus own consumption, where own consumption represents all amounts of product produced or purchased and used in company operations. The figures presented in ***Figure 14*** are the combined results for light fuel oil, heavy fuel oil, kerosene, and diesel. The source-site ratio for fuel oil in Canada is 1.01.

Figure 14 – Canadian Source-Site Ratio Calculations for Fuel Oil

Year	Total Refinery Production	Refinery Production - Own Consumption	Source-Site Ratio
2011	42,640,710	42,341,682	1.01
2012	44,273,371	44,001,588	1.01
2013	x	x	x
2014	x	x	x
2015	x	x	x
Average (2011-2015)			**1.01**

Sample Calculation for 2011: (42,640,710 / 42,341,682) = 1.01

Source: Statistics Canada, Table 134-0004. Values in Million cubic meters. http://www5.statcan.gc.ca/cansim

x: Values are suppressed from 2013 – 2015 to meet the confidentiality requirements of the Statistics Act and are therefore not used in the calculation.

Propane

Propane is a fuel that can be generated either as a bi-product of petroleum-refining or natural gas processing. Once created, propane is considered a primary fuel that is burned on site to produce heat and/or electricity. The source-site ratio must account for losses incurred in fuel distribution, storage, and dispensing. These values are obtained using data from Statistics Canada on propane supply. The source-site ratio can be computed directly from the information in Table 128-0012, Supply and Demand of Natural Gas Liquids, Annual. The source-site ratio is obtained by dividing the total production by the total production minus producer consumption. This calculation is summarized in ***Figure 15***. The source-site ratio for propane in Canada is 1.04.

Figure 15 – Canadian Source-Site Ratio Calculations for Propane

Year	Total Production	Total Production - Producer Consumption	Source-Site Ratio
2011	x	x	x
2012	x	x	x
2013	254,915	245,430	1.04
2014	257,968	250,540	1.03
2015	254,680	245,582	1.04
Average (2011-2015)			**1.04**

Sample Calculation for 2013: (254,915 / 245,430) = 1.04

Source: Statistics Canada, Table 128-0012. Values in Terajoules. http://www5.statcan.gc.ca/cansim

x: Values are suppressed from 2011 – 2012 to meet the confidentiality requirements of the Statistics Act therefore unused in the calculation

District Steam

District steam is a type of secondary energy that is generated off-site and delivered to a facility. Efficiencies for district steam systems are similar in Canada and in the U.S. As a result, the source-site ratio for district steam in Canada is computed using the same efficiency calculations for each specific type of system. See the section on U.S. source-site ratios for details. However, further research was conducted on the market share of combined heat and power (CHP) systems in Canada. CHP systems comprise about 7% of the district steam market in Canada (vs. 43% in the U.S.) based on estimates derived from the Canadian Industrial Energy End-Use Data and Analysis Centre (CIEEDAC) District Energy Inventory for Canada, 2014 (published March 2016). **Therefore, the national source-site ratio for district steam in Canada is 1.33.** Note that values used for Canada are based on updated U.S. efficiency calculations that will be available in the August 2018 technical reference guide.

District Hot Water

District hot water is a type of secondary energy that is generated off-site and delivered to a facility. Given the similar performance of steam and hot water, and the prevalence of combined steam and hot water systems, the source-site ratio of 1.33 for district steam is also used for district hot water. See the section on U.S. source-site ratios for details. **The source-site ratio for district hot water in Canada is 1.33.**

District Chilled Water

District chilled water is a type of secondary energy that is generated off-site and delivered to a facility. The source-site ratio must account for losses that occur when the primary fuel is converted into the secondary form of energy and for any losses that occur when the secondary energy is distributed to the facility. District chilled water is generated by three main technologies in Canada: electric chillers, deep water source cooling and steam-driven chillers. All three systems were incorporated into the source-site ratio to accurately reflect the market.

The efficiency of electric chillers in Canada described in terms of the Coefficient of Performance (COP) was computed using U.S. calculations (see the section on U.S. district chilled water source-site ratios for details). The types of district chilled water systems and typical efficiencies are similar in Canada. However, the source-site ratio for electricity, which is different in Canada, is incorporated into the calculation.

Figure 17 – Canadian Source-Site Ratio for Electric Chillers

Input Parameters	Value
Electricity Input to Chiller (kBtu) for 1 kBtu On-Site Cooling (1/COP)	0.3125
Source Energy Input to Chiller (kBtu) for 1 kBtu On-Site Cooling (Electricity Input x Source-Site Ratio for Electricity)	0.61
Source-Site Ratio for Electric Chillers	**0.61**

Deep water source cooling is more prevalent in Canada than in the U.S. In Canada, deep water sources are used as heat sinks. The average COP range was estimated on an annual basis based on industry data and takes into account system distribution losses (about 1.5%) and part-load impacts. The input energy accounts for all energy required in a deep water source cooling system, including pumping energy, back-up chillers and any auxiliary energy use.

Figure 18 – Canadian Source-Site Ratio for Deep Water Source Cooling

Input Parameters	Low End	High End
Average Range for Deep Water Cooling System COP	8	12
Average System COP	10	
Source Energy Input to Deep Water Source Cooling system (kBtu) for 1 kBtu On-Site Cooling (1/COP x Fuel % x Source-Site Ratio for Input Fuel)	0.15	
Source-Site Ratio for Deep Water Source Cooling	**0.15**	

Steam-driven chillers, often fired by natural gas, constitute a much smaller portion of total chilled water generation. The efficiency of steam-driven chillers in Canada described in terms of the COP was computed using U.S. calculations (see the section on U.S. district chilled water source-site ratios for details). The types of district chilled water systems and typical efficiencies are similar in Canada. However, the source-site ratio for natural gas, which is slightly different in Canada, is incorporated into the calculation.

Figure 19 – Canadian Source-Site Ratio for Steam-Driven Chillers

Input Parameters	Low End	High End
Average COP	0.9214	
Natural Gas Input to Chiller (kBtu) for 1 kBtu On-Site Cooling (1/COP)	1.09	
Source-Site Ratio for Steam-Driven Chillers	**1.10**	

Although there is limited available data through CIEEDAC or IDEA providing the exact technology breakdown between electric chillers, deep source water cooling and steam-driven chillers, electric chillers are known to be the dominant technology, followed by deep water source cooling and steam-driven chillers. The electric chilled water source-site ratio is 0.61, the deep water source cooling source-site ratio is 0.15, and the natural gas-fired, steam-driven chilled water source-site ratio is 1.10. Based on limited available data, we deduced that about 80% of district chilled water comes from electric chillers, about 15% from deep water source cooling and about 5% from steam-driven chillers. The weighted average ratio across the three technologies is 0.57. Therefore, **the source-site ratio for district chilled water is 0.57.**

Wood

Wood is a type of primary energy that is combusted on site to produce heat and/or electricity. The source-site ratio must account for any losses that occur in the storage, transportation, and delivery of wood to the building. There are not considered to be any transmission or distribution losses associated with the delivery of wood to a site. Therefore, the source-site ratio for wood is 1.0.

Coal

Coal is a type of primary energy that is burned on-site to produce heat and/or electricity. The source-site ratio must account for any losses that occur in the storage, transportation and delivery of coal to a building. There is no direct quantifiable loss of coal that occurs when it is stored, transported, or delivered to a facility. Therefore, the source-site ratio for coal is 1.0.

Other

Portfolio Manager includes the capacity for many types of fuels, each of which falls into one of the preceding categories. In the event that a building using a different fuel on-site (e.g., waste biomass), then a user may select the "Other" category. In these situations, because the primary fuel source is not reported, it is not possible to quantify losses associated with conversion, transportation, or distribution. Hence, the source-site ratio is 1.0.