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Addendum: Updated Capital Cost and Performance Characteristic Estimates for Utility Scale Electricity Generating Plants in the Electricity Market Module (EMM) of the National Energy Modeling System (NEMS)

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Introduction

The current and future projected cost and performance characteristics of new electric generating capacity are critical inputs into the development of energy projections and analyses. The construction and operating costs, along with the performance characteristics of new generating plants, play an important role in determining the mix of capacity additions that will serve future demand for electricity. These parameters also help to determine how new capacity competes against existing capacity, and the response of the electric generators to the imposition of environmental controls on conventional pollutants or any limitations on greenhouse gas emissions.

Consistent with EIA's practice of developing periodic assessments, EIA commissioned an external consultant to develop up-to-date cost and performance estimates for utility-scale electric generating plants for AEO2020. As for the prior studies, this information allows EIA to compare the costs of different electric generating technologies on a standardized basis and is a key input enhancement to the National Energy Model System (NEMS).

This report contains cost and performance estimates developed by Sargent & Lundy for 25 "reference technology" cases for different types of electric generators. Developing the characteristics of each reference technology case included the specification of representative plant sizes and configurations and major equipment components, including emission controls, based on current information from similar facilities recently constructed or under development in the United States and abroad. In each successive study contracted by EIA, the evolution of technology, environmental requirements, and generator preferences influenced the attributes associated with the reference generating technology. Where these characteristics remain substantially similar between the study conducted for AEO2016 and the study conducted for AEO2020, reference technology case costs are comparable and considered "updated;" where these characteristics differ between the two studies the reference technology costs are reported as "new" (See discussion in Findings below).

To produce its overnight capital cost estimates, Sargent & Lundy assumed that the power plant developer or owner will hire an engineering, procurement and construction (EPC) contractor for turnkey construction of the project, representing the total cost a developer would expect to incur during the construction of a project, excluding financing costs. The specific overnight costs for each type of facility are divided into:

- Civil and structural material and installation cost covering all material and associated labor for civil and structural tasks
- Mechanical equipment supply and installation cost including all mechanical equipment and associated labor for mechanical tasks
- Electrical and instrumentation and controls supply and installation including all costs for transformers, switchgear, control systems, wiring, instrumentation, and raceways
- Project indirect costs including engineering, construction management, as well as start-up and commissioning. The fees include contractor overhead costs, fees, and profit

Sargent & Lundy estimated labor, maintenance, minor repairs, and general and administrative (G&A) costs based on multiple sources including actual projects, vendor publications, and internal resources. Variable O&M costs, such as ammonia, water, and miscellaneous chemicals and consumables, are directly proportional to the electricity generated. Fuel costs were estimated for reference unit types using representative fuel specifications for coal, natural gas, and biomass.

Findings

Table 1 summarizes updated cost estimates for reference case utility–scale generating technologies, including three powered by coal, seven by natural gas, three by solar energy and by wind, two by uranium and battery storage, and one each by hydroelectric, biomass, geothermal, and municipal solid waste. EIA does not model all of these generating plant types, but included them in the study in order to present consistent cost and performance information for a broad range of generating technologies and to aid in the evaluation for potential inclusion of new or different technologies or technology configurations in future analyses.
The specific technologies represented in the NEMS model for AEO2020 that use the cost data from this report are identified in the last column of Table 1.

Table 2 provides a comparison of "updated" overnight cost estimates for technologies "substantially similar" to those developed for the 2016 report. To facilitate comparisons, the costs are expressed in 2019 dollars.[5] As previously

noted, costs are developed using a consistent methodology that includes a broad project scope and includes indirect and owners costs. Notable changes include:

- **Solar Photovoltaic:** The overnight capital costs for solar photovoltaic single–axis tracking technologies decreased by 51% from the costs presented in the 2016 study, (fixed tilt solar photovoltaic technologies were not included for this report). The overall decrease in costs can be attributed to a decline in the component costs and the construction cost savings for the balance of plant systems.
- **Onshore Wind**: This study includes costs for onshore wind broken into categories that distinguish between two types of regions, Coastal and Great Plains, each with a different base capital cost. Projects built in the Great Plains region (as represented by the low-cost Southwest Power Pool/South region (SPPS) in Table 3 are generally characterized by large tracts of relatively flat terrain. Projects often built in the coastal regions (as represented by the New England region (ISNE) in the table) can be much smaller, with more challenging terrain and smaller or patchwork tracts of land. Overnight costs for wind plants in SPP-south use the interior wind base cost, as adjusted to account for regional variation in labor and materials cost. These costs are approximately 14% less than the costs in the same region estimated from the 2016 study. Costs within the New England region are based on the coastal wind estimate, as adjusted for regional variation in labor and materials, and are approximately 36% lower than same-region costs estimated from the 2016 study.
- **Battery Storage**: In this study, 2-hour and 4-hour battery storage systems were included as "new" reference case technologies; the addendum to the 2016 report included 8-hour battery storage technology.
- **Ultra Supercritical Coal (USC) with and without carbon capture and storage (CCS):** From AEO2016 onward, NEMS only included USC with carbon capture and sequestration (CCS) since both technologies were in compliance with the New Source Performance Standards (NSPS) for CO2 emissions under Section 111(b) of the Clean Air Act (finalized in October 2015). In AEO2020, EIA also includes an ultra supercritical coal-fired generation technology without CCS, since EPA in December 2018 repealed its earlier finding that partial (30%) CCS was the "best system of emissions reductions" (BSER) for greenhouse gas reductions, proposing to replace it with the most efficient demonstrated steam cycle, which EIA assumes to be represented by ultra supercritical coal. By comparison with the preceding report, the overnight capital cost for USC without CCS is 5% lower, USC with partial CCS is 15% lower, and USC with 90% CCS is nearly unchanged.
- **Single-shaft Combined Cycle and Multi-shaft Combined Cycle**: In this report, EIA revised the definition of combined cycle generating technologies to correspond to their configuration: multi-shaft vs. single shaft. The updated overnight capital cost for single- and multi-shaft CC plants both declined from the 2016 study, by 7-8%, with the cost for multi-shaft plant costs being approximately 12% lower compared with a single-shaft plant. Combined cycle with carbon capture and storage (ANGCC/CCS) was not included in the 2016 study but has been added as a new technology in this study, using the single-shaft configuration.

Impact of location on power plant capital costs

The estimates provided in this report are representative of a generic facility located in a region without any special issues that would alter its cost. However, the cost of building power plants in different regions of the United States can vary significantly.

Sargent & Lundy estimated capital cost adjustment factors to account for technology deployment at various U.S. locations using published labor rates for each location to create a wage rate factor for each location against the base rate (the "30 City Average"). The location factors were then improved by adding a regional labor productivity factor.

In order to reflect these costs in EIA's modeling, these adjustments were aggregated to represent the 25 Electricity Market Module regions. EIA also assumes that the development of certain technologies is not feasible in given regions for geographic, logistical, or regulatory reasons. The impact of regional cost adjustments is summarized in Table 3.

Summary

While the estimates provided by Sargent & Lundy for this report are key inputs for EIA electric market projections, they are not the sole driver of electric generation capacity expansion decisions. The evolution of the electricity mix in each of the 25 regions modeled in AEO2020 is sensitive to many factors, including the projected evolution of capital costs over the modeling horizon, projected fuel costs, the characteristic of wholesale power markets (regulated or competitive), the existing generation mix, additional costs associated with environmental controls, and future electricity demand.

Users interested in additional details regarding these updated cost estimates should review the consultant study prepared by Sargent & Lundy in the full report.