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Levelized Cost and Levelized Avoided Cost of New Generation Resources in the *Annual Energy Outlook 2020*

Levelized cost of electricity (LCOE) and levelized avoided cost of electricity (LACE) are, respectively, estimates of the revenue required to build and operate a generator over a specified cost recovery period and the revenue available to that generator over the same period. This paper presents average values of LCOE and LACE for electric generating technologies entering service in 2022, 2025,[1] and 2040 as represented in the National Energy Modeling System (NEMS) for the U.S. Energy Information Administration's (EIA) *Annual Energy Outlook 2020* (AEO2020) Reference case.[2] The costs for electric generating facilities entering service in 2025 are presented in the body of this report, and those costs for 2022[3] and 2040 are included in Appendices A and B, respectively. Both a capacity-weighted average based on projected capacity additions and a simple average (unweighted) of the regional values across the 25 U.S. supply regions of the NEMS electricity market module (EMM) are provided, together with the range of regional values.

Both LCOE and LACE are simplifications of modeled decisions, and do not not fully capture all the factors considered in NEMS. Nevertheless, when used together, these values provide an intuitive framework for understanding economic competitiveness between generation technologies in the capacity expansion decisions than considering either one alone.

Levelized Cost of Electricity

Levelized cost of electricity represents the average revenue per unit of electricity generated that would be required to recover the costs of building and operating a generating plant during an assumed financial life and duty cycle.[4] LCOE is often cited as a convenient summary measure of the overall competiveness of different generating technologies.

Key inputs to calculating LCOE include capital costs, fuel costs, fixed and variable operations and maintenance (O&M) costs, financing costs, and an assumed utilization rate for each plant type.[5] The importance of each of these factors varies across technologies. For technologies with no fuel costs and relatively small variable O&M costs, such as solar and wind electric generating technologies, LCOE changes nearly in proportion to the estimated capital cost of the technology. For technologies with significant fuel cost, both fuel cost and capital cost estimates significantly affect LCOE. Incentives, including state or federal tax credits (see text box "*AEO2020 representation of tax incentives for*

[1] Given the long lead-time and licensing requirements for some technologies, the first feasible year that all technologies are available is 2025.
[2] The AEO2020 is available on EIA's website.
[3] Appendix A shows LCOE and LACE for the subset of technologies available to be built in 2022.
[4] *Duty cycle* refers to the typical utilization or dispatch of a plant to serve base, intermediate, or peak load. Wind, solar, or other intermittently available resources are not dispatched and do not necessarily follow a duty cycle based on load conditions.
[5] The specific assumptions for each of these factors are given in the *Assumptions to the Annual Energy Outlook*.

renewable generation"), also affect the calculation of LCOE. As with any projection, these factors are uncertain because their values can vary regionally and temporally as technologies evolve and as fuel prices change.

AEO2020 representation of tax incentives for renewable generation

Federal tax credits for certain renewable generation facilities can substantially reduce the realized cost of these facilities. Based on the following and where applicable, the LCOE tables show the cost both with and without tax credits that EIA assumed would be available in the year in which the plant enters service.

Production Tax Credit (PTC): New wind, geothermal, and closed-loop biomass plants receive $24 per megawatthour (MWh) of generation; other PTC-eligible technologies receive $12/MWh. The PTC values are adjusted for inflation and applied during the plant's first 10 years of service. Plants that were under construction before the end of 2016 received the full PTC. After 2016, wind continues to be eligible for the PTC but at a $/MWh rate that declines by 20% in 2017, 40% in 2018, 60% in 2019[6], and expires completely in 2020. Based on documentation released by the Internal Revenue Service (IRS), EIA assumes that wind plants have four years after beginning construction to come online and claim the PTC. As a result, wind plants entering service in 2021 will receive $19.20/MWh, and those plants entering service in 2023 will receive $9.60/MWh (inflation adjusted).

Investment Tax Credit (ITC): In June 2018, the IRS issued Notice 2018-59, a beginning of construction guidance for the ITC. Based on the guideline, EIA assumes all solar projects coming online before January 1, 2024 will receive the full 30% ITC. Solar projects include both utility-scale solar plants—those with capacity rating of 1 megawatt (MW) or greater—and small-scale systems—those systems with a capacity rating of less than 1 MW. All commercial and utility-scale plants with a construction start date on or after January 1, 2022, or those plants placed in service after December 31, 2023, receive a 10% ITC. The ITC, however, expires completely for residential-owned systems starting in 2022. Results in this levelized cost report only include utility-scale solar facilities and do not include small-scale solar facilities.

Both onshore and offshore wind projects are eligible to claim the ITC in lieu of the PTC. Although EIA expects that onshore wind projects will choose the PTC, EIA assumes offshore wind projects will claim the ITC in lieu of the PTC because of the relatively higher capital costs for those projects.

Levelized Avoided Cost of Electricity

Actual plant investment decisions consider the specific technological and regional characteristics of a project, which involve many other factors not reflected in LCOE values. One such factor is the projected utilization rate, which depends on the varying amount of electricity required over time and the existing resource mix in an area where additional capacity is needed. A related factor is the capacity value, which depends on both the existing capacity mix and load characteristics in a region. Because load must be continuously balanced, generating units with the capability to vary output to follow demand

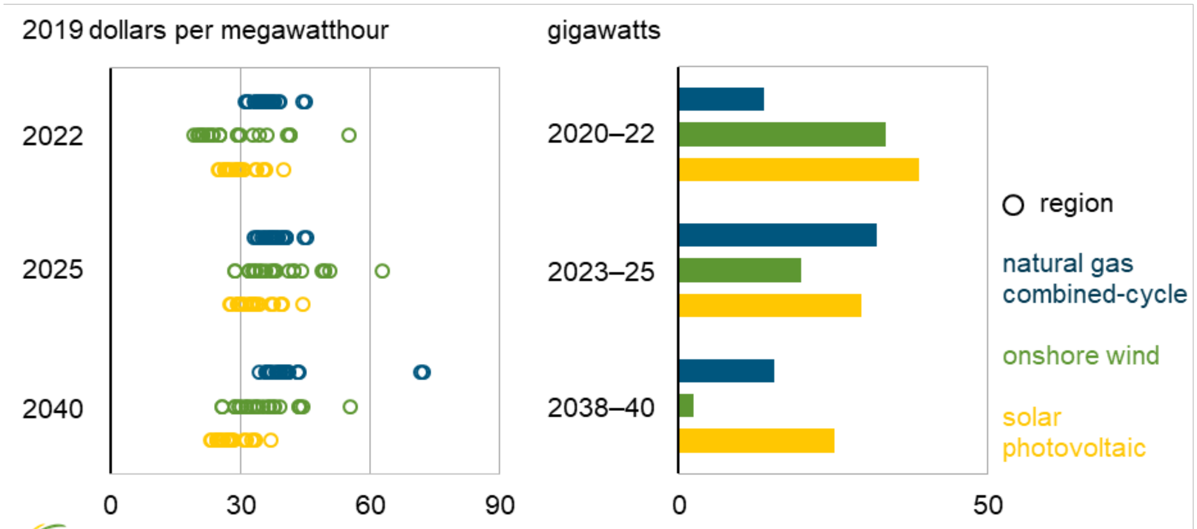
[6] The Taxpayer Certainty and Disaster Tax Relief Act of 2019 that passed in December 2019 included a one-year extension to with PTC. The legislation extended PTC through 2020 and restored the PTC to 60% (from 40%) of its full value for facilities that start construction during the 2020 calendar year. This legislative change occurred too late to be included in the AEO2020 and therefore will be reflected in AEO2021.

(dispatchable technologies) generally have more value to a system than less flexible units (non-dispatchable technologies) that use intermittent resources to operate. The LCOE values for dispatchable and non-dispatchable technologies are listed separately in the following tables because comparing them must be done carefully.

Levelized Avoided Cost of Electricity

LCOE does not capture all of the factors that contribute to actual investment decisions, making the direct comparison of LCOE across technologies problematic and misleading as a method to assess the economic competitiveness of various generation alternatives. Figure 1 below illustrates the limitations of using LCOE alone. On average, in AEO2020, wind LCOE is shown to be the same as or lower than natural gas-fired combined-cycle (CC) LCOE in 2022. More wind generating capacity than CC is installed between 2020 and 2022. Wind LCOE remains about the same or lower than CC on average in 2040, but EIA projects much more CC capacity to be installed than wind between 2038 and 2040.

Figure 1. Levelized cost of electricity (with applicable tax subsidies) by region and total incremental capacity additions for selected generating technologies entering into service in 2022, 2025, and 2040



Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*

EIA compares economic competitiveness between generation technologies by considering the value of the plant in serving the electric grid along with LCOE. This value provides a proxy measure for potential revenues from sales of electricity generated from a candidate project displacing (or the cost of avoiding) another marginal asset. EIA sums this value over a project's financial life and converted to a level annualized value, that is divided by the average annual output of the project, to develop levelized avoided cost of electricity.[7] Using LACE and LCOE together provides a more intuitive indication of economic competitiveness for each technology than either metric separately when several technologies are available to meet load. EIA calculates a LACE-to-LCOE ratio (or value-cost ratio) for each technology

[7] EIA's website provides further discussion of the levelized avoided cost concept and its use in assessing economic competitiveness.

to determine which project provides the most value relative to its cost. Projects with a value-cost ratio greater than one (i.e., LACE is greater than LCOE) are more economically attractive as new builds than those with a value-cost ratio less than one (i.e., LACE is less than LCOE).

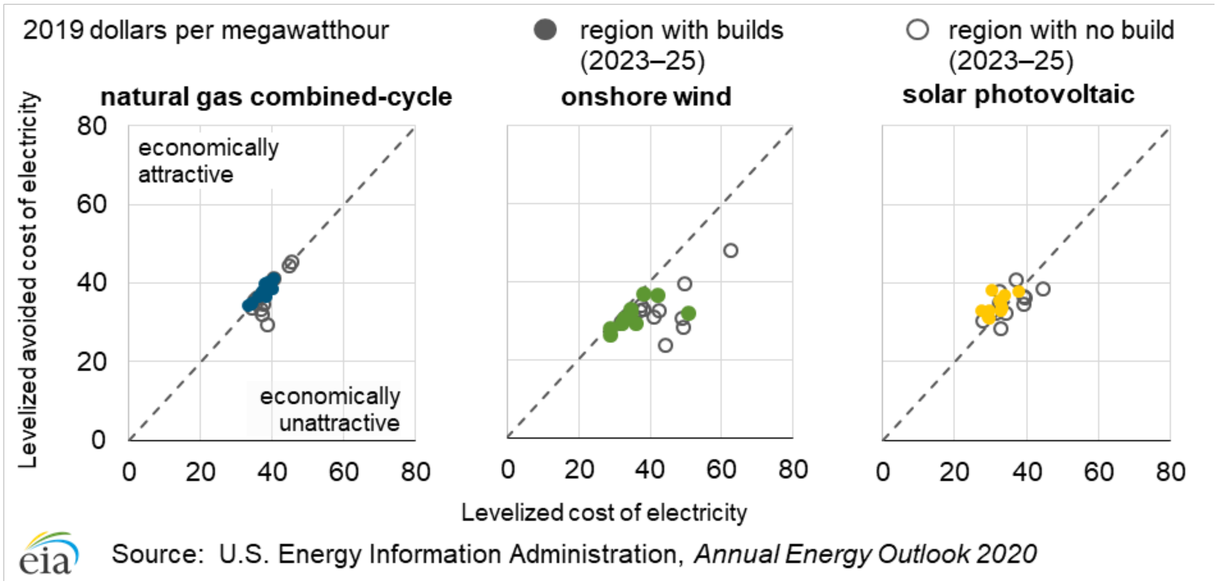
Estimating LACE is more complex than estimating LCOE because it requires information about how the system would operate without the new option. EIA calculates LACE based on the marginal value of energy and capacity that would result from adding a unit of a given technology to the system as it exists or is projected to exist at a specific future date. LACE represents the potential value available to the project owner from the project's contribution to satisfy both energy and capacity requirements. LACE accounts for both the variation in daily and seasonal electricity demand and the characteristics of the existing generation fleet to which new capacity will be added. Therefore, LACE compares the prospective new generation resource against the mix of new and existing generation and capacity that it would displace. For example, a wind resource that would primarily displace generation from a relatively expensive natural gas-fired peaker unit will usually have a different value than one that would displace generation from a more efficient natural gas-fired combined-cycle unit or coal-fired unit with low fuel costs.

Although the economic decisions for capacity additions in EIA's long-term projections do not use either LACE or LCOE concepts, the LACE and value-cost ratio presented in this report are generally more representative of the factors contributing to the build decisions found in EIA's long-term projections than looking at LCOE alone. Figure 2 below shows selected generating technologies that are feasible to come online in 2025. The x-axis is LCOE, and the y-axis is LACE. The diagonal lines are breakeven lines, so anything above them is economically attractive to build because the value (or LACE) is higher than the cost (or LCOE). Each dot represents an electricity market region of the United States as modeled in NEMS. Colored dots show regions where the technology is built in the AEO projection; open circles show where the technology is not built between 2023 and 2025. CC and solar photovoltaic (PV) have colored dots mostly above or at the diagonal lines. Onshore wind has mostly colored dots and open circles at or below the diagonal line. This pattern is partly because the builds are calculated from capacity added in the preceding three years, and onshore wind was subject to greater tax incentives in those three years than in 2025 alone. In addition, some regions are adding uneconomic capacity builds to fulfill state-level renewable portfolio standards (RPS) that require that a certain percentage of generation come from renewables. Even so, looking at both LCOE and LACE together as shown in Figure 2 is more indicative of the full analysis from the AEO2020 model shown in Figure 1 than LCOE alone.

Nonetheless, both the LACE and LCOE estimates are simplifications of modeled decisions, and they may not fully capture all factors considered in NEMS or match modeled results. EIA calculates levelized costs using an assumed set of capital and operating costs, but investment decisions may be affected by factors other than the project's value relative to its costs. For example, the inherent uncertainty about future fuel prices, future policies, or local considerations for system reliability may lead plant owners or investors who finance plants to place a value on portfolio diversification or other risk-related concerns. EIA considers many of these factors in its analysis of technology choice in the electricity sector in NEMS, but not all of these concepts are included in LCOE or LACE calculations. Future policy-related factors, such as new environmental regulations or tax credits for specific generation sources, can affect investment decisions. The LCOE and LACE values presented here are derived from the AEO2020

Reference case, which includes state-level renewable electricity requirements as of October 2019 and a phaseout of federal tax credits for renewable generation.

Figure 2. Levelized cost of electricity and levelized avoided cost of electricity by region for selected generation technologies, 2025 online year



LCOE and LACE calculations

EIA calculates LCOE values based on a 30-year cost recovery period, using a real after-tax weighted average cost of capital (WACC) of 4.3%.[8] In reality, a plant's cost recovery period and cost of capital can vary by technology and project type. Starting in AEO2020, EIA represents an ultra-supercritical[9] (USC) coal generation technology without carbon capture and sequestration (CCS). In December 2018, the U.S. Environmental Protection Agency (EPA) amended earlier 2015 findings that partial CCS was the *best system of emissions reductions* (BSER) for greenhouse gas reductions and proposed to replace it with the most efficient demonstrated steam cycle, which EIA assumes to be represented by ultra-supercritical coal technology.

The levelized capital component reflects costs calculated using tax depreciation schedules consistent with tax laws without a sunset date, which vary by technology. For AEO2020, EIA assumes a corporate tax rate of 21% as specified in the Tax Cuts and Jobs Act of 2017. For technologies eligible for the ITC or PTC, EIA reports LCOE both with and without tax credits, which phaseout and expire based on current laws and regulations in AEO2020 cases. Some technologies, notably solar PV, are used in both utility-

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[8]The real WACC of 4.3% corresponds to a nominal after-tax rate of 6.6% for plants entering service in 2025. For plants entering service in 2022 and 2040, the nominal WACC used to calculate LCOE was 6.5% and 6.6%, respectively. An overview of the WACC assumptions and methodology is available in the [Electricity Market Module of the National Energy Modeling System: Model Documentation 2018](#).

[9] USC coal plants are compatible with CCS technologies because they use boilers that heat coal to higher temperatures, which increases the pressure of steam to improve efficiency and results in less coal use and fewer carbon emissions than other boiler technologies.

scale generation and in distributed residential and commercial applications. The LCOE and LACE calculations presented here apply only to the utility-scale use of those technologies. Costs are expressed in terms of net alternating current (AC) power available to the grid for the installed capacity.

The LCOE values shown in Tables 1a and 1b are averages of region-specific LCOE values weighted by the projected regional capacity builds in AEO2020 (Table 1a) and unweighted averages (simple average, Table 1b) for new plants coming online in 2025.[10] EIA developed the weights based on the cumulative capacity additions during three years, reflecting the two years preceding the online year and the online year (e.g., the capacity weight for a 2025 online year represents the cumulative capacity additions from 2023 through 2025.)

Table 1a. Estimated levelized cost of electricity (LCOE, capacity-weighted[1]) for new generation resources entering service in 2025 (2019 dollars per megawatthour)

Plant type	Capacity factor (percent)	Levelized capital cost	Levelized fixed O&M[2]	Levelized variable O&M	Levelized transmis-sion cost	Total system LCOE	Levelized tax credit[3]	Total LCOE including tax credit
Dispatchable technologies								
Ultra-supercritical coal	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
Combined cycle	87	7.48	1.59	26.40	1.13	36.61	*NA*	36.61
Combustion turbine	30	16.10	2.65	46.51	3.44	68.71	*NA*	68.71
Advanced nuclear	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
Geothermal	90	20.36	14.50	1.16	1.45	37.47	-2.04	35.44
Biomass	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
Non-dispatchable technologies								
Wind, onshore	40	23.51	7.51	0.00	3.08	34.10	*NA*	34.10
Wind, offshore	45	84.00	27.89	0.00	3.15	115.04	*NA*	115.04
Solar photovoltaic[4]	30	24.12	5.77	0.00	2.91	32.80	-2.41	30.39
Hydroelectric[5,6]	73	28.89	7.64	1.39	1.62	39.54	*NA*	39.54

[1]The capacity-weighted average is the average levelized cost per technology, weighted by the new capacity coming online in each region. The capacity additions for each region are based on additions from 2023 to 2025. Technologies for which capacity additions are not expected do not have a capacity-weighted average and are marked as *NB*, or not built.
[2]O&M = operations and maintenance.
[3]The tax credit component is based on targeted federal tax credits such as the production tax credit (PTC) or investment tax credit (ITC) available for some technologies. It reflects tax credits available only for plants entering service in 2025 and the substantial phaseout of both the PTC and ITC as scheduled under current law. Technologies not eligible for PTC or ITC are indicated as *NA,* or not available. The results are based on a regional model, and state or local incentives are not included in LCOE calculations. See text box on page 2 for details on how the tax credits are represented in the model.
[4]Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.
[5]As modeled, EIA assumes that hydroelectric generation has seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season.
[6]Costs are for 2023 online year. See page 6 for details on the exception.
Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*

[10] Hydroelectric plants use 2023 as the in-service year because cost data are not available within the outlook to assess LCOE in 2025.

Table 1b. Estimated levelized cost of electricity (LCOE, unweighted) for new generation resources entering service in 2025 (2019 dollars per megawatthour)

Plant type	Capacity factor (percent)	Levelized capital cost	Levelized fixed O&M[1]	Levelized variable O&M	Levelized transmis-sion cost	Total system LCOE	Levelized tax credit[2]	Total LCOE including tax credit
Dispatchable technologies								
Ultra-supercritical coal	85	47.57	5.43	22.27	1.17	76.44	*NA*	76.44
Combined cycle	87	8.40	1.59	26.88	1.20	38.07	*NA*	38.07
Combustion turbine	30	16.17	2.65	44.33	3.47	66.62	*NA*	66.62
Advanced nuclear	90	56.12	15.36	9.06	1.10	81.65	-6.76	74.88
Geothermal	90	20.38	14.48	1.16	1.45	37.47	-2.04	35.43
Biomass	83	39.92	17.22	36.44	1.25	94.83	*NA*	94.83
Non-dispatchable technologies								
Wind, onshore	40	29.63	7.52	0.00	2.80	39.95	*NA*	39.95
Wind, offshore	44	90.95	28.65	0.00	2.65	122.25	*NA*	122.25
Solar photovoltaic[3]	29	26.14	6.00	0.00	3.59	35.74	-2.61	33.12
Hydroelectric[4,5]	59	37.28	10.57	3.07	1.87	52.79	*NA*	52.79

[1]O&M = operations and maintenance.

[2]The tax credit component is based on targeted federal tax credits such as the production tax credit (PTC) or investment tax credit (ITC) available for some technologies. It reflects tax credits available only for plants entering service in 2025 and the substantial phaseout of both the PTC and ITC as scheduled under current law. Technologies not eligible for PTC or ITC are indicated as *NA,* or not available. The results are based on a regional model, and state or local incentives are not included in LCOE calculations. See text box on page 2 for details on how the tax credits are represented in the model.

[3]Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.

[4]As modeled, EIA assumes that hydroelectric generation has seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season.

[5]Costs are for 2023 online year. See page 6 for details on the exception.

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*

EIA evaluated LCOE and LACE for each technology based on assumed capacity factors, which generally correspond to the high end of their likely utilization range. This convention is consistent with the use of LCOE to evaluate competing technologies in baseload operation such as coal and nuclear plants. Although sometimes used in baseload operation, some technologies, such as CC plants, are also built to serve load-following or other intermediate dispatch duty cycles. Combustion turbines that are typically used for peak-load duty cycles are evaluated at a 30% capacity factor, which reflects the upper end of their typical economic utilization range. The duty cycle for intermittent resources is not operator controlled, but rather, it depends on weather that will not necessarily correspond to operator-dispatched duty cycles. As a result, LCOE values for wind and solar technologies are not directly comparable with the LCOE values for other technologies that may have a similar average annual capacity factor. Consequently, they are shown separately as non-dispatchable technologies. Similarly, hydroelectric resources, including facilities where storage reservoirs allow for more flexible day-to-day operation, generally have high seasonal variation in output. EIA shows them as non-dispatchable to discourage comparison with technologies that have more consistent seasonal availability. The capacity factors for solar, wind, and hydroelectric resources are the average of the capacity factors (weighted or unweighted) for the marginal site in each region, which can vary significantly by region, and will not necessarily correspond to the cumulative projected capacity factors for both new and existing units for resources in AEO2020 or in other EIA analyses.

Table 2 shows a range of LCOE values, which represent the significant regional variation in LCOE values from local labor markets and the cost and availability of fuel or energy resources (such as windy sites). For example, the LCOE for incremental onshore wind capacity ranges from $28.72/MWh in the region with the highest-quality wind resources to $62.72/MWh in the region with the lowest-quality wind resources and/or higher capital costs for the best sites. Because onshore wind plants will most likely be built in regions that offer low costs and high value, the weighted average cost across regions is closer to the low end of the range at $34.10/MWh. Costs for wind generators may include additional expenses associated with transmission upgrades needed to access remote resources, as well as other factors that markets may not internalize into the market price for wind power.

Table 2. Regional variation in levelized cost of electricity (LCOE) for new generation resources entering service in 2025 (2019 dollars per megawatthour)

	Without tax credits				With tax credits[1]			
Plant type	**Minimum**	**Simple average**	**Capacity-weighted average[2]**	**Maximum**	**Minimum**	**Simple average**	**Capacity-weighted average[2]**	**Maximum**
Dispatchable technologies								
Ultra-supercritical coal	65.10	76.44	*NB*	91.27	65.10	76.44	*NB*	91.27
Combined cycle	33.35	38.07	36.61	45.31	33.35	38.07	36.61	45.31
Combustion turbine	58.48	66.62	68.71	81.37	58.48	66.62	68.71	81.37
Advanced nuclear	71.90	81.65	*NB*	92.04	65.13	74.88	*NB*	85.28
Geothermal	35.13	37.47	37.47	39.60	33.35	35.43	35.44	37.40
Biomass	86.19	94.83	*NB*	139.96	86.19	94.83	*NB*	139.96
Non-dispatchable technologies								
Wind, onshore	28.72	39.95	34.10	62.72	28.72	39.95	34.10	62.72
Wind, offshore	102.68	122.25	115.04	155.55	102.68	122.25	115.04	155.55
Solar photovoltaic (PV)[3]	29.75	35.74	32.80	48.09	27.57	33.12	30.39	44.50
Hydroelectric[4,5]	35.37	52.79	39.54	63.24	35.37	52.79	39.54	63.24

[1]Levelized cost with tax credits reflects tax credits available for plants entering service in 2025. See note 1 in Tables 1a and 1b.

[2]The capacity-weighted average is the average levelized cost per technology, weighted by the new capacity coming online in each region. The capacity additions for each region are based on additions from 2023 to 2025. Technologies for which capacity additions are not expected do not have a capacity-weighted average and are marked as *NB,* or not built.

[3]Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.

[4]As modeled, EIA assumes that hydroelectric generation has seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season.

[5]Costs are for 2023 online year. See page 6 for details on the exception.

Note: EIA calculated the levelized costs for non-dispatchable technologies based on the capacity factor for the marginal site modeled in each region that can vary significantly by region. The capacity factor ranges for these technologies are 37%–47% for onshore wind, 41%–50% for offshore wind, 25%–33% for solar PV, and 30%–80% for hydroelectric. The levelized costs are also affected by regional variations in construction labor rates and capital costs as well as resource availability.

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*

LACE accounts for the differences in the grid services each technology is providing and recognizes that intermittent resources, such as wind or solar, have substantially different duty cycles than the baseload, intermediate, and peaking duty cycles of conventional generators. Table 3 provides the range of LACE estimates for different capacity types. EIA calculated the LACE in this table by assuming the same maximum capacity factor as used for the LCOE. Values are not shown for combustion turbines and internal combustion engines because they are generally built for their capacity value to meet a reserve margin and are not typically built for generation requirements or to collect avoided energy costs.

Table 3. Regional variation in levelized avoided cost of electricity (LACE) for new generation resources entering service in 2025 (2019 dollars per megawatthour)

Plant type	Minimum	Simple average	Capacity-weighted average[1]	Maximum
Dispatchable technologies				
Ultra-supercritical coal	29.50	36.47	*NB*	41.49
Combined cycle	29.32	37.45	37.15	45.22
Advanced nuclear	29.86	36.25	*NB*	41.35
Geothermal	38.12	41.71	41.74	44.90
Biomass	29.61	37.76	*NB*	45.63
Non-dispatchable technologies				
Wind, onshore	23.60	32.39	31.37	48.13
Wind, offshore	25.36	33.75	37.29	42.76
Solar photovoltaic[2]	28.36	34.10	33.59	40.91
Hydroelectric[3,4]	23.21	34.21	36.31	41.48

[1]The capacity-weighted average is the average levelized cost per technology, weighted by the new capacity coming online in each region. The capacity additions for each region are based on additions from 2023 to 2025. Technologies for which capacity additions are not expected do not have a capacity-weighted average and are marked as *NB*, or not built.
[2]Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.
[3]As modeled, EIA assumes that hydroelectric generation has seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season.
[4]Costs are for 2023 online year. See page 6 for details on the exception.
Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*

When the LACE of a particular technology exceeds its LCOE at a given time and place, that technology would generally be economically attractive to build. The build decisions in the real world and as modeled in AEO2020, however, are more complex than a simple LACE-to-LCOE comparison because they include such factors as policy and non-economic drivers. Nevertheless, the value-cost ratio (the ratio of LACE-to-LCOE) provides a reasonable point of comparison of first-order economic competitiveness among a wider variety of technologies than is possible using either LCOE or LACE tables individually. In Tables 4a and 4b, a value index of less than one indicates that the cost of the marginal new unit of capacity exceeds its value to the system, and a value-cost ratio greater than one indicates that the marginal new unit brings in value higher than its cost by displacing more expensive generation and capacity options. The *average value-cost ratio* represents the average of the ratio of LACE-to-LCOE calculation, where the ratio is calculated for each of the 25 EMM regions. This range of ratios is not based on the ratio between the minimum and maximum values shown in Tables 2 and 3, but rather it represents the lower and upper bounds resulting from the ratio of LACE-to-LCOE calculations for each of the 25 regions.

Table 4a. Value-cost ratio (capacity-weighted) for new generation resources entering service in 2025

Plant type	Average capacity-weighted[1] LCOE[2] with tax credits (2019 dollars per megawatthour)	Average capacity-weighted[1] LACE[2] (2019 dollars per megawatthour)	Average value-cost ratio[3]
Dispatchable technologies			
Ultra-supercritical coal	*NB*	*NB*	*NB*
Combined cycle	36.61	37.15	1.02
Advanced nuclear	*NB*	*NB*	*NB*
Geothermal	35.44	41.74	1.18
Biomass	*NB*	*NB*	*NB*
Non-dispatchable technologies			
Wind, onshore	34.10	31.37	0.92
Wind, offshore	115.0	37.29	0.32
Solar photovoltaic[4]	30.39	33.59	1.11
Hydroelectric[5,6]	39.54	36.31	0.96

[1]The capacity-weighted average is the average levelized cost per technology, weighted by the new capacity coming online in each region. The capacity additions for each region are based on additions from 2023 to 2025. Technologies for which capacity additions are not expected do not have a capacity-weighted average and are marked as *NB*, or not built.
[2]LCOE = levelized cost of electricity, LACE = levelized avoided cost of electricity.
[3]The *average value-cost ratio* represents the economic value or the average of the ratio of LACE-to-LCOE calculation, where the ratio is calculated for each of the 25 regions based on the cost with tax credits for each technology, as available.
[4]Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.
[5]As modeled, EIA assumes that hydroelectric generation has seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season.
[6]Costs are for 2023 online year. See page 6 for details on the exception.
Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*

As shown in Table 4a, the capacity-weighted average value-cost ratio is greater than one for solar PV, CC, and geothermal in 2025, suggesting that these technologies will be built in regions where they are economically viable. Furthermore, the capacity-weighted average value-cost ratio for CC is close to one, suggesting that the technology has been an attractive marginal capacity addition and that the market has developed the technology to an equilibrium point where the net economic value is close to breakeven after having met load growth or displaced higher cost generation.[11]

[11] For a more detailed discussion of the LACE versus LCOE measures, see [Assessing the Economic Value of New Utility-Scale Electricity Generation Projects](#).

Table 4b. Value-cost ratio (unweighted) for new generation resources entering service in 2025

Plant type	Average unweighted LCOE[1] with tax credits (2019 dollars per megawatthour)	Average unweighted LACE[1] (2019 dollars per megawatthour)	Average value-cost ratio[2]	Minimum[3]	Maximum[3]
Dispatchable technologies					
Ultra-supercritical coal	76.44	36.47	0.48	0.34	0.54
Combined cycle	38.07	37.45	0.98	0.76	1.05
Advanced nuclear	74.88	36.25	0.49	0.35	0.57
Geothermal	35.43	41.71	1.18	1.06	1.32
Biomass	94.83	37.76	0.40	0.30	0.45
Non-dispatchable technologies					
Wind, onshore	39.95	32.39	0.83	0.53	0.97
Wind, offshore	122.25	33.75	0.28	0.16	0.37
Solar photovoltaic[4]	33.12	34.10	1.04	0.86	1.27
Hydroelectric[5,6]	52.79	34.21	0.66	0.40	1.06

[1] LCOE = levelized cost of electricity, LACE = levelized avoided cost of electricity.

[2]The *average value-cost ratio* represents the economic value or the average ratio of LACE-to-LCOE calculation, where the ratio is calculated for each of the 25 regions based on the cost with tax credits for each technology, as available.

[3]The range of unweighted value-cost ratio is not based on the ratio between the minimum values shown in Tables 2 and 3, but it represents the lower and upper bounds resulting from the ratio of LACE-to-LCOE calculations for each of the 25 regions.

[4]Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.

[5]As modeled, EIA assumes that hydroelectric generation has seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season.

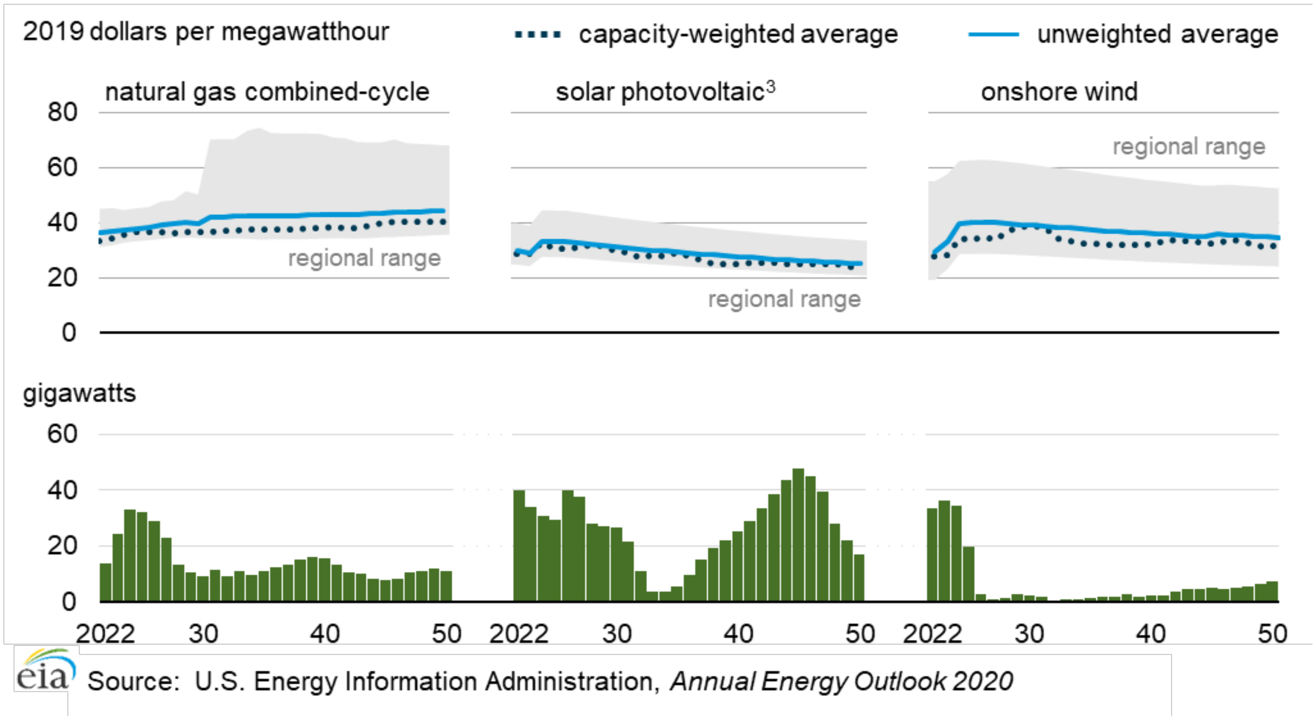
[6]Costs are for 2023 online year. See page 6 for details on the exception.

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*

LCOE and LACE projections

Figure 3 shows capacity-weighted and unweighted LCOE for CC, solar PV, and onshore wind plants entering service from 2022 to 2050 in the AEO2020 Reference case. Changes in costs over time reflect a number of different model factors, sometimes working in different directions. For both solar PV and onshore wind, LCOE increases in the near term with the phasedown and expiration of ITC and PTC, respectively. However, LCOE eventually declines over time because of technology improvement that tends to reduce LCOE through lower capital costs or improved performance (as measured by heat rate for CC plants or capacity factor for onshore wind or solar PV plants), which offsets the loss of the tax credits. The availability of high-quality resources may also be a factor. As the best, least-cost resources are used first, future development will occur in less favorable areas, potentially resulting in lower-performing resources, higher project development costs, and higher costs to access transmission lines. For CC, changing fuel prices also factor into the change in LCOE, as well as any environmental regulations that affect capital or operating costs.

Figure 3. Capacity-weighted[1] and unweighted levelized cost of electricity (LCOE)[2] projections and three-year moving capacity additions for selected generating technologies, 2022–50

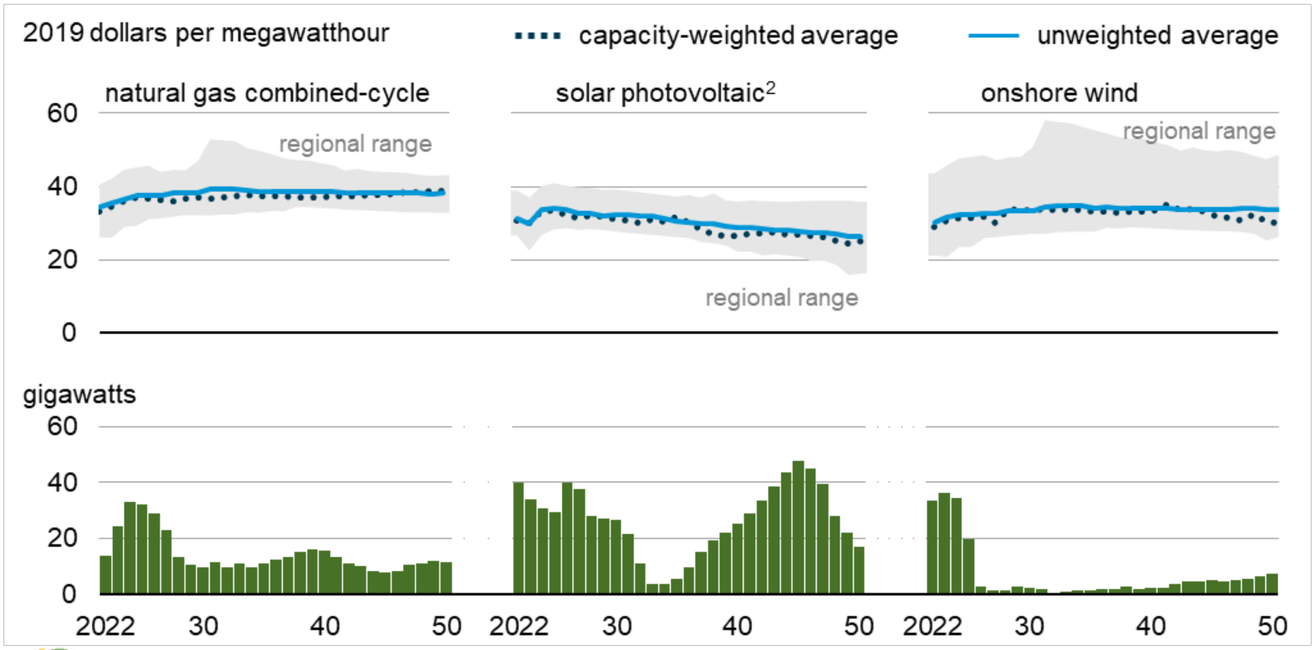


[1]Capacity-weighted average is the average levelized cost per technology, weighted by the new capacity coming online in the previous three years in each region. For example, plants coming online in 2025 are based on additions from 2023 to 2025.
[2]Levelized-cost includes tax credits available for plants entering service during the projection period. See note 1 in Tables 1a and 1b.
[3]Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.

For all three technologies, the capacity-weighted average LCOE and unweighted average LCOE are not far apart from each other. In addition, all three technologies continue to be installed throughout the projection period so the capacity-weighted average LCOE stays lower than the unweighted LCOE, reflecting the build-out in low-cost regions. The capacity-weighted average LCOE and unweighted average LCOE for solar PV are closer to each other because new builds are expected across many regions throughout the projection period. The projected regional range for CC is generally narrow in the early years, but this range widens in later years because of the increase in variable O&M costs for plants in California as a result of California's phaseout of fossil generation starting in 2030.

Figure 4 shows capacity-weighted and unweighted averages LACE over time. Changes in the value of generation, represented by LACE, are primarily a function of load growth. Wind and solar may show strong daily or seasonal generation patterns within any given region; as a result, the value of such renewable generation may see significant reductions as these time periods become more saturated with generation from resources with similar hourly operation patterns. As this saturation occurs, generation from new facilities must compete with lower-cost options in the dispatch merit order, as seen with the LACE for solar PV. The LACE for onshore wind, on the other hand, increases throughout the projection period.

Figure 4. Capacity-weighted[1] and unweighted levelized avoided cost of electricity (LACE) projections and three-year moving capacity additions for selected generating technologies, 2022–50



Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*

[1]Capacity-weighted average is the average levelized cost per technology, weighted by the new capacity coming online in the previous three years in each region. For example, plants coming online in 2025 are based on additions from 2023 to 2025.
[2]Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.

Similar behaviors and patterns emerge with LACE as with LCOE; the capacity-weighted and the unweighted LACE stay close to each other throughout the projection period while the capacity-weighted LACE generally remains lower than the unweighted LACE.

As illustrated in Figure 5, when considering both the value and cost of building and operating a power plant, CC, solar PV, and onshore wind all reach market equilibrium or a break-even point. The break-even point represents a stable solution point where LACE equals LCOE. Once a technology achieves a value-cost ratio greater than one, its value-cost ratio tends to remain close to one as seen with CC and solar PV. If the value-cost ratio is less than one, as seen with onshore wind in the near to mid-term, continued load growth, technology cost declines, or perhaps escalation in the fuel cost of a competing resource will tend to reduce the technology costs or increase the technology value to the grid over time. Similarly, if the value-cost ratio becomes significantly greater than one, the market will quickly build-out the technology until it meets the demand growth or displaces the higher cost incumbent generation. In all technologies, the capacity-weighted value-cost ratio stays mostly above the unweighted value-cost ratio, indicating that the capacity is being added in regions where it is most economical.

Figure 5. Value-cost ratio and three-year moving capacity additions for selected generating technologies, 2022–50

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*

[1]Capacity-weighted average is the average levelized cost per technology, weighted by the new capacity coming online in the previous three years in each region. For example, plants coming online in 2025 are based on additions from 2023 to 2025.
[2]Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.

Market shocks may cause a divergence between LACE and LCOE and therefore disturb the market equilibrium. These market shocks include technology change, policy developments, or fuel price volatility that can increase or decrease the value-cost ratio of any given technology. However, EIA expects the market to correct the divergence by either building the high-value resource (if the value-cost ratio increased) or waiting for slow-acting factors such as load growth to increase the value in the case of a value-cost ratio decrease, as seen for the capacity-weighted average value-cost ratios of both wind and solar PV.

Appendix A: LCOE tables for new generation resources entering service in 2022

Table A1a. Estimated levelized cost of electricity (LCOE, capacity-weighted[1]) for new generation resources entering service in 2022 (2019 dollars per megawatthour)

Plant type	Capacity factor (percent)	Levelized capital cost	Levelized fixed O&M[2]	Levelized variable O&M	Levelized transmis-sion cost	Total system LCOE	Levelized tax credit[3]	Total LCOE including tax credit
Dispatchable technologies								
Combined cycle	87	7.10	1.59	23.73	1.11	33.53	*NA*	33.53
Combustion turbine	30	17.33	2.65	40.76	3.45	64.19	*NA*	64.19
Non-dispatchable technologies								
Wind, onshore	42	26.86	7.17	0.00	2.62	36.65	-8.94	27.71
Solar photovoltaic[4]	30	28.54	5.88	0.00	3.02	37.44	-8.56	28.88

[1]The capacity-weighted average is the average levelized cost per technology, weighted by the new capacity coming online in each region. The capacity additions for each region are based on additions from 2020 to 2022.

[2]O&M = operations and maintenance.

[3]The tax credit component is based on targeted federal tax credits such as the production tax credit (PTC) or investment tax credit (ITC) available for some technologies. It reflects tax credits available only for plants entering service in 2022 and the substantial phaseout of both the PTC and ITC as scheduled under current law. Technologies not eligible for PTC or ITC are indicated as *NA,* or not available. The results are based on a regional model, and state or local incentives are not included in LCOE calculations. See text box on page 2 for details on how the tax credits are represented in the model.

[4]Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*

Table A1b. Estimated levelized cost of electricity (LCOE, unweighted) for new generation resources entering service in 2022 (2019 dollars per megawatthour)

Plant type	Capacity factor (percent)	Levelized capital cost	Levelized fixed O&M[1]	Levelized variable O&M	Levelized transmis-sion cost	Total system LCOE	Levelized tax credit[2]	Total LCOE including tax credit
Dispatchable technologies								
Combined cycle	87	8.05	1.59	25.49	1.14	36.27	*NA*	36.27
Combustion turbine	30	16.17	2.65	40.69	3.30	62.81	*NA*	62.81
Non-dispatchable technologies								
Wind, onshore	41	28.38	7.36	0.00	2.59	38.33	-8.94	29.40
Solar photovoltaic[3]	29	29.15	6.00	0.00	3.41	38.57	-8.75	29.82

[1] O&M = operations and maintenance.

[2]The tax credit component is based on targeted federal tax credits such as the production tax credit (PTC) or investment tax credit (ITC) available for some technologies. It reflects tax credits available only for plants entering service in 2022 and the substantial phaseout of both the PTC and ITC as scheduled under current law. Technologies not eligible for PTC or ITC are indicated as *NA*, or not available. The results are based on a regional model, and state or local incentives are not included in LCOE calculations. See text box on page 2 for details on how the tax credits are represented in the model.

[3]Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*

Table A2. Regional variation in levelized cost of electricity (LCOE) for new generation resources entering service in 2022 (2019 dollars per megawatthour)

Plant type	Range for total system levelized costs				Range for total system levelized costs with tax credits[1]			
	Minimum	Simple average	Capacity-weighted average[2]	Maximum	Minimum	Simple average	Capacity-weighted average[2]	Maximum
Dispatchable technologies								
Combined cycle	31.25	36.27	33.53	45.06	31.25	36.27	33.53	45.06
Combustion turbine	55.23	62.81	64.19	73.61	55.23	62.81	64.19	73.61
Non-dispatchable technologies								
Wind, onshore	28.25	38.33	36.65	64.03	19.31	29.40	27.71	55.09
Solar photovoltaic (PV)[3]	32.13	38.57	37.44	51.97	24.84	29.82	28.88	39.95

[1]Levelized cost with tax credits reflects tax credits available for plants entering service in 2022. See note 1 in Tables A1a and A1b.
[2]The capacity-weighted average is the average levelized cost per technology, weighted by the new capacity coming online in each region. The capacity additions for each region are based on additions from 2020 to 2022.
[3]Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.
Note: EIA calculated the levelized costs for non-dispatchable technologies based on the capacity factor for the marginal site modeled in each region that can vary significantly by region. The capacity factor ranges for these technologies are 37%–51% for onshore wind and 25%–33% for solar PV. The levelized costs are also affected by regional variations in construction labor rates and capital costs as well as resource availability.
Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*

Table A3. Regional variation in levelized avoided cost of electricity (LACE) for new generation resources entering service in 2022 (2019 dollars per megawatthour)

Plant type	Minimum	Simple average	Capacity-weighted average[1]	Maximum
Dispatchable technologies				
Combined cycle	26.19	34.38	33.13	40.56
Non-dispatchable technologies				
Wind, onshore	21.21	30.35	28.88	43.61
Solar photovoltaic[2]	26.68	31.38	30.91	38.94

[1]The capacity-weighted average is the average levelized cost per technology, weighted by the new capacity coming online in each region. The capacity additions for each region are based on additions from 2020 to 2022.
[2]Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.
Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*

Table A4a. Value-cost ratio (capacity-weighted) for new generation resources entering service in 2022

Plant type	Average capacity-weighted[1] LCOE[2] with tax credits (2019 dollars per megawatthour)	Average capacity-weighted[1] LACE[2] (2019 dollars per megawatthour)	Average value-cost ratio[3]
Dispatchable technologies			
Combined cycle	33.53	33.13	0.99
Non-dispatchable technologies			
Wind, onshore	27.71	28.88	1.11
Solar photovoltaic[4]	28.88	30.91	1.07

[1]The capacity-weighted average is the average levelized cost per technology, weighted by the new capacity coming online in each region. The capacity additions for each region are based on additions from 2020 to 2022.
[2]LCOE = levelized cost of electricity, LACE = levelized avoided cost of electricity.
[3]The *average value-cost ratio* represents the net economic value or the average of the ratio of LACE-to-LCOE calculation, where the ratio is calculated for each of the 25 regions based on the cost with tax credits for each technology, as available.
[4]Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.
Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*

Table A4b. Value-cost ratio (unweighted) for new generation resources entering service in 2022

Plant type	Average unweighted LCOE[1] with tax credits (2019 dollars per megawatthour)	Average unweighted LACE[1] (2019 dollars per megawatthour)	Average value-cost ratio[2]	Minimum[3]	Maximum[3]
Dispatchable technologies					
Combined cycle	36.27	34.38	0.95	0.72	1.04
Non-dispatchable technologies					
Wind, onshore	29.40	30.35	1.10	0.59	1.76
Solar photovoltaic[4]	29.82	31.38	1.06	0.84	1.18

[1]LCOE = levelized cost of electricity, LACE = levelized avoided cost of electricity.
[2]The *average value-cost ratio* represents the net economic value or the average ratio of LACE-to-LCOE calculation, where the ratio is calculated for each of the 25 regions based on the cost with tax credits for each technology, as available.
[3]The range of unweighted value-cost ratio is not based on the ratio between the minimum values shown in Tables A2 and A3, but it represents the lower and upper bounds resulting from the ratio of LACE-to-LCOE calculations for each of the 25 regions.
[4]Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.
Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*

Appendix B: LCOE and LACE tables for new generation resources entering service in 2040

Table B1a. Estimated levelized cost of electricity (LCOE, capacity-weighted[1]) for new generation resources entering service in 2040 (2019 dollars per megawatthour)

Plant type	Capacity factor (percent)	Levelized capital cost	Levelized fixed O&M[2]	Levelized variable O&M	Levelized transmis-sion cost	Total system LCOE	Levelized tax credit[3]	Total LCOE including tax credit
Dispatchable technologies								
Ultra-supercritical coal	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
Combined cycle	87	6.65	1.59	28.73	1.19	38.17	*NA*	38.17
Combustion turbine	30	13.64	2.65	48.83	3.50	68.62	*NA*	68.62
Advanced nuclear	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
Geothermal	90	19.31	15.63	1.16	1.55	37.64	-1.93	35.71
Biomass	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
Non-dispatchable technologies								
Wind, onshore	40	22.23	7.44	0.00	2.97	32.64	*NA*	32.64
Wind, offshore	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
Solar photovoltaic[4]	31	17.81	5.52	0.00	3.25	26.59	-1.78	24.81
Hydroelectric[5]	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*

[1]The capacity-weighted average is the average levelized cost per technology, weighted by the new capacity coming online in each region. The capacity additions for each region are based on additions from 2038 to 2040. Technologies for which capacity additions are not expected do not have a capacity-weighted average and are marked as *NB*, or not built.

[2]O&M = operations and maintenance.

[3]The tax credit component is based on targeted federal tax credits such as the production tax credit (PTC) or investment tax credit (ITC) available for some technologies. It reflects tax credits available only for plants entering service in 2040 and the substantial phaseout of both the PTC and ITC as scheduled under current law. Technologies not eligible for PTC or ITC are indicated as *NA*, or not available. The results are based on a regional model, and state or local incentives are not included in LCOE calculations. See text box on page 2 for details on how the tax credits are represented in the model.

[4]Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.

[5]As modeled, EIA assumes that hydroelectric generation has seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season.

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*

Table B1b. Estimated levelized cost of electricity (LCOE, unweighted) for new generation resources entering service in 2040 (2019 dollars per megawatthour)

Plant type	Capacity factor (percent)	Levelized capital cost	Levelized fixed O&M[1]	Levelized variable O&M	Levelized transmis-sion cost	Total system LCOE	Levelized tax credit[2]	Total LCOE including tax credit
Dispatchable technologies								
Ultra-supercritical coal	85	43.97	5.43	22.17	1.25	72.81	*NA*	72.81
Combined cycle	87	7.50	1.59	32.52	1.28	42.89	*NA*	42.89
Combustion turbine	30	13.89	2.65	52.15	3.70	72.39	*NA*	72.39
Advanced nuclear	90	48.21	15.36	9.47	1.18	74.22	-4.85	69.37
Geothermal	90	18.86	15.88	1.16	1.55	37.44	-1.89	35.56
Biomass	83	33.25	17.22	35.02	1.34	86.83	*NA*	86.83
Non-dispatchable technologies								
Wind, onshore	40	25.51	7.49	0.00	2.97	35.97	*NA*	35.97
Wind, offshore	44	53.85	28.83	0.00	2.85	85.53	*NA*	85.53
Solar photovoltaic[3]	29	19.86	6.00	0.00	3.83	29.70	-1.99	27.71
Hydroelectric[4]	70	40.98	9.22	1.39	2.00	53.58	*NA*	53.58

[1]O&M = operations and maintenance.

[2]The tax credit component is based on targeted federal tax credits such as the production tax credit (PTC) or investment tax credit (ITC) available for some technologies. It reflects tax credits available only for plants entering service in 2040 and the substantial phaseout of both the PTC and ITC as scheduled under current law. Technologies not eligible for PTC or ITC are indicated as *NA*, or not available. The results are based on a regional model, and state or local incentives are not included in LCOE calculations. See text box on page 2 for details on how the tax credits are represented in the model.

[3]Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.

[4]As modeled, EIA assumes that hydroelectric generation has seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season.

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*

Table B2. Regional variation in levelized cost of electricity (LCOE) for new generation resources entering service in 2040 (2019 dollars per megawatthour)

	Range for total system levelized costs				Range for total system levelized costs with tax credits[1]			
Plant type	**Minimum**	**Simple average**	**Capacity-weighted average[2]**	**Maximum**	**Minimum**	**Simple average**	**Capacity-weighted average[2]**	**Maximum**
Dispatchable technologies								
Ultra-supercritical coal	61.80	72.81	*NB*	87.88	61.80	72.81	*NB*	87.88
Combined cycle	34.27	42.89	38.17	72.32	34.27	42.89	38.17	72.32
Combustion turbine	58.89	72.39	68.62	110.80	58.89	72.39	68.62	110.80
Advanced nuclear	64.57	74.22	*NB*	83.25	59.72	69.37	*NB*	78.41
Geothermal	30.80	37.44	37.64	42.51	29.47	35.56	35.71	40.15
Biomass	78.96	86.83	*NB*	129.36	78.96	86.83	*NB*	129.36
Non-dispatchable technologies								
Wind, onshore	25.79	35.97	32.64	55.32	25.79	35.97	32.64	55.32
Wind, offshore	74.47	85.53	*NB*	105.39	74.47	85.53	*NB*	105.39
Solar photovoltaic (PV)[3]	24.70	29.70	26.59	39.81	23.04	27.71	24.81	37.08
Hydroelectric[4]	53.28	53.58	*NB*	54.16	53.28	53.58	*NB*	54.16

[1]Levelized cost with tax credits reflects tax credits available for plants entering service in 2040. See note 1 in Tables B1a and B1b.

[2]The capacity-weighted average is the average levelized cost per technology, weighted by the new capacity coming online in each region. The capacity additions for each region are based on additions from 2038 to 2040. Technologies for which capacity additions are not expected do not have a capacity-weighted average and are marked as *NB*, or not built.

[3]Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.

[4]As modeled, EIA assumes that hydroelectric generation has seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season.

Note: EIA calculated the levelized costs for non-dispatchable technologies based on the capacity factor for the marginal site modeled in each region that can vary significantly by region. The capacity factor ranges for these technologies are 38%–47% for onshore wind, 41%–50% for offshore wind, 25%–33% for solar PV, and 65%–73% for hydroelectric. The levelized costs are also affected by regional variations in construction labor rates and capital costs as well as resource availability.

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*

Table B3. Regional variation in levelized avoided cost of electricity (LACE) for new generation resources entering service in 2040 (2019 dollars per megawatthour)

Plant type	Minimum	Simple average	Capacity-weighted average[1]	Maximum
Dispatchable technologies				
Ultra-supercritical coal	34.36	37.65	*NB*	43.08
Combined cycle	34.19	38.53	37.17	46.38
Advanced nuclear	34.25	37.52	*NB*	43.01
Geothermal	39.66	42.68	43.33	45.96
Biomass	34.50	38.86	*NB*	46.75
Non-dispatchable technologies				
Wind, onshore	28.60	34.04	33.68	52.05
Wind, offshore	30.63	34.55	*NB*	43.26
Solar photovoltaic[2]	22.25	28.90	26.42	35.90
Hydroelectric[3]	42.97	44.08	*NB*	44.63

[1]The capacity-weighted average is the average levelized cost per technology, weighted by the new capacity coming online in each region. The capacity additions for each region are based on additions from 2038 to 2040. Technologies for which capacity additions are not expected do not have a capacity-weighted average and are marked as *NB*, or not built.
[2]Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.
[3]As modeled, EIA assumes that hydroelectric generation has seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season.
Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*

Table B4a. Value-cost ratio (capacity-weighted) for new generation resources entering service in 2040

Plant type	Average capacity-weighted[1] LCOE[2] with tax credits (2019 dollars per megawatthour)	Average capacity-weighted[1] LACE[2] (2019 dollars per megawatthour)	Average value-cost ratio[3]
Dispatchable technologies			
Ultra-supercritical coal	*NB*	*NB*	*NB*
Combined cycle	38.17	37.17	0.98
Advanced nuclear	*NB*	*NB*	*NB*
Geothermal	35.71	43.33	1.24
Biomass	*NB*	*NB*	*NB*
Non-dispatchable technologies			
Wind, onshore	32.64	33.68	1.04
Wind, offshore	*NB*	*NB*	*NB*
Solar photovoltaic[4]	24.81	26.42	1.07
Hydroelectric[5]	*NB*	*NB*	*NB*

[1]The capacity-weighted average is the average levelized cost per technology, weighted by the new capacity coming online in each region. The capacity additions for each region are based on additions from 2038 to 2040. Technologies for which capacity additions are not expected do not have a capacity-weighted average and are marked as *NB*, or not built.
[2]LCOE = levelized cost of electricity, LACE = levelized avoided cost of electricity.
[3]The *average value-cost ratio* represents the economic value or the average of the ratio of LACE-to-LCOE calculation, where the ratio is calculated for each of the 25 regions based on the cost with tax credits for each technology, as available.
[4]Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.
[5]As modeled, EIA assumes that hydroelectric generation has seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season.
Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*

Table B4b. Value-cost ratio (unweighted) for new generation resources entering service in 2040

Plant type	Average unweighted LCOE[1] with tax credits (2019 dollars per megawatthour)	Average unweighted LACE[1] (2019 dollars per megawatthour)	Average value-cost ratio[2]	Minimum[3]	Maximum[3]
Dispatchable technologies					
Ultra-supercritical coal	72.81	37.65	0.52	0.44	0.59
Combined cycle	42.89	38.53	0.93	0.63	1.01
Advanced nuclear	69.37	37.52	0.54	0.45	0.63
Geothermal	35.56	42.68	1.22	1.03	1.52
Biomass	86.83	38.86	0.45	0.33	0.50
Non-dispatchable technologies					
Wind, onshore	35.97	34.04	0.96	0.72	1.14
Wind, offshore	85.53	34.55	0.41	0.30	0.51
Solar photovoltaic[4]	27.71	28.90	1.05	0.85	1.17
Hydroelectric[5]	53.58	44.08	0.82	0.79	0.84

[1]LCOE = levelized cost of electricity, LACE = levelized avoided cost of electricity.

[2]The *average value-cost ratio* represents the economic value or the average ratio of LACE-to-LCOE calculation, where the ratio is calculated for each of the 25 regions based on the cost with tax credits for each technology, as available.

[3]The range of unweighted value-cost ratio is not based on the ratio between the minimum values shown in Tables B2 and B3, but it represents the lower and upper bounds resulting from the ratio of LACE-to-LCOE calculations for each of the 25 regions.

[4]Costs are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.

[5]As modeled, EIA assumes that hydroelectric generation has seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season.

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*