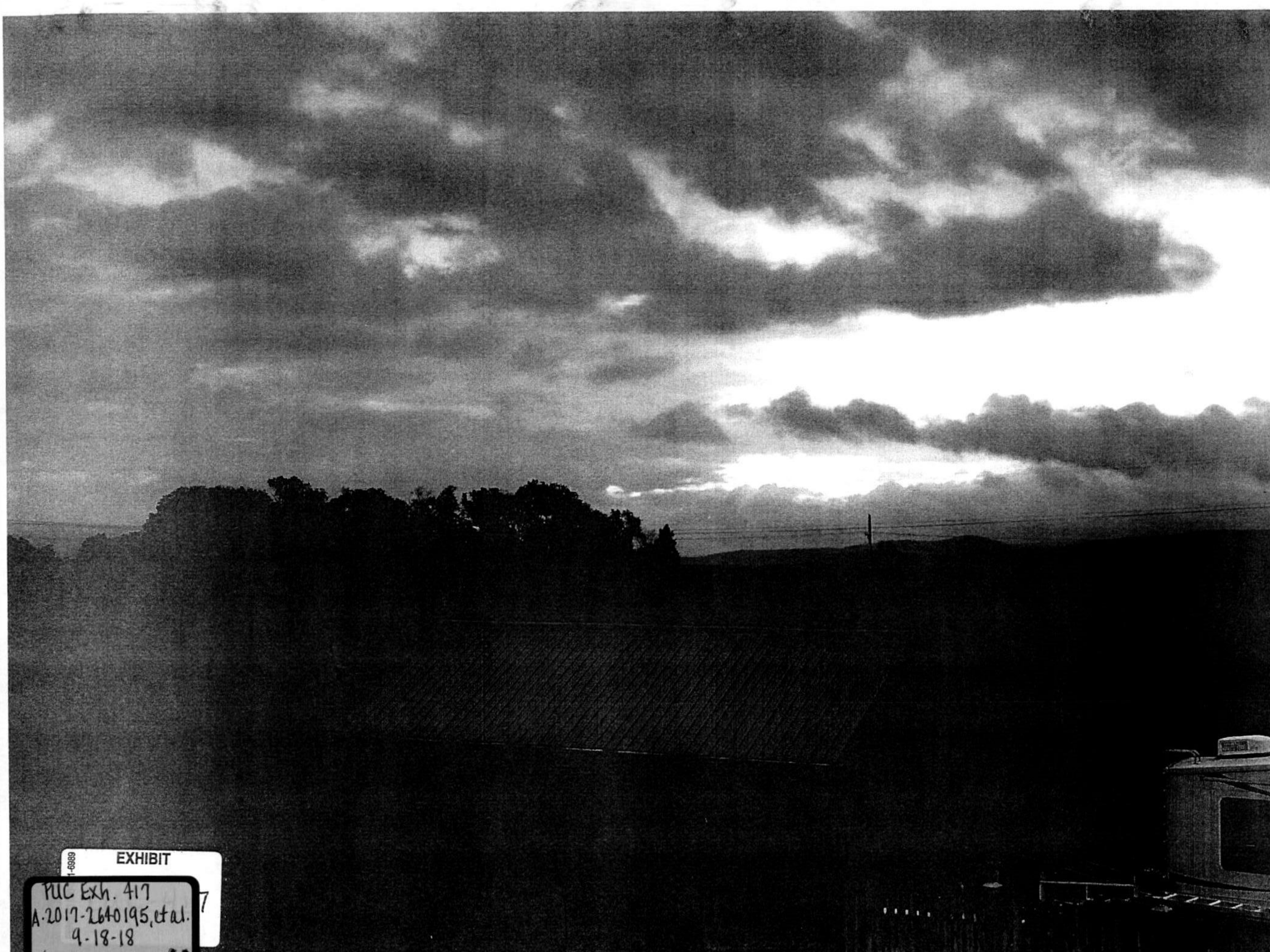

EXHIBIT

PUC Exh. 417
A-2017-2640195, et al.
9-18-18
Chambersburg MJD

EXHIBIT

PUC-418

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PUC Exh. 418
A-2017-2640195, etal.
4-18-18
Chambersburg Mo

PUC Exh. 419
A-2017-2640195, et al
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Chambersburg MJO

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A-2017-2640195, et al
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Chambersburg Mo

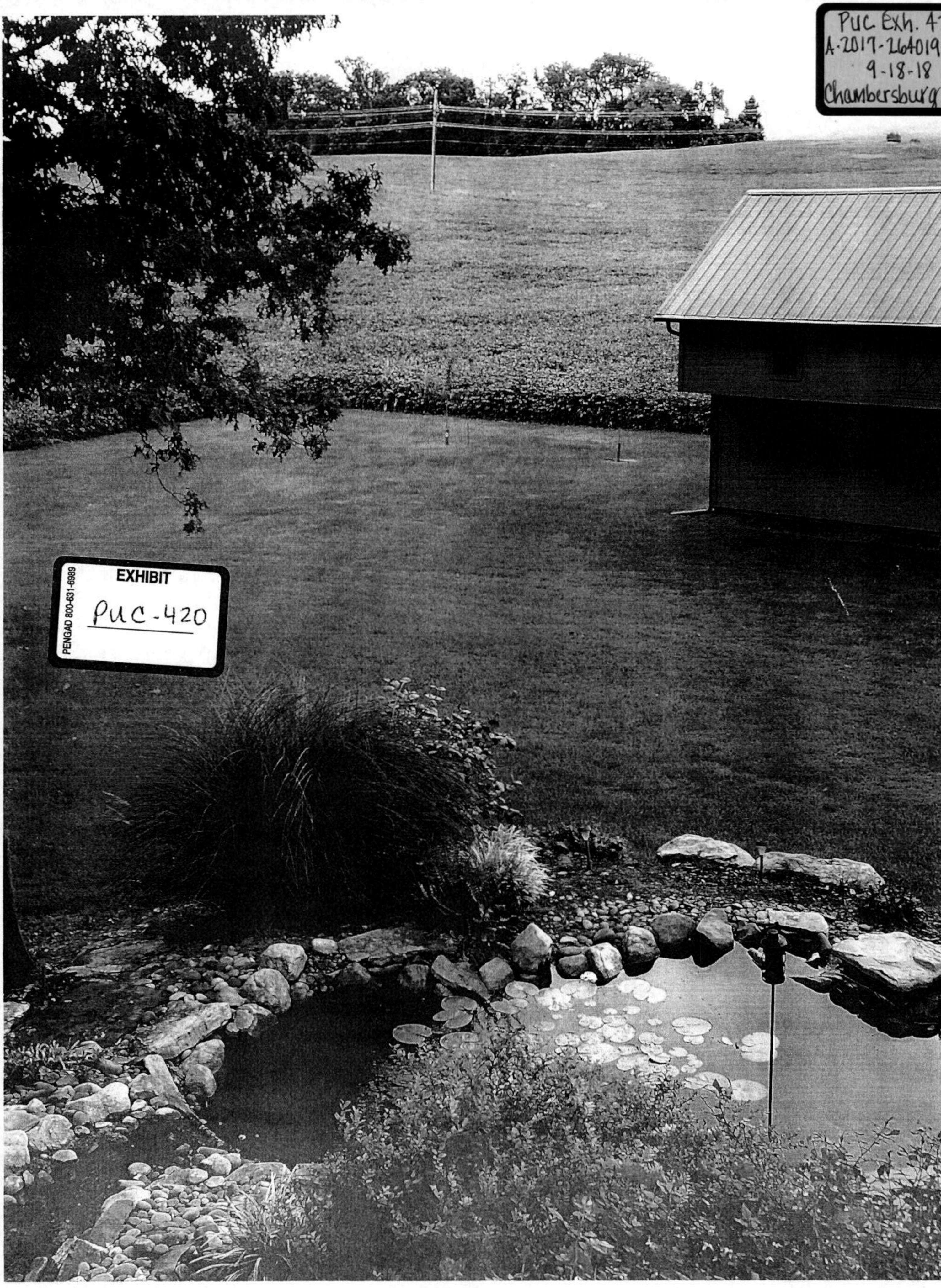


EXHIBIT
PUC-420
PENGAD 800-631-6989

2017

ANNUAL REPORT + 2018 Forecast

Heath Talhelm, Town Council President and Walter Bietsch, Mayor at the Utility Departments' addition under construction.

The Only Town In Pennsylvania with All Services & Utilities:

Electric Distribution • Electric Generation • Water • Sewer
Trash • Stormwater • Natural Gas • Police • Emergency Services
Land Use • Recreation • Public Works • Community Development

Electric

A Unique Chambersburg Tradition
Award Winning Municipal Electric System

By Ron Pezon, PE, CEM, CSDP, CDSM

The Borough's municipal electric utility has been diligently serving the expanding energy needs of our community for approximately 124 years; operating around the clock, logging some of the best reliability available and at prices competing with the lowest cost electric utilities in the Country.

Sometimes it appears that today's Chambersburg Electric Department operates much like the small town commercial electric utilities of yesteryear, but in other ways, Chambersburg is able to enjoy the vast benefits of today's competitive wholesale power purchasing marketplace to find inexpensive power supply for our homes and businesses. The Borough's operating model uses a legacy or traditional utility infrastructure consisting of generation, transmission, substation, distribution systems, meters and services. This is unique as deregulation has forced commercial, for-profit utilities, to no longer maintain this "vertically integrated" organization model. As a municipal non-profit community utility, we can still maintain this classic organization, which if managed well, is able to deliver the best of power reliability and prices to our end-users.

Our Mission: "The Chambersburg Electric Department with character, competence, and collaboration will provide to our customers valuable energy products and services that are safe, reliable, and competitively priced. The Electric Department will produce economic and other benefits to the Borough, its citizens, its customers, and employees, while operating in a professional and courteous manner within a structure of local accountability and local control."

The continuous improvement philosophy implemented in the Borough over the past several decades has begun to pay "dividends" in upgraded equipment, well trained experienced personnel, and knowledge of customer needs. Not only do the Borough residents notice the high quality of its electric services, but so did our national professional association.

Reliable Public Power Provider (RP3)

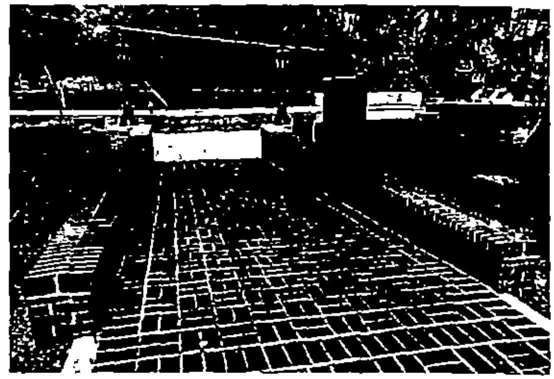
The American Public Power Association, an organization serving over 2,000 public electric utilities like Chambersburg recognized Chambersburg Electric for the fourth time in 2017.

RP3 stands for Reliable Public Power Provider. The American Public Power Association instituted the RP3 Program to recognize public power entities that have achieved high levels of operational safety, personnel development, system development, and electric system reliability. The Chambersburg Electric Department has achieved this high-level of performance with APPA's RP3 recognition since 2009.

RP3 RELIABLE PUBLIC POWER PROVIDER™
American Public Power Association

Accomplishments 2017

Consistent with our mission and that recognition, the Department made some fairly significant improvements to the "Park of the Valiant" and various other electric supply systems during the past year.

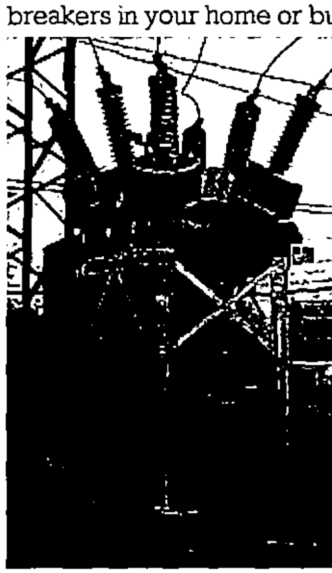


New Ramp from 2nd Street to the "Park of the Valiant" honoring Electric Department.

That Park with the fountain on North 2nd Street near the original power plant site commemorates the day in 1904 the public and media rose up to defend ownership of the municipally owned electric system including its first generator. The old entrance to the park was a set of deteriorating steps. The entrance was upgraded to a nice gentle ramp, suitable now for opening up the park facility to all Borough residents.

Further, as an example of continual infrastructure upgrades, Chambersburg replaced three old transmission circuit breakers that were nearing the end of their useful lives. We attempt to replace critical components before they are overloaded, malfunction, or fail. If not replaced, system electrical devices can sometimes fail in service catastrophically causing possibly numerous extended customer power outages.

In function, these large circuit breakers work just like the circuit breakers in your home or business; these are just way-larger! See the new Grant Street Substation circuit breaker below.

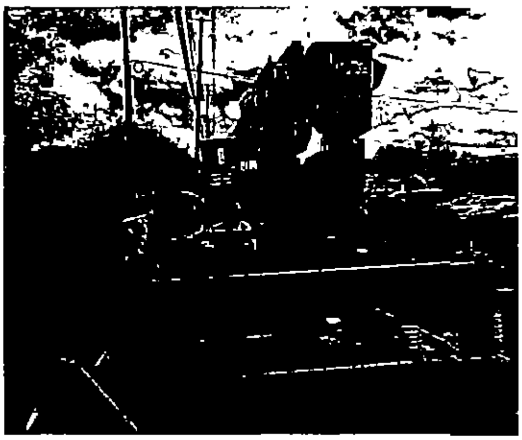


New Grant Street Substation Breaker

The department finished extending a new 12 kV distribution feeder to connect the Commerce Street Substation to a feeder that comes from the Cree Substation (Walker Road area). In 2018, the Commerce Street feeder cable will pick up the residential and business services presently connected to the old 4 kV circuit in that area. There will be weeks of many small short-duration local outages planned around the Broad Street area while the transformers and electric service drops are transferred over. After all of the services are transferred, there will be a subsequent somewhat longer outage to finally swap all the customers from the old line to the new upgraded line. The strategy of replacing old and obsolete equipment before it fails significantly reduces outage frequencies and durations. The old over head wires will be removed, making a more reliable and nicer looking streetscape in that neighborhood.

The Department is ultimately working to connect each of the Boroughs seven electric substation outputs for added system load transferability and reliability. This distribution system design and operating practice allows the line crews to isolate a problem and restore power to the largest number of customers possible in most cases in the shortest amount of time. In some of the more severe outage cases then, we can switch many customers to the "good sections" of line from another substation while we figure out how to repair the damaged facilities, and then subsequently repair them. This planning and operating practice limits the number of customers affected and reduces outage time experiences to a minimum. Our practice is called "restore and repair" using these pre-purposed multiple substations, feeders, and field installed switch-points.

An example of that safe and successful practice is shown below, where line crew members (L-R) Chuck, Keith, Rob, and line worker leader Rich have finished up an emergency repair on a switch damaged from a vehicle hit on Lincoln Way East.



Line Crews Recap Repairs Made to a Damaged Overhead Switch

Overall reliability can be significantly improved using the restore and repair concept switch points, and transfer capabilities. In larger electric utility systems these switching facilities and operating practices are often too expensive to implement. Chambersburg, with its compact system design is well-suited for this "best of class" system development and operating practice.

With all the spending on the system over the years you would think rates would have to climb accordingly. Well, not so in Chambersburg, at least due to the system improvement costs alone.

Rates

In recent history, we did see power purchase costs, and therefore rates, similarly climb into the lower double digits per kWh. Residential rates rose to about 12.6 cents per kWh at its worst time in recent history. From that high point in 2010 as a reminder, rates were forecasted to rise even further, but over the subsequent five years, staff consistently lowered costs while Borough Council consistently lowered overall electric rates in the following way, with a long term plan in mind:

The long term plan devised, and through favorable state legislation on power bidding around that time was changed from

Year	Month	Rate Reduction
2010	June	7.5%
	October	7.5%
2013	May	5%
	November	5%
2014	November	3.7%

the usual one-supplier concept to purchasing multiple power supplies from various power suppliers and over different term lengths. This new practice was the beginning of lowering and smoothing out for Borough residents the volatility of electric rates as seen in the markets from time to time.

The change in overall rates, from where the rates were proposed to go in 2010 as compared to where they actually went was a net reduction from that plan of about 30% over the subsequent 5-year period. The rate schedules were all lowered further in 2013 and finally in 2014 as a direct result of the new portfolio power purchasing strategy adopted by council on May 14, 2012. The new multiple source and block portfolio approach approved by Council was responsible for significantly lowering then, and stabilizing power supply costs over the past three years.

Expanding the Power Supply Portfolio:

Unlike the now widespread investor-owned electric utilities of today, Chambersburg, using its locally owned and operated system keeps most of the benefits of municipal management within the Borough and for the exclusive benefit of its residents.

Instead of each business and citizen having to wisely select their own power supply arrangement (or worse yet, let the big utility decide what they think is best for you), your local power supply team shops the wholesale electric marketplace to get you the best least cost electricity on your behalf. We pool all the needs of the citizens and businesses in Chambersburg and ***WeShop4U*** as a power "pool"; up to twice per year for the Borough's 11,400 or so retail customers, the power supply team goes shopping for bulk power deals. Also, the Borough, through its power generation is able to bring back home some of the outside or "market" derived financial benefits to its customers in the form of stable rates and power quality.

In 2017 and through 2023, the Borough will enjoy more than 18 different power supply agreements. The Borough also owns about 30 MW of dual-fueled (Natural Gas/Fuel Oil) reciprocating engine generation capability at two power plant locations that is sold to the regional transmission operator called "PJM" (Pennsylvania, Jersey, Maryland Interconnection). These generation assets, along with the power purchases from the Landfill Gas to power generators help offset the sometimes very

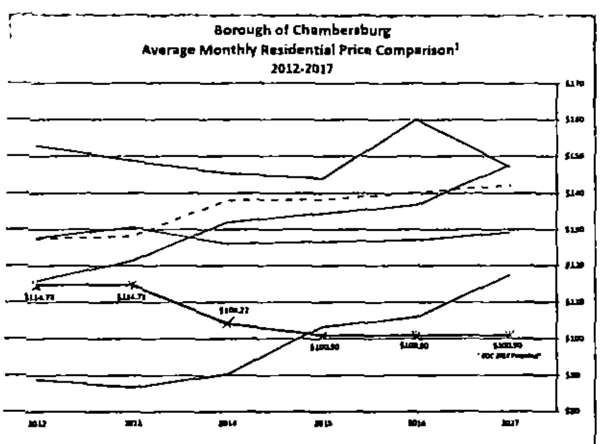
electricity in summer and winter. The power pur-
eam regularly considers options to fill in the un-pro-
cancies in the portfolio plan to stabilize power prices
the future.

ıg the Borough's renewable, sustainable energy ob-
that make sense) in 2017 the power purchase team
valuating some small scale "community" solar electric
on projects. The power purchasing team will evalu-
and other technologies as they come along however
be implemented without first performing rigorous fi-
valuations with positive results and second, bringing
osals to Council for community discussion and possi-
oval based on merits and long term viability.

es Chambersburg's Overall Rate Compare?

a is the only state in the union that generates electric-
consumers entirely from public power entities simi-
igger than Chambersburg. According to the official
a government website ("Annual Average Electricity
mparison by State"), as of 2015, Washington State was
irst as lowest customer cost per kWh (a standard unit
icity cost and measurement) at 7.41 cents per kWh.
a, the whole state itself, being fully public power, was
15th in the U.S. at 9.04 cents per kWh. Chambersburg
to be compared in this study would just inch ahead
s to be ranked 16th at an overall 9.12 cents per kWh in
inois was listed as 16th at 9.28 cents per kWh). Overall
Pennsylvania ranked 31st in the U.S. coming in at 10.41
r kWh according to the study or about 14% higher on
than Chambersburg in that year. The national aver-
t per kWh in 2015 was right around Pennsylvania at
ents per kWh. The states ranked in the study with the
cost per kWh were Alaska and Hawaii at 17.94 and
ents per kWh respectively.

ersburg has not changed electric rates since Novem-
2014. This was accomplished even while replacing
grading aging infrastructure during that time and to this
hereas, simply reading the news, we know that many
ding Pennsylvania utilities have already or will raise
tes since this study was conducted in 2015 and with
ucture upgrades often as the most common reason.



rage Residential Customer Monthly Bill
nparison Using 1,000 kWh/Month

Electric rates in the Borough did rise for a time as we saw too in the outside world. Due to Town Council's strategic actions since 2010 however, Chambersburg's rates have come down to what is now below that of ***all*** surrounding investor-owned utilities. As a result of the new portfolio approach, the Borough's electric rates have settled in well below that of the state average for both overall electric rates and the typical (1,000 kWh/month) residential bill.

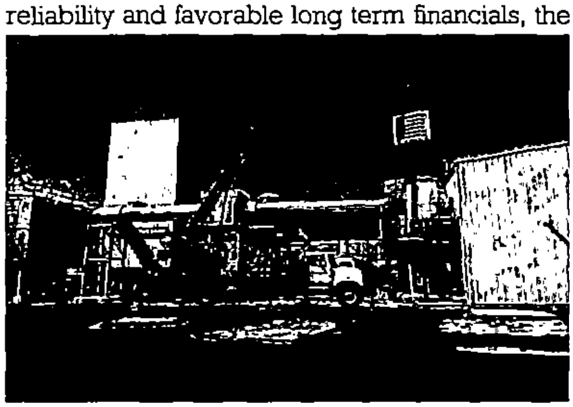
Renewable Energy and Sustainability

In 2017, due to its broad variety of accomplishments, the Borough was recognized as a Sustainable Pennsylvania Community by the Pennsylvania Municipal League in partnership with Sustainable Pittsburgh.

The Federal EPA award-winning Landfill Methane Outreach Program "Project of the Year 2013" Landfill gas to energy plant is nearing its halfway point in the initial ten year agreement. The Borough is looking at time-extension possibilities and various other viable expansion pricing structures in the coming years, including an Energy Power Partner's (EPP) owned small community solar power generating station with its power to also come back into Chambersburg on the Express Generator Feeder (EGF) or "extension cord" as the term was coined back in the day. The New York Power Authority hydro-electric power, landfill gas plant purchases, roof top solar, and new renewable power contracts are helping the Borough achieve a sustained estimated 16% renewable energy contribution toward is overall annual energy use.

Borough-Owned Generation Assets:

Chambersburg buys all of its power "wholesale" through the energy "portfolio" and re-sells it through the internal transmission and distribution systems to its retail customers. The department sells all of the power "generated" to the PJM bringing home its financial benefits to directly help lower the overall annual power supply costs. To maintain such high electricity delivery reliability and favorable long term financials, the Electric Department must routinely conduct maintenance on facilities and sometimes perform significant repair and/or upgrade projects.



Replacing CO Panel at Orchard Park Generating Station

Both of the Borough-owned Falling Spring and the Orchard Park Generating Stations were professionally tested for emissions compliance and subsequently passed the state's approved interim permitting standard stack tests in 2017. Maintenance of emission systems for compliance sometimes means that the very large carbon monoxide (CO) emission reducing panels need to be cleaned or replaced as shown hanging from the crane.

The Borough operates its generation assets according to strict Federal and State environmental regulations. In 2017, the power supply team performed routine and preventative maintenance on many of the generators and auxiliary equipment to ensure quick start ups and dependable and safe plant operations.

Jerry Howe, Power Supply Supv. Inspects CO Catalyst Change-Out

The department finished the relay and protection portion of the upgrade project at the Falling Spring Generating Station, Grant Street Substation critical to decommissioning an outdoor set of metal clad switchgear built in the early 1970's, and which is considered by many evaluators to be at the end of its useful life. The decommissioning project required replacing generator protection relays and will yet require moving the generator #5 and #6 power outputs over to another newer set of indoor switchgear at the Grant Street Substation allowing continued reliable generation sales to the PJM.

Substation Improvements and Feeder Ties

We continue to upgrade area substations, feeders, and transformers to serve the growing electricity needs of the community. The electric load is growing as a result of the good economic climate in this area that we have been experiencing over the past at least 5 years. Chambersburg's distribution systems are typically being built out in a way modeled after the best reliable systems.

In a sense, with the reliability achievements of late, the whole of Chambersburg on average would be considered a "Premium Power Park" by any state or national standard. Our infrastructure is just that good.

The Borough has a long term plan to upgrade substation transformers to meet the growing load and building out substation ties through existing and new feeder ties such that load can be transferred from one substation to another. The load transfer capability allows the line crews to "restore and repair". This means that they can transfer most customers to another distribution feeder restoring their power after isolating the problem, then repairing the problem section of line.

Pulling in New Conductor along Broad Street

The department also focuses on the worst performing circuits to reduce momentary outages as well as the extended outages from aged distribution facilities.

2018 Reliability:

Chambersburg has long strived to be one of the best electric system's for deliverability and reliability. The department systematically maintains and replaces obsolete equipment, attempting to replace or repair devices prior to them failing in service. It takes less time to replace equipment in a planned and organized way than it does to make repairs under emergency conditions. Usually, the "predictive" approach is more effective in keeping reliability up and costs down as compared to waiting for things to fail, sometimes catastrophically, and while in service.

The Electric Department and its customers continue to enjoy among the highest reliability statistics in the nation due to maintaining and upgrading/replacing aged infrastructure whenever possible prior to equipment failures.

There are several measurements for "reliability" in the electric utility industry. The main two measurements that we use are the System Average Interruption Duration Index (SAIDI) and the System Average Interruption Frequency Index (SAIFI). Outages over 5 minutes are counted in the statistics for the duration index and momentary interruptions (those 5 minutes or less) are counted in the frequency index. We all know what extended outages are. Momentary interruptions are those annoying outages required to clear a major fault/short circuit on the system, when power is restored right away, but unfortunately it makes some older clocks without battery back-up "blink", needing to be reset.

You can see in the chart below that Chambersburg stacks up well against all Pennsylvania utilities, big and small. Neighboring West Penn Power logged, according to the PA PUC 2016 Reliability Report, that on average every customer on their system was out of power for 163 minutes each during that year. Every customer served by the Borough in 2016 was out of power for an overall average of 12 minutes each.

2016 Systems Reliability Scorecards Compared
(No Major Events)

- **Borough Average 2016 SAIDI:** **12 Minutes**
- ***Small EDC (PUC),* 2016 SAIDI:** **43 Minutes**
  (Citizens, Pike UGI, Wellsboro)
- **Large Investor Owned Utilities 2016 SAIDI:** **124 Minutes**

(Duquesne,PECO,PPL,Met Ed,Penne'ec,Penn Power, West Penn Power 163 Min)

SAIDI - System Average Interruption Duration Index (On average how many minutes per year is every customer on the system out of power)

U.S. Energy Information Administration

EXHIBIT
PUC-422

PUC Exh. 422
A-2017-2640195, et al.
9-18-18
Chambersburg MO

Analysis & Projections
Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants

Release Date: November 22, 2016

Addendum - Capital Cost Estimates for Additional Utility Scale Generating Plants Release Date: April 7, 2017

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.

EIA commissioned an external consultant to develop up–to-date cost and performance estimates for utility–scale electric generating plants for AEO2013.[1] This information allowed EIA to compare the costs of different power plant technologies on a standardized basis and was a key input enhancement to the National Energy Model System (NEMS). For the AEO2016 development, EIA commissioned the same consultant group to update the cost and performance estimates for a select set of the technologies evaluated in the original 2012 study. This paper summarizes the results of the findings and discusses how EIA used the updated information to analyze the development of new capacity in the electric power sector.

Developing updated estimates: key design considerations

The focus of the 2016 update was to gather current information on the "overnight" construction costs, operating costs, and performance characteristics for a wide range of generating technologies.[2] The estimates were developed through costing exercises, using a common methodology across technologies. Comparing cost estimates developed on a similar basis using the same methodology is of particular importance to ensure modeling consistency.

Each technology is represented by a generic facility of a specific size and configuration, in a location that does not have unusual constraints or infrastructure requirements. Where possible, costs estimates were based on information on system design, configuration, and construction derived from actual or planned projects known to the consultant, using generic assumptions for labor and materials rates. When this information was not available, the project costs were estimated using a more generic technology representation and costing models that account for the current labor and materials rates necessary to complete the construction of a generic facility as well as consistent assumptions for the contractual relationship between the project owner and the construction contractor.

The specific overnight costs for each type of facility were broken down to include:

- **Civil and structural costs:** allowance for site preparation, drainage, the installation of underground utilities, structural steel supply, and construction of buildings on the site

- **Mechanical equipment supply and installation:** major equipment, including but not limited to, boilers, flue gas desulfurization scrubbers, cooling towers, steam turbine generators, condensers, photovoltaic modules, combustion turbines, wind turbines, and other auxiliary equipment
- **Electrical and instrumentation and control:** electrical transformers, switchgear, motor control centers, switchyards, distributed control systems, and other electrical commodities
- **Project indirect costs:** engineering, distributable labor and materials, craft labor overtime and incentives, scaffolding costs, construction management start up and commissioning, and fees for contingency[3]
- **Owners costs:** development costs, preliminary feasibility and engineering studies, environmental studies and permitting, legal fees, insurance costs, property taxes during construction, and the electrical interconnection costs, including a tie-in to a nearby electrical transmission system

Non–fuel operations and maintenance (O&M) costs associated with each of the power plant technologies were evaluated as well. The O&M costs that do not vary significantly with a plant's electricity generation are classified as fixed, including salaries for facility staff and maintenance that is scheduled on a calendar basis. The costs incurred to generate electricity are classified as variable such as the cost of consumable materials and maintenance that may be scheduled based on the number of operating hours or start–stop cycles of the plant. The heat rates4 were also evaluated for the appropriate technologies. It should be noted that all estimates provided in this report are broad in scope. A more in– depth cost assessment would require a more detailed level of engineering and design work, tailored to a specific site.

Findings

Table 1 summarizes updated cost estimates for generic utility–scale generating technologies, including four powered by coal, six by natural gas, three by solar energy, and one each by wind, biomass, uranium, and battery storage. 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 AEO2016 that use the cost data from this report are identified in the last column of Table 1.

Table 2 compares the updated overnight cost estimates to those developed for the 2013 report. To facilitate comparisons, the costs are expressed in 2016 dollars.[5]Notable changes include:

- **Ultra Supercritical Coal (USC) with and without carbon capture and storage (USC/CCS).** USC with carbon capture and storage was added for this study to help meet EPA's 111b new source performance standard for carbon emissions. While USC without carbon capture cannot be built under current regulations, inclusion of this technology maintains the capability to analyze policy alternatives that may exclude 111b requirements.
- **Conventional Natural Gas Combined Cycle (NGCC) and Advanced Natural Gas Combined Cycle (ANGCC):** The updated overnight capital cost for conventional and advanced NGCC plants remained level relative to the cost in the 2013 study. The capacity of the NGCC unit increased from 400 MW in the 2013 study to 429 MW, while the capacity of the ANGCC unit increased from 620 MW to 702 MW for ANGCC to reflect trends toward larger installations for this technology.
- **Onshore Wind:** Overnight costs for onshore wind decreased by approximately 25 percent relative to the 2013 study, primarily due to lower wind turbine prices. EIA adjusted regional cost factors for wind plants from those reported in this report for inclusion in AEO 2016 [Table 8.2]. The regional factors in this report primarily account for regional variation in labor and materials costs, but subsequent evaluation of the regional variation in wind plant costs found that other factors, such as typical plant size, may account for a larger share of the observed regional differences in cost for the wind plants.
- **Solar Photovoltaic:** The overnight capital costs for solar photovoltaic technologies decreased by 67 percent for the 20 MW fixed tilt photovoltaic systems from the costs presented in the 2013 study. Solar photovoltaic single–axis

tracking systems were introduced in this report (including both a 20 MW and 150 MW system configurations). There is not a significant difference in Capital costs between fixed–tilt and single–axis–tracking systems. The overall decreases in costs can be attributed to a decline in the component costs and the construction cost savings for the balance of plant systems.

As previously noted, costs are developed using a consistent methodology that includes a broad project scope and includes indirect and owners costs. The cost figures will not necessarily match those derived in other studies that employ different approaches to cost estimation.

EIA's analysis of technology choice in the electric power sector

EIA's modeling employs a net present value (NPV) capital budgeting methodology to evaluate different investment options for new power plants. Estimates of the overnight capital cost, fixed and variable operations and maintenance costs, and plant heat rates for generic generating technologies serve as a starting point for developing the total cost of new generating capacity. However, other parameters also play a key role in determining the total capital costs. Because several of these factors are dynamic, the realized overall capital cost for given technologies can vary based on a variety of circumstances. Five of the most notable parameters are:

- **Financing:** EIA determines the cost of capital required to build new power plants by calculating a weighted average cost of capital using a mix of macro–economic parameters determined through EIA's modeling and an assumed capital structure for the electric power industry.
- **Lead Time:** The amount of time needed to build a given type of power plant varies by technology. Projects with longer lead times increase financing costs. Each year of construction represents a year of additional interest charges before the plant is placed in service and starts generating revenue. Furthermore, plants with front–weighted construction and development profiles will incur higher interest charges during construction than plants where most of the construction expenditures occur at the end of the development cycle.
- **Inflation of material and construction costs:** The projected relationship between the rate of inflation for the overall economy and key drivers of plant costs, such as materials and construction, are important elements impacting overall plant costs. A projected economy–wide inflation rate that exceeds the projected inflation rate for materials and construction costs results in a projected decline in real (inflation–adjusted) capital costs and vice versa.
- **Resource Supply:** Technologies such as wind, geothermal, or hydroelectric must be sited in suitable locations to take advantage of the particular resource. In order to capture the site specific costs associated with these technologies, EIA develops upward sloping supply curves for each of these technologies. These curves assume that the lowest –cost, most–favorable resources will be developed first, and when only higher–cost, less–favorable sites remain, development costs will increase and/or project performance will decrease.
- **Learning by doing:** The overnight capital costs developed for the report serve as an input to EIA's long term modeling and represent the cost of construction for a project that could begin as early as 2015. However, these costs are assumed to decrease over time in real terms as equipment manufacturers, power plant owners, and construction firms gain more experience with certain technologies. The rate at which these costs decline is often referred to as the learning rate.

EIA determines learning rates at the power plant component level, not for the power plant technology itself because some technologies share the same component types. It is assumed that the knowledge and experienced gained through the manufacture and installation of a given component in one type of power plant can be carried over to the same component in another type of plant. As an example, the experience gained through the construction of natural gas combustion turbine plants can be leveraged to influence the overall cost of building a Natural Gas Combined Cycle unit, which in part, includes the components of a combustion turbine natural gas plant. Other technologies, such as nuclear power and pulverized coal (PC) plants without CCS, do not share component systems, and their learning rates are determined solely as a function of the amount of capacity built over time.

Technologies and their components are represented in the NEMS model at various stages of maturity. EIA classifies technologies into three such stages: mature, evolutionary, and revolutionary. The initial learning rate is evaluated for each technology. The technology classification determines how the rate of cost reduction changes as each technology progresses through the learning function. Generally, overnight costs for technologies and associated components decline at a specified rate based on a doubling of new capacity. The cost decline is fastest for revolutionary technologies and slower for evolutionary and mature technologies.[6]

The capacity additions used to influence learning are primarily developed from NEMS results. However, external capacity additions from international projects are also included for some technologies, to account for additional learning from such projects. For power plant technologies with multiple components, the capacity additions are weighted by the contribution of each component to the overall plant construction cost.[7]

Table 3 classifies the status of each technology and component as modeled in AEO2016.

The NEMS model also assumes that efficiency for all fossil–fueled plants improves as a result of learning by doing. The power plant heat rates provided by the consultant are intended to represent the characteristics of a plant that starts construction in 2015 referred to as "first–of–a–kind." NEMS assumes that the heat rate for all fossil fueled technologies declines over time to a level referred to as an "nth–of– a–kind" heat rate.[8] The magnitude of heat rate improvement depends on the current state of the technology, with revolutionary technologies seeing a more significant decline in heat rate than mature technologies. Heat rate improvements are independent of capacity expansion. Fixed and variable O&M are not assumed to achieve learning–related savings. The performance of wind plants, as measured by capacity factor, is also assumed to improve as a result of learning by doing.[9]

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. The report includes location–based cost adjustment tables for each technology in 64 metropolitan areas. These adjustments were made to reflect the impact of remote location costs, costs associated with seismic design that may vary by region, and labor wage and productivity differences by region. In order to reflect these costs in Ela's modeling, these adjustments were aggregated to represent the 22 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 regional cost adjustments and development restrictions are summarized in Table 4.

Subsequent peer review of these results indicated that the regional factors used for wind plants do not adequately reflect observed regional variation of wind plant costs, which appear to be substantially determined by factors other than those considered above. In particular, EIA found a significant regional variation in typical plant size that generally correlated with regional variation in installation costs. Therefore, EIA does not use the regional factors included in this report for its analysis of wind technologies. Regional factors used for AEO2016 and related analyses can be found in Table 8.2 of the AEO2016 Assumptions document, and are also shown in Table 4.

Summary

The estimates provided by the consultant for this report are key inputs for EIA electric market projections, but they are not the sole driver of electric generation capacity expansion decisions. The evolution of the electricity mix in each of the 22 regions modeled in AEO2016 is sensitive to many factors, including the projected evolution of capital costs over the modeling horizon, projected fuel costs, whether wholesale power markets are regulated or competitive, the existing generation mix, additional costs associated with environmental control requirements, and future electricity demand.

Users interested in additional details regarding these updated cost estimates should review the consultant study prepared by Leidos Engineering, LLC in Appendix B.

see full report report

see addendum

Footnotes

[1] U.S. Energy Information Administration, Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants 2013.

[2] The term "overnight" refers to the cost of the project as if no interest were incurred during its construction.

[3] Fees for contingency include contractor overhead costs, fees, profit, and construction.

[4] Heat Rate is a measure of generating station thermal efficiency commonly stated as Btu per kilowatthour.

[5] U.S. Energy Information Administration, Annual Energy Outlook 2016, Table 20, GDP chain-type price index.

[6] U.S. Energy Information Administration, Electricity Market Module Assumptions Document, Table 8.3.

[7] U.S. Energy Information Administration, Electricity Market Module Assumptions Document Table 8.4.

[8] U.S. Energy Information Administration, AEO2016 Cost and Performance Characteristics of New Central Station Electricity Generating Technologies, Table 8.2.

[9] U.S. Energy Information Administration, Renewable Fuels Module

Independent Statistics & Analysis
U.S. Energy Information Administration

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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.

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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 occuring 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 (RMPA)
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.

Converters

Home / Power Conversion / Convert Megawatt to Kilovolt Ampere

Like 0

Convert Megawatt to Kilovolt Ampere

Please provide values below to convert megawatt [MW] to kilovolt ampere [kV*A], or *vice versa*.

From: 429 megawatt

To: 429000 kilovolt ampere

Convert Clear

Result: 429 megawatt = 429000 kilovolt ampere

Megawatt to Kilovolt Ampere Conversion Table

Megawatt [MW]	Kilovolt Ampere [kV*A]
0.01 MW	10 kV*A
0.1 MW	100 kV*A
1 MW	1000 kV*A
2 MW	2000 kV*A
3 MW	3000 kV*A
5 MW	5000 kV*A
10 MW	10000 kV*A
20 MW	20000 kV*A
50 MW	50000 kV*A
100 MW	100000 kV*A
1000 MW	1000000 kV*A

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How to Convert Megawatt to Kilovolt Ampere

1 MW = 1000 kV*A
1 kV*A = 0.001 MW

Example: convert 15 MW to kV*A:
15 MW = 15 × 1000 kV*A = 15000 kV*A

Popular Power Unit Conversions

hp to kw
hp to watts
BTU to Ton
kw to hp
watts to hp
Ton to BTU

Convert Megawatt to Other Power Units

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Megawatt to Petawatt
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Megawatt to Terawatt

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Common Unit Systems