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Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2018

This paper presents average values of levelized costs and levelized avoided costs for generating technologies entering service in 2020, 2022,[1] and 2040 as represented in the National Energy Modeling System (NEMS) for the *Annual Energy Outlook 2018* (AEO2018) Reference case.[2] The costs for generating technologies entering service in 2022 are presented in the body of the report, with those for 2020[3] and 2040 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 22 U.S. supply regions of the NEMS electricity market module (EMM) are provided, together with the range of regional values.

Levelized Cost of Electricity (LCOE)

Levelized cost of electricity (LCOE) is often cited as a convenient summary measure of the overall competiveness of different generating technologies. It represents the per-megawatthour cost (in discounted real dollars) of building and operating a generating plant over an assumed financial life and duty cycle.[4] 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 these factors varies among the technologies. For technologies such as solar and wind generation that have no fuel costs and relatively small variable O&M costs, LCOE changes in rough proportion to the estimated capital cost of generation capacity. For technologies with significant fuel cost, both fuel cost and overnight cost estimates significantly affect LCOE. The availability of various incentives, including state or federal tax credits (see text box on page 2), can also affect the calculation of LCOE. As with any projection, there is uncertainty about all of these factors, and their values can vary regionally and temporally as technologies evolve and as fuel prices change.

Note that actual plant investment decisions are affected by the specific technological and regional characteristics of a project, which involve many other factors not reflected in LCOE values. The projected utilization rate, which depends on the load shape and the existing resource mix in an area where additional capacity is needed, is one such factor. The existing resource mix in a region can directly affect the economic viability of a new investment through its effect on the economics surrounding the displacement of existing resources. For example, a wind resource that would primarily displace existing

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[1] Given the long lead-time and licensing requirements for some technologies, the first feasible year that all technologies are available is 2022.

[2] AEO2018 reports are available at http://www.eia.gov/outlooks/aeo/.

[3] Appendix A shows LCOE and LACE for the subset of technologies available to be built in 2020.

[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*, available at http://www.eia.gov/outlooks/aeo/assumptions/.

natural gas generation will usually have a different economic value than one that would displace existing coal generation. 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 balanced on a continuous basis, generating units with the capability to vary output to follow demand (dispatchable technologies) generally have more value to a system than less flexible units (non-dispatchable technologies), or than units using intermittent resource to operate. The LCOE values for dispatchable and non-dispatchable technologies are listed separately in the tables, because comparing them must be done carefully.

The direct comparison of LCOE across technologies is, therefore, often problematic and can be misleading as a method to assess the economic competitiveness of various generation alternatives because projected utilization rates, the existing resource mix, and capacity values can all vary dramatically across regions where new generation capacity may be needed.

AEO2018 representation of tax incentives for renewable generation

Federal tax credits for certain renewable generation facilities have the potential to substantially reduce the realized cost of these facilities. Where applicable, the LCOE tables show both the cost with and without tax credits assumed to be available in the year in which the plant enters service, as follows.

Production Tax Credit (PTC): New wind, geothermal, and biomass plants receive 24 dollars per megawatthour ($/MWh); technologies other than wind, geothermal, and closed-loop biomass receive $12/MWh. The PTC values are adjusted for inflation and given over the plant's first 10 years of service if the plants are under construction before the end of 2016. After 2016, wind continues to be eligible for the PTC but at a dollar-per-megawatthour rate that declines by 20% in 2017, 40% in 2018, 60% in 2019, and expires completely in 2020. Based on documentation released by the Internal Revenue Service (IRS, see https://www.irs.gov/irb/2016-23_IRB/ar07.html), EIA assumes that wind plants have four years after beginning construction to bring the plants online and claim the PTC. As a result, wind plants entering service in 2020 will receive the full credit, and those entering service in 2022 will receive $14/MWh (inflation-adjusted).

Investment Tax Credit (ITC): New solar photovoltaic (PV) and thermal plants are eligible to receive a 30% ITC on capital expenditures if the plants are under construction before the end of 2019, after which the ITC tapers off for new starts to 26% in 2020 and to 22% in 2021. ITC expires for residential-owned systems and declines to 10% for business and utility-scale systems in 2022 and each year thereafter. All commercial and utility-scale plants placed in service after December 31, 2023 receive a 10% ITC regardless of the date construction started. Results in this levelized cost report only include utility-scale solar facilities and do not include small-scale solar facilities. In NEMS, EIA assumes a two-year construction lead time for new utility-scale solar PV plants and a three-year construction lead time for new solar thermal plants. EIA assumes that all utility-scale solar plants entering service in 2019 receive the full 30% tax credit. PV plants entering service in 2022 receive 26%, whereas solar thermal plants entering service in 2022, having begun construction a year earlier, receive 30%. Both onshore and offshore wind projects are eligible to claim the ITC in lieu of the PTC. While it is expected that onshore wind projects would choose the PTC, EIA assumes offshore wind projects will claim the ITC in lieu of the PTC because of the high capital costs for those projects.

Levelized Avoided Cost of Electricity (LACE)

Conceptually, an alternative assessment of economic competitiveness between generation technologies can be gained by considering the avoided cost, a measure of what it would cost the grid to generate the electricity that would be displaced by a new generation project. Avoided cost, which provides a proxy measure for the annual economic value of a candidate project, may be summed over its financial life and converted to a level annualized value that is divided by average annual output of the project to develop its *levelized* avoided cost of electricity (LACE).[6] The LACE value may then be compared with the LCOE value to provide an indication of whether or not the project's value exceeds its cost when multiple technologies are available to meet load. Using both the LCOE and LACE in combination provides a better assessment of economic competitiveness than either measure separately.

Estimating avoided costs is more complex than estimating levelized costs because it requires information about how the system would operate without the new option being considered. In this discussion, the calculation of avoided costs is 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 specified future date and represents the potential value available to the project owner from the project's contribution to satisfying both energy and capacity requirements. Although the economic decisions for capacity additions in EIA's long-term projections do not use either LACE or LCOE concepts; however, the LACE and net economic values presented in this report are generally more representative of the factors contributing to the build-decisions than looking at 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. Finally, although levelized cost calculations are generally made using an assumed set of capital and operating costs, investment decisions may be affected by factors other than the projects value relative to costs—for example, the inherent uncertainty about future fuel prices, future policies, or local consideration 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 the factors discussed in the previous paragraphs 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 AEO2018 Reference case, which includes state-level renewable electricity requirements as of October 2017 and a phase out of federal tax credits for renewable generation.

LCOE and LACE calculations

LCOE values are calculated based on a 30-year cost recovery period, using a real after-tax weighted average cost of capital (WACC) of 4.5%.[7] In reality, the cost recovery period and cost of capital can vary

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[6] Further discussion of the levelized avoided cost concept and its use in assessing economic competitiveness can be found in this link: http://www.eia.gov/renewable/workshop/gencosts/.

[7] The real WACC of 4.5% corresponds to a nominal after-tax rate of 7.0% for plants entering service in 2022. For plants entering service in 2020 and 2040, the nominal WACC used to calculate LCOE was 6.2% and 7.0%, respectively. An overview of the WACC assumptions and methodology can be found in the *Electricity Market Module of the National Energy Modeling System: Model Documentation*. This report can be found at https://www.eia.gov/analysis/pdfpages/m068index.php.

by technology and project type. In the AEO20018 Reference case, there is a 3-percentage-point increase to the cost of capital when evaluating investments in new coal-fired power plants and new coal-to-liquids (CTL) plants without carbon capture and sequestration (CCS) and pollution control retrofits. This increase reflects financial risks associated with major investments in long-lived power plants with a relatively higher rate of carbon dioxide (CO2) emissions. AEO2018 takes into account two coal-fired technologies that are compliant with the New Source Performance Standard (NSPS) for CO2 emissions under Section 111(b) of the Clean Air Act. One technology is designed to capture 30% of CO2 emissions and would still be considered a high emitter relative to other new sources; thus, it may continue to face potential financial risk if CO2 emission controls are further strengthened. Another technology is designed to capture 90% of CO2 emissions and would not face the same financial risk; therefore, it does not receive the 3-percentage-point increase in cost of capital. As a result, the LCOE values for a coal-fired plant with 30% CCS are higher than they would be if the same cost of capital were used for all technologies.

The levelized capital component reflects costs calculated using tax depreciation schedules consistent with permanent tax law, which vary by technology.[8] For technologies eligible for ITC or PTC, LCOE is reported both with and without tax credits, which are assumed to phase out and expire based on current laws and regulations. Some technologies, notably solar PV, are used in both utility-scale generation and in distributed end-use 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.

LCOE and LACE for each technology is evaluated based on the associated capacity factor, which generally corresponds to the high end of its 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. Some technologies, such as combined-cycle (CC) plants, while sometimes used in baseload operation, are also built to serve load-following or other intermediate dispatch duty cycles. Simple conventional or advanced combustion turbines (CT) 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 wind and solar resources is not operator controlled, but it is dependent on the weather or availability of sunlight; therefore, it will not necessarily correspond to operator-dispatched duty cycles. As a result, LCOE values for wind and solar technologies are not directly comparable to the LCOE values for other technologies that may have a similar average annual capacity factor; therefore, 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. They are also shown as non-dispatchable to discourage comparison with technologies that have more consistent seasonal availability. The capacity factors for solar, wind, and hydroelectric resources are averages of the capacity factor (weighted or unweighted) for the marginal site in each region, which can vary significantly by region, and will not necessarily

[8]The AEO2018 was prepared prior to passage of the Tax Cuts and Jobs Act of 2017. The new tax rate and depreciation schedules are expected to affect all technologies and will be incorporated into future EIA analyses of energy markets.

correspond to projected capacity factors for these resources in the AEO2018 or in other EIA analyses that represent capacity factors of cumulative capacity additions and existing units.

The LCOE values shown in Table 1a are a weighted average of region-specific LCOE values using weights reflecting the projected regional capacity builds in AEO2018 for new plants coming online in 2022.

Table 1a. Estimated levelized cost of electricity (capacity-weighted average[1]) for new generation resouces entering service in 2022 (2017 $/MWh)

Plant type	Capacity factor (%)	Levelized capital cost	Levelized fixed O&M	Levelized variable O&M	Levelized transmission cost	Total system LCOE	Levelized tax credit[2]	Total LCOE including tax credit
Dispatchable technologies								
Coal with 30% CCS[3]	NB	NB	NB	NB	NB	NB	NA	NB
Coal with 90% CCS[3]	NB	NB	NB	NB	NB	NB	NA	NB
Conventional CC	87	13.0	1.5	32.8	1.0	48.3	NA	48.3
Advanced CC	87	15.5	1.3	30.3	1.1	48.1	NA	48.1
Advanced CC with CCS	NB	NB	NB	NB	NB	NB	NA	NB
Conventional CT	NB	NB	NB	NB	NB	NB	NA	NB
Advanced CT	30	22.7	2.6	51.3	2.9	79.5	NA	79.5
Advanced nuclear	90	67.0	12.9	9.3	0.9	90.1	NA	90.1
Geothermal	91	28.3	13.5	0.0	1.3	43.1	-2.8	40.3
Biomass	83	40.3	15.4	45.0	1.5	102.2	NA	102.2
Non-dispatchable technologies								
Wind, onshore	43	33.0	12.7	0.0	2.4	48.0	-11.1	37.0
Wind, offshore	45	102.6	20.0	0.0	2.0	124.6	-18.5	106.2
Solar PV[4]	33	48.2	7.5	0.0	3.3	59.1	-12.5	46.5
Solar thermal	NB	NB	NB	NB	NB	NB	NB	NB
Hydroelectric[5]	65	56.7	14.0	1.3	1.8	73.9	NA	73.9

[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 in 2020–2022. Technologies for which capacity additions are not expected do not have a capacity-weighted average and are marked as *NB* or not built.

[2]The tax credit component is based on targeted federal tax credits such as the PTC or ITC available for some technologies. It reflects tax credits available only for plants entering service in 2022 and the substantial phase out 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]Because Section 111(b) of the Clean Air Act requires conventional coal plants to be built with CCS to meet specific CO2 emission standards, two levels of CCS removal are modeled: 30%, which meets the NSPS, and 90%, which exceeds the NSPS but may be seen as a build option in some scenarios. The coal plant with 30% CCS is assumed to incur a 3 percentage-point increase to its cost of capital to represent the risk associated with higher emissions.

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

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

CCS=carbon capture and sequestration. CC=combined-cycle (natural gas). CT=combustion turbine. PV=photovoltaic.

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2018*.

Table 1b reports an unweighted average across all 22 EMM regions for the same generation resources projected to come online in 2022.

Table 1b. Estimated levelized cost of electricity (unweighted average) for new generation resources entering service in 2022 (2017 $/MWh)

Plant type	Capacity factor (%)	Levelized capital cost	Levelized fixed O&M	Levelized variable O&M	Levelized transmission cost	Total system LCOE	Levelized tax credit[1]	Total LCOE including tax credit
Dispatchable technologies								
Coal with 30% CCS[2]	85	84.0	9.5	35.6	1.1	130.1	NA	130.1
Coal with 90% CCS[2]	85	68.5	11.0	38.5	1.1	119.1	NA	119.1
Conventional CC	87	12.6	1.5	34.9	1.1	50.1	NA	50.1
Advanced CC	87	14.4	1.3	32.2	1.1	49.0	NA	49.0
Advanced CC with CCS	87	26.9	4.4	42.5	1.1	74.9	NA	74.9
Conventional CT	30	37.2	6.7	51.6	3.2	98.7	NA	98.7
Advanced CT	30	23.6	2.6	55.7	3.2	85.1	NA	85.1
Advanced nuclear	90	69.4	12.9	9.3	1.0	92.6	NA	92.6
Geothermal	90	30.1	13.2	0.0	1.3	44.6	-3.0	41.6
Biomass	83	39.2	15.4	39.6	1.1	95.3	NA	95.3
Non-dispatchable technologies								
Wind, onshore	41	43.1	13.4	0.0	2.5	59.1	-11.1	48.0
Wind, offshore	45	115.8	19.9	0.0	2.3	138.0	-20.8	117.1
Solar PV[3]	29	51.2	8.7	0.0	3.3	63.2	-13.3	49.9
Solar thermal	25	128.4	32.6	0.0	4.1	165.1	-38.5	126.6
Hydroelectric[4]	64	48.2	9.8	1.8	1.9	61.7	NA	61.7

[1]The tax credit component is based on targeted federal tax credits such as the PTC or ITC available for some technologies. It reflects tax credits available only for plants entering service in 2022 and the substantial phase out 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.

[2]Because Section 111(b) of the Clean Air Act requires conventional coal plants to be built with CCS to meet specific CO2 emission standards, two levels of CCS removal are modeled: 30%, which meets the NSPS, and 90%, which exceeds the NSPS but may be seen as a build option in some scenarios. The coal plant with 30% CCS is assumed to incur a 3 percentage-point increase to its cost of capital to represent the risk associated with higher emissions.

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

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

CCS=carbon capture and sequestration. CC=combined-cycle (natural gas). CT=combustion turbine. PV=photovoltaic.

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2018*.

Table 2. Regional variation in levelized cost of electricity for new generation resources entering service in 2022 (2017 $/MWh)

Plant type	Range for total system levelized costs: Minimum	Simple average	Capacity-weighted average[2]	Maximum	Range for total system levelized costs with tax credits[1]: Minimum	Simple average	Capacity-weighted average[2]	Maximum
Dispatchable technologies								
Coal with 30% CCS[3]	117.2	130.1	NB	191.1	117.2	130.1	NB	191.1
Coal with 90% CCS[3]	110.5	119.1	NB	139.5	110.5	119.1	NB	139.5
Conventional CC	44.5	50.1	48.3	78.5	44.5	50.1	48.3	78.5
Advanced CC	43.5	49.0	48.1	76.8	43.5	49.0	48.1	76.8
Advanced CC with CCS	66.5	74.9	NB	84.8	66.5	74.9	NB	84.7
Conventional CT	87.2	98.7	NB	144.9	87.2	98.7	NB	144.9
Advanced CT	75.0	85.1	79.5	128.5	75.0	85.1	79.5	128.5
Advanced nuclear	89.7	92.6	90.1	97.5	89.7	92.6	90.1	97.5
Geothermal	41.7	44.6	43.1	49.5	39.2	41.6	40.3	45.8
Biomass	74.0	95.3	102.2	111.2	74.0	95.3	102.2	111.2
Non-dispatchable technologies								
Wind, onshore	40.7	59.1	48.0	77.3	29.7	48.0	37.0	66.2
Wind, offshore	122.2	138.0	124.6	168.5	103.8	117.1	106.2	142.3
Solar PV[4]	42.3	63.2	59.1	113.9	34.2	49.9	46.5	88.2
Solar thermal	145.1	165.1	NB	187.9	111.9	126.6	NB	144.3
Hydroelectric[5]	49.6	61.7	73.9	73.9	49.6	61.7	73.9	73.9

[1]Levelized cost with tax credits reflects tax credits available for plants entering service in 2022. 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 in 2020–2022. Technologies for which capacity additions are not expected do not have a capacity-weighted average and are marked as *NB* or not built.

[3]Because Section 111(b) of the Clean Air Act requires conventional coal plants to be built with CCS to meet specific CO2 emission standards, two levels of CCS removal are modeled: 30%, which meets the NSPS, and 90%, which exceeds the NSPS but may be seen as a build option in some scenarios. The coal plant with 30% CCS is assumed to incur a 3 percentage-point increase to its cost of capital to represent the risk associated with higher emissions.

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

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

CCS=carbon capture and sequestration. CC=combined-cycle (natural gas). CT=combustion turbine. PV=photovoltaic.

Note: The levelized costs for non-dispatchable technologies are calculated based on the capacity factor for the marginal site modeled in each region, which can vary significantly by region. The capacity factor ranges for these technologies are as follows: 37%–46% for onshore wind, 41%–50% for offshore wind, 22%–34% for solar PV, 21%–26% for solar thermal, 30%–79% 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 2018*.

Table 2 shows the significant regional variation in LCOE values based on local labor markets and the cost and availability of fuel or energy resources such as windy sites. For example, without consideration of the PTC, the LCOE for incremental onshore wind capacity ranges from $40.7/MWh in the region with the best available wind resources to $77.3/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 $48.0/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 or may not internalize into the market price for wind power.

As previously indicated, LACE provides an estimate of the cost of generation and capacity resources displaced by a marginal unit of new capacity of a particular type, thus providing an estimate of the value of building that new capacity. This estimate is especially important to consider for intermittent resources, such as wind or solar, that 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. The LACE estimates in this table have been calculated assuming the same maximum capacity factor as in the LCOE. Values are not shown for combustion turbines, because combustion turbines are generally built for their capacity value to meet a reserve margin rather than to meet generation requirements and avoided energy costs.

Table 3. Regional variation in levelized avoided cost of electricity for new generation resources entering service in 2022 (2017 $/MWh)

Plant type	Minimum	Simple average	Capacity-weighted average[1]	Maximum
Dispatchable technologies				
Coal with 30% CCS[2]	38.5	46.8	NB	74.9
Coal with 90% CCS[2]	38.5	46.8	NB	74.9
Conventional CC	38.5	47.2	46.5	74.9
Advanced CC	38.5	47.2	47.5	74.9
Advanced CC with CCS	38.5	47.2	NB	74.9
Advanced nuclear	38.6	45.1	43.3	51.7
Geothermal	45.9	57.3	66.8	74.6
Biomass	38.2	47.1	45.1	74.6
Non-dispatchable technologies				
Wind, onshore	35.9	41.1	42.9	72.1
Wind, offshore	41.6	47.3	47.6	76.6
Solar PV[3]	36.5	55.3	72.4	78.6
Solar thermal	35.8	59.7	NB	83.3
Hydroelectric[4]	40.6	52.6	74.6	74.6

[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 in 2020-2022. Technologies for which capacity additions are not expected do not have a capacity-weighted average and are marked as *NB* or not built.

[2]Because Section 111(b) of the Clean Air Act requires conventional coal plants to be built with CCS to meet specific CO2 emission standards, two levels of CCS removal are modeled: 30%, which meets the NSPS, and 90%, which exceeds the NSPS but may be seen as a build option in some scenarios. The coal plant with 30% CCS is assumed to incur a 3 percentage-point increase to its cost of capital to represent the risk associated with higher emissions.

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

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

CCS=carbon capture and sequestration. CC=combined-cycle (natural gas). CT=combustion turbine. PV=photovoltaic.

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2018*.

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 the AEO2018, however, are more complex than a simple LACE to LCOE comparison because they include such factors as policy and non-economic drivers. Nevertheless, the net economic value (difference between LACE and 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 negative net difference indicates that the cost of the marginal new unit of capacity exceeds its value to the system, and a net positive difference indicates that the marginal new unit brings in value higher than its cost by displacing more expensive generation and capacity options. The *Average Net Difference* represents the average of the *LACE minus LCOE* calculation, where the difference is calculated for each of the 22 regions. This range of differences is not based on the difference between the minimum and maximum values shown in Tables 2 and 3 but represents the lower and upper bound resulting from the LACE minus the LCOE calculations for each of the 22 regions.

Table 4a. Difference between capacity-weighted levelized avoided cost of electricity and capacity-weighted levelized cost of electricity with tax credits for new generation resources entering service in 2022 (2017 $/MWh)

Plant type	Average capacity-weighted[1] LCOE with tax credits	Average capacity-weighted[1] LACE	Average net difference[2]
Dispatchable technologies			
Coal with 30% CCS[3]	NB	NB	NB
Coal with 90% CCS[3]	NB	NB	NB
Conventional CC	48.3	46.5	-1.7
Advanced CC	48.1	47.5	-0.6
Advanced CC with CCS	NB	NB	NB
Advanced nuclear	90.1	43.3	-46.8
Geothermal	40.3	66.8	26.5
Biomass	102.2	45.1	-57.1
Non-dispatchable technologies			
Wind, onshore	37.0	42.9	5.9
Wind, offshore	106.2	47.6	-58.6
Solar PV[4]	46.5	72.4	25.8
Solar thermal	NB	NB	NB
Hydroelectric[5]	73.9	74.6	0.7

[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 in 2020–2022. Technologies for which capacity additions are not expected do not have a capacity-weighted average and are marked as *NB* or not built.
[2]The *Average net difference* represents the net economic value or the average of the LACE minus LCOE calculation, where the difference is calculated for each of the 22 regions based on the cost with tax credits for each technology, as available.
[3]Because Section 111(b) of the Clean Air Act requires conventional coal plants to be built with CCS to meet specific CO2 emission standards, two levels of CCS removal are modeled: 30%, which meets the NSPS, and 90%, which exceeds the NSPS but may be seen as a build option in some scenarios. The coal plant with 30% CCS is assumed to incur a 3 percentage-point increase to its cost of capital to represent the risk associated with higher emissions.
[4]Costs are expressed in terms of net AC power available to the grid for the installed capacity.
[5]As modeled, hydroelectric is assumed to have seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season.
CCS=carbon capture and sequestration. CC=combined-cycle (natural gas). CT=combustion turbine. PV=photovoltaic.
Source: U.S. Energy Information Administration, *Annual Energy Outlook 2018*.

As shown in Table 4a, the capacity-weighted average net difference is above zero in 2022 for geothermal, solar PV, and onshore wind, suggesting that these technologies are being built in regions where they are economically viable. Although the capacity-weighted average net difference for advanced CC is negative, it is close to zero, which suggests that the technology has been the most attractive marginal capacity addition and the market has developed the technology to the point where the net economic value is close to breakeven after having met load growth and/or displaced higher cost generation.[9]

Table 4b. Difference between unweighted levelized avoided cost of electricity and unweighted levelized cost of electricity with tax credits for new generation resources entering service in 2022 (2017 $/MWh)

Plant type	Average unweighted LCOE with tax credits	Average unweighted LACE	Average net difference[1]	Minimum[2]	Maximum[2]
Dispatchable technologies					
Coal with 30% CCS[3]	130.1	46.8	-83.3	-116.2	-71.3
Coal with 90% CCS[3]	119.1	46.8	-72.3	-83.8	-63.2
Conventional CC	50.1	47.2	-2.9	-10.2	1.2
Advanced CC	49.0	47.2	-1.8	-9.1	1.3
Advanced CC with CCS	74.9	47.2	-27.7	-35.4	-6.4
Advanced nuclear	92.6	45.1	-47.5	-53.3	-41.0
Geothermal	41.6	57.3	15.7	5.7	34.7
Biomass	95.3	47.1	-48.2	-59.6	-33.3
Non-dispatchable technologies					
Wind, onshore	48.0	41.1	-6.9	-26.5	19.3
Wind, offshore	117.1	47.3	-69.8	-92.1	-31.1
Solar PV[4]	49.9	55.3	5.4	-27.0	30.7
Solar thermal	126.6	59.7	-66.9	-94.5	-48.3
Hydroelectric[5]	61.7	52.6	-9.0	-18.7	0.7

[1]The *Average net difference* represents the net economic value or the average of the LACE minus LCOE calculation, where the difference is calculated for each of the 22 regions based on the cost with tax credits for each technology, as available.
[2]The range of unweighted differences is not based on the difference between the minimum values shown in Tables 2 and 3, but represents the lower and upper bound resulting from the LACE minus LCOE calculations for each of the 22 regions.
[3]Because Section 111(b) of the Clean Air Act requires conventional coal plants to be built with CCS to meet specific CO2 emission standards, two levels of CCS removal are modeled: 30%, which meets the NSPS, and 90%, which exceeds the NSPS but may be seen as a build option in some scenarios. The coal plant with 30% CCS is assumed to incur a 3 percentage-point increase to its cost of capital to represent the risk associated with higher emissions.
[4]Costs are expressed in terms of net AC power available to the grid for the installed capacity.
[5]As modeled, hydroelectric is assumed to have seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season.
CCS=carbon capture and sequestration. CC=combined-cycle (natural gas). CT=combustion turbine. PV=photovoltaic.
Source: U.S. Energy Information Administration, *Annual Energy Outlook 2018*.

[9] For a more detailed discussion of the LACE versus LCOE measures, see *Assessing the Economic Value of New Utility-Scale Electricity Generation Projects*, which can be found at http://www.eia.gov/renewable/workshop/gencosts/pdf/lace-lcoe_070213.pdf

LCOE and LACE projections

Table 5 compares LCOE with the applicable tax credit, LACE, and net difference between LACE and LCOE for advanced CC, onshore wind, and solar PV plants entering service in 2022 and 2040 (as shown in Appendix B). Changes in costs between 2022 and 2040 reflect a number of different factors, sometimes working in different directions. Technology improvement tends to reduce LCOE through lower capital costs or improved performance (as measured by heat rate for advanced CC plants or capacity factor for onshore wind or solar PV plants). For advanced CC plants, changing fuel prices also factor into the change in LCOE. For wind and solar resources, the availability of high-quality resources may also be a factor. As the best, least-cost resources are utilized, future development will occur in less favorable areas, potentially resulting in higher project development costs, higher costs to access transmission lines, or access to lower-performing resources. Changes in the value of generation are a function of load growth. Wind and solar may show strong daily or seasonal generation patterns; as a result, the value of such renewable generation may see significant reductions as these time periods become more saturated with generation from similar resources and generation from new facilities must compete with lower-cost options in the dispatch merit order.

Table 5. Levelized cost of electricity, levelized avoided cost of electricity, and net economic value for selected generating technologies entering service in 2022 and 2040 (2017 $/MWh)

	Advanced CC		Onshore wind		Solar PV[1]	
Indicator	**2022**	**2040**	**2022**	**2040**	**2022**	**2040**
Capacity-weighted[2]						
LCOE[3]	48.1	47.6	37.0	56.4	46.5	40.8
LACE	47.5	48.1	42.9	67.6	72.4	56.7
Average net difference[4]	-0.6	0.5	5.9	11.2	25.8	15.9
Unweighted						
LCOE[3]	49.0	51.7	48.0	49.7	49.9	48.1
LACE	47.2	50.9	41.1	44.7	55.3	58.4
Average net difference[4]	-1.8	-0.8	-6.9	-4.9	5.4	10.3

[1]Costs are expressed in terms of net AC power available to the grid for the installed capacity.

[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 in 2020–2022 for plants coming online in 2022 and in 2038–2040 for plants coming online in 2040.

[3]Levelized-cost with tax credits reflects tax credits available for plants entering service in 2022 and 2040. See note 1 in Tables 1a and 1b.

[4]The *Average net difference* represents the net economic value or the average of the LACE minus LCOE calculation, where the difference is calculated for each of the 22 regions based on the cost with tax credits for each technology, as available.

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2018*.

Appendix A: LCOE tables for new generation resources entering service in 2020

Table A1a. Estimated levelized cost of electricity (capacity-weighted average[1]) for new generation resources entering service in 2020 (2017 $/MWh)

Plant type	Capacity factor (%)	Levelized capital cost	Levelized fixed O&M	Levelized variable O&M	Levelized transmission cost	Total system LCOE	Levelized tax credit[2]	Total LCOE including tax credit
Dispatchable technologies								
Conventional CC	87	11.1	1.5	33.6	1.0	47.1	NA	47.1
Advanced CC	87	13.2	1.3	29.5	1.0	45.1	NA	45.1
Conventional CT	30	30.7	6.7	48.0	2.7	88.1	NA	88.1
Advanced CT	30	19.5	2.6	52.7	2.7	77.5	NA	77.5
Non-dispatchable technologies								
Wind, onshore	42	32.7	13.1	0.0	2.4	48.1	-17.5	30.6
Solar PV[3]	31	46.5	8.1	0.0	3.1	57.7	-13.9	43.8

[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 in 2018-2020.

[2]The tax credit component is based on targeted federal tax credits such as the PTC or ITC available for some technologies. It reflects tax credits available only for plants entering service in 2020 and the substantial phase out 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 power available to the grid for the installed capacity.

CC=combined-cycle (natural gas). CT=combustion turbine. PV=photovoltaic.

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2018*.

Table A1b. Estimated levelized avoided cost of electricity (unweighted average) for new generation resources entering service in 2020 (2017 $/MWh)

Plant type	Capacity factor (%)	Levelized capital cost	Levelized fixed O&M	Levelized variable O&M	Levelized transmission cost	Total system LCOE	Levelized tax credit[1]	Total LCOE including tax credit
Dispatchable technologies								
Conventional CC	87	11.5	1.5	34.1	1.1	48.1	NA	48.1
Advanced CC	87	13.1	1.3	31.1	1.1	46.7	NA	46.7
Conventional CT	30	33.9	6.7	49.9	3.1	93.6	NA	93.6
Advanced CT	30	21.7	2.6	55.8	3.1	83.2	NA	83.2
Non-dispatchable technologies								
Wind, onshore	40	40.4	13.7	0.0	2.5	56.6	-17.5	39.1
Solar PV[2]	29	51.3	8.7	0.0	3.2	63.2	-15.4	47.8

[1]The tax credit component is based on targeted federal tax credits such as the PTC or ITC available for some technologies. It reflects tax credits available only for plants entering service in 2020 and the substantial phase out 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.

[2]Costs are expressed in terms of net AC power available to the grid for the installed capacity.

CC=combined-cycle (natural gas). CT=combustion turbine. PV=photovoltaic.

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2018*.

Table A2. Regional variation in levelized cost of electricity for new generation resources entering service in 2020 (2017 $/MWh)

	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								
Conventional CC	43.3	48.1	47.1	58.1	43.3	48.1	47.1	58.1
Advanced CC	42.0	46.7	45.1	56.5	42.0	46.7	45.1	56.5
Conventional CT	85.8	93.6	88.1	111.8	85.8	93.6	88.1	111.8
Advanced CT	75.8	83.2	77.5	100.9	75.8	83.2	77.5	100.9
Non-dispatchable technologies								
Wind, onshore	40.1	56.6	48.1	70.4	22.6	39.1	30.6	52.9
Solar PV[3]	42.4	63.2	57.7	114.0	32.9	47.8	43.8	84.3

[1]Levelized cost with tax credits reflects tax credits available for plants entering service in 2020. 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 in 2018–2020.

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

CC=combined-cycle (natural gas). CT=combustion turbine. PV=photovoltaic.

Note: The levelized costs for non-dispatchable technologies are calculated 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 as follows: 36%–45% for onshore wind and 22%–34% 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 2018*.

Table A3. Regional variation in levelized avoided cost of electricity for new generation resources entering service in 2020 (2017 $/MWh)

Plant type	**Minimum**	**Simple average**	**Capacity-weighted average[1]**	**Maximum**
Dispatchable technologies				
Conventional CC	38.6	45.5	45.0	58.4
Advanced CC	38.6	45.5	46.2	58.4
Conventional CT	42.2	58.7	60.6	77.8
Advanced CT	42.2	58.7	61.7	77.8
Non-dispatchable technologies				
Wind, onshore	34.0	40.2	38.0	50.8
Solar PV[2]	32.5	52.1	53.4	71.6

[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 in 2018–2020.

[2]Costs are expressed in terms of net AC power available to the grid for the installed capacity.

CC=combined-cycle (natural gas). CT=combustion turbine. PV=photovoltaic.

Source: U.S. Energy Information Administration, Annual Energy Outlook 2018.

Table A4a. Difference between capacity-weighted levelized avoided cost of electricity and capacity-weighted levelized cost of electricity with tax credits for new generation resources entering service in 2020 (2017 $/MWh)

Plant type	Average capacity-weighted[1] LCOE with tax credits	Average capacity-weighted[1] LACE	Average net difference[2]
Dispatchable technologies			
Conventional CC	47.1	45.0	-2.1
Advanced CC	45.1	46.2	1.2
Conventional CT	88.1	60.6	-27.5
Advanced CT	77.5	61.7	-15.8
Non-dispatchable technologies			
Wind, onshore	30.6	38.0	7.3
Solar PV[3]	43.8	53.4	9.6

[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 in 2018–2020.
[2]The *Average net difference* represents the net economic value or the average of the LACE minus LCOE calculation, where the difference is calculated for each of the 22 regions based on the cost with tax credits for each technology, as available.
[3]Costs are expressed in terms of net AC power available to the grid for the installed capacity.
CC=combined-cycle (natural gas). CT=combustion turbine. PV=photovoltaic.
Source: U.S. Energy Information Administration, *Annual Energy Outlook 2018*.

Table A4b. Difference between unweighted levelized avoided cost of electricity and unweighted levelized cost of electricity with tax credits for new generation resources entering service in 2020 (2017 $/MWh)

Plant type	Average unweighted LCOE with tax credits	Average unweighted LACE	Average net difference[1]	Minimum[2]	Maximum[2]
Dispatchable technologies					
Conventional CC	48.1	45.5	-2.6	-9.3	4.2
Advanced CC	46.7	45.5	-1.1	-7.6	6.1
Conventional CT	93.6	58.7	-34.9	-53.7	-22.2
Advanced CT	83.2	58.7	-24.4	-42.9	-12.6
Non-dispatchable technologies					
Wind, onshore	39.1	40.2	1.1	-13.0	20.5
Solar PV[3]	47.8	52.1	4.3	-27.6	14.2

[1]The *Average net difference* represents the net economic value or the average of the LACE minus LCOE calculation, where the difference is calculated for each of the 22 regions based on the cost with tax credits for each technology, as available.
[2]The range of unweighted differences is not based on the difference between the minimum values shown in Tables A2 and A3, but represents the lower and upper bound resulting from the LACE minus LCOE calculations for each of the 22 regions.
[3]Costs are expressed in terms of net AC power available to the grid for the installed capacity.
CC=combined-cycle (natural gas). CT=combustion turbine. PV=photovoltaic.
Source: U.S. Energy Information Administration, *Annual Energy Outlook 2018*.

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

Table B1a. Estimated levelized cost of electricity (capacity-weighted average[1]) for new generation resources entering service in 2040 (2017 $/MWh)

Plant type	Capacity factor (%)	Levelized capital cost	Levelized fixed O&M	Levelized variable O&M	Levelized transmission cost	Total system LCOE	Levelized tax credit[2]	Total LCOE including tax credit
Dispatchable technologies								
Coal with 30% CCS[3]	NB	NB	NB	NB	NB	NB	NB	NB
Coal with 90% CCS[3]	NB	NB	NB	NB	NB	NB	NB	NB
Conventional CC	87	9.4	1.5	38.3	0.9	50.1	NA	50.1
Advanced CC	87	10.4	1.3	35.0	1.0	47.6	NA	47.6
Advanced CC with CCS	NB	NB	NB	NB	NB	NB	NB	NB
Conventional CT	NB	NB	NB	NB	NB	NB	NB	NB
Advanced CT	30	17.3	2.6	58.7	2.9	81.5	NA	81.5
Advanced nuclear	NB	NB	NB	NB	NB	NB	NB	NB
Geothermal	93	18.6	15.5	0.0	1.3	35.4	-1.9	33.5
Biomass	NB	NB	NB	NB	NB	NB	NB	NB
Non-dispatchable technologies								
Wind, onshore	38	38.9	14.2	0.0	3.3	56.4	NA	56.4
Wind, offshore	NB	NB	NB	NB	NB	NB	NB	NB
Solar PV[4]	32	33.2	8.0	0.0	2.9	44.1	-3.3	40.8
Solar thermal	NB	NB	NB	NB	NB	NB	NB	NB
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 in 2038–2040. Technologies for which capacity additions are not expected do not have a capacity-weighted average and are marked as *NB* or not built.

[2]The tax credit component is based on targeted federal tax credits such as the PTC or ITC available for some technologies. It reflects tax credits available only for plants entering service in 2040 and the substantial phase out 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]Because Section 111(b) of the Clean Air Act requires conventional coal plants to be built with CCS to meet specific CO2 emission standards, two levels of CCS removal are modeled: 30%, which meets the NSPS, and 90%, which exceeds the NSPS but may be seen as a build option in some scenarios. The coal plant with 30% CCS is assumed to incur a 3 percentage-point increase to its cost of capital to represent the risk associated with higher emissions.

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

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

CCS=carbon capture and sequestration. CC=combined-cycle (natural gas). CT=combustion turbine. PV=photovoltaic.

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2018*.

Table B1b. Estimated levelized cost of electricity (unweighted average) for new generation resources entering service in 2040 (2017 $/MWh)

Plant type	Capacity factor (%)	Levelized capital cost	Levelized fixed O&M	Levelized variable O&M	Levelized transmission cost	Total system LCOE	Levelized tax credit[1]	Total LCOE including tax credit
Dispatchable technologies								
Coal with 30% CCS[2]	85	66.8	9.5	36.2	1.1	113.6	NA	113.6
Coal with 90% CCS[2]	85	54.5	11.0	35.8	1.1	102.4	NA	102.4
Conventional CC	87	10.4	1.5	40.6	1.1	53.6	NA	53.6
Advanced CC	87	11.3	1.3	38.0	1.1	51.7	NA	51.7
Advanced CC with CCS	87	20.0	4.4	50.4	1.1	75.9	NA	75.9
Conventional CT	30	30.6	6.7	60.3	3.1	100.8	NA	100.8
Advanced CT	30	17.7	2.6	61.2	3.1	84.7	NA	84.7
Advanced nuclear	90	54.4	12.9	9.8	1.0	78.1	NA	78.1
Geothermal	92	27.4	19.2	0.0	1.3	47.9	-2.7	45.2
Biomass	83	31.5	15.4	36.8	1.1	84.8	NA	84.8
Non-dispatchable technologies								
Wind, onshore	40	33.7	13.5	0.0	2.5	49.7	NA	49.7
Wind, offshore	45	88.2	19.9	0.0	2.3	110.4	NA	110.4
Solar PV[3]	29	40.1	8.7	0.0	3.3	52.1	-4.0	48.1
Solar thermal	24	103.6	33.7	0.0	4.2	141.4	-10.4	131.1
Hydroelectric[4]	61	42.9	9.4	4.1	2.0	58.4	NA	58.4

[1]The tax credit component is based on targeted federal tax credits such as the PTC or ITC available for some technologies. It reflects tax credits available only for plants entering service in 2040 and the substantial phase out 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.

[2]Because Section 111(b) of the Clean Air Act requires conventional coal plants to be built with CCS to meet specific CO2 emission standards, two levels of CCS removal are modeled: 30%, which meets the NSPS, and 90%, which exceeds the NSPS but may be seen as a build option in some scenarios. The coal plant with 30% CCS is assumed to incur a 3 percentage-point increase to its cost of capital to represent the risk associated with higher emissions.

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

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

CCS=carbon capture and sequestration. CC=combined-cycle (natural gas). CT=combustion turbine. PV=photovoltaic.

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2018*.

Table B2. Regional variation in levelized cost of electricity for new generation resources entering service in 2040 (2017 $/MWh)

	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								
Coal with 30% CCS[3]	101.3	113.6	NB	171.6	101.3	113.6	NB	171.6
Coal with 90% CCS[3]	94.2	102.4	NB	121.6	94.2	102.4	NB	121.6
Conventional CC	47.7	53.6	50.1	81.6	47.7	53.6	50.1	81.6
Advanced CC	45.6	51.7	47.6	78.8	45.6	51.7	47.6	78.8
Advanced CC with CCS	70.6	75.9	NB	83.0	70.6	75.9	NB	83.0
Conventional CT	92.1	100.8	NB	134.7	92.1	100.8	NB	134.7
Advanced CT	77.0	84.7	81.5	114.5	77.0	84.7	81.5	114.5
Advanced nuclear	75.7	78.1	NB	81.9	75.7	78.1	NB	81.9
Geothermal	35.4	47.9	35.4	69.6	33.5	45.2	33.5	65.3
Biomass	67.6	84.8	NB	104.1	67.6	84.8	NB	104.1
Non-dispatchable technologies								
Wind, onshore	34.5	49.7	56.4	63.6	34.5	49.7	56.4	63.6
Wind, offshore	97.8	110.4	NB	133.8	97.8	110.4	NB	133.8
Solar PV[4]	35.4	52.1	44.1	92.2	33.0	48.1	40.8	84.5
Solar thermal	121.0	141.4	NB	160.0	112.3	131.1	NB	148.5
Hydroelectric[5]	42.5	58.4	NB	70.1	42.5	58.4	NB	70.1

[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 in 2038–2040. Technologies for which capacity additions are not expected do not have a capacity-weighted average and are marked as *NB* or not built.
[3]Because Section 111(b) of the Clean Air Act requires conventional coal plants to be built with CCS to meet specific CO2 emission standards, two levels of CCS removal are modeled: 30%, which meets the NSPS, and 90%, which exceeds the NSPS but may be seen as a build option in some scenarios. The coal plant with 30% CCS is assumed to incur a 3 percentage-point increase to its cost of capital to represent the risk associated with higher emissions.
[4]Costs are expressed in terms of net AC power available to the grid for the installed capacity.
[5]As modeled, hydroelectric is assumed to have seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season.
CCS=carbon capture and sequestration. CC=combined-cycle (natural gas). CT=combustion turbine. PV=photovoltaic.
Note: The levelized costs for non-dispatchable technologies are calculated 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 as follows: 37%–46% for onshore wind, 41%–50% for offshore wind, 22%–34% for solar PV, 21%–26% for solar thermal, 35%–79% 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 2018*.

Table B3. Regional variation in levelized avoided cost of electricity for new generation resources entering service in 2040 (2017 $/MWh)

Plant type	Minimum	Simple average	Capacity-weighted average[1]	Maximum
Dispatchable technologies				
Coal with 30% CCS[2]	36.1	50.3	NB	80.0
Coal with 90% CCS[2]	36.1	50.3	NB	80.0
Conventional CC	36.0	50.9	48.5	79.9
Advanced CC	36.0	50.9	48.1	79.9
Advanced CC with CCS	36.0	50.9	NB	79.9
Advanced nuclear	36.4	48.5	NB	59.3
Geothermal	35.5	56.0	79.2	79.2
Biomass	35.5	50.4	NB	79.2
Non-dispatchable technologies				
Wind, onshore	31.6	44.7	67.6	74.0
Wind, offshore	34.2	50.9	NB	83.2
Solar PV[3]	43.4	58.4	56.7	87.8
Solar thermal	50.7	65.3	NB	98.5
Hydroelectric[4]	35.5	53.3	NB	79.2

[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 in 2038–2040. Technologies for which capacity additions are not expected do not have a capacity-weighted average and are marked as *NB* or not built.
[2]Because Section 111(b) of the Clean Air Act requires conventional coal plants to be built with CCS to meet specific CO2 emission standards, two levels of CCS removal are modeled: 30%, which meets the NSPS, and 90%, which exceeds the NSPS but may be seen as a build option in some scenarios. The coal plant with 30% CCS is assumed to incur a 3 percentage-point increase to its cost of capital to represent the risk associated with higher emissions.
[3]Costs are expressed in terms of net AC power available to the grid for the installed capacity.
[4]As modeled, hydroelectric is assumed to have seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season.
CCS=carbon capture and sequestration. CC=combined-cycle (natural gas). CT=combustion turbine. PV=photovoltaic.
Source: U.S. Energy Information Administration, *Annual Energy Outlook 2018*.

Table B4a. Difference between capacity-weighted levelized avoided cost of electricity and capacity-weighted levelized cost of electricity with tax credits for new generation resources entering service in 2040 (2017 $/MWh)

Plant type	Average capacity-weighted[1] LCOE with tax credits	Average capacity-weighted[1] LACE	Average net difference[2]
Dispatchable technologies			
Coal with 30% CCS[3]	NB	NB	NB
Coal with 90% CCS[3]	NB	NB	NB
Conventional CC	50.1	48.5	-1.5
Advanced CC	47.6	48.1	0.5
Advanced CC with CCS	NB	NB	NB
Advanced nuclear	NB	NB	NB
Geothermal	33.5	79.2	45.7
Biomass	NB	NB	NB
Non-dispatchable technologies			
Wind, onshore	56.4	67.6	11.2
Wind, offshore	NB	NB	NB
Solar PV[4]	40.8	56.7	15.9
Solar thermal	NB	NB	NB
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 in 2038–2040. Technologies for which capacity additions are not expected do not have a capacity-weighted average and are marked as *NB* or not built.

[2]The *Average net difference* represents the net economic value or the average of the LACE minus LCOE calculation, where the difference is calculated for each of the 22 regions based on the cost with tax credits for each technology, as available.

[3]Because Section 111(b) of the Clean Air Act requires conventional coal plants to be built with CCS to meet specific CO2 emission standards, two levels of CCS removal are modeled: 30%, which meets the NSPS, and 90%, which exceeds the NSPS but may be seen as a build option in some scenarios. The coal plant with 30% CCS is assumed to incur a 3 percentage-point increase to its cost of capital to represent the risk associated with higher emissions.

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

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

CCS=carbon capture and sequestration. CC=combined-cycle (natural gas). CT=combustion turbine. PV=photovoltaic.

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2018*.

Table B4b. Difference between unweighted levelized avoided cost of electricity and unweighted levelized cost of electricity with tax credits for new generation resources entering service in 2040 (2017 $/MWh)

Plant type	Average unweighted LCOE with tax credits	Average unweighted LACE	Average net difference[1]	Minimum[2]	Maximum[2]
Dispatchable technologies					
Coal with 30% CCS[3]	113.6	50.3	-63.3	-91.5	-49.7
Coal with 90% CCS[3]	102.4	50.3	-52.1	-62.0	-38.5
Conventional CC	53.6	50.9	-2.7	-12.5	0.9
Advanced CC	51.7	50.9	-0.8	-11.2	2.2
Advanced CC with CCS	75.9	50.9	-25.1	-35.7	-0.3
Advanced nuclear	78.1	48.5	-29.5	-42.4	-21.6
Geothermal	45.2	56.0	10.8	-12.1	45.7
Biomass	84.8	50.4	-34.4	-58.5	-20.0
Non-dispatchable technologies					
Wind, onshore	49.7	44.7	-4.9	-20.6	18.1
Wind, offshore	110.4	50.9	-59.5	-77.5	-18.3
Solar PV[4]	48.1	58.4	10.3	-24.3	41.8
Solar thermal	131.1	65.3	-65.7	-90.5	-40.3
Hydroelectric[5]	58.4	53.3	-5.1	-14.0	9.1

[1]The *Average net difference* represents the net economic value or the average of the LACE minus LCOE calculation, where the difference is calculated for each of the 22 regions based on the cost with tax credits for each technology, as available.
[2]The range of unweighted differences is not based on the difference between the minimum values shown in Tables B2 and B3, but represents the lower and upper bound resulting from the LACE minus LCOE calculations for each of the 22 regions.
[3]Because Section 111(b) of the Clean Air Act requires conventional coal plants to be built with CCS to meet specific CO2 emission standards, two levels of CCS removal are modeled: 30%, which meets the NSPS, and 90%, which exceeds the NSPS but may be seen as a build option in some scenarios. The coal plant with 30% CCS is assumed to incur a 3 percentage-point increase to its cost of capital to represent the risk associated with higher emissions.
[4]Costs are expressed in terms of net AC power available to the grid for the installed capacity.
[5]As modeled, hydroelectric is assumed to have seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season.
CCS=carbon capture and sequestration. CC=combined-cycle (natural gas). CT=combustion turbine. PV=photovoltaic.
Source: U.S. Energy Information Administration, *Annual Energy Outlook 2018*.