TECH CORNER

U.S. Grid-Electricity Source Energy Factor for phius 2021

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Phius 2021 certification modeling will use a future source energy factor for electricity generation to reflect future grid conditions more appropriately and to better weigh the impact of electricity versus natural gas use on site. The calculated factor for the United States is 1.80 for grid electricity, which reflects a 2050 outlook. The calculation methodology is described in detail below.

Background

In past versions of PHIUS+, the source-site ratio for grid electricity was defined by the Energy Star Portfolio Manager and was determined based on past generation and consumption data from the EIA (Energy Information Administration). The calculation methodology accounts for the total primary fuel needed to deliver heat and electricity to the site, including conversion losses at the plant as well as transmission and distribution losses incurred to deliver electricity to the building.

Under PHIUS+ 2018, the source-to-site ratio for grid electricity for the US was 2.80, which was an average of the EIA reported data from 2012-2016, as shown in Table 1.

Table 1: *U.S Source-Site Ratio Calculations for Electricity*

Year	Primary Energy Consumed for Generation	Net Generation	T&D Losses	Source-Site Ratio
2012	35.08	13.27	0.90	2.83
2013	35.16	13.32	0.87	2.82
2014	35.34	13.43	0.83	2.80
2015	34.62	13.37	0.83	2.76
2016	34.10	13.37	1.01	2.76
Average (2012-2016)				**2.80**

Sample Calculation for 2012: 35.08 / (13.27 – 0.90) = 2.83

Geographic Scale for Source-Site Ratios

For phius certification, the source energy factor will continue to be a national average.

The goal of phius certification is to provide design guidance and set performance targets for buildings. Because the source energy target does not change based on the building's location, it is most appropriate to use national-level source-site ratios.

Rationale: Excerpt from Energy Star Portfolio Manager:

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.

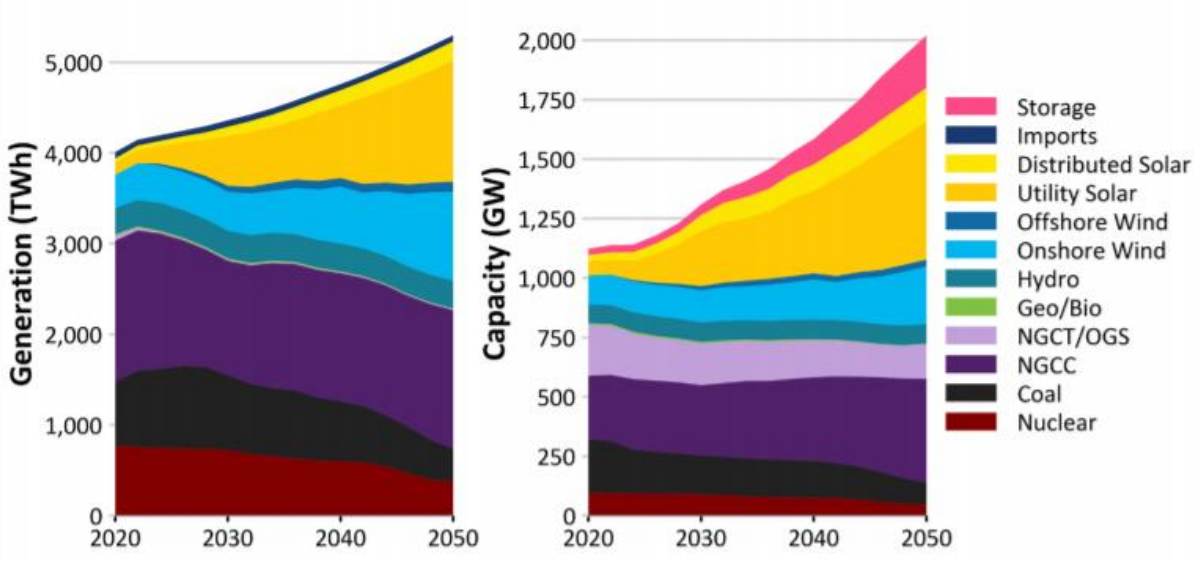
3. Building Focus. The key unit of analysis is the building. It is the efficiency of the building, not the utility, which is evaluated. Under this approach, two buildings with identical operation and energy efficiency will receive the same source energy result regardless of their geographic location or utility company. 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.

Calculation Methodology

The calculation for a future source energy factor for the United States required the combination of three data sources: (1) the projected future electricity generation mix, (2) fuel conversion energy factors per generation type, and (3) total system losses from transmission, distribution and storage.

Part 1: Electricity Generation Mix

The future electricity generation mix scenario is taken from research from the National Renewable Energy Laboratory (NREL), the 2020 Standard Scenarios Report: A U.S. Electricity Sector Outlook. This report publishes data on 45 forward looking grid scenarios, studying the impact of future



variables (such variation in fuel cost, high or low renewable energy costs, etc.) relative to a reference case. The reference or default case is titled the 'Mid-Case Scenario' and reports on future grid generation and capacity mixes projected out to 2050 **based on policies that were in place as of June 30, 2020.**

The projections are done on a state-by-state level. The state-by-state projected generation for the year 2050 was summed to arrive at the total generation mix at the national scale. This was used to determine the percentage of the annual electricity generation that will be covered by each generation type as shown in Table 2.

Table 2: Projected 2050 U.S. Electric Grid Generation Mix

Generation Type	**Generation (TWh)**	**Percentage of Total Generation Mix** *(including storage)*
Biopower	7.01	0.1%
CSP	0.00	0.0%
Coal	347.06	6.8%
Geothermal	26.49	0.5%
Hydro	282.42	5.6%
Imports	67.35	1.3%
Land-based Wind	950.45	18.7%
Natural Gas - Combined Cycle	1526.44	30.1%
Natural Gas - Combustion Turbine	11.56	0.2%
Nuclear	377.57	7.4%
Offshore Wind	111.56	2.2%
Oil-Gas-Steam	0.00	0.0%
Rooftop PV	209.05	4.1%
Storage	-160.81	-3.2%
Utility PV	1321.92	26.0%

While the NREL report does provide estimated CO_2 emissions associated with the projected generation mix per state, it does not provide source energy factors. Therefore, other informational resources were utilized to convert the predicted electricity generation mix to a national source energy factor.

Part 2: Fuel Conversion Energy Factors

The next step to convert generation type to a source energy factor is to use fuel conversion factors. The EIA has published heat rate factors for all non-renewable generation types published in NREL's future projected grid mix. Heat rates vary based on the efficiency of the conversion process of the

equipment. Therefore, a single fuel type (i.e. natural gas) has a different heat rate for combined cycle versus combustion turbine due to varying equipment used for the conversion of fuel to electricity.

The EIA data provides the last 10 years of Average Tested Heat Rates by Prime Mover and Energy Source. There have been very minor improvements in efficiency of electricity generation in the past 10 years. The reported heat rate factors from the past 5 years of available data (2014-2018) were averaged and that average value was used as a more forward-looking approach. The heat rate values per generation type are shown in Table 3.

Table 3: Fuel Conversion Rates used for each Generation Type

Generation Type	Heat Rate (BTU/kWh)	Fuel Conversion Factor
Biopower	N/A	1
CSP	N/A	1
Coal	10,048	2.95
Geothermal	N/A	1
Hydro	N/A	1
Imports	N/A	1.83
Land-based Wind	N/A	1
Natural Gas – Combined Cycle	7,648	2.242
Natural Gas – Combustion Turbine	11,242	3.295
Nuclear	10,458	3.065
Offshore Wind	N/A	1
Oil-Gas-Steam	10,202	2.990
Rooftop PV	N/A	1
Storage	N/A	N/A
Utility PV	N/A	1

The heat rate, expressed in BTU/kWh, can be expressed as an energy conversion factor by converting to a unitless metric. This is done by dividing by 3412 kWh/BTU as shown in the chart above. It is assumed that all renewable energy resources have a fuel conversion factor of 1.

The electricity from the 'imports' category comes from Canada. Therefore, the conversion factor for imported electricity is estimated based on the reported source energy factor of 1.96 from the 2020 Energy Star Portfolio Manager report. In the report, it is estimated that roughly 6.55% of that is due to transmission and distribution losses, and therefore the fuel conversion factor alone is estimated as (1.96*1-0.0655) = 1.83.

Energy storage is categorized as a generation source in the future generation mix but its contribution is a negative number. This is accounting for the loss of storing energy and then dispatching it later. For example, the typical round-trip efficiency for battery storage is 80%. The negative contribution is -3.17%, and this will be factored into the next conversion step below.

Part 3: System Losses - Transmission, Distribution & Storage

The last variable needed to calculate a source energy factor based on generation type is the system wide losses that consist of transmission and distribution (T&D) and energy storage.

Transmission and Distribution

The Energy Star Portfolio Manager data shown in Table 1 reports T&D losses per year for 2012-2016. The average of these years is 6.65%. However, minor grid improvements have been made since then. The Emissions & Generation Resource Integrated Database (eGRID) reports more recent data, from 2018, that is broken down into the various interconnects. According to eGRID2018, the US average transmission and distribution loss is 4.87%. This value was used for the transmission and distribution loss assumption for the future scenario.

Table 4: eGRID2019 Grid Gross Loss (%)

Power Grid	Grid Gross Loss (%)
Eastern	4.88%
Western	4.80%
ERCOT	4.87%
Alaska	5.12%
Hawaii	5.14%
U.S.	**4.87%**

Energy Storage

The energy storage losses from the 2020 NREL Mid-Case Scenario future generation mix scenario is reported as -3.17% of the total mix. This was categorized as a total system loss in the calculation.

These two loss factors were combined to reach a total system loss of $(4.87 + 3.17) = 8.04\%$.

Calculation Methodology Summary:

Step 1: Use NREL's mid-case scenario for the US national grid mix in 2050 to determine the generation type mix.
Step 2: Use the EIA heat rate values to account for conversion of fuel to electricity based on generation type.
Step 3: Use eGRID2018 data for national transmission and distribution loss and the NREL mid-case scenario data from Step 1 for energy storage losses to determine system wide losses.
Step 4: Calculate using the factors above.

4a. Assign a fuel conversion rate to each generation type.

4b. Take the value for each generation type from 4a above and divide by (1-system conversion loss %) to determine the source energy factor per generation type.
4c. Multiply the calculated source energy factors per generation type in 4b by the predicted percentage each type is projected in the mix.
4d. Sum the result of each type to estimate a US national average electricity grid source energy factor of 1.8 for 2050.

Table 5: Calculated Source Energy Factors per Generation Type and for U.S. Average

Step 4	*Step 4a*	*Step 4b*		*Step 4c*
Generation Type	**Fuel Conversion Factor**	**Source Energy Factor**	**Percentage of Total Generation Mix** *(excluding storage)*	**Weighted SE Factor of Total**
Biopower	1	1.09	0.1%	0.00
CSP	1	1.09	0.0%	0.00
Coal	2.95	3.20	6.6%	0.21
Geothermal	1	1.09	0.5%	0.01
Hydro	1	1.09	5.4%	0.06
Imports	1.83	1.99	1.3%	0.03
Land-based Wind	1	1.09	18.1%	0.20
Natural Gas - Combined Cycle	2.24	2.44	29.1%	0.71
Natural Gas - Combustion Turbine	3.29	3.58	0.2%	0.01
Nuclear	3.07	3.33	7.2%	0.24
Offshore Wind	1	1.09	2.1%	0.02
Oil-Gas-Steam	2.99	3.25	0.0%	0.00
Rooftop PV	1	1.09	4.0%	0.04
Utility PV	1	1.09	25.2%	0.27
TOTAL				1.80