



Cost and Performance Characteristics of New Generating Technologies, *Annual Energy Outlook 2020*

The tables presented below will be incorporated into the Electricity Market Module chapter of the U.S. Energy Information Administration's (EIA) *Annual Energy Outlook 2020* (AEO2020) Assumptions document. Table 1 represents EIA's assessment of the cost to develop and install various generating technologies used in the electric power sector. Generating technologies typically found in end-use applications, such as combined heat and power or roof-top photovoltaics (PV), will be described elsewhere in the Assumptions document. The costs shown in Table 1, except as noted below, are the costs for a typical facility for each generating technology before adjusting for regional cost factors. Overnight costs exclude interest accrued during plant construction and development. Technologies with limited commercial experience may include a technological optimism factor to account for the tendency to underestimate the full engineering and development costs for new technologies during technology research and development.

All technologies demonstrate some degree of variability in cost, based on project size, location, and access to key infrastructure (such as grid interconnections, fuel supply, and transportation). For wind and solar PV, in particular, the cost favorability of the lowest-cost regions compound the underlying variability in regional cost and create a significant differential between the unadjusted costs and the capacity-weighted average national costs as observed from recent market experience. To account for this difference, Table 1 shows a weighted average cost for both wind and solar PV, based on the regional cost factors assumed for these technologies in AEO2020 and the actual regional distribution of the builds that occurred in 2018.

Table 2 shows a full listing of the overnight costs for each technology and [electricity region](#), if the resource or technology is available to be built in the given region. The regional costs reflect the impact of locality adjustments, including one to address ambient air conditions for technologies that include a combustion turbine and one to adjust for additional costs associated with accessing remote wind resources. Temperature, humidity, and air pressure can affect the available capacity of a combustion turbine, and EIA's modeling addresses these possible effects through an additional cost multiplier by region. Unlike most other generation technologies where fuel can be transported to the plant, wind generators must be located in areas with the best wind resources. Sites that are located near existing transmission with access to a road network or are located on lower development cost lands are generally built up first, after which additional costs may be incurred to access sites with less favorable characteristics. EIA represents this possibility through a multiplier applied to the wind plant capital costs that increases as the best sites in a region are developed.

Table 1. Cost and performance characteristics of new central station electricity generating technologies

Technology	First available year ¹	Size (MW)	Lead time (years)	Base overnight cost ² (2019 \$/kW)	Technological optimism factor ³	Total overnight cost ^{4,5} (2019 \$/kW)	Variable O&M ⁶ (2019 \$/MWh)	Fixed O&M (2019\$/kW-yr)	Heat rate ⁷ (Btu/kWh)
Ultra-supercritical coal (USC)	2023	650	4	3,661	1.00	3,661	4.48	40.41	8,638
USC with 30% carbon capture and sequestration (CCS)	2023	650	4	4,539	1.03	4,652	7.05	54.07	9,751
USC with 90% CCS	2023	650	4	5,851	1.03	5,997	10.93	59.29	12,507
Combined-cycle—single shaft	2022	418	3	1,079	1.00	1,079	2.54	14.04	6,431
Combined-cycle—multi shaft	2022	1,083	3	954	1.00	954	1.86	12.15	6,370
Combined-cycle with 90% CCS	2022	377	3	2,470	1.04	2,569	5.82	27.48	7,124
Internal combustion engine	2021	21	2	1,802	1.00	1,802	5.67	35.01	8,295
Combustion turbine— aeroderivative ⁸	2021	105	2	1,170	1.00	1,170	4.68	16.23	9,124
Combustion turbine—industrial frame	2021	237	2	710	1.00	710	4.48	6.97	9,905
Fuel cells	2022	10	3	6,671	1.10	7,339	0.59	30.65	6,469
Advanced nuclear	2025	2,156	6	6,016	1.05	6,317	2.36	121.13	10,461
Distributed generation—base	2022	2	3	1,555	1.00	1,555	8.57	19.28	8,946
Distributed generation—peak	2021	1	2	1,868	1.00	1,868	8.57	19.28	9,934
Battery storage	2020	50	1	1,383	1.00	1,383	0.00	24.70	NA
Biomass	2023	50	4	4,080	1.01	4,104	4.81	125.19	13,500
Geothermal ^{9,10}	2023	50	4	2,680	1.00	2,680	1.16	113.29	9,156
Municipal solid waste—landfill gas	2022	36	3	1,557	1.00	1,557	6.17	20.02	8,513
Conventional hydropower ¹⁰	2023	100	4	2,752	1.00	2,752	1.39	41.63	NA
Wind ⁵	2022	200	3	1,319	1.00	1,319	0.00	26.22	NA
Wind offshore ⁹	2023	400	4	4,356	1.25	5,446	0.00	109.54	NA
Solar thermal ⁹	2022	115	3	7,191	1.00	7,191	0.00	85.03	NA
Solar photovoltaic —tracking ^{5,9,11}	2021	150	2	1,331	1.00	1,331	0.00	15.19	NA

¹ Represents the first year that a new unit could become operational.

² Base cost includes project contingency costs.

³ The technological optimism factor is applied to the first four units of a new, unproven design; it reflects the demonstrated tendency to underestimate actual costs for a first-of-a-kind unit.

⁴ Overnight capital cost includes contingency factors and excludes regional multipliers (except as noted for wind and solar PV) and learning effects. Interest charges are also excluded. The capital costs represent current costs for plants that would come online in 2020.

⁵ Wind and solar PV technologies' total overnight cost in the table shows the average input value across all 25 electricity market regions, as weighted by the respective capacity of that type installed during 2018 in each region to account for the substantial regional variation in wind and solar costs (as shown in Table 4). The input value used for onshore wind in AEO2020 was \$1,260 per kilowatt (kW) and for solar PV with tracking it was \$1,307/kW, which represents the cost of building a plant excluding regional factors. Region-specific factors contributing to the substantial regional variation in cost include differences in typical project size across regions, accessibility of resources, and variation in labor and other construction costs through the country.

⁶ O&M = Operations and maintenance.

⁷ The nuclear average heat rate is the weighted average tested heat rate for nuclear units as reported on the Form EIA-860, *Annual Electric Generator Report*. No heat rate is reported for battery storage because it is not a primary conversion technology; conversion losses are accounted for when the electricity is first generated; electricity-to-storage losses are accounted for through the additional demand for electricity required to meet load. For hydropower, wind, solar, and geothermal technologies, no heat rate is reported because the power is generated without fuel combustion and no set British thermal unit conversion factors exist. The model calculates the [average heat rate for fossil generation](#) in each year to report primary energy consumption displaced for these resources.

⁸ Combustion turbine aeroderivative units can be built by the model before 2021, if necessary, to meet a region's reserve margin.

⁹ Capital costs are shown before investment tax credits are applied.

¹⁰ Because geothermal and hydropower cost and performance characteristics are specific for each site, the table entries show the cost of the least expensive plant that could be built in the Northwest region for hydro and Great Basin region for geothermal, where most of the proposed sites are located.

¹¹ Costs and capacities are expressed in terms of net AC (alternating current) power available to the grid for the installed capacity.

Sources: Input costs are primarily based on a report provided by external consultants: Sargent & Lundy, December 2019. Hydropower site costs for non-powered dams were most recently updated for AEO2018 using data from Oak Ridge National Lab

Table 2. Total overnight capital costs of new electricity generating technologies by region

2019 dollars per kilowatt

Technology	1 TRE	2 FRCC	3 MISW	4 MISC	5 MISE	6 MISS	7 ISNE	8 NYCW	9 NYUP	10 PJME	11 PJMW	12 PJMC	13 PJMD
Ultra-supercritical coal (USC)	3,402	3,523	3,892	3,923	3,973	3,521	4,242	NA	4,146	4,280	3,651	4,601	3,940
USC with 30% CCS	4,362	4,499	4,906	4,959	5,004	4,506	5,338	NA	5,231	5,372	4,651	5,710	5,000
USC with 90% CCS	5,660	5,826	6,273	6,395	6,407	5,860	6,785	NA	6,611	6,796	5,975	7,236	6,350
CC—single shaft	974	1,011	1,125	1,119	1,147	1,003	1,294	1,717	1,298	1,296	1,075	1,299	1,237
CC—multi shaft	848	886	1,003	1,004	1,030	880	1,131	1,549	1,112	1,137	931	1,192	1,051
CC with 90% CCS	2,409	2,466	2,614	2,604	2,644	2,454	2,728	3,090	2,666	2,706	2,488	2,820	2,592
Internal combustion engine	1,695	1,744	1,871	1,924	1,903	1,756	1,972	2,472	1,898	1,973	1,768	2,150	1,836
CT—aeroderivative	1,035	1,087	1,242	1,227	1,264	1,078	1,316	1,685	1,270	1,309	1,122	1,438	1,191
CT—industrial frame	626	658	754	746	769	653	801	1,034	772	797	680	878	723
Fuel cells	7,042	7,191	7,531	7,793	7,653	7,272	7,939	9,346	7,617	7,871	7,251	8,392	7,474
Advanced nuclear	5,963	6,120	6,494	7,008	6,766	6,290	7,156	NA	6,676	6,992	6,180	7,688	6,432
Dist. generation—base	1,384	1,425	1,536	1,597	1,581	1,390	1,778	2,540	1,799	1,862	1,596	1,597	1,358
Dist. Generation—peak	1,795	1,864	1,847	1,905	1,852	1,818	1,940	2,631	1,915	2,055	1,894	1,899	1,767
Battery storage	1,383	1,385	1,363	1,431	1,386	1,415	1,425	1,420	1,388	1,392	1,379	1,397	1,392
Biomass	3,808	3,944	4,292	4,371	4,385	3,944	4,873	6,614	4,888	4,974	4,182	4,982	4,766
Geothermal	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MSW—landfill gas	1,467	1,509	1,613	1,662	1,642	1,520	1,702	2,120	1,637	1,701	1,528	1,850	1,587
Conventional hydropower	NA	4,905	1,609	NA	NA	NA	1,808	NA	3,699	3,843	3,530	3,349	3,399
Wind	1,231	NA	1,260	1,259	1,509	1,260	1,670	NA	2,037	1,670	1,260	1,668	1,739
Wind offshore	5,319	5,446	5,446	NA	6,521	NA	5,446	5,478	6,643	5,446	5,446	7,210	5,672
Solar thermal	6,937	7,049	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Solar PV—tracking	1,289	1,265	1,318	1,355	1,341	1,275	1,354	1,593	1,341	1,381	1,304	1,423	1,301

Technology	14 SRCA	15 SRSE	16 SRCE	17 SPPS	18 SPPC	19 SPPN	20 SRSG	21 CANO	22 CASO	23 NWPP	24 RMRG	25 BASN
Ultra-supercritical coal (USC)	3,522	3,615	3,593	3,546	3,768	3,586	3,737	NA	NA	3,959	3,701	3,861
USC with 30% CCS	4,509	4,610	4,578	4,522	4,772	4,564	4,761	NA	NA	5,004	4,711	4,888
USC with 90% CCS	5,871	5,976	5,951	5,839	6,136	5,881	6,117	NA	NA	6,418	6,027	6,306
CC—single shaft	991	1,003	1,023	1,001	1,063	992	975	1,451	1,374	1,135	919	994
CC—multi shaft	869	883	901	879	944	872	839	1,278	1,202	985	790	887
CC with 90% CCS	2,424	2,425	2,477	2,427	2,508	2,390	2,211	2,802	2,708	2,558	2,079	2,335
Internal combustion engine	1,765	1,785	1,785	1,752	1,847	1,770	1,787	2,157	2,098	1,904	1,764	1,888
CT—aeroderivative	1,072	1,081	1,109	1,080	1,156	1,087	981	1,406	1,324	1,212	950	1,082
CT— industrial frame	649	656	673	654	702	659	594	860	808	737	575	658
Fuel cells	7,325	7,372	7,368	7,191	7,492	7,256	7,357	8,480	8,305	7,705	7,216	7,686
Advanced nuclear	6,371	6,382	6,438	6,116	6,468	6,114	6,342	NA	NA	6,865	6,143	6,872
Dist. Generation—base	1,358	1,418	1,409	1,460	1,515	1,521	1,555	1,933	1,933	1,569	1,638	1,569
Dist. Generation—peak	1,767	1,868	1,786	1,850	1,888	1,848	2,157	2,145	2,145	1,956	2,246	1,956
Battery storage	1,428	1,408	1,419	1,376	1,385	1,368	1,400	1,440	1,441	1,416	1,371	1,426
Biomass	3,959	4,033	4,009	3,962	4,209	4,045	4,333	5,616	5,389	4,480	4,292	4,292
Geothermal	NA	NA	NA	NA	NA	NA	2,817	2,794	2,262	2,734	NA	2,680
MSW—landfill gas	1,529	1,545	1,545	1,515	1,595	1,529	1,545	1,859	1,809	1,645	1,525	1,632
Conventional hydropower	1,892	4,105	1,297	NA	1,711	1,971	3,262	3,323	4,478	2,752	3,286	3,591
Wind	1,503	1,703	1,260	1,260	1,260	1,260	1,260	2,782	2,185	1,670	1,260	1,260
Wind offshore	4,901	NA	NA	NA	NA	NA	NA	7,126	5,446	5,446	NA	NA
Solar thermal	NA	NA	NA	7,007	7,279	6,936	7,268	8,614	8,430	7,736	6,984	7,751
Solar PV—tracking	1,327	1,284	1,282	1,263	1,313	1,272	1,285	1,443	1,409	1,317	1,300	1,312

Notes: Costs include contingency factors and regional cost and ambient conditions multipliers. Interest charges are excluded. The costs are shown before investment tax credits are applied.

NA = not available; plant type cannot be built in the region because of a lack of resources, sites, or specific state legislation.

USC = ultra-supercritical, CCS = carbon capture and sequestration, CC = combined cycle, CT = combustion turbine, PV = photovoltaic, MSW = municipal solid waste

[Electricity Market Module region map](#)

Source: U.S. Energy Information Administration, Office of Electricity, Coal, Nuclear and Renewables Analysis

Updated March 2020: EIA changed regional costs for solar thermal to NA in regions where resource quality may be insufficient to support significant development of solar thermal power.

