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How Is Primary Energy Defined and Used?

SUMMARY

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Morgan Smith
Analyst in Energy Policy

A fundamental consideration in energy policy debates is the amount of primary energy—from oil, coal, nuclear power, renewables, and other resources—produced and consumed in the United States and throughout the world. However, defining and measuring primary energy requires making a variety of assumptions and calculations that may vary based on the technologies and applications being assessed.

Primary energy is defined as the first usable energy produced from an energy source after its extraction from nature—that is, the amount of energy first available for practical use. Primary energy can take the form of heat generated by the combustion of various fuels (reported in British thermal units, or Btu) or of electricity generated from some renewable energy (RE) resources (reported in kilowatt-hours, or kWh). A calculation of primary energy can measure the energy consumed for a given application, including all the energy consumed in all the previous steps needed to make the energy available for that application.

Calculations of primary energy are used to compare national and international energy statistics; compare the contributions of various energy sources to meet energy demands; calculate the efficiency of energy use and energy losses; and calculate contributions to energy savings for clean energy standards, energy tax credits, or energy efficiency targets. Primary energy consumption in the United States varies from year to year but has on average been declining since 2000. In 2023, the United States consumed 93.59 quadrillion Btu of primary energy: 38% derived from petroleum, 36% from natural gas, and 9% each from nuclear power, coal, and RE resources. Those renewable resources included 5.4% from biomass, 1.6% from wind, 1.0% from solar, 0.9% from hydroelectric, and 0.1% from geothermal.

A variety of challenges and considerations go into calculating primary energy for various energy technologies and end use applications. The increasing use of RE technologies such as solar, wind, and hydroelectric power are creating one such challenge, because they do not consume fuel for their operation. When these RE technologies generated a relatively small fraction of U.S. electricity, the U.S. Energy Information Administration (EIA) calculated their primary energy value based on the average heat rate—the electricity generated per unit of fuel consumed—of the U.S. fleet of fossil fuel-powered generators. In 2023, EIA determined that—since RE technologies generated a larger fraction of U.S. electricity—it was less appropriate to base the calculation of RE's primary energy on thermal power plant efficiencies. EIA now bases the calculation directly on the kilowatt-hours of electricity generated.

Other challenges and considerations for the calculation and use of primary energy include the aging of various electricity generators (and their resulting decreased efficiencies), the changing mix of generator technologies in the U.S. fleet, the theoretical and as-designed efficiencies of existing or newly designed generators, and the various inefficiencies in energy delivery systems—including the national power grid, fuel pipelines, and other energy delivery networks. Primary energy is important to determining and comparing energy sources and technologies for various economic sectors, including manufacturing and food processing; for developing and implementing policies on energy efficiency for buildings and equipment; and for developing and implementing policies for technologies such as electric vehicles and heat pumps.

Topics for possible congressional consideration related to the definition and use of primary energy calculations could include

- specifying the type of approach to primary energy accounting the U.S. Department of Energy uses in the appliance and equipment standards program;
- specifying the type of approach to primary energy calculations used in renewable or clean energy standards, energy efficiency standards, or energy tax credit programs;
- specifying the type of approach to primary energy calculations used in international agreements and cooperation—including U.S. commitments and contributions to greenhouse gas emissions reductions—or in trade policy;
- how or whether primary energy calculations are incorporated into federal energy incentives; and
- sharing primary energy best practices and analysis methods to support states in their policy developments.

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Primary energy is defined as the first usable energy produced from an energy source after its extraction from nature—that is, the amount of energy first available for practical use. Examples of primary energy sources include coal, natural gas, biomass, biofuels, nuclear fuel, sunlight, and wind. These sources contain energy—in their chemical or nuclear bonds, in photons, or as kinetic energy—but that energy is not in a form that is readily usable. A fundamental consideration in energy policy debate is the amount of primary energy produced and consumed in the United States and throughout the world.

Measuring primary energy can involve complex assumptions and calculations. This report briefly explains those complexities, describes how statistics about primary energy are used in formulating energy policy, and discusses potential considerations for Congress.

Introduction to Primary Energy

A calculation of primary energy can measure the energy consumed for a given purpose, including all the energy consumed in the various steps needed to make the energy available for use. Primary energy is often employed to assess large-scale uses of energy—for example, assessing all energy consumed to generate electricity for the power grid or calculating how much energy might be saved if all residential lighting applications switched to LED lamps.

As its name suggests, primary energy is the first stage in a series of stages at which the energy available for use can be calculated. The later stages of this series are *secondary*, *tertiary* (in some cases), *final*, and *useful* energy. Some (but not all) energy conversion pathways include a tertiary stage. For example, coal may be converted to a synthetic gas, which can be converted to electricity at a power plant. In this example, coal is the primary, synthetic gas is the secondary, and electricity is the tertiary energy form. Final energy is the amount of energy delivered to the end user, and useful energy is the amount of energy that is actually applied to the end use.

For any given application, one can calculate any or all of these energy stages. For the LED lamp example, the amount of primary energy would be the total energy consumed to generate the electricity needed to power a given number of lamps. Secondary energy would be how much electricity was actually generated. Final energy would be how much electricity was actually delivered to all the lamps. Useful energy would be how many lumen-hours of energy all the lamps emit.[1]

Following the first law of thermodynamics, no energy is destroyed when converting energy from one stage to the next (i.e., from one form of energy to the next). However, *usable* energy is lost with each conversion—often in the form of waste heat.[2] Thermal forms of energy also degrade, per the second law of thermodynamics, such that the energy becomes less useful for making electricity as the temperature decreases. Therefore, there is always less usable energy in later stages of the series—less in the secondary than in the primary energy stage, still less in the final energy stage, and the least amount in the useful energy stage.

[1] The *lumen* is the International System of Units (SI) metric for the rate of light-giving energy radiating from a lamp.

[2] The waste heat generated by earlier conversion or transfer processes is excluded when calculating the energy available at a given stage. For example, the waste heat from a natural gas power plant is excluded from the calculation of electricity generated as secondary energy. The energy losses during transmission and distribution in the power grid are excluded from the calculation of electricity delivered as final energy to homes or businesses. The waste heat from a lamp is excluded when calculating the light emitted as usable energy by the lamp.

Calculating Primary Energy

To calculate primary energy, first the form of that energy must be defined. Measures of primary energy include

- heat (in British thermal units, or Btu) generated by the combustion of fossil fuels such as coal, natural gas, or oil; from the combustion of biomass; or generated by the reaction of nuclear fuel; and
- electricity (in kilowatt-hours, or kWh) generated by solar photovoltaic (PV), solar thermal, wind, geothermal, hydropower, or marine generators.[3]

Calculations of primary energy incorporate various assumptions and boundary conditions. First, the calculation of primary energy includes all upstream energy—that is, all the energy from the energy sources, whether it was applied to any given application or lost as waste in previous conversions. Second, the calculation does not include energy expended to extract the sources from nature (for example, it would not include energy used in mining the coal). Third, the calculation does not consider any further downstream effects or losses.

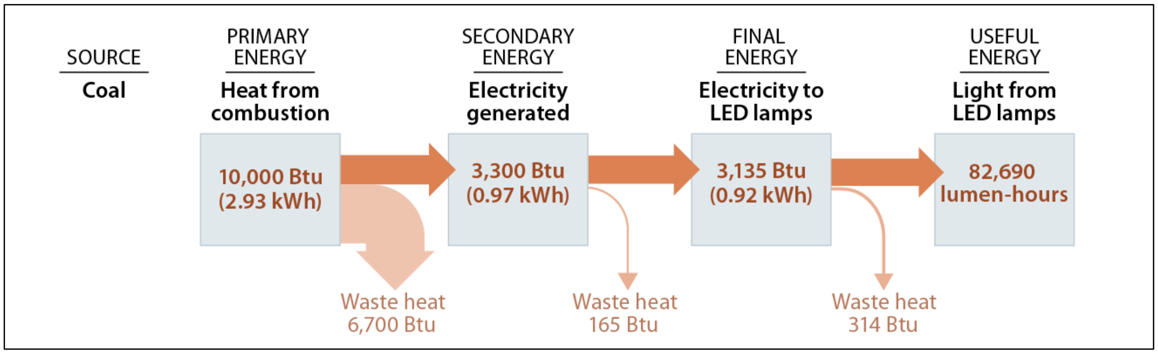
Calculations of the amount of primary energy consumed to generate electricity for the grid would incorporate the inefficiencies of the various generators' technologies used to convert the energy from the fuels to electricity. Any inefficiencies in the electrical transmission and distribution systems are not included, because those are downstream. The calculation of primary energy consumed in LED lamps includes the generation losses and those electricity transmission and distribution losses associated with delivering the electricity to the lamps. Additionally, the inefficiencies of the lamp technology itself are included.[4] An illustration of the energy stages from primary energy through useful energy is provided in **Figure 1**.

[3] Based on the general definition of primary energy, electricity from solar and wind generators would normally be considered secondary energy, since the primary forms—solar energy and kinetic wind energy—would not be practically usable. In October 2023, the U.S. Energy Information Administration (EIA) changed the way it calculates primary energy for these noncombustible renewable energy sources. Now the generated electricity is considered the primary energy. Similarly, though solar thermal and geothermal power generate heat, EIA defines the generated electricity to be the primary energy form. For more details on this change, see "Primary Energy in the Electric Power Sector."

[4] Calculating the usable energy for lamps would include only the energy, in lumens, of the output light—upstream losses would be calculated as part of the lamp's consumption of primary energy.

Figure 1. Illustration of Energy Stages from Primary Energy Through Useful Energy

(from coal to LED lamps)



Source: CRS starting from an example of 10,000 Btu using average efficiency values for the various stages.

Notes: Primary energy excludes energy used to produce coal. Btu = British thermal units; kWh = kilowatt-hours. One kWh is equivalent to 3,412 Btu.

The calculation of secondary energy is similar to the calculation of primary energy, but it calculates the amount of energy available one stage downstream from primary. Electricity as available to the grid is secondary energy when it has been converted from the primary energy source, such as coal or natural gas. Other secondary energy forms include gasoline, charcoal, and hydrogen.

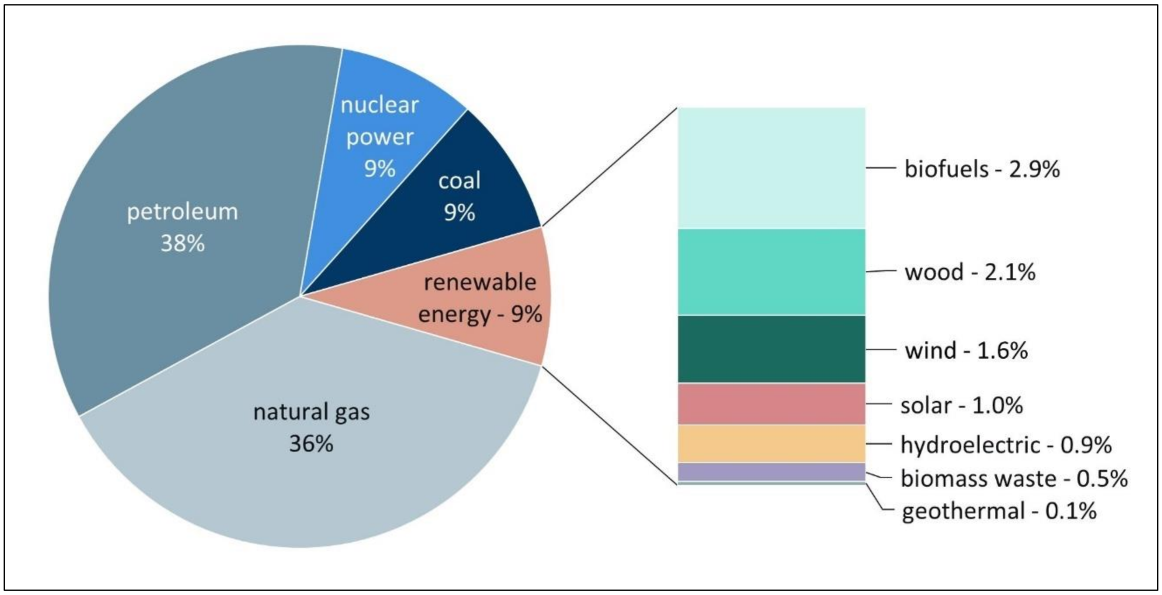
The classification of some forms of secondary energy can be challenging because they may appear to overlap with the other stages. Electricity generated by solar PV or wind generators is considered primary energy, but once it is transmitted to the grid and delivered elsewhere, it is secondary energy. Additionally, other conversion processes have additional considerations for this classification. For example, in some processes coal is turned into synthetic gas or biomass is converted into biofuels. The energy embodied in the synthetic gas or the biofuel is secondary energy. If those secondary forms are combusted at a power plant to generate electricity, the energy in the resulting electricity is considered tertiary energy. If the secondary forms are not combusted for electricity, but are instead distributed to end users, the energy they contain, as delivered to the customer, is final energy.

How Calculations of Primary Energy Are Used

While calculations of each of the stages of energy transformation from primary to useful can provide valuable analysis for energy demand and consumption, primary energy calculations provide the highest-level, most comprehensive assessment of energy consumption and production. Primary energy calculations are used to

- compare national and international energy statistics (see **Figure 2**);
- compare the contributions of various energy sources to meeting energy demands;
- calculate the efficiency of energy conversions; and
- calculate contributions to energy savings for potential policy options, including clean energy standards, energy tax credits, or energy efficiency targets.

Figure 2. U.S. Primary Energy Consumption by Energy Source, 2023

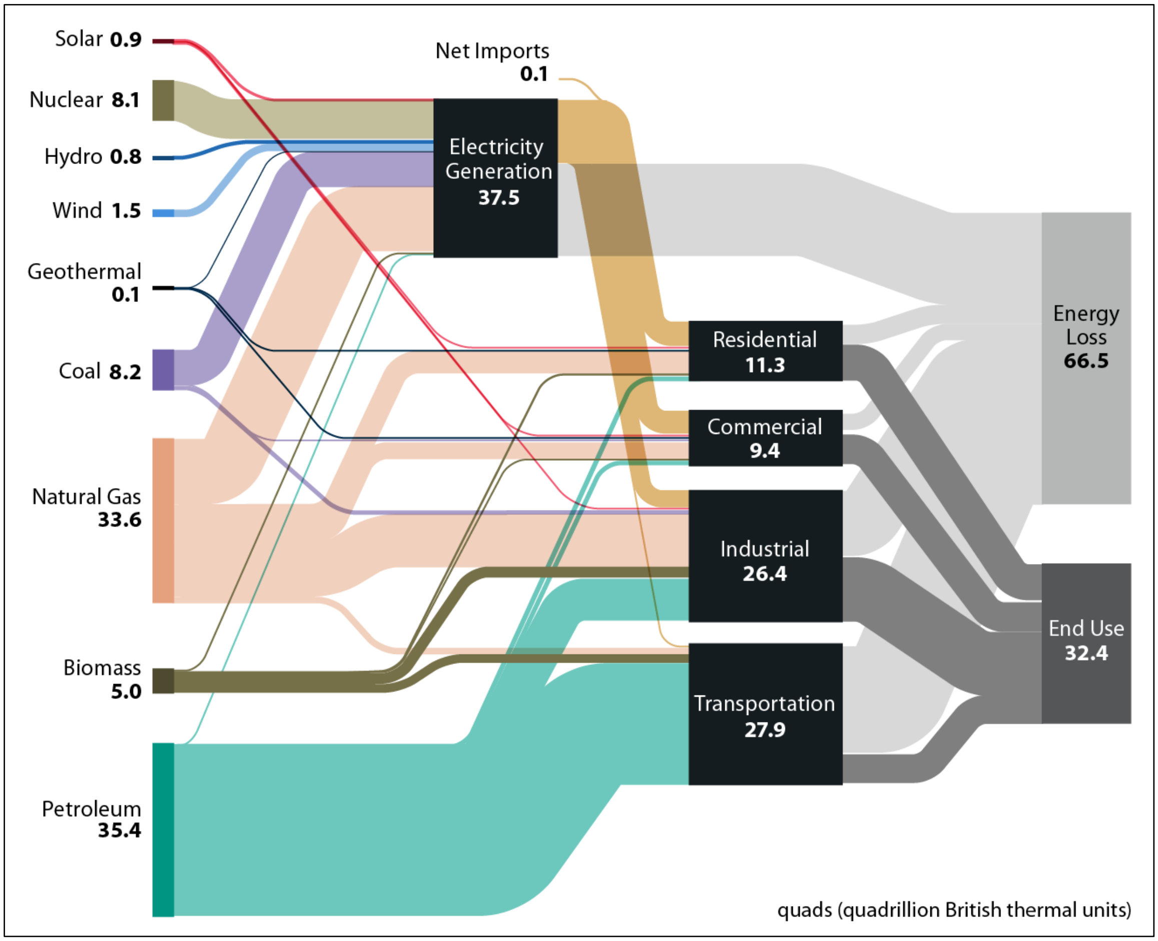


Source: Figure created by CRS using data from U.S. Energy Information Administration, "U.S. Energy Facts Explained," https://www.eia.gov/energyexplained/us-energy-facts/.

Figure 3 shows U.S. primary energy consumption in 2023, starting from the various primary energy resources at the far left. The energy flows show how much primary energy is consumed by various sectors, including the electric power, residential, commercial, industrial, and transportation sectors. The boxes on the far right show how much total primary energy is applied to end uses versus how much is lost.

Figure 3. U.S. Primary Energy Consumption, 2023

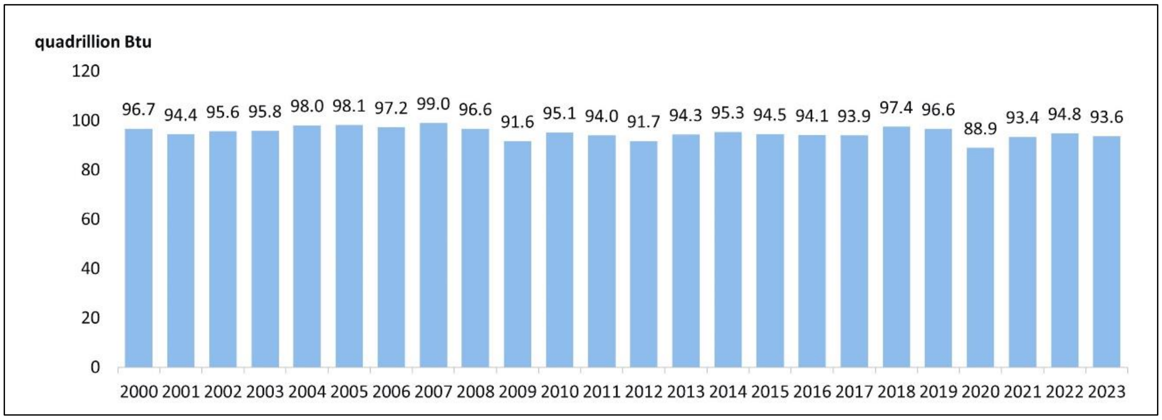
(in quadrillion Btu)



Source: Figure created by CRS using data from Lawrence Livermore National Laboratory, "Energy Flow Charts," 2024, https://flowcharts.llnl.gov/commodities/energy.

Figure 4 depicts U.S. annual primary energy consumption from 2000 through 2023. The data show variations from year to year. Total U.S. primary energy consumption in 2023 was 3.2% lower than in 2000. The average annual decrease from 2000 to 2023 was 0.14%.

Figure 4. U.S. Annual Primary Energy Consumption, 2000-2023



Source: Figure created by CRS using data from U.S. Energy Information Administration, *Monthly Energy Review* data from 2000 to 2023, https://www.eia.gov/totalenergy/data/monthly/.

Primary Energy in the Electric Power Sector

One major use of primary energy calculations is to identify the total (i.e., primary) energy consumed to generate electricity for the grid. To calculate the physical energy content of the various thermal generators, the primary energy is defined as the heat generated by the conversion processes, such as fossil fuel combustion. The amount of primary energy is dependent on the energy content of the fuel and the heat rate of the reactor, and it includes the energy that might be lost to waste heat.[5]

A complication arises when trying to calculate the primary energy for noncombustible renewable energy (RE) sources, such as hydroelectric, wind, or solar power. For RE (other than biomass, which may be combusted), there is no set conversion value to determine the primary energy values for these sources. The U.S. Energy Information Administration's (EIA's) method for calculating these primary energy values is called the *captured energy approach*—also known as the *physical energy content method*.[6] The data depicted in **Figure 4** were calculated using this approach. For noncombustible renewable energy sources, EIA defines the primary energy as the electricity generated—that is, "the net energy available for direct consumption after transformation of a noncombustible renewable into electricity."[7] This approach does not include the energy lost in the conversion—from kinetic or solar energy—to electricity.[8]

The different energy sources are measured using different physical units—various volume measurements for liquid or gas fuels, weight measurements for some solid fuels, and kWh for electricity. To facilitate comparison, EIA converts them into Btu based on each source's average energy content. For the electricity from noncombustible renewables, EIA uses a constant conversion factor of 3,412 Btu/kWh.

[5] *Heat rate* is the energy generated per unit of fuel consumed. For electricity generators, EIA defines this as British thermal units (Btu) of fuel consumed per kilowatt-hour (kWh) of electricity generated.

[6] EIA, *Monthly Energy Review*, May 2023, Tables E1a and E1b, pp. 250-251, https://www.eia.gov/totalenergy/data/monthly/archive/00352305.pdf (hereinafter EIA, *Monthly Energy Review*, May 2023).

[7] EIA, *Monthly Energy Review*, May 2023.

[8] For more information on the captured energy approach, see "Other Considerations in Calculating or Using Primary Energy."

Considerations for Noncombustible Renewable Energy Sources

EIA's current method of calculating primary energy for noncombustible RE sources is illustrative of evolving applications for primary energy calculations. Prior to the switch to the physical energy content method, EIA used a fossil fuel equivalency method. That method treated the generated electricity as the secondary energy and back-calculated the total primary energy. A direct calculation of primary energy was not done because of two main factors: first, because of the inherent technical challenges to directly calculating the primary energy, and second, because noncombustible RE sources accounted for a relatively small contribution to U.S. electricity generation overall.[9] When the RE fraction of generation is small, the fossil fuel equivalency method is more appropriate because RE generation would most likely displace fossil fuel generation. When the RE generation fraction is high, it is less likely to replace or displace fossil fuel generation; therefore, the direct comparison is less appropriate.

Instead of a direct calculation, the fossil fuel equivalency method calculated how much primary energy would have been consumed to generate that amount of electricity using the prevailing mix of fossil fuel generation capacity in the grid. Thus, the primary energy for those renewables was based on fossil fuel-based electricity generation efficiencies. In 2023, EIA determined that—since RE technologies generated a larger fraction of U.S. electricity—it was less appropriate to base the calculation of RE's primary energy on thermal power plant efficiencies.

Table 1 compares U.S. primary energy consumption of selected energy resources, using both the fossil fuel equivalency and physical energy content methods. When these values are calculated using the fossil fuel equivalency method, renewables represent 9% of the total energy consumption.[10] In comparison, when the physical energy content method is used, renewables represent 4% of the total consumption.[11]

Table 1. Estimates of Primary Energy Consumption, 2022

(in trillion Btu)

Energy Source	Estimate Using Fossil Fuel Equivalency Method	Estimate Using Physical Energy Content Method
Nonrenewables		
Coal	9,846	n/a
Natural Gas	33,409	n/a
Nuclear	8,146	n/a
Petroleum	35,847	n/a
Subtotal, Nonrenewables	87,247	
% of Total	91%	96%
Renewables		
Hydroelectric Power	2,317	894
Geothermal Power	214	122

[9] For more information on the technical challenges, see "Other Considerations in Calculating or Using Primary Energy."

[10] EIA, *Monthly Energy Review*, May 2023, Table 1.3, p. 7.

[11] In terms of electricity generation, in 2022 the selected consumables generated 79% while the selected renewables generated 21%. EIA, *Monthly Energy Review*, May 2023, Tables 1.3, 4.3, 6.1, 7.2a, 8.2, A.3, and A.6.

Energy Source	Estimate Using Fossil Fuel Equivalency Method	Estimate Using Physical Energy Content Method
Solar Power[a]	1,870	761
Wind Power	3,845	1,484
Subtotal, Renewables	8,246	3,261[b]
% of Total	9%	4%
Total, Selected Energy Sources	**95,493**	**90,509**[c]

Source: U.S. Energy Information Administration (EIA), *Monthly Energy Review*, May 2023, Tables 1.3, 4.3, 6.1, 8.2, A.3, and A.6.

Notes: EIA applies the physical energy content method only to the selected noncombustible renewable energy sources shown here. Btu = British thermal units; n/a = not applicable.

a. Includes both small- and utility-scale solar and both thermal and photovoltaic (PV) generation.

b. Total for renewables includes 128 trillion Btu of direct consumption of solar and geothermal power—64 trillion Btu of each. Direct consumption can include geothermal energy used for direct heating—for example, space heating—or solar PV electricity consumed at the generation site and not delivered to the grid.

c. The total 90,509 is the sum of 87,247 from the nonrenewables estimated using the fossil fuel equivalency method and 3,261 from the renewables estimated using the physical energy content method.

The physical energy content method is used by the International Energy Agency and other international organizations, such as the United Nations Statistical Commission and Eurostat.[12] Using this common method allows U.S. energy data to be more directly compared with international energy data. Potentially, future developments in the energy sector or other needs could drive additional updates to the primary energy calculation methods used for noncombustible renewables or other energy sources, technologies, or applications.

Other Considerations in Calculating or Using Primary Energy

The calculations of primary energy from thermal electricity generation (i.e., from fossil fuels, nuclear fuel, or biomass) depend on the specific heat content of the fuels used and the heat rate (i.e., efficiency) of the generators. Different fuel types and newer, more efficient generators can decrease primary energy values, whereas other factors can increase them. For example, replacing electricity generation fueled by coal with generation fueled by natural gas can increase conversion efficiencies because the combustion temperature of natural gas is higher. Also, the deployment of more natural-gas-fired combined-cycle (NGCC) power plants can increase conversion efficiency, because the NGCC turbines capture energy from both the expansion of the combusted gas and from expanding steam generated using the exhaust heat from the combustion process.

At the economy-wide level, these increases in thermal generation efficiency (and resulting reductions in primary energy needed to deliver the same amount of useful energy) can be counteracted somewhat by other factors. One factor is the aging of the U.S. fleet of generators.

[12] There are some variations in the application of this method. For example, Eurostat's implementation of the physical energy content method includes geothermal, solar thermal, and heat pumps (which it refers to as *ambient heat sources*) with the other thermal generators and defines heat generated as the primary energy. EIA explicitly includes geothermal and solar thermal with the other noncombustible renewables. EIA treats waste heat recovery technologies as downstream of primary energy. EIA considers the heat generated to be the primary energy form for heat pumps. Eurostat, "Statistics Explained: Calculation Methodologies for the Share of Renewables in Energy Consumption," August 23, 2023, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Calculation_methodologies_for_the_share_of_renewables_in_energy_consumption&oldid=245027.

Older generators tend to be less efficient in both design and operation, resulting in increased heat rates and increased primary energy values. U.S. nuclear reactors have relatively higher heat rates (i.e., they are less efficient) than other, newer thermal power plants. U.S. nuclear reactors were not necessarily designed for fuel efficiency and have relatively lower operating temperatures and higher heat rates than they could have with other design priorities. Some advanced nuclear reactor designs with water as the working fluid in the steam turbine—not yet deployed in the United States—have higher operating temperatures, greater energy efficiencies, and lower heat rates.

Portions of the U.S. industrial sector are pursuing decarbonization, which could affect the sector's primary energy consumption.[13] Part of decarbonization includes seeking alternative energy sources for process heating. Industrial *process heating* is the "use of thermal energy to produce, treat, or alter manufactured goods."[14] Approximately 70% of manufacturing energy consumption is for process heating, and around 80% of that energy comes from fossil fuels.[15] If the industrial sector transitions away from fossil fuels for process heating, it could increase its use of secondary energy sources, such as hydrogen and electricity, and potentially increase its use of other primary energy sources, such as solar thermal heat or geothermal heat. If the processes used to generate this process heat are more efficient than current processes, the total primary energy consumption for industrial process heating could decrease.[16]

The physical energy content method is used to provide a primary energy calculation sufficient for the uses mentioned above.[17] An alternative method, which EIA terms the *incident energy approach*, calculates the full technical potential primary energy based on "the gross energy that first strikes an energy conversion device." Calculating this incident energy for any given electricity-generating technology is very challenging, particularly at a large scale. Additionally, it is not generally required for the types of analyses primary energy calculations are used for.[18]

A full incident energy calculation for solar PV, for example, would require determining the actual amount of solar insolation (the amount of solar energy that reaches the earth's surface in a given area over a given time) for a solar panel or installation. Then, that determination would have to be repeated for each PV installation to determine the total incident energy for all solar PV. A similar analysis could be performed for other power technologies—for example, determining the incident kinetic energy in wind swept by turbine blades or possibly the total nuclear energy content in nuclear fuel (including in the spent fuel).

Instead, in practice, assumptions are made about the average heat value of fossil fuels to calculate primary energy. For nuclear reactions, the primary energy is the heat generated. For solar PV,

[13] For example, in March 2024 the U.S. Department of Energy (DOE) selected 33 decarbonization projects for support in the areas of chemicals and refining, cement and concrete, iron and steel, aluminum and metals, food and beverages, glass, process heating, and pulp and paper using funding provided by the Infrastructure Investment and Jobs Act (P.L. 117-58) and P.L. 117-169 (commonly referred to as the Inflation Reduction Act). DOE, "Biden-Harris Administration Announces $6 Billion to Transform America's Industrial Sector, Strengthen Domestic Manufacturing, and Slash Planet-Warming Emissions," press release, March 25, 2024.

[14] DOE, "Industrial Decarbonization Basics," https://www.energy.gov/eere/iedo/industrial-decarbonization-basics.

[15] DOE, "2018 Manufacturing Static Energy Sankey Diagrams," 2022, https://www.energy.gov/eere/iedo/2018-manufacturing-static-energy-sankey-diagrams; International Renewable Energy Agency, "Solar Heat for Industrial Processes: Technology Brief," January 2015, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_ETSAP_Tech_Brief_E21_Solar_Heat_Industrial_2015.pdf.

[16] Changing the energy resources used could also decrease fuel costs, manufacturing costs, or environmental costs related to previous fossil fuel consumption and related greenhouse gas emissions.

[17] As an example of an alternative analysis, a detailed scientific study of the energy efficiency of solar photovoltaic panel technology might determine the full technical potential energy of a panel or an installation.

[18] EIA, *Monthly Energy Review*, September 2024, https://www.eia.gov/totalenergy/data/monthly/archive/00352409.pdf.

solar thermal, geothermal, wind, hydropower, and marine generators, the primary energy is electricity. The corresponding primary energy values are more immediately and directly measurable and enable a feasible calculation of primary energy.

Considerations for Congress

The definition and use of primary energy can potentially affect federal policy areas if used by federal agencies to interpret and implement laws and regulations; if used by Congress to establish requirements or standards for energy policies or energy tax credits; and if used when coordinating federal actions with other national, state, or local governments.

Federal agencies, such as DOE, sometimes use calculations of primary energy to interpret federal laws and regulations. One example involves the rulemakings relating to the Energy Policy and Conservation Act (P.L. 94-163), as discussed below. The law requires energy efficiency standards for consumer products and commercial and industrial equipment.[19]

DOE has modified its approach to accounting for energy consumed by appliances and equipment several times since the initial rulemakings on energy efficiency standards in the 1980s. DOE referred to electricity in terms of "source or primary energy; that is, the energy that is necessary to generate and transmit electricity."[20] A later rulemaking for furnaces referred to "primary electricity."[21] In a 1996 policy statement, DOE stated that "DOE considers the energy savings associated with the production of the fuel used by the appliance covered by the standard (i.e., source energy)."[22] In 2001, DOE began using calculations of delivered energy (which DOE called "site energy") and primary energy. DOE used delivered energy for fossil fuel consumption and primary energy for electricity consumption. This primary energy calculation included "energy losses that occur in the generation, transmission, and distribution [of electricity]."[23] Starting in 2011, DOE changed its approach to one using a full fuel-cycle (FFC) analysis. DOE's FFC analysis takes primary energy consumption and then applies conversion factors (to account for the energy used to extract the fuels) to determine the FFC impacts. The conversion factors "represent the ratio of estimated FFC energy use for each unit of primary energy" and there are different conversion factors for each primary energy source.[24]

Congress could specify the type of approach to energy accounting DOE uses in the appliance and equipment standards program. Moving from site energy analysis to primary energy analysis to FFC analysis results in generally more comprehensive estimates of the energy and environmental impacts, but each successive calculation is more analytically challenging and data intensive.

Some Members of recent Congresses have introduced bills establishing national RE standards, clean energy standards, and energy efficiency standards, including the Clean Energy Standard Act of 2019 (H.R. 2597, 116th Congress), the American Renewable Energy Act of 2021 (H.R. 3959, 117th Congress), and the Climate Solutions Act of 2023 (H.R. 5496, 118th Congress). These standards would have established various requirements for sourcing clean or renewable electricity (as defined in the bills) or reducing overall energy use.

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19 84 *Federal Register* 36038 (July 26, 2019). DOE determined in 2011 that it would use the full fuel-cycle measures of energy and emissions when evaluating the impacts of new or amended energy efficiency standards. 76 *Federal Register* 51282c (August 18, 2011).

20 49 *Federal Register* 39380 (August 30, 1983).

21 55 *Federal Register* 47938 (November 17, 1989).

22 61 *Federal Register* 36979 (July 15, 1996).

23 75 *Federal Register* 51423, p. 16.

24 75 *Federal Register* 51423, p. 25.

Future energy standards could incorporate the consideration and definition of primary energy when calculating energy consumption or energy savings for assigning energy credits. Considering primary energy would enable these standards to be energy source-neutral.[25] This could reduce the need for different standards for each energy source. Energy source-neutral standards could be particularly applicable where multiple energy options are available for technologies such as automobiles (electric vehicles vs. internal combustion vehicles), for buildings and appliances (gas stoves vs. electric stoves), and for industrial applications (fossil fuels vs. electricity, for process heating). Energy source-neutral standards could enable easier incorporation of emerging energy technologies or alternative energy-saving measures—such as waste heat recovery—into these standards.

Having compatible sets of definitions for primary energy and energy use could be useful for comparing U.S. energy statistics and related data to international approaches and standards when developing international policy or contributing to international research and development. Compatible definitions could be useful in the development of clean or renewable energy technologies, in comparing those technologies to other energy technologies, and in international research and development initiatives. Compatible definitions could be useful when developing domestic energy efficiency standards and related emissions standards to help meet U.S. commitments and contributions to global greenhouse gas emissions reductions. Compatible definitions could also be useful when developing trade policies related to the energy efficiency or embodied emissions of trade goods (for example, appliances, equipment, or energy commodities).

In 2022, Congress enacted P.L. 117-169 (commonly referred to as the Inflation Reduction Act), which established the Clean Energy Investment Tax Credit, a technology-neutral tax incentive tied to the total greenhouse gas emissions of energy generation installations. If Congress wanted to instead base tax credits for energy technologies on energy consumption and efficiency, primary energy could be used as a metric instead of greenhouse gas emissions.

Another policy option could include federal efforts to identify and share primary energy best practices and analysis methods to support states in incorporating primary energy calculations into their own policies.

Author Information

Morgan Smith
Analyst in Energy Policy

[25] Some studies have shown greater impacts from energy savings policies when they target primary energy rather than final energy savings. M. Rodríguez et al., "Targeting Energy Savings? Better on Primary Than Final Energy and Less on Intensity Metrics," *Energy Economics*, vol. 125 (September 2023), https://doi.org/10.1016/j.eneco.2023.106797.