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Cost and Performance Characteristics of New Generating Technologies, Annual Energy Outlook 2017

The tables presented below will be incorporated in the Electricity Market Module chapter of the AEO2017 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 AEO2017 and the actual regional distribution of the builds that occurred in 2015.

Table 8.3 presents a full listing of the overnight costs for each technology and electricity region (http://www.eia.gov/forecasts/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 in 2016 (2016 $/kW)	Project Contingency Factor[2]	Technological Optimism Factor[3]	Total overnight cost in 2016[4,10] (2016 $/kW)	Variable O&M[5] (2016 $/MWh)	Fixed O&M (2016$/kW/yr)	Heat rate[6] in 2016 (Btu/kWh)	nth-of-a-kind heat rate (Btu/kWh)
Coal with 30% carbon sequestration	2020	650	4	4,586	1.07	1.03	5,030	7.06	69.56	9,750	9,221
Coal with 90% carbon sequestration	2020	650	4	5,072	1.07	1.03	5,562	9.54	80.78	11,650	9,257
Conv Gas/Oil Comb Cycle	2019	702	3	923	1.05	1.00	969	3.48	10.93	6,600	6,350
Adv Gas/Oil Comb Cycle (CC)	2019	429	3	1,013	1.08	1.00	1,094	1.99	9.94	6,300	6,200
Adv CC with carbon sequestration	2019	340	3	1,917	1.08	1.04	2,153	7.08	33.21	7,525	7,493
Conv Comb Turbine[7]	2018	100	2	1,040	1.05	1.00	1,092	3.48	17.39	9,920	9,600
Adv Comb Turbine	2018	237	2	640	1.05	1.00	672	10.63	6.76	9,800	8,550
Fuel Cells	2019	10	3	6,252	1.05	1.10	7,221	44.91	0.00	9,500	6,960
Adv Nuclear	2022	2,234	6	5,091	1.10	1.05	5,880	2.29	99.65	10,459	10,459
Distributed Generation - Base	2019	2	3	1,463	1.05	1.00	1,536	8.10	18.23	8,981	8,900
Distributed Generation - Peak	2018	1	2	1,757	1.05	1.00	1,845	8.10	18.23	9,975	9,880
Biomass	2020	50	4	3,540	1.07	1.00	3,790	5.49	110.34	13,500	13,500
Geothermal[8,9]	2020	50	4	2,586	1.05	1.00	2,715	0.00	117.95	9,510	9,510
MSW - Landfill Gas	2019	50	3	8,059	1.07	1.00	8,623	9.14	410.32	18,000	18,000
Conventional Hydropower[9]	2020	500	4	2,220	1.10	1.00	2,442	2.66	14.93	9,510	9,510
Wind[10]	2019	100	3	1,576	1.07	1.00	1,686	0.00	46.71	9,510	9,510
Wind Offshore	2020	400	4	4,648	1.10	1.25	6,391	0.00	77.30	9,510	9,510
Solar Thermal[8]	2019	100	3	3,908	1.07	1.00	4,182	0.00	70.26	9,510	9,510
Photovoltaic[8,10,11]	2018	150	2	2,169	1.05	1.00	2,277	0.00	21.66	9,510	9,510

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

[2] - A contingency allowance is defined by the American Association of Cost Engineers as the "specific provision for unforeseeable elements of costs within a defined project scope; particularly important where previous experience has shown that unforeseeable events which will increase costs are likely to occur"

[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 including contingency factors, excluding regional multipliers (except as noted for wind and solar PV) and learning effects. Interest charges are also excluded. These represent costs of new projects initiated in 2016.

[5] - O&M = Operations and maintenance.

[6] - For hydro, wind, solar and geothermal technologies, the heat rate shown represents the average heat rate for conventional thermal generation as of 2014. This 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."

[7] - 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 hydro 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 solar PV's 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 2015 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 AEO 2017 was $1861/kW and for solar PV was $2388/kW , 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.

Sources: Costs are consistent with those used in AEO2016, and are primarily based on a report provided by external consultants, which can be found here: http://www.eia.gov/analysis/studies/powerplants/capitalcost/.

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

2016 $/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% carbon sequestration	4,696	4,934	4,776	4,821	5,050	N/A	N/A	4,737	5,404	4,885	5,065
Coal with 90% carbon sequestration	5,240	5,450	5,463	5,325	5,555	N/A	N/A	5,609	5,930	5,404	5,626
Conv Gas/Oil Comb Cycle	886	916	925	946	1,076	1,561	1,561	1,094	1,146	968	992
Adv Gas/Oil Comb Cycle (CC)	1,048	1,070	1,039	1,081	1,215	1,665	1,665	1,234	1,283	1,085	1,130
Adv CC with carbon sequestration	2,010	2,085	2,093	2,071	2,205	3,141	3,141	2,217	2,355	2,109	2,168
Conv Comb Turbine	1,049	1,089	1,037	1,080	1,134	1,537	1,537	1,119	1,201	1,081	1,107
Adv Comb Turbine	652	674	647	674	728	1,041	1,041	723	784	674	694
Fuel Cells	6,766	6,932	7,257	7,039	7,286	8,751	8,751	7,185	7,416	7,213	7,199
Adv Nuclear	5,639	5,721	5,921	5,795	6,127	N/A	N/A	6,221	6,285	5,874	5,991
Distributed Generation - Base	1,367	1,407	1,507	1,502	1,756	2,508	2,508	1,777	1,839	1,559	1,576
Distributed Generation - Peak	1,773	1,841	1,754	1,825	1,916	2,599	2,599	1,891	2,030	1,828	1,871
Biomass	3,494	3,593	3,862	3,668	3,903	4,650	4,650	3,919	4,036	3,771	3,828
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	7,933	8,183	8,692	8,350	8,701	10,865	10,865	8,614	8,908	8,597	8,571
Conventional Hydropower	N/A	N/A	N/A	3,088	3,335	N/A	N/A	2,639	N/A	N/A	2,632
Wind	1,638	N/A	2,234	1,843	2,498	N/A	2,271	2,271	2,271	2,234	2,234
Wind Offshore	5,835	8,436	6,429	6,460	6,557	8,187	8,187	6,333	6,557	6,359	6,429
Solar Thermal	3,563	3,789	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Photovoltaic	2,403	1,945	2,288	2,074	2,674	3,551	2,275	2,151	2,524	3,301	2,186

Technology	12 (SRDA)	13 (SRGW)	14 (SRSE)	15 (SRCE)	16 (SRVC)	17 (SPNO)	18 (SPSO)	19 (AZNM)	20 (CAMX)	21 (NWPP)	22 (RMPA)
Coal with 30% carbon sequestration	4,734	5,136	4,752	4,680	4,565	4,960	4,820	5,578	5,705	5,177	5,662
Coal with 90% carbon sequestration	5,258	5,791	5,289	5,215	5,134	5,536	5,380	6,248	6,322	5,781	6,248
Conv Gas/Oil Comb Cycle	884	1,004	910	888	862	960	925	1,057	1,220	1,007	1,133
Adv Gas/Oil Comb Cycle (CC)	1,045	1,143	1,073	1,066	1,025	1,109	1,085	1,295	1,396	1,190	1,337
Adv CC with carbon sequestration	2,026	2,228	2,040	1,996	1,954	2,143	2,079	2,436	2,514	2,227	2,418
Conv Comb Turbine	1,062	1,128	1,092	1,043	1,032	1,103	1,081	1,260	1,254	1,143	1,312
Adv Comb Turbine	662	704	691	650	648	688	676	797	808	718	965
Fuel Cells	6,831	7,343	6,802	6,845	6,730	7,069	6,946	7,120	7,546	7,141	6,917
Adv Nuclear	5,674	5,968	5,656	5,686	5,621	5,809	5,739	5,839	N/A	5,897	5,880
Distributed Generation - Base	1,373	1,587	1,401	1,392	1,341	1,496	1,442	1,536	1,909	1,550	1,618
Distributed Generation - Peak	1,796	1,906	1,845	1,764	1,745	1,865	1,827	2,130	2,119	1,932	2,218
Biomass	3,524	3,854	3,505	3,540	3,460	3,687	3,623	3,790	4,078	3,797	3,547
Geothermal	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4,025	2,771	2,715	N/A
MSW - Landfill Gas	8,045	8,787	7,976	8,045	7,856	8,408	8,209	8,468	9,097	8,468	8,166
Conventional Hydropower	3,179	2,246	3,179	1,347	1,966	1,778	2,672	2,153	2,464	2,442	2,838
Wind	2,420	2,234	2,420	2,420	2,420	1,536	1,536	2,006	2,010	2,006	1,536
Wind Offshore	6,391	N/A	5,873	N/A	5,771	N/A	N/A	N/A	6,666	6,493	N/A
Solar Thermal	N/A	N/A	N/A	N/A	N/A	N/A	3,835	4,106	4,675	4,132	3,851
Photovoltaic	2,075	1,810	1,822	1,539	1,906	1,594	2,060	2,452	2,578	1,615	2,117

Table shows overnight capital costs for projects initiated in 2016. 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: plant type cannot be built in the region due to lack of resources, sites or specific state legislation.
Region map: http://www.eia.gov/forecasts/aeo/pdf/nerc_map.pdf