

Appendix E

Alternative Measures for the Energy Content of Noncombustible Renewables

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Energy sources are measured in different physical units: liquid fuels in barrels or gallons, gases in cubic feet, coal in short tons, and electricity in kilowatthours. EIA converts each source into common British thermal units (Btu) to allow comparison among different types of energy and to calculate total energy concepts.

Noncombustible renewables (hydroelectric, geothermal, solar, and wind energy) are resources from which energy is extracted without burning or combusting fuel. When noncombustible renewables generate electricity, there is no fuel combustion and, therefore, no set Btu conversion factors for the energy sources.¹

There are three broadly accepted ways to convert electricity generated from noncombustible renewables into Btu of primary energy—the captured energy, fossil fuel equivalency, and incident energy approaches. Each of these methods are described in detail below.

Captured Energy Approach

The captured energy approach converts primary energy consumption of noncombustible renewables from kilowatthours (kWh) to Btu using the constant conversion factor representing the heat content of electricity—3,412 Btu per kWh. Captured energy reflects the primary energy captured for economic use and does not include losses. In other words, it represents the net energy available for direct consumption after the transformation of a noncombustible renewable source of energy into electricity, where captured energy is the energy measured as the "output" of a generating unit, such as electricity from a wind turbine or solar plant.

The captured energy approach is often used to show the economically significant portion of the energy transformation associated with renewable energy sources. There is no market for the resource-specific energy apart from its immediate, site-specific energy conversion, and there is no substantive opportunity cost to its continued exploitation.² This approach is preferred by the *UN International Recommendations for Energy Statistics* (IRES) because the detailed data needed to estimate quantities of incident energy are not available now and are not likely to develop soon. This approach is also more closely tied to a physical market commodity, that is, electricity net generation, than the conceptual measure derived using the fossil fuel equivalency approach.

Fossil Fuel Equivalency Approach

The fossil fuel equivalency approach converts the consumption of noncombustible renewable electricity (in kWh) to Btu by applying a fossil fuel equivalency factor, based on the fossil-fuels heat rate (Table A6). The fossil-fuels heat rate is equal to the average thermal efficiency across fossil-fueled fired generating plants based on fuel consumption and net generation data reported to EIA. The fossil fuel equivalent consumption represents the energy consumed as if the electricity were generated by fossil fuels and is useful for analysis when considering the amount of primary fossil fuel energy displaced by renewable energy sources.

However, unlike the captured energy approach, the fossil fuel equivalency approach is not as directly tied to any real market or physical quantity. The fossil fuel equivalency approach measures neither primary energy consumption nor fossil fuels actually displaced. Additionally, its use becomes increasingly problematic as noncombustible renewables begin to displace other renewables instead of fossil fuels.

Incident Energy Approach

Incident energy is the mechanical, radiation, or thermal energy that is measurable as the "input" of the device. EIA defines "incident energy" for noncombustible renewables as the gross energy that first strikes an energy conversion device:

- For hydroelectric, the energy contained in the water passing through the penstock (a closed conduit for carrying water to the turbines)
- For geothermal, the energy contained in the hot fluid at the surface of the wellbore
- For wind, the energy contained in the wind that passes through the rotor disc
- For solar, the energy contained in the sunlight that strikes the panel or collector mirror

The incident energy approach converts noncombustible renewable electricity to Btu by accounting for the “losses” that result from an inability to convert 100% of incident energy to a useful form of energy. EIA has not published total primary energy consumption statistics based on this approach because it is difficult to obtain accurate estimates of input energy without creating undue burden on survey respondents and possible concern about the quality of the resulting data. Few renewable electricity power plants track cumulative input energy due to its lack of economic significance or other purpose. In addition, estimated energy efficiencies of renewable conversion technologies vary significantly across technologies, site-specific configurations, and environmental factors.³

EIA now using the captured energy approach

Starting with the September 2023 *Monthly Energy Review* (MER), EIA began converting electricity generation from noncombustible renewables into Btu using the captured energy approach rather than the fossil fuel equivalency approach in its main data tables (reflected in MER Sections 1, 2, and 10). The Btu values of hydroelectric, geothermal, solar, and wind energy consumption and, consequently, total primary energy consumption and total energy production are lower for all time periods because of the new conversion factor (the heat content of electricity from Table A6).

After a thorough review of the alternative approaches, EIA made the change for two primary reasons. First, adopting the captured energy approach promotes international comparability in energy statistics by adopting the standards provided in IRES. Second, as renewable energy continues to represent an increasingly larger portion of U.S. energy consumption over time, the fossil fuel equivalent values of generation from renewable sources become less relevant to our data users than the electrical energy provided by renewable sources.

Some analysts may still prefer to use the measures based on the fossil fuel equivalency approach, which was previously used by EIA. MER Tables E1–E4 present noncombustible renewable energy statistics using the fossil fuel equivalency approach.

¹Direct use of noncombustible renewables in the form of heat (e.g., solar thermal heating) is estimated separately and is measured in Btu.

²There is an initial opportunity cost when a facility is first built: water behind a dam might flood land that could have been used for other purposes, or a solar panel might shade an area that could have used the sunlight. But that is a “fixed” opportunity cost that does not change during the operation of the plant.

³Based on EIA research conducted in 2016, engineering estimates of conversion efficiencies for noncombustible renewables range from less than 20% for solar photovoltaics and geothermal to 90% for large-scale hydroelectricity plants. Those estimates are notional indications of the energy output as a percent of energy input at each technology based on typical equipment operating within the normal operating range for that technology.

Table E3. Primary Energy Consumption by Source, Fossil Fuel Equivalency Approach
(Quadrillion Btu)

	Fossil Fuels ^a				Nuclear Electric Power	Renewable Energy ^b						Total ^g
	Coal	Natural Gas ^c	Petroleum ^d	Total ^e		Hydroelectric Power ^f	Geothermal	Solar	Wind	Bio-mass	Total	
1950 Total	12.347	5.968	13.298	31.615	0.000	1.415	NA	NA	NA	1.562	2.978	34.599
1955 Total	11.167	8.998	17.225	37.380	.000	1.360	NA	NA	NA	1.424	2.784	40.178
1960 Total	9.838	12.385	19.874	42.091	.006	1.608	(s)	NA	NA	1.320	2.928	45.041
1965 Total	11.581	15.769	23.184	50.515	.043	2.059	.002	NA	NA	1.335	3.396	53.953
1970 Total	12.265	21.795	29.499	63.501	.239	2.634	.006	NA	NA	1.431	4.070	67.817
1975 Total	12.663	19.948	32.699	65.323	1.900	3.155	.034	NA	NA	1.499	4.687	71.931
1980 Total	15.423	20.235	34.159	69.782	2.739	2.900	.053	NA	NA	2.475	5.428	78.021
1985 Total	17.478	17.703	30.866	66.035	4.076	2.970	.097	(s)	(s)	3.016	6.084	76.334
1990 Total	19.173	19.603	33.500	72.281	6.104	3.046	.171	.059	.029	2.735	6.040	84.433
1995 Total	20.089	22.671	34.341	77.162	7.075	3.205	.152	.068	.033	3.101	6.559	90.931
2000 Total	22.580	23.824	38.152	84.620	7.862	2.811	.164	.063	.057	3.008	6.104	98.702
2005 Total	22.797	22.565	40.217	85.623	8.161	2.703	.181	.058	.178	3.114	6.233	100.101
2010 Total	20.834	24.575	35.321	80.723	8.434	2.539	.208	.090	.923	4.506	8.266	97.512
2011 Total	19.658	24.955	34.639	79.263	8.269	3.103	.212	.110	1.168	4.616	9.210	96.868
2012 Total	17.378	26.089	33.833	77.304	8.062	2.629	.212	.156	1.340	4.517	8.853	94.380
2013 Total	18.039	26.805	34.398	79.224	8.244	2.562	.214	.225	1.601	4.861	9.464	97.130
2014 Total	17.998	27.383	34.658	80.017	8.338	2.466	.214	.337	1.727	5.013	9.758	98.294
2015 Total	15.549	28.191	35.368	79.090	8.337	2.320	.212	.427	1.776	5.008	9.743	97.398
2016 Total	14.226	28.400	35.712	78.319	8.427	2.471	.210	.570	2.095	5.053	10.399	97.371
2017 Total	13.837	28.055	36.043	77.907	8.419	2.765	.210	.777	2.342	5.035	11.128	97.647
2018 Total	13.252	31.163	36.892	81.281	8.438	2.661	.209	.915	2.481	5.094	11.360	101.230
2019 Total	11.316	32.264	36.866	80.425	8.452	2.562	.201	1.016	2.633	5.046	11.458	100.468
2020 Total	9.181	31.669	32.331	73.169	8.251	2.501	.203	1.211	2.963	4.535	11.413	92.994
2021 Total	10.549	31.711	35.243	77.454	8.131	2.225	.205	1.520	3.345	4.740	12.035	97.754
2022 January	1.008	3.708	2.915	7.626	.737	.213	.018	.102	.330	.403	1.067	9.440
February	.838	3.156	2.726	6.718	.646	.188	.016	.116	.332	.369	1.021	8.391
March	.733	2.875	3.063	6.665	.660	.215	.017	.154	.379	.411	1.176	8.508
April	.663	2.436	2.858	5.951	.578	.177	.017	.174	.407	.392	1.167	7.704
May	.745	2.315	2.982	6.033	.662	.206	.017	.195	.371	.411	1.200	7.904
June	.870	2.395	2.967	6.227	.687	.229	.016	.203	.298	.413	1.159	8.088
July	1.018	2.677	2.986	6.676	.719	.217	.017	.202	.260	.414	1.110	8.524
August	.997	2.652	3.064	6.709	.720	.186	.017	.189	.218	.420	1.030	8.479
September	.783	2.370	2.943	6.091	.666	.150	.017	.172	.241	.386	.966	7.736
October	.673	2.441	2.999	6.110	.616	.127	.017	.155	.289	.412	.999	7.734
November	.690	2.862	2.931	6.480	.648	.158	.018	.114	.363	.406	1.058	8.196
December	.871	3.494	2.884	7.243	.722	.180	.018	.096	.341	.408	1.044	9.023
Total	9.888	33.379	35.319	78.529	8.061	2.245	.205	1.872	3.827	4.847	12.997	99.728
2023 January	.750	3.421	2.868	7.036	.741	.196	.018	.105	.331	.415	1.065	8.852
February	.582	3.053	2.678	6.310	.636	.172	.016	.123	.357	.373	1.042	7.995
March	.620	3.128	3.006	6.752	.657	.184	.018	.163	.376	.421	1.161	8.578
April	.500	2.500	2.878	5.876	.592	.171	.017	.194	.369	.392	1.143	7.618
May	.550	2.387	3.014	5.949	.639	.239	.017	.221	.278	.430	1.185	7.782
June	.705	2.446	2.991	6.140	.677	.186	.016	.224	.238	.418	1.083	7.906
July	.913	2.757	2.975	6.641	.730	.190	.017	.237	.242	.420	1.104	8.480
August	.903	2.774	3.108	6.782	.729	.184	.016	.225	.245	.433	1.102	8.618
September	.716	2.465	2.911	6.088	.685	.146	.017	.197	.245	.410	1.015	7.788
October	.628	2.526	3.067	6.219	.642	.135	.018	.180	.311	.424	1.067	7.929
November	.629	2.923	2.978	6.528	.651	.147	.018	.137	.315	.413	1.029	8.210
December	.676	3.305	2.975	6.950	.720	.164	.018	.121	.328	.437	1.069	8.744
Total	8.172	33.683	35.448	77.271	8.099	2.114	.205	2.127	3.634	4.984	13.065	98.499
2024 January	.876	R 3.823	2.885	R 7.584	.722	.189	.018	.129	.301	.406	1.043	R 9.354
February	.559	3.068	2.728	R 6.352	.675	.173	.016	.158	.358	.397	1.103	8.131
March	.490	R 2.889	2.924	6.299	.662	.201	.016	.203	.393	.422	1.236	8.196
April	.467	2.471	2.875	5.808	.602	.167	.017	.239	.408	.401	1.232	7.640
May	.560	2.408	3.079	R 6.044	.679	.195	.016	.272	.333	.428	1.244	R 7.968
June	.718	R 2.508	2.901	R 6.122	.713	.183	.016	.290	.328	.412	1.229	R 8.069
July	.833	R 2.832	3.051	R 6.714	.730	.183	.017	.291	.241	.437	1.169	R 8.624
August	.814	R 2.806	3.067	R 6.683	.729	.184	.017	.286	.248	.434	1.170	R 8.592
September	.663	2.503	2.893	6.055	.655	.144	.016	.245	.249	.414	1.068	7.785
9-Month Total	5.978	25.309	26.403	57.662	6.168	1.620	.149	2.114	2.858	3.752	10.493	74.360
2023 9-Month Total	6.239	24.930	26.429	57.574	6.086	1.668	.151	1.689	2.681	3.711	9.900	73.617
2022 9-Month Total	7.654	24.582	26.504	58.696	6.075	1.781	.152	1.507	2.835	3.621	9.896	74.775

^a Includes non-combustion use of fossil fuels.
^b Most data are estimates. See Table E4 for notes on series components and estimation.
^c Natural gas only; excludes supplemental gaseous fuels. See Note 3, "Supplemental Gaseous Fuels," at end of Section 4.
^d Petroleum products supplied; excludes biofuels. Biofuels are included in "Biomass."
^e Includes coal coke net imports. See Tables 1.4c.
^f Conventional hydroelectric power.
^g Includes coal coke net imports and electricity net imports, which are not separately displayed. See Tables 1.4c.
R=Revised. NA=Not available. (s)=Less than 0.5 trillion Btu.

Notes: • See "Primary Energy Consumption" in Glossary.
• See Table D1 for estimated energy consumption for 1635–1945. • Totals may not equal sum of components due to independent rounding.
• Geographic coverage is the 50 states and the District of Columbia.
Web Page: See <http://www.eia.gov/totalenergy/data/monthly/#appendices> (Excel and CSV files) for all available annual data beginning in 1949 and monthly data beginning in 1973.
Sources: • **Fossil Fuels** and **Nuclear Electric Power**: Table 1.3. • **Renewable Energy**: Table E4. • **Total**: Calculated as the sum of Fossil Fuels, Nuclear Electric Power, Renewable Energy, and Electricity Net Imports (see Table 1.4c).

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