Levelized Cost of New Generation Resources in the Annual Energy Outlook 2011

This paper presents average national levelized costs for generating technologies that are brought on line in 2016[1] as represented in the National Energy Modeling System (NEMS) as configured for the *Annual Energy Outlook 2011* (AEO2011) reference case.[2]

Levelized cost is often cited as a convenient summary measure of the overall competiveness of different generating technologies. Levelized cost represents the present value of the total cost of building and operating a generating plant over an assumed financial life and duty cycle, converted to equal annual payments and expressed in terms of real dollars to remove the impact of inflation. Levelized cost reflects overnight capital cost, fuel cost, fixed and variable O&M cost, financing costs, and an assumed utilization rate for each plant type.[3] For technologies such as solar and wind generation that have no fuel costs and relatively small O&M costs, levelized cost changes in rough proportion to the estimated overnight capital cost of generation capacity. For technologies with significant fuel cost, both fuel cost and overnight cost estimates significantly affect levelized cost. The availability of various incentives including state or federal tax credits can also impact the calculation of levelized cost. The values shown in the tables below do not incorporate any such incentives. As with any projections, there is uncertainty about all of these factors and their values can vary regionally and across time as technologies evolve.

It is important to note that actual plant investment decisions are affected by the specific technological and regional characteristics of a project, which involve numerous considerations other than the levelized cost of competing technologies. 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 back out existing natural gas generation will generally have a higher value than one that would back out existing coal generation under fuel price conditions where the variable cost of operating existing gas-fired plants exceeds that of operating existing coal-fired plants.

A related factor is the ***capacity value***, which depends on both the existing capacity mix and load characteristics in a region. Since load must be balanced on a continuous basis, units whose output can be varied to follow demand generally have more value to a system than less flexible units or those whose operation is tied to the availability of an intermittent resource. Policy-related factors, such as investment or production tax credits for specified generation sources, can also impact investment decisions. Finally, although

[1] 2016 is shown because the long lead times needed for some technologies means that they could not be brought on line prior to 2016 unless they were already under construction.
[2] The full report is available at http://www.eia.doe.gov/oiaf/aeo/index.html.
[3] The specific assumptions for each of these factors are given in the *Assumptions to the Annual Energy Outlook*, available at http://www.eia.doe.gov/oiaf/aeo/assumption/index.html.

levelized cost calculations are generally made using an assumed set of capital and operating costs, the inherent uncertainty about future fuel prices and future policies, may cause plant owners or investors who finance plants to place a value on ***portfolio diversification***. EIA considers all of these factors in its analyses of technology choice in the electricity sector.

The levelized cost shown for each utility-scale generation technology in the tables below are calculated based on a 30-year cost recovery period, using a real after tax weighted average cost of capital (WACC) of 7.4 percent. However, in the AEO2011 reference case a 3-percentage point increase in the cost of capital is added when evaluating investments in greenhouse gas (GHG) intensive technologies like coal-fired power and coal-to-liquids (CTL) plants without carbon control and sequestration (CCS). While the 3-percentage point adjustment is somewhat arbitrary, in levelized cost terms its impact is similar to that of a $15 per metric ton of carbon dioxide (CO_2) emissions fee when investing in a new coal plant without CCS, similar to the costs used in simulations that utilities and regulators have used in their resource planning. The adjustment should not be seen as an increase in the actual cost of financing, but rather as representing the implicit hurdle being added to GHG-intensive projects to account for the possibility they may eventually have to purchase allowances or invest in other GHG emission-reducing projects that offset their emissions. As a result, the levelized capital costs of coal-fired plants without CCS are higher than would otherwise be expected.

In the table below, the levelized cost for each technology is evaluated based on the capacity factor indicated, which generally corresponds to the maximum availability of each technology. Simple combustion turbines (conventional or advanced technology) are typically used for peak load duty cycles, and are thus evaluated at a 30 percent capacity factor. The duty cycle for intermittent renewable resources of wind and solar is not operator controlled, but dependent on the weather or solar cycle (that is, sunrise/sunset). The availability of wind or solar will not necessarily correspond to operator dispatched duty cycles and, as a result, their levelized costs are not directly comparable to those for other technologies (even where the average annual capacity factor may be similar).

As mentioned above, the costs shown in Table 1 are national averages. However, there is significant local variation in costs based on local labor markets and the cost and availability of fuel or energy resources such as windy sites (Table 2). For example, regional wind costs range from $82/MWh in the region with the best available resources in 2016 to $115/MWh in regions where the best sites have been claimed by 2016. Costs shown for wind may include additional costs 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.

Table 1. Estimated Levelized Cost of New Generation Resources, 2016.

Plant Type	Capacity Factor (%)	U.S. Average Levelized Costs (2009 $/megawatthour) for Plants Entering Service in 2016				
		Levelized Capital Cost	Fixed O&M	Variable O&M (including fuel)	Transmission Investment	Total System Levelized Cost
Conventional Coal	85	65.3	3.9	24.3	1.2	94.8
Advanced Coal	85	74.6	7.9	25.7	1.2	109.4
Advanced Coal with CCS	85	92.7	9.2	33.1	1.2	136.2
Natural Gas-fired						
Conventional Combined Cycle	87	17.5	1.9	45.6	1.2	66.1
Advanced Combined Cycle	87	17.9	1.9	42.1	1.2	63.1
Advanced CC with CCS	87	34.6	3.9	49.6	1.2	89.3
Conventional Combustion Turbine	30	45.8	3.7	71.5	3.5	124.5
Advanced Combustion Turbine	30	31.6	5.5	62.9	3.5	103.5
Advanced Nuclear	90	90.1	11.1	11.7	1.0	113.9
Wind	34	83.9	9.6	0.0	3.5	97.0
Wind – Offshore	34	209.3	28.1	0.0	5.9	243.2
Solar PV[1]	25	194.6	12.1	0.0	4.0	210.7
Solar Thermal	18	259.4	46.6	0.0	5.8	311.8
Geothermal	92	79.3	11.9	9.5	1.0	101.7
Biomass	83	55.3	13.7	42.3	1.3	112.5
Hydro	52	74.5	3.8	6.3	1.9	86.4

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

Source: Energy Information Administration, Annual Energy Outlook 2011, December 2010, DOE/EIA-0383(2010)

Table 2. Regional Variation in Levelized Cost of New Generation Resources, 2016.

Plant Type	Range for Total System Levelized Costs (2009 $/megawatthour)		
	Minimum	Average	Maximum
Conventional Coal	85.5	94.8	110.8
Advanced Coal	100.7	109.4	122.1
Advanced Coal with CCS	126.3	136.2	154.5
Natural Gas-fired			
Conventional Combined Cycle	60.0	66.1	74.1
Advanced Combined Cycle	56.9	63.1	70.5
Advanced CC with CCS	80.8	89.3	104.0
Conventional Combustion Turbine	99.2	124.5	144.2
Advanced Combustion Turbine	87.1	103.5	118.2
Advanced Nuclear	109.7	113.9	121.4
Wind	81.9	97.0	115.0
Wind – Offshore	186.7	243.2	349.4
Solar PV[1]	158.7	210.7	323.9
Solar Thermal	191.7	311.8	641.6
Geothermal	91.8	101.7	115.7
Biomass	99.5	112.5	133.4
Hydro	58.5	86.4	121.4

Source: Energy Information Administration, Annual Energy Outlook 2011, December 2010, DOE/EIA-0383(2010)