



Cost and Performance Characteristics of New Generating Technologies, Annual Energy Outlook 2018

The tables presented below will be incorporated in the Electricity Market Module chapter of the AEO2018 Assumptions document. Table 8.2 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 8.2, except as noted below, represent 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 during technology research and development to underestimate the full engineering and development costs for new technologies.

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 correct for this, Table 8.2 shows a weighted average cost for both wind and solar PV based on the regional cost factors assumed for these technologies in the AEO2018 and the actual regional distribution of the builds that occurred in 2016. For AEO2018, the electricity model includes two solar PV technologies, one using single-axis tracking technology and the other using fixed tilt arrays.

Table 8.3 presents a full listing of the overnight costs for each technology and electricity region (http://www.eia.gov/outlooks/aeo/pdf/nerc_map.pdf), if the resource or technology is available to be built in the given region. The regional costs reflect the impact of locational 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 impact the available capacity of a combustion turbine, and EIA’s modeling addresses this 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. As sites near existing transmission, with access to a road network, or otherwise located on lower-development-cost lands are utilized, additional costs may be incurred to access sites with less favorable characteristics. EIA represents this through a multiplier applied to the wind plant capital costs that increases as the best sites in a given region are developed.

Table 8.2. Cost and performance characteristics of new central station electricity generating technologies

Technology	First available year ¹	Size (MW)	Lead time (years)	Base overnight cost (2017 \$/kW)	Project Contingency Factor ²	Technological Optimism Factor ³	Total overnight cost ^{4,10} (2017 \$/kW)	Variable O&M ⁵ (2017 \$/MWh)	Fixed O&M (2017\$/kW/yr)	Heat rate ⁶ (Btu/kWh)	nth-of-a-kind heat rate (Btu/kWh)
Coal with 30% carbon sequestration (CCS)	2021	650	4	4,641	1.07	1.03	5,089	7.17	70.70	9,750	9,221
Coal with 90% CCS	2021	650	4	5,132	1.07	1.03	5,628	9.70	82.10	11,650	9,257
Conv Gas/Oil Combined Cycle (CC)	2020	702	3	935	1.05	1.00	982	3.54	11.11	6,600	6,350
Adv Gas/Oil CC	2020	429	3	1,026	1.08	1.00	1,108	2.02	10.10	6,300	6,200
Adv CC with CCS	2020	340	3	1,936	1.08	1.04	2,175	7.20	33.75	7,525	7,493
Conv Combustion Turbine ⁷	2019	100	2	1,054	1.05	1.00	1,107	3.54	17.67	9,880	9,600
Adv Combustion Turbine	2019	237	2	648	1.05	1.00	680	10.81	6.87	9,800	8,550
Fuel Cells	2020	10	3	6,192	1.05	1.10	7,132	45.64	0.00	9,500	6,960
Adv Nuclear	2022	2,234	6	5,148	1.10	1.05	5,946	2.32	101.28	10,460	10,460
Distributed Generation - Base	2020	2	3	1,479	1.05	1.00	1,553	8.23	18.52	8,969	8,900
Distributed Generation - Peak	2019	1	2	1,777	1.05	1.00	1,866	8.23	18.52	9,961	9,880
Battery Storage	2018	30	1	2,067	1.05	1.00	2,170	7.12	35.60	N/A	N/A
Biomass	2021	50	4	3,584	1.07	1.00	3,837	5.58	112.15	13,500	13,500
Geothermal ^{8,9}	2021	50	4	2,615	1.05	1.00	2,746	0.00	119.87	9,271	9,271
MSW - Landfill Gas	2020	50	3	8,170	1.07	1.00	8,742	9.29	417.02	18,000	18,000
Conventional Hydropower ⁹	2021	500	4	2,634	1.10	1.00	2,898	1.33	40.05	9,271	9,271
Wind ¹⁰	2020	100	3	1,548	1.07	1.00	1,657	0.00	47.47	9,271	9,271
Wind Offshore ⁸	2021	400	4	4,694	1.10	1.25	6,454	0.00	78.56	9,271	9,271
Solar Thermal ⁸	2020	100	3	3,952	1.07	1.00	4,228	0.00	71.41	9,271	9,271
Solar PV - tracking ^{8,11}	2019	150	2	2,004	1.05	1.00	2,105	0.00	22.02	9,271	9,271
Solar PV - fixed tilt ^{8,11}	2019	150	2	1,763	1.05	1.00	1,851	0.00	22.02	9,271	9,271

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

² - AACE International, the Association for the Advancement of Cost Engineering, has defined contingency as “An amount added to an estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs.”

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

⁴ - Overnight capital cost including contingency factors, excluding regional multipliers (except as noted for wind and solar PV) and learning effects. Interest charges are also excluded. These represent current costs for plants that would come online in 2018.

⁵ - O&M = Operations and maintenance.

⁶ - For hydropower, wind, solar and geothermal technologies, the heat rate shown represents the average heat rate for conventional thermal generation as of 2016. This heat rate is used for purposes of calculating primary energy consumption displaced for these resources, and does not imply an estimate of their actual energy conversion efficiency. 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.

⁷ - Conventional combustion turbine units can be built by the model prior to 2018 if necessary to meet a given region's reserve margin.

⁸ - Capital costs are shown before investment tax credits are applied.

⁹ - Because geothermal and hydropower cost and performance characteristics are specific for each site, the table entries represent the cost of the least expensive plant that could be built in the Northwest Power Pool region, where most of the proposed sites are located.

¹⁰ - Wind and both solar PV technologies' total overnight cost shown in the table represents the average input value across all 22 electricity market regions, as weighted by the respective capacity of that type installed during 2016 in each region to account for the substantial regional variation in wind and solar costs (as shown in Table 8.3). The input value used for wind in AEO2018 was \$1,887 per kilowatt (kW), for solar PV with tracking was \$2,207/kW, and for solar PV fixed tilt was \$2,068, representing 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.

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

Source: Input costs are consistent with those used in AEO2017, and are primarily based on a report provided by external consultants, which can be found here: <http://www.eia.gov/analysis/studies/powerplants/capitalcost/>. The base costs above reflect calculated learning cost reductions based on recent builds occurring since the cost report was provided. The cost differential between the two PV technologies was based on Lawrence Berkeley National Lab's Utility-Scale Solar Report. Hydropower site costs for non-powered dams were updated for AEO2018 using data from Oak Ridge National Lab.

Table 8.3. Total overnight capital costs of new electricity generating technologies by region

2017 \$/kW

Technology	1 (ERCT)	2 (FRCC)	3 (MROE)	4 (MROW)	5 (NEWE)	6 (NYCW)	7 (NYLI)	8 (NYUP)	9 (RFCE)	10 (RFCM)	11 (RFCW)
Coal with 30% CCS	4,560	4,764	5,034	4,893	5,334	N/A	N/A	4,967	5,563	5,059	5,140
Coal with 90% CCS	5,043	5,268	5,549	5,409	5,867	N/A	N/A	5,493	6,112	5,594	5,668
Conv Gas/Oil Combined Cycle (CC)	899	928	937	959	1,091	1,583	1,583	1,109	1,162	981	1,006
Adv Gas/Oil CC	1,062	1,084	1,052	1,095	1,230	1,687	1,687	1,250	1,300	1,099	1,145
Adv CC with CCS	2,030	2,106	2,115	2,092	2,227	3,173	3,173	2,239	2,379	2,131	2,190
Conv Combustion Turbine	1,063	1,104	1,052	1,095	1,149	1,558	1,558	1,134	1,217	1,096	1,122
Adv Combustion Turbine	661	683	655	683	737	1,054	1,054	732	794	682	703
Fuel Cells	6,683	6,847	7,168	6,953	7,196	8,644	8,644	7,096	7,325	7,125	7,111
Adv Nuclear	5,702	5,785	5,987	5,860	6,195	N/A	N/A	6,291	6,356	5,940	6,059
Distributed Generation - Base	1,382	1,423	1,524	1,519	1,775	2,537	2,537	1,797	1,859	1,577	1,594
Distributed Generation - Peak	1,792	1,862	1,773	1,846	1,938	2,628	2,628	1,912	2,052	1,849	1,892
Battery Storage	2,126	2,143	2,168	2,163	2,201	2,543	2,543	2,163	2,221	2,168	2,173
Biomass	3,538	3,638	3,910	3,714	3,952	4,708	4,708	3,968	4,086	3,818	3,875
Geothermal	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MSW - Landfill Gas	8,043	8,296	8,812	8,465	8,821	11,015	11,015	8,733	9,030	8,716	8,689
Conventional Hydropower	N/A	5,165	N/A	1,694	1,904	N/A	N/A	3,896	4,047	N/A	3,527
Wind	1,573	N/A	2,371	1,604	2,510	N/A	2,725	2,246	2,132	2,475	1,817
Wind Offshore	5,893	6,454	6,493	6,524	6,622	8,268	8,268	6,396	6,622	6,422	6,493
Solar Thermal	3,603	3,831	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Solar PV - tracking	2,220	1,798	2,114	1,917	2,471	3,282	2,103	1,988	2,333	3,050	2,020
Solar PV – fixed tilt	2,081	1,685	1,982	1,797	2,316	3,076	1,970	1,863	2,186	2,859	1,893
	4,560	4,764	5,034	4,893	5,334	N/A	N/A	4,967	5,563	5,059	5,140

Technology	12 (SRDA)	13 (SRGW)	14 (SRSE)	15 (SRCE)	16 (SRVC)	17 (SPNO)	18 (SPSO)	19 (AZNM)	20 (CAMX)	21 (NWPP)	22 (RMPPA)
Coal with 30% CCS	4,642	5,171	4,601	4,652	4,489	4,896	4,759	4,942	5,665	5,008	4,876
Coal with 90% CCS	5,139	5,713	5,088	5,144	4,958	5,409	5,262	5,459	6,230	5,527	5,375
Conv Gas/Oil Combined Cycle (CC)	896	1,018	923	901	874	973	938	1,072	1,237	1,021	1,149
Adv Gas/Oil CC	1,059	1,158	1,087	1,080	1,039	1,123	1,099	1,312	1,414	1,205	1,354
Adv CC with CCS	2,047	2,251	2,061	2,017	1,974	2,164	2,100	2,461	2,539	2,250	2,443
Conv Combustion Turbine	1,077	1,143	1,107	1,058	1,047	1,118	1,096	1,278	1,271	1,159	1,330
Adv Combustion Turbine	670	713	700	658	656	697	685	807	818	727	977
Fuel Cells	6,747	7,253	6,718	6,761	6,647	6,982	6,861	7,032	7,453	7,054	6,832
Adv Nuclear	5,738	6,035	5,720	5,749	5,684	5,874	5,803	5,904	N/A	5,963	5,946
Distributed Generation - Base	1,389	1,605	1,417	1,407	1,356	1,513	1,459	1,553	1,931	1,567	1,636
Distributed Generation - Peak	1,816	1,928	1,866	1,784	1,765	1,886	1,848	2,154	2,143	1,954	2,243
Battery Storage	2,139	2,191	2,134	2,137	2,126	2,159	2,146	2,160	2,254	2,177	2,149
Biomass	3,568	3,902	3,549	3,584	3,503	3,733	3,668	3,837	4,129	3,845	3,591
Geothermal	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4,070	2,802	2,746	N/A
MSW - Landfill Gas	8,156	8,908	8,086	8,156	7,964	8,523	8,322	8,585	9,223	8,585	8,279
Conventional Hydropower	N/A	N/A	4,323	1,366	1,993	1,802	N/A	3,435	3,500	2,898	3,460
Wind	2,217	1,625	2,217	2,217	2,046	1,527	1,567	2,869	2,205	1,824	1,663
Wind Offshore	6,454	N/A	5,931	N/A	5,828	N/A	N/A	N/A	6,732	6,557	N/A
Solar Thermal	N/A	N/A	N/A	N/A	N/A	N/A	3,878	4,152	4,727	4,178	3,894
Solar PV - tracking	1,917	1,673	1,684	1,423	1,762	1,473	1,904	2,266	2,383	1,493	1,957
Solar PV – fixed tilt	1,797	1,568	1,578	1,333	1,651	1,381	1,785	2,124	2,233	1,399	1,834

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.

N/A: Not available; plant type cannot be built in the region due to lack of resources, sites or specific state legislation.

Electricity Market Module region map: http://www.eia.gov/outlooks/aeo/pdf/nerc_map.pdf.