Independent Statistics & Analysis
U.S. Energy Information Administration

Updates to Cost Assumptions in the Electricity Market Module (EMM) of the National Energy Modeling System (NEMS)

December 2019

Independent Statistics & Analysis
www.eia.gov

U.S. Department of Energy
Washington, DC 20585

This report was prepared by the U.S. Energy Information Administration (EIA), the statistical and analytical agency within the U.S. Department of Energy. By law, EIA's data, analyses, and forecasts are independent of approval by any other officer or employee of the United States Government. The views in this report therefore should not be construed as representing those of the Department of Energy or other Federal agencies.

Updates to Cost Assumptions in the Electricity Market Module (EMM) of the National Energy Modeling System (NEMS)

Purpose

EIA models generation costs in the Electricity Market Module (EMM), a module of the National Energy Modeling System[1] (NEMS). Prior to AEO2019, EMM modeled non-fuel costs with two components: 1) a one-time increase in aging-related capital expenditure (CAPEX) cost when plants reach 30 years of operation, and 2) operations and maintenance (O&M) costs that remained constant (in real dollar terms) over time. To ensure continued applicability of its modeling of electric sector spending in a period of accelerating retirements, EIA commissioned Sargent & Lundy (S&L) to review the EMM cost assumptions for all non-nuclear generating units, with a particular emphasis on coal and other fossil-fueled plants, which have the most extensive historical data available. This report summarizes the S&L report findings and describes resulting adjustments made to EMM.

S&L Findings

S&L recommended that EIA revise its input assumptions for fossil generators to reflect differences in spending based on the most significant factor each generating technology, and incorporate updated baseline cost estimates based on the underlying dataset they provided.

S&L used both publicly-available data from the Federal Energy Regulatory Commission (FERC) Form No. 1 (FERC Form 1) as well as proprietary electric utility financial data in its analysis. S&L defined CAPEX as the yearly changes in FERC Form 1 plant in service accounts and also used FERC Form 1 data for O&M costs. In addition, to the extent permissible S&L used proprietary data from its actual projects to assemble a characterization of life extension and repowering costs. To determine how aging affected generator spending S&L used regression analysis on CAPEX and total O&M time series data to determine whether plant age was statistically significant. S&L determined that the cost impact of aging was consistent over time, but was a significant consideration for only a limited number of electric generating technology types. To expand on the range of possible contributing factors, S&L tested a number of other variables, including unit size and operating profile (number of operating hours and unit starts), and found those factors to be significant for some electric generating technology types.

Capital Expenditures

S&L determined that discretionary spending was notable for most coal steam and gas/oil steam plants and that different plants might incur the same type of expense at different points in time due to differences in plant-specific economic, locational, or operational circumstances. In particular, S&L found that age was a statistically significant factor in CAPEX for coal steam generators, with higher costs incurred over time at plants with flue gas desulfurization equipment, (FGD or scrubbers) than those without FGDs (see Table 1). On the other hand, for gas/oil combined cycle (CC) and combustion turbine

[1] https://www.eia.gov/analysis/pdfpages/0581(2009)index.php

(CT) units, most capital spending is related to major maintenance events. These events are generally vendor-specified and based on cumulative hours of operation and/or cumulative starts.

S&L examined additional variables such as plant capacity (in megawatts, or MW), capacity factor, external market conditions, regulatory environment, fuel characteristics, and environmental controls in order to better understand the significant variability in spending as a function of age. The size of the plant (capacity) was found to be a statistically significant variable in CAPEX for gas and oil steam plants and wind turbines.

O&M Expenditures

For O&M expenditures, S&L did not find aging to be a significant factor for fossil-fueled generators. However, based on the characteristics of the dataset, S&L applied engineering judgement to determine that unit size may be a more appropriate basis for estimating O&M costs, and recommended average O&M values for fossil plants across several different ranges based on total plant capacity.

S&L found aging to be a significant factor for hydroelectric plants and wind turbines, but due to differences with current EIA assumptions (and the limited dataset for reported wind turbine costs) they did not recommend its use without additional analysis of the source data.

Table 1: Summary of key drivers in generating unit spending from S&L report and the approach for implementation in the EMM

Prime Mover	**Energy Source**	**CAPEX Spending**		**O&M Spending**	
		Significant variable (1) *Reference to S&L Exec Summary (ES) table*	**New EMM Determinant** (2)	**Significant variable** (1)	**New EMM Determinant** (2)
Fossil-fired					
Steam turbine	Coal	Age *(ES-3)*	Age	-	Capacity/Region
	Gas/Oil	Capacity *(ES-5)*	Capacity	-	Capacity/Region
Combined cycle	Gas/Oil	Operating Hours *(ES-7)*	n/a (3)	-	Capacity/CF (4)
Combustion turbine	Gas/Oil	Starts *(ES-7)*	n/a (3)	-	Capacity/CF (4)
Renewables					
Hydroelectric turbine (Conv)	Water	Age	n/c	Age	n/c
Hydraulic turbine/reversible (PS)	Water	-	n/c		n/c
Solar thermal (tower)	Sun	-	n/c		n/c
Solar PV (tracking)	Sun	-	n/c		n/c
Steam turbine	Geothermal	-	n/c		n/c
Wind turbine	Wind	Capacity *(ES-11)*	n/c	Age	n/c

NOTES
(1) Found to be statistically significant in S&L regression analysis of time series data, or in the case of CC/CT as standard practice in financing arrangements
(2) Variable selected in EMM which corresponds/approximates S&L findings

(3) Based on report recommendations, CAPEX for CC/CT will be included in variable O&M spending, converting from $/kilowatt (kW) to $/megawatthour (MWh) based on plant capacity factor
(4) CF: capacity factor
n/c: no change from current EMM treatment

Implementation in NEMS for AEO2019

EIA adapted the recommendations of the S&L study into the EMM for use in the Annual Energy Outlook 2019 (AEO2019) cycle to improve projections for generating capacity, generator dispatch, and electricity prices. The S&L report recommendations were used to improve EMM projections by creating an updated historic baseline for O&M and CAPEX expenditures for all fossil-fueled generating types and incorporating revised projections for ongoing investment based on aging where it was determined appropriate.

EIA recognized the need to update its estimates of electric generator spending to ensure current cost patterns are reflected in the EMM for each generating technology. Because not all of S&L's recommendations were readily adaptable to input in NEMS, Table 1 summarizes S&L's findings as to statistically significant determinants of CAPEX and O&M expenditures and EIA's choice of variables to represent the updated view of generator spending based on the report. Specific descriptions of the changes to inputs by technology are discussed in this section.

Coal Steam

S&L found that aging is a significant factor in CAPEX for all coal plants, with an additional adder for plants with FGD. The AEO2019 coal plant CAPEX costs over time reflect this S&L-developed regression equation for plants both with and without FGD:

CAPEX = 16.53 + (0.126 × age) + (5.68 × FGD)

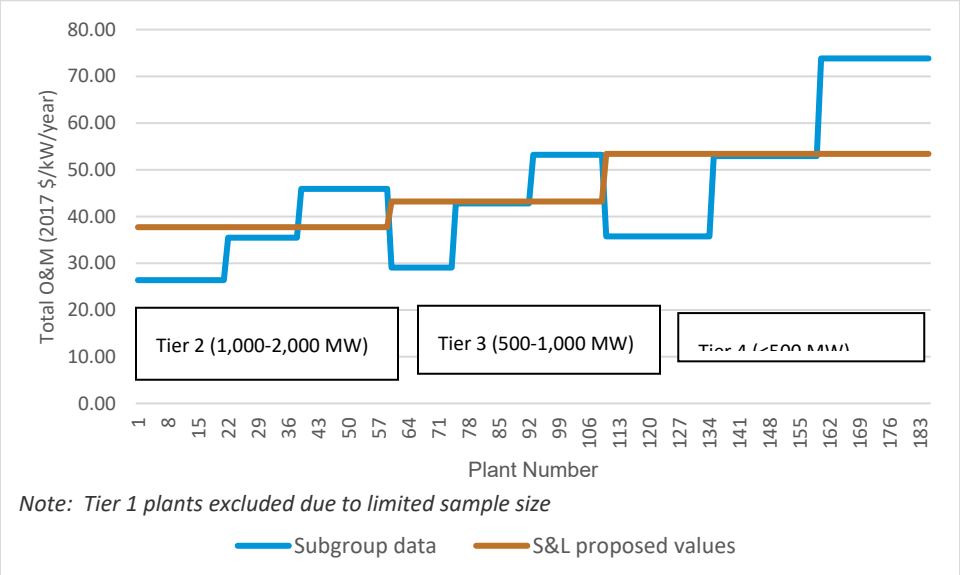
Where FGD = 1 if a plant has an FGD; zero otherwise (2017 $/kW)

S&L did not find a statistically significant relationship between age and O&M expenditures for coal steam capacity and recommended average O&M values for coal plants across four different tiers based on total plant capacity. At this level of aggregation, S&L's approach created modeling issues for EIA so EIA further analyzed the plant level costs in these four tiers to identify three subcategories to reflect low, medium and high cost categories within each tier. For FERC Form 1 reporting units, EIA re-sorted the average unit cost data for each tier from highest to lowest cost to create three subgroups with the same number of units in each, and assigned plants the average cost for their tier and subgroup. Plants that were not in the data sample analyzed (primarily those not reporting to FERC) were assigned an input cost based on their size tier and the cost group that was most prevalent for their regional location. Using this approach provides additional diversity to the distribution of costs, (see Figure 1).

Gas/oil steam

S&L found unit size to be a significant factor for gas/oil steam plant capital expenditures, so EIA will apply the same CAPEX cost in all years of operation, based on the size classification of the plant. No similar relationship was found for O&M, but S&L calculated average O&M for the same size categories that EIA will use. For both CAPEX and O&M, EIA also implemented the cost subgroup methodology described for coal to develop a larger range of cost inputs within each capacity tier.

Figure 1: Comparison of S&L recommended coal O&M assumptions vs. AEO2019 tiered subgroup approach



Gas/oil combined cycle/combustion turbine

Although prior to AEO2019, EIA modeled CAPEX for combustion turbines and combined cycle plants as a constant fixed cost with a one-time step increase in costs at 30 years of age, the report instead found that most CAPEX spending for gas/oil CC and gas/oil CT plants is associated with vendor-specified major maintenance events generally based on factors such as the number of starts or total operating hours. S&L noted that typical financing arrangements for power projects include a major maintenance reserve account (MMRA) to mitigate the risk of maintenance spending uncertainty. MMRAs are funded by annual contributions against project earnings and thus smooth uneven maintenance expenditures in a levelized annual payment expressed in dollars per megawatthour. S&L recommended that CAPEX for CC/CT be recovered as a variable cost.

As for the other fossil technologies, S&L provided O&M and CAPEX inputs by capacity tier for the CC and CT plants and EIA developed additional cost subgroup estimates within the tiers. The derived O&M cost estimate was then input for the fixed O&M cost assumption and the CAPEX estimate was converted to a variable cost based on each plant's capacity factor and input as the variable O&M cost assumption.

Renewables

While the focus of the report was on fossil-fired generators, S&L also collected and analyzed information on renewable units to the extent that it was available. After thorough analysis, S&L found that either 1) the CAPEX and O&M values derived were higher than the existing values used in the EMM and outside the range of values published in the Annual Energy Outlook (AEO) or by other sources, or 2) S&L ended up with a relatively small number of observations for wind turbines, (about one-tenth of the number available for fossil generation), making it more likely that a few projects with higher than expected O&M costs might skew the results for aging than in a larger, more representative dataset. Without additional analysis, S&L did not recommend use of the study regression results for renewable technologies in the EMM.