PJM's Capacity Market: Clearing Prices, Power Plants, and Environmental Justice

Image Credit: Hannah Price

Authors:

Joshua R. Castigliego

Elizabeth A. Stanton, PhD

Sagal Alisalad

Tanya Stasio

Eliandro Tavares

Applied Economics Clinic

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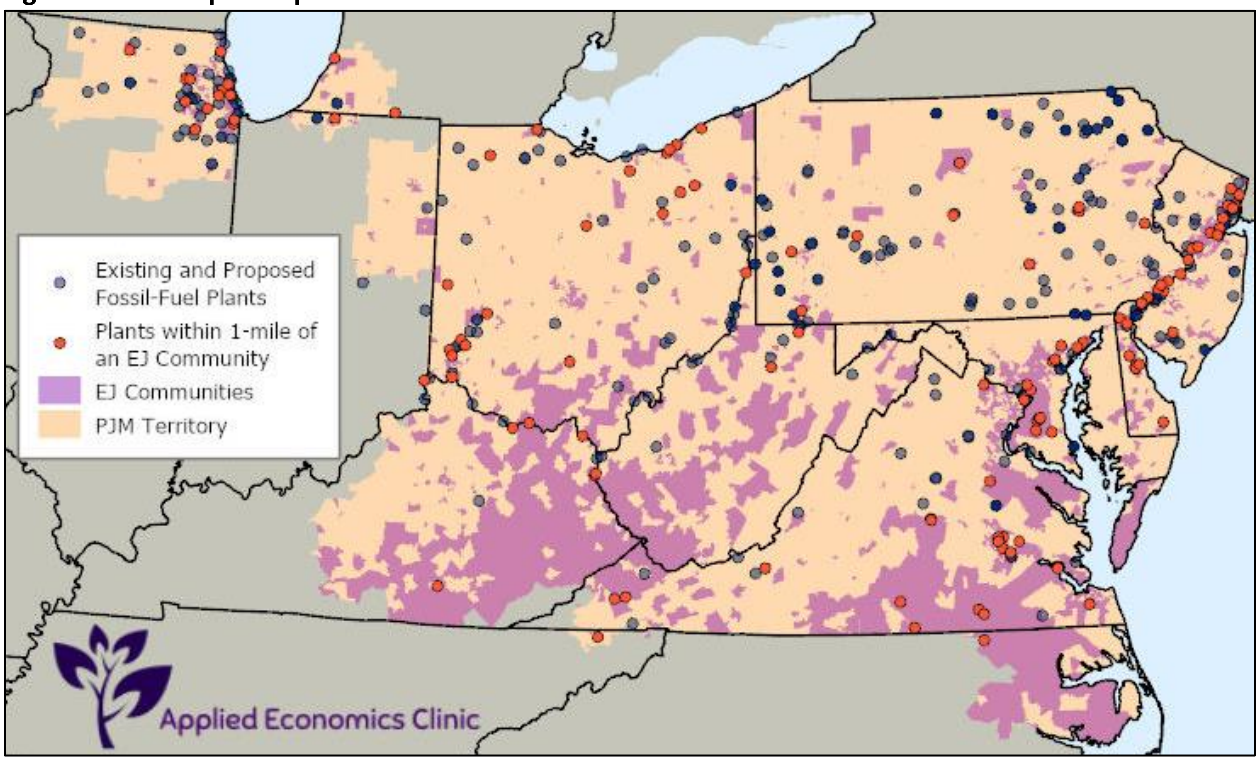
Executive Summary

Fossil fuel power plants abound from Chicago to the Jersey Shore, part of a 13-state power grid run by PJM. The cost to keep gas and coal-fired plants operating in PJM affects electricity bills for more than 65 million people, and emissions from power plants affect public health and exacerbate climate change. Of the nearly 1,200 existing and proposed gas- and coal-fired electric generating units at 383 power plants in PJM, more than half are located within 1 mile of an Environmental Justice (EJ) community (see Figure ES-1). As defined in Pennsylvania, where PJM is headquartered, EJ communities are those in which 20 percent or more of households are low-income and/or where 30 percent or more of residents are Black, Indigenous, and People of Color (BIPOC). Nationwide and in the PJM region, low-income Black people face the highest risk of death from power plants' fine particulate emissions.

Figure ES-1. PJM power plants and EJ communities

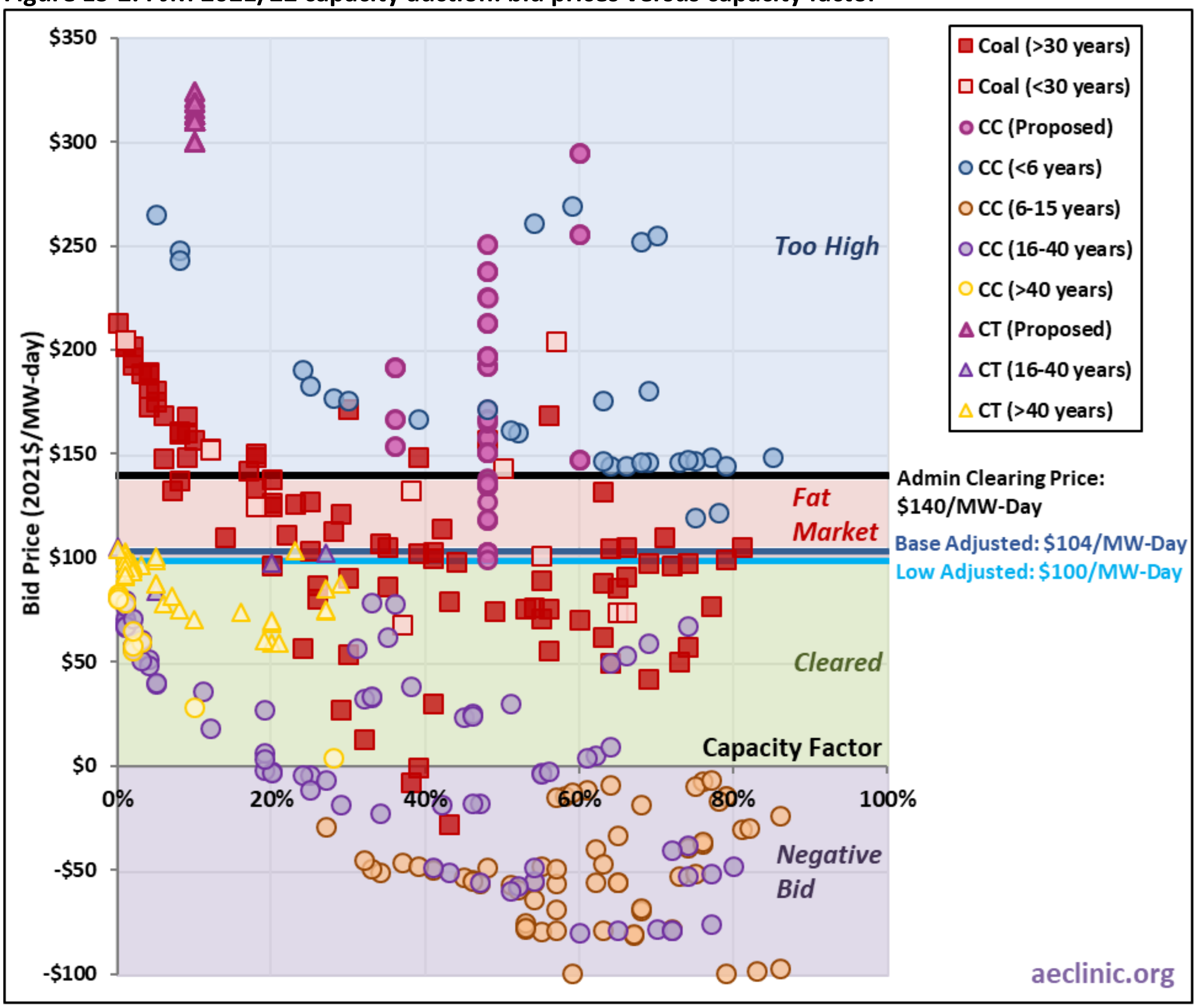


This Applied Economics Clinic (AEC) report reviews the economics of power plants in the PJM region, focusing on the "capacity payments" given to owners of generating units that promise to be available if needed to generate power at times of peak customer demand. We find that PJM has consistently overestimated its peak demand and as a result spent too much money on capacity payments, and generating units—including many in or near EJ communities—are kept online despite being uneconomic and unnecessary to provide reliable electric service.

AEC adjusted PJM's forecasts and market design to better represent customer demand and other market conditions, and estimated the prices that individual generating units bid into the 2021/22 capacity auction, which took place in 2018. The actual bids by power plant owners are not made public, so we model them based on available cost and revenue data. PJM's overestimate of customer demand and costs of new generating units raises market clearing prices and capacity payments to power plant owners, resulting in what we call a "fat market" with payments made to unnecessary power plants and higher costs to customers. In place of PJM's $140 per megawatt-day (MW-day) fat market clearing price, we estimate a clearing price of $100 to $104 per MW-day to serve customer needs without adding unnecessary costs. **Our leaner, adjusted clearing price would lower customer bills without sacrificing reliable electric service and put an end to capacity payments propping up the bottom lines of uneconomic power plants, many of them in or near EJ communities.**

Our analysis shows 77 gas- and coal-fired generating units with estimated bid prices less than PJM's $140 per MW-day but more than AEC's adjusted $100-104 per MW-day (see Figure ES-2).

Figure ES-2. PJM 2021/22 capacity auction: bid prices versus capacity factor



Note: "Admin Clearing Price" refers to PJM's clearing price for the 2021/22 capacity auction; "Base Adjusted" and "Low Adjusted" are the resultant clearing prices of AEC's analysis (described in detail in Appendix A – Capacity Demand: Demand Curve Adjustments). "CC" and "CT" refer to gas combined-cycle and gas combustion turbine generating units, respectively; and the years listed in the legend are the age of each unit as of 2018.

These are the "fat-market" units that would not have received capacity payments if the auction used our adjusted demand assumptions. Some of these units are old, others are still in the planning stages, and many have relatively low capacity factors (meaning that they do not operate very often).

The following are key summary findings:

- 35 gigawatts (GW) of unnecessary capacity from 77 existing and proposed gas- and coal-fired generating units cleared only because of PJM's fat market; for reference, 164 total GW cleared in PJM's 2021/22 capacity auction.

- Fat-market capacity bought in PJM's 2021/22 auction cost customers $4.3 billion dollars in extra cost, about $67 a year on the average customer bill.

- Of the 1,050 existing coal and gas generating units in the PJM region, 851 units (81 percent) are within 5 miles of an EJ community. The majority—609 units (58 percent)—are within 1 mile of an EJ community. More than one-third—376 units (36 percent)—are sited within an EJ community.

- Of the 77 existing and proposed gas- and coal-fired units receiving capacity payments only because of PJM's fat-market over-procurement, 48 units (62 percent) are within 5 miles of an EJ community; 33 units (43 percent) are within 1 mile.

- Of the fat-market beneficiary units located within 1 mile of an EJ community, 6 are proposed gas units (for which capacity payments are an important step toward receiving financing to begin construction); 13 are existing gas-fired units; and 14 are existing coal-fired units.

- In Maryland, New Jersey, Ohio, and Virginia, every single gas and coal unit benefitting from 2021/22 fat-market capacity payments in PJM is located within 5 miles of an EJ community. In Delaware, Illinois, and Kentucky every fat-market unit is within 1 mile of an EJ community.

- Among the 147 existing and proposed units with capacity that is too expensive to clear even with the fat market in place, more than half (83) are located within 5 miles of an EJ community; more than one-quarter (43) are within 1 mile of an EJ community; more than one-fifth (35 units) are located directly within an EJ community.

- Existing and proposed units that are already uneconomic in PJM's capacity auction and located close to EJ communities are primarily in Maryland, Ohio, Pennsylvania, and Virginia, with some in Delaware, Illinois, Kentucky, Michigan, New Jersey, and West Virginia. Among the 26 total existing units within 1 mile of an EJ community across the PJM region, 10 are in Virginia.

Over-procurement of capacity has important real-world impacts that could be resolved by taking a different approach to estimating future customer demand and capacity market design.

We offer the following recommendations developed in the course of our analysis:

1. PJM should reconsider its methodology for forecasting three-year ahead demand; the current methodology appears to result in a consistent overestimate year after year.

2. PJM should reconsider its methodology for designing a capacity demand curve, including comparison of its methods to those used in other regional electric grid operating systems. Small adjustments in the shape and slope of the demand curve have big impacts on the clearing price.

3. PJM should provide additional opportunities for a wider and more diverse set of stakeholder comment and third-party review of its proposed demand curve before holding every auction. Assessment by a larger set of experts may improve the accuracy of the demand curve, permit consideration of more diverse technical, social and environmental factors in the design of a final demand curve, and provide Federal Energy Regulatory Commission (FERC) with more comprehensive input and guidance in their assessment of auction processes.

4. PJM along with state and local governments should take steps to include the voices and concerns of power plant host communities—and especially EJ communities—when considering changes to their market design. For the best decision-making, it is not possible to subsume the full range of power plants' impacts in market prices. Environmental and social impacts have a role to play in equitable and reliable power supply.

Table of Contents

About the Applied Economics Clinic

Based in Arlington, Massachusetts, the Applied Economics Clinic (AEC) is a mission-based non-profit consulting group that offers expert services in the areas of energy, environment, consumer protection, and equity from seasoned professionals while providing on-the-job training to the next generation of technical experts.

AEC's non-profit status allows us to provide lower-cost services than most consultancies and when we receive foundation grants, AEC also offers services on a pro bono basis. AEC's clients are primarily public interest organizations—non-profits, government agencies, and green business associations—who work on issues related to AEC's areas of expertise. Our work products include expert testimony, analysis, modeling, policy briefs, and reports, on topics including energy and emissions forecasting, economic assessment of proposed infrastructure plans, and research on cutting-edge, flexible energy system resources.

AEC works proactively to support and promote diversity in our areas of work by providing applied, on-the-job learning experiences to graduate students—and occasionally highly qualified undergraduates—in related fields such as economics, environmental engineering, and political science. Over the past four years, AEC has hosted research assistants from Boston University, Brandeis University, Clark University, Tufts University, and the University of Massachusetts-Amherst. AEC is committed to a just workplace that is diverse, pays a living wage, and is responsive to the needs of its full-time and part-time staff.

Founded by Clinic Director and Senior Economist Elizabeth A. Stanton, PhD in 2017, AEC's talented researchers and analysts provide a unique service-minded consulting experience. Dr. Stanton has had two decades of professional experience as a political and environmental economist leading numerous studies on environmental regulation, alternatives to fossil fuel infrastructure, and local and upstream emissions analysis. AEC professional staff includes experts in electric, multi-sector and economic systems modeling, climate and emissions analysis, green technologies, and translating technical information for a general audience. AEC's staff are committed to addressing climate change and environmental injustice in all its forms through diligent, transparent, and comprehensible research and analysis.

I. Introduction

Reliable electric service is essential to the safety, health, and wellbeing of communities. The fundamental breakdown of Texas' electric supply and delivery in February 2021 brought this message home for families and businesses throughout the United States: long-term outages combined with freezing temperatures left many Texans without electricity, heat, water, and internet for days—and in some cases weeks. Without reliable access to the electricity needed to run fans and air conditioning, summer heat waves can be just as dangerous as winter storms: In 2021, record-breaking heat was recorded throughout the Northwest states, including in areas of Washington and Oregon where many buildings have not previously needed cooling systems.

Ensuring that enough electric supply is available to meet everyday customer needs and demand in times of emergencies and extreme temperatures is not left to chance. Several U.S. electric grid operators hold auctions for a promise to supply electricity (or strategically reduce demand) when called upon in a future year. Power plant owners are paid for these commitments, earning "capacity payments" for each megawatt of electricity they promise to provide at times of peak demand and suffering financial penalties if they fail to run when called upon.

The "PJM" grid operator oversees electric supply and transmission in Pennsylvania, New Jersey, Maryland, Delaware, Ohio, West Virginia, and Washington D.C.—as well as in parts of Indiana, Illinois, Kentucky, Michigan, North Carolina, and Virginia—serving 65 million residential, commercial, and industrial customers. PJM has operated a three-year-in-advance capacity auction (called the "Reliability Pricing Model" or RPM) since 2007, paying power plants throughout the Mid-Atlantic and Ohio Valley to keep the lights on.

The purpose of PJM's capacity market is to ensure a reliable supply of electricity, even in emergencies and during times of peak need. To accomplish this, PJM requires utilities and other electric distributors to purchase enough capacity commitments for their expected hour of highest demand in the year plus 9 percent (see Appendix A for explanation of this "Forecast Pool Requirement"). The result of the region's capacity auction, however, has been to purchase not 109 percent of actual peak demand but 112 to 114 percent of peak need in each of the last five years prior to the 2021/22 auction (i.e., the 2016/17 through 2020/21 capacity auctions). In short, PJM is operating what we are calling a "fat" market: overestimates of demand and unrealistic demand curves created an inflated market that unnecessarily pays power plant owners at consumer expense.

Over-procurement increases the cost to both electric customers and the communities in which power plants are located in the name of ensuring reliable electric service. This Applied Economics Clinic (AEC) report reviews the extent of PJM's over-procurement of capacity and identifies power plants that likely received money from the 2021/22 capacity auction but would not have had PJM used a more realistic estimation of customer demand and the cost of new generation. (For clarification, customer demand refers to both forecasts of peak load and the administrative demand curve that PJM uses to represent customer demand for capacity). AEC also analyzes the location of these so-called "fat-market beneficiaries" with a focus on plants in or near Environmental Justice (EJ) communities (communities with high shares of Black, Indigenous, and People of Color (BIPOC) individuals and/or low-income households). Without the fat in PJM's capacity auction, certain power plants (many of them in or near EJ communities) would not receive capacity payments, greatly increasing the chance that they would be retired or never built in the first place.

The report begins in **Section II** with a primer on electric-sector capacity markets to orient those readers who may not be familiar with their workings. **Section III** briefly explains the reasons behind PJM's over-procurement and its effects, and presents the results of our analysis in numbers of generating units and megawatts of capacity in operation due to the fat market. **Section IV** layers in an EJ analysis, showing the proximity of power plants benefiting from the fat market to vulnerable communities. **Section V** concludes the report with policy recommendations for PJM and its stakeholders. Several appendices provide more detailed information on AEC assumptions, data, and methodologies. **Appendix A** explains PJM's capacity demand estimation process and our adjustments to it. **Appendix B** describes our method of estimating power plants' bids into the capacity auction. **Appendix C** provides the methodology used for our EJ analysis and mapping exercises. **Appendix D** presents additional historical data and **Appendix E** presents citations used in the Section II primer.

II. Understanding the PJM Capacity Market

This report addresses the effects that inflated forecasts of demand for electricity have on both utility customers' bills and the health and welfare of communities in which power plants are located. AEC's analysis focuses on capacity resources (electric supply—or demand reduction—that is available at the moment of peak demand) and the PJM "capacity auction," which is designed to ensure that Mid-Atlantic and Ohio Valley states have enough power at times of peak electric demand and in emergencies. Following along with our analysis of supply and demand for electric resources requires some familiarity with the workings and terminology of energy capacity markets. Readers who are already well versed in these topics may wish to skip over this chapter, whereas readers with less experience may find value in it as a primer.

This chapter introduces readers to connections between the electric sector and social equity, an overview of the PJM region and its capacity auction process, and a step-by-step explanation of how supply, demand, and market outcomes are determined. A few definitions of key terms may assist readers in better understanding the material discussed:

Energy is the flow of electricity; it is the total number of megawatt-hours (MWh) used over the course of a year.

The **energy market** organizes (1) the demand for energy in each 5-minute period across days and years together with (2) the supply of energy in each 5-minute period. There is a day-ahead market where utilities (and other electric distributors) buy enough megawatt-hours to supply their customers the next day and a real-time market to correct any over- or under-estimated forecasts of demand from the day-ahead market.

Capacity is the total potential for electric generation at a given moment, measured in megawatts (MW).

Peak is the highest demand for electricity in a single moment across a year, measured in megawatts (MW).

The **reliability requirement** scales up forecasted peak demand (by about 9 percent in PJM) to account for power plants or transmission lines that are not able to operate when called on.

The **capacity auction** is held three years in advance to secure sufficient capacity resources in PJM (i.e., the potential to provide energy when needed): for example, an auction in 2018 to address capacity needs expected in 2021/22. The three-year gap allows for new power plants to be built if needed to supply the forecasted reliability requirement.

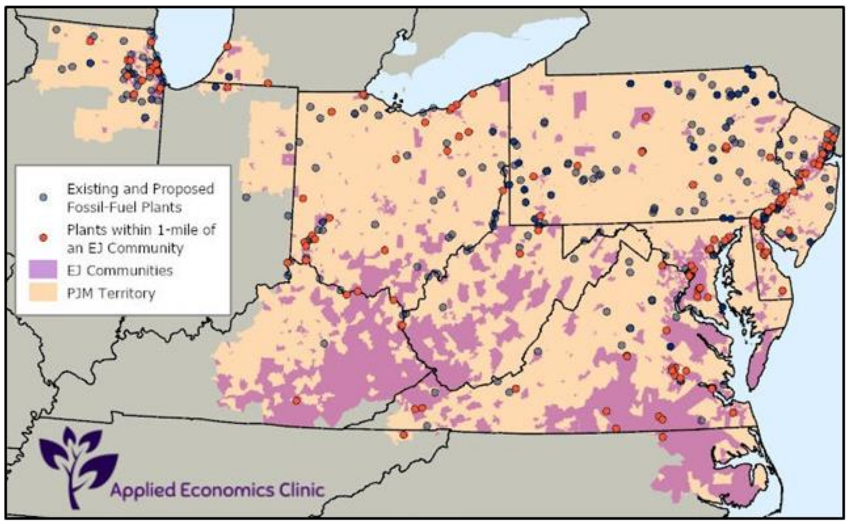
The forecasted peak demand (plus reliability requirement) is compared to the supply of capacity resources to calculate a **clearing price** (this chapter explains how). The clearing price is the capacity payment (per megawatt-day of capacity) that bidding power plants receive if they succeed in the capacity auction. Every successful generating unit gets the same per megawatt-day price.

A **fat market** describes a condition when customer demand has been over-estimated or overly cautious procurement has taken place resulting in too many power plants receiving payments to stand ready to operate if called upon. The result of a fat market is too much money charged on customer bills and too many power plants staying online, ready to operate, throughout the region.

1 The capacity auction matters for social equity.

Out of 1,050 gas and coal-fired generating units, and another 133 gas units in stages of approval or construction in the PJM electric zone in 2017, **635 units** are located within 1-mile of an **Environmental Justice community** where: 20% of residents live at or below the poverty line and/or 30% or more are BIPOC.

PJM's '**capacity auction**'—the topic of this report—plays a critical role in which of these plants are paid enough to stick around at consumers' expense, polluting local air and water. Many of these same plants are the most expensive to keep running and drive up customers' bills.



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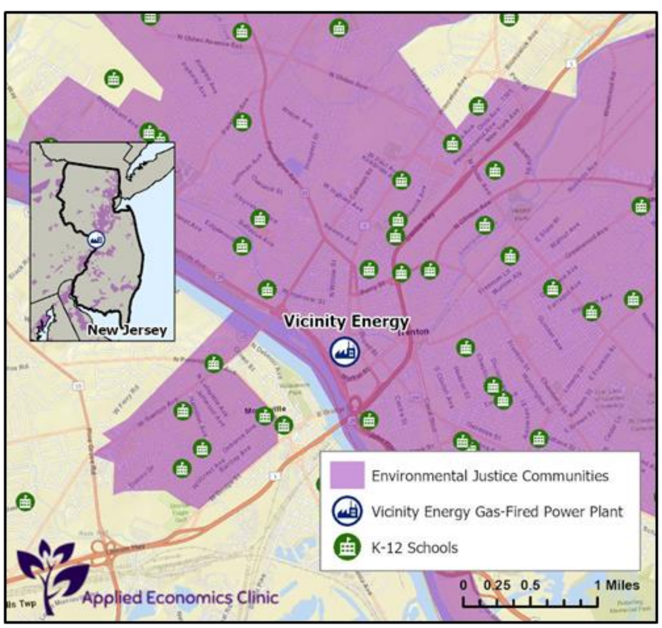
2 Power plants have serious health and safety impacts on people living and working nearby.



EJ communities like Trenton, New Jersey face the highest energy burdens, other disproportionate economic burdens, and are more likely to have health conditions that increase their vulnerability to power outages and poor air quality.

The Vicinity Energy gas-fired power plant, for example, is located **within a mile of ten K-12 schools** and thousands of homes in Trenton and surrounding communities. While less polluting than coal and oil, combustion of utility gas is associated with asthma, bronchitis, lung cancer, and heart disease, and leaked methane kills trees and other plants close to the site of leakage.

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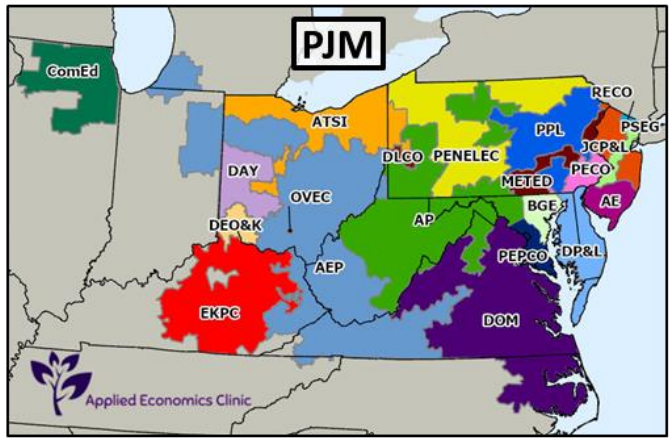
3 PJM runs the electric grid in the Mid-Atlantic.

What is PJM? PJM is the Regional Transmission Organization (RTO) that controls, coordinates, and monitors the Mid-Atlantic electric grid. The smaller zones within PJM are used to manage grid congestion problems.

What does PJM do?

- Runs the daily markets in which utilities buy electricity from generators
- Forecasts its customers' annual and peak electric needs
- Runs 'capacity auctions' (called Reliability Pricing Model or RPM) meant to secure enough future generation to satisfy customer electric demand at peak times



PJM includes: all of **P**ennsylvania, New **J**ersey, **M**aryland, Delaware, Ohio, West Virginia, and Washington, D.C.; and parts of Indiana, Illinois, Kentucky, Michigan, North Carolina, and Virginia.

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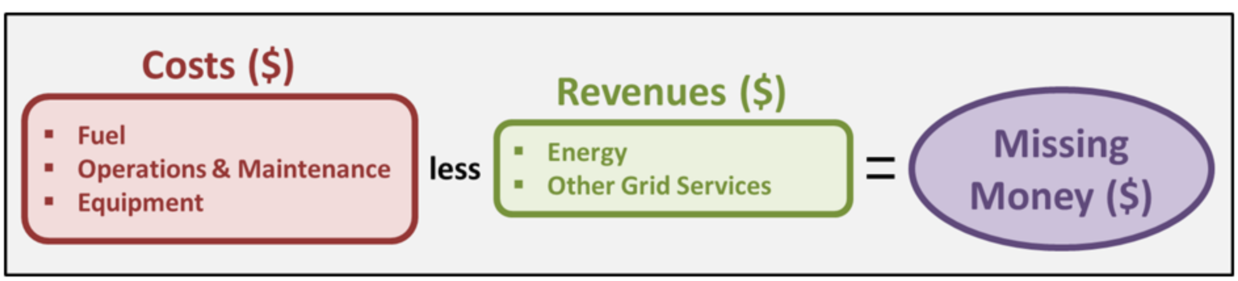
4 How can power plants afford to sit idle much of the year? What pays their bills?

PJM's **capacity auction** pays plant owners to keep idle plants ready to run when electric demand is very high. Power plant owners bid into the market the amount of money they need to remain ready to run even if they are never called to run. These bids are based on the plant's 'missing money': **Total plant costs** less **expected revenues for providing electricity and other services** equals the **'missing' money** still needed to stay in business. More profitable plants (that need less missing money) receive additional money from the capacity auction. **Emissions and other local impacts** are <u>not considered</u> for PJM decisions.



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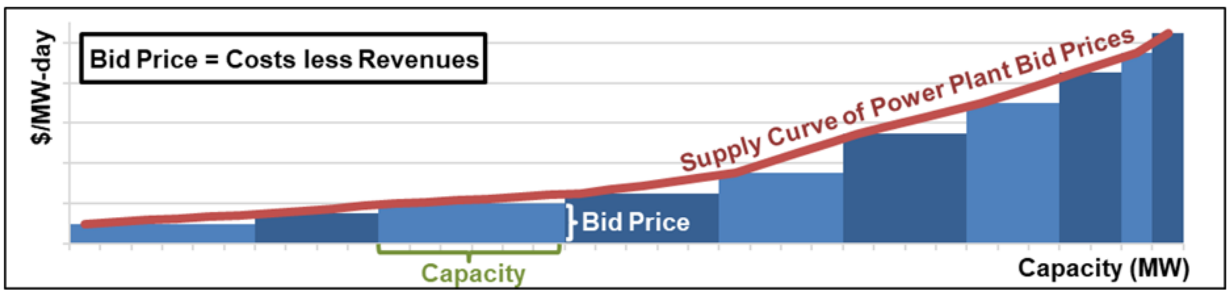
5 How do capacity auctions work?

Each power plant enters a ‘bid’ in the auction: the generating **capacity** in megawatts (MW) that it is offering at its ‘missing money’ **bid price**: costs less revenues; for many plants this is zero or close to it. The **supply curve** orders these bids from least to most expensive. Lowest cost bids are selected, up to the capacity needed for reliable service. All selected plants receive the **clearing price**: the bid price ($/MW-day) of the most expensive plant chosen.

Bid prices are the power plant’s own account of its finances—which leaves some room for over- or under-bidding. ***OVER-BIDDING*** (forbidden by PJM but difficult to prove) might result in a higher capacity payment or price the plant out of the auction. ***UNDER-BIDDING*** might bring the bid low enough to clear in the auction and receive capacity payments.



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6 Which plants get the clearing price?

Lowest pollution? No! Greenhouse gas emissions, local water and air pollutants, risks to nearby neighborhoods and ecosystems: None of these are considerations.

Best for health and safety? No! PJM capacity auctions do not consider health and safety, or anything about plant location other than Zones (see the map in Tile 4).

Most jobs where they are needed? No! Capacity auctions do not consider job creation or other local economic impacts.

Most profitable? Yes! The most profitable plants are the most likely to ‘clear’ in the auction and therefore receive payments. These are the plants making the most revenue compared to their costs.

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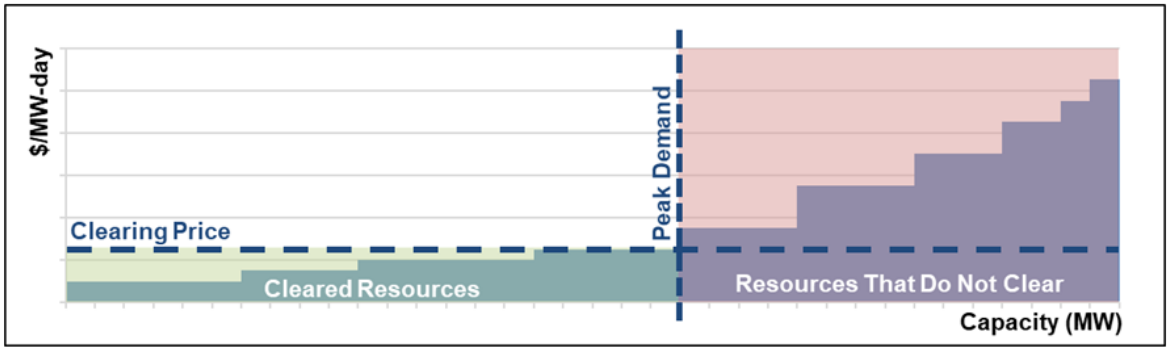
7 Who gets paid what in the capacity auction?



PJM's capacity auction may determine which power plants retire and which new plants are built. Every plant that 'clears' in the capacity auction receives a payment equal to the 'clearing price' times the number of MWs it offered. Every plant that does not 'clear' gets **nothing at all** and may need to retire or put new construction on hold.

So, what plants 'clear' and get paid? The plants with the lowest bid prices, up until enough capacity has cleared to meet the highest ('peak') demand for electricity (plus a reliability contingency). When peak demand is overestimated, more resources clear than are actually needed: a so-called **'fat market'**.

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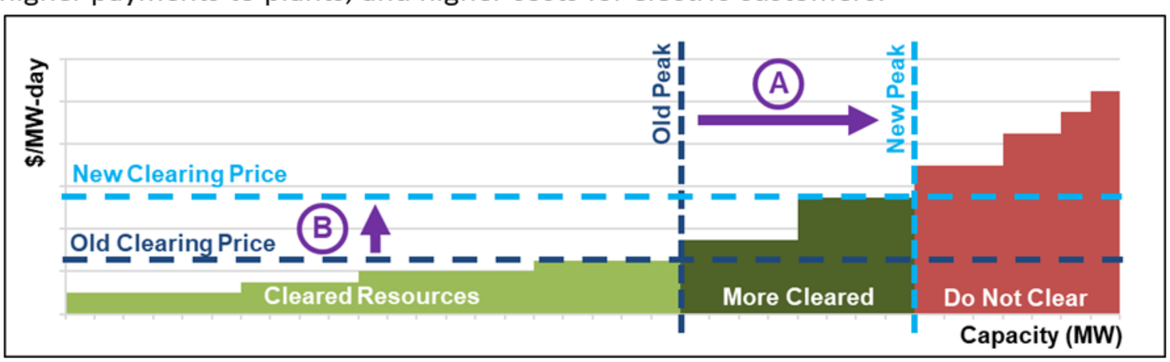
8 Does the capacity auction benefit consumers?

The capacity auction's purpose is to make sure **enough power plants** are available to keep the lights on (i.e. supply peak demand) while choosing plants with the **lowest costs** for customers. **Too much capacity equals unnecessary costs.** To succeed in benefitting consumers, power plants must correctly bid their costs less their revenues; and PJM must provide a good estimate of peak demand. If PJM overestimates peak demand [A], too many resources clear the auction (a 'fat market'). The clearing price is the price of the most expensive plant that clears, so a higher demand forecast means a higher clearing price [B], higher payments to plants, and higher costs for electric customers.



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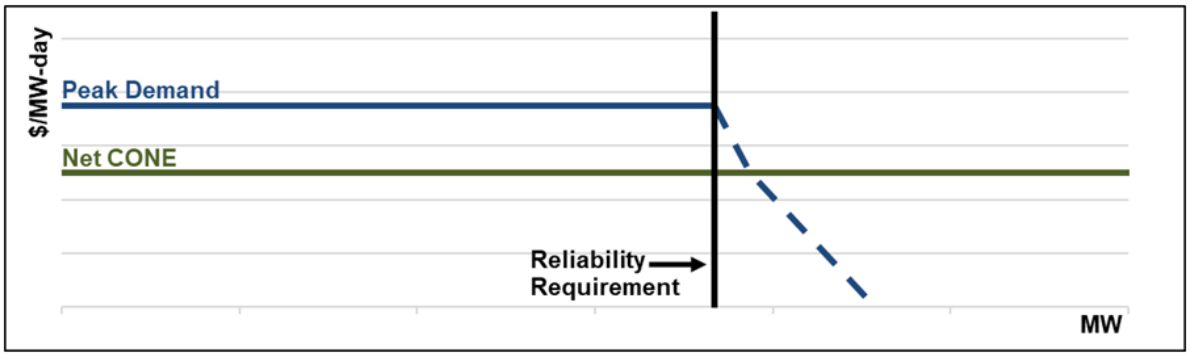
9 How does PJM estimate customer demand?

The demand curve used in the PJM capacity auction is a little more complicated than a vertical line. (In these graphs, a vertical line would mean that customers are willing to pay any price to get a specific amount of desired electricity.)

PJM believes that above the required electric capacity needed to reliably supply peak demand, customers are still willing to pay for electricity, but not to pay as much: that's the **dashed line** in this graph. PJM estimates the flat part of the line as 1.5 times a level known as '**Net CONE**': that's a generic per MW cost to build a new gas-fired power plant.



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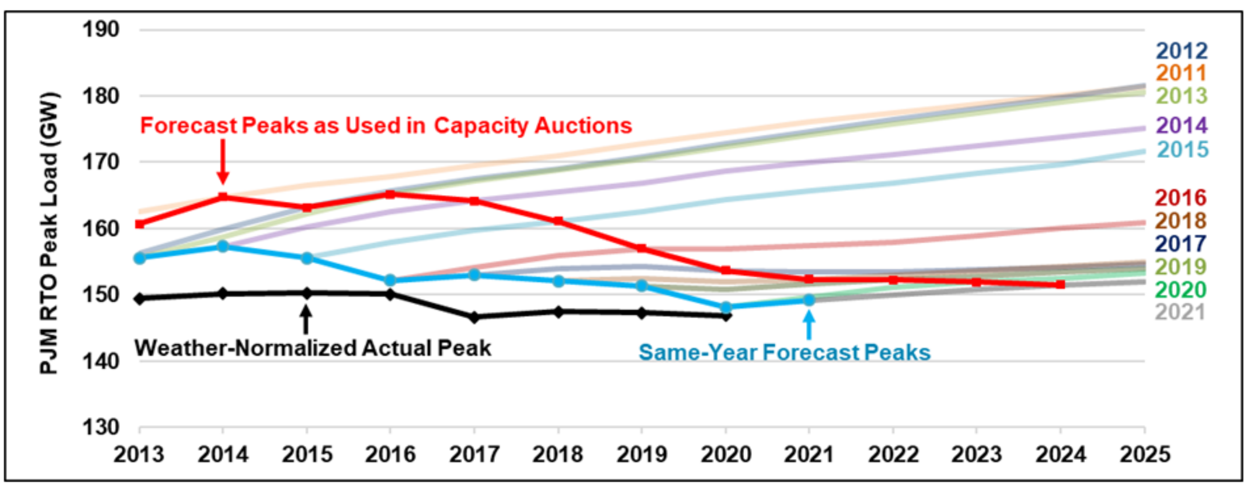
10 How could the demand curve be wrong?

For use in its capacity auction, PJM needs to predict both customer demand and the likely cost of new power plants three-years in advance—and they don't have a crystal ball! Each line in the graph below represents a forecast made in a different year (see years at right). Every year electric demand is forecasted to be low in the short-run and high in the long-run.



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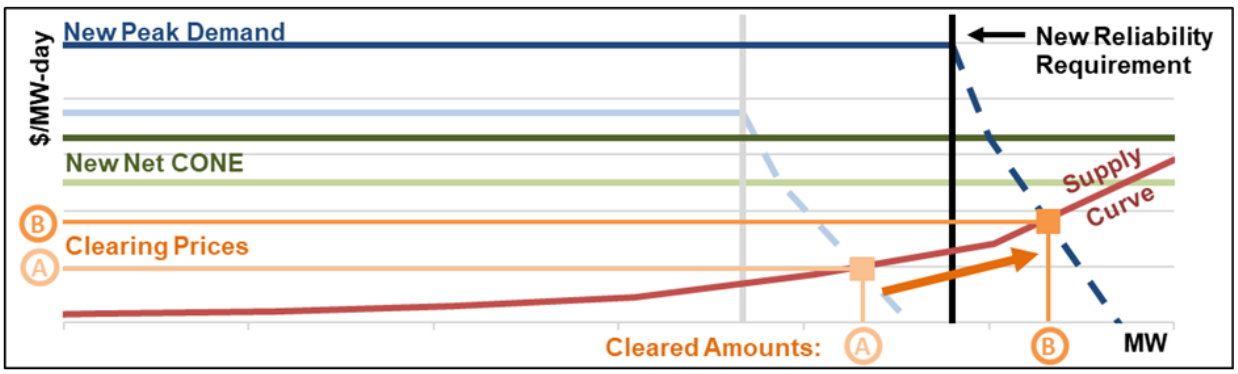
11 Two kinds of demand curve errors.

The graph below combines two kinds of mistakes, showing 'correct' values in light colors and 'incorrect' values in dark colors.

- First, PJM—and grid operators everywhere—often overestimate customer demand and the **reliability requirement**.
- Second, PJM can also overestimate the future **cost of new power plants (Net CONE)**. Both errors push the **demand curve** up and out from [A] to [B] and increase the **clearing price** (and customer costs).



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12 The capacity auction impacts equity.

PJM's capacity auction plays a critical role in determining which plants stay in operation, which are shut down, and which are approved for new construction. These decisions affect not only neighborhoods surrounding power plants, but also utility customers' bills, especially for low- and moderate-income customers.

Both the demand curve designed by PJM and the bid prices submitted by power plants **matter for social equity.** Overestimating either future peak demand or the expected costs of new gas-fired power plants creates a 'fat market' with more units than are needed getting capacity payments. Power plants' bids are confidential, and there are clear advantages to underestimating bids (to try to receive capacity payments) or overestimating bids (to raise the clearing price and get higher payments).

This report examines the impacts of cutting the fat out of the PJM capacity auction. We find that better estimation of customer demand would result in an annual savings of $4.3 billion or about $67 per electric customer. We also found that nearly half of PJM's coal and gas plants are located within a mile of EJ communities including plants that rely on fat market conditions. A leaner capacity market has the potential to benefit both electric customers and EJ communities.

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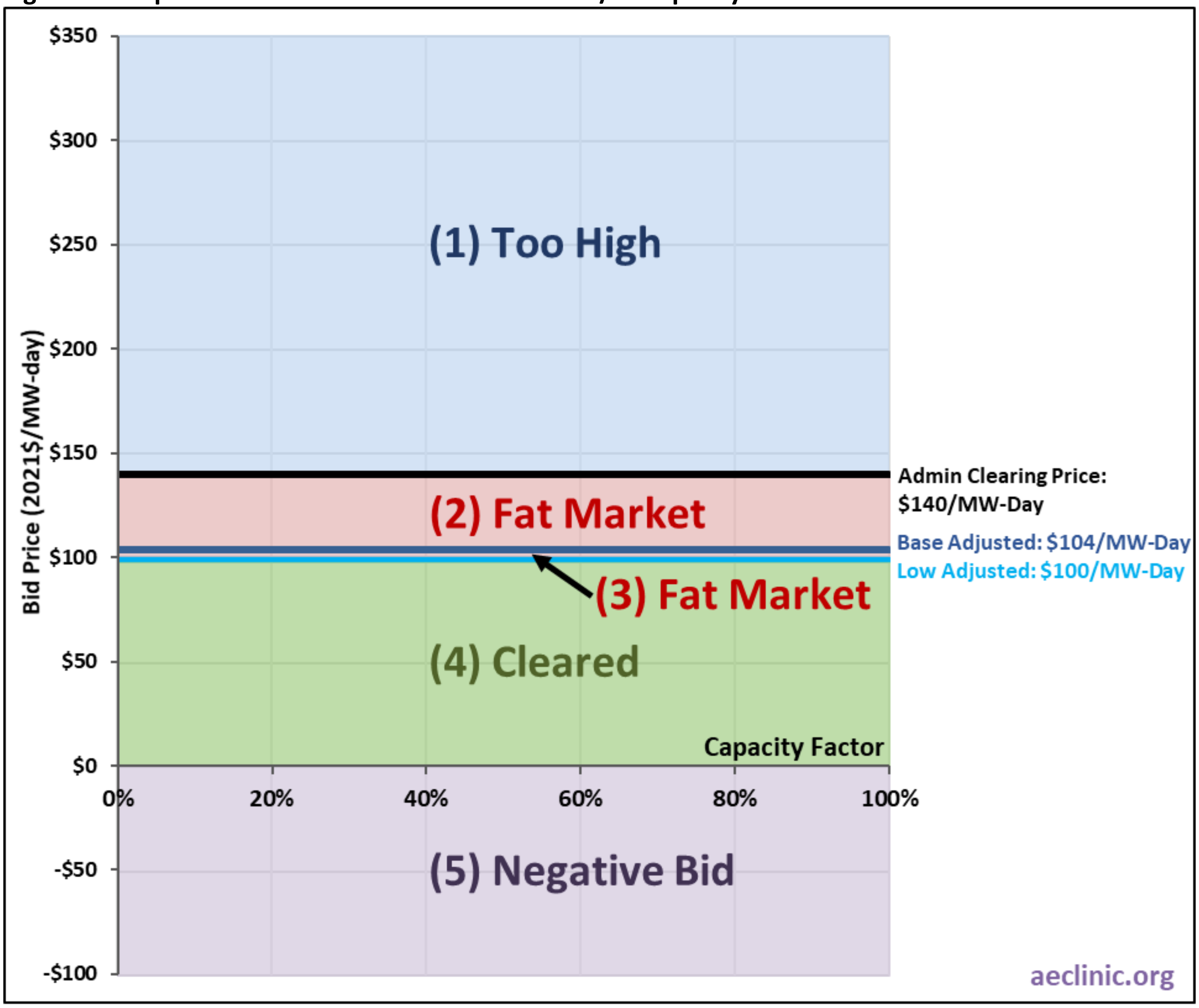
III. Fat Markets Keep Uneconomic Power Plants Running

In 2018, PJM's 2021/22 Reliability Pricing Model (RPM, or capacity auction) set an RTO-wide clearing price of $140 per MW-day in 2021 dollars. This administrative clearing price (see Figure 1) allowed 163,627 MW of capacity to "clear" the market and receive $140 per MW-day, paid for by consumers.

All generating units that bid into the auction at a higher price (see Figure 1) did not clear and will not receive capacity payments in the 2021/22 delivery year (unless they clear in subsequent incremental auctions). Our estimates (described in Appendix A) show that PJM overestimated its reliability requirement resulting in too high of a clearing price. Units with bid prices between PJM's $140 per MW-day and AEC's adjusted clearing price of $100-104 per MW-day benefited from a "fat market": these units would not have cleared had PJM used a more accurate reliability requirement and clearing price.

Figure 1. Bid price estimation blocks for PJM's 2021/22 capacity auction



Uneconomic units have bid prices that exceed the clearing price

In order to examine the importance of PJM's capacity market assumptions leading to a fat market where some of the region's more expensive generating units receive capacity payments and, therefore, stay online, AEC calculated two alternative hypothetical bid prices by making adjustments to PJM's assumptions: a "Base Adjusted" clearing price of $104 per MW-day and a "Low Adjusted" clearing price of $100 per MW-day. (These adjustments and the assumptions behind them are discussed in detail in Appendix A of this report.)

These adjustments correct PJM's overestimated reliability requirement (how much capacity is needed), its presumed Cost of New Entry (CONE, or the likely cost of a new gas peaker plant), and its demand curve. Shifting the demand curve lower along the existing supply curve lowers the clearing prices, with the result that units must bid a lower price to successfully clear the capacity market and receive payments. (See Section II above for a detailed explanation of the working of PJM's capacity market.)

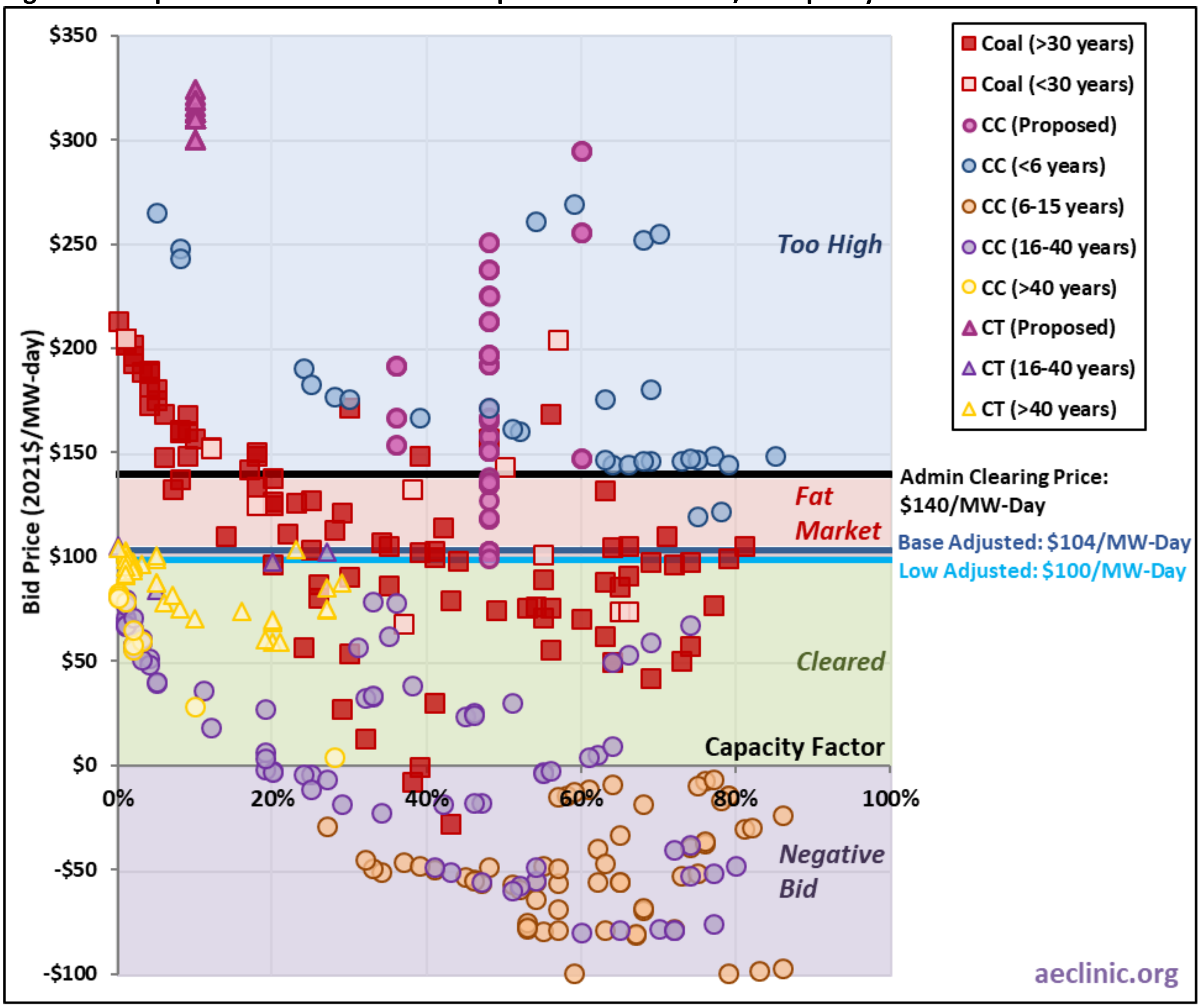
Figure 1 (above) shows the range of bid prices at which:

- units failed to clear the 2021/22 PJM capacity auction—**(1) too high**;
- units cleared in the actual 2021/22 PJM capacity auction, but would not clear if our adjusted clearing prices were used instead—**(2)** and **(3) fat market**; as well as,
- units with bid prices at which adjusting the clearing price would not prevent them from clearing—**(4) cleared** and **(5) negative** bids. (In the actual capacity auction, many power plant owners expect their energy and ancillary market revenues to exceed costs and therefore do not require additional revenues from the capacity market. These units are bid in at $0 and not at a negative value–we depict negative values here to better show the results of typical bid calculations.

Figure 2 (below) shows these same clearing prices together with AEC's estimated unit-by-unit bid prices for 324 existing and 126 proposed gas- and coal-fired generating units in PJM. (The methodology used to develop these bid price estimates is presented in detail in Appendix B of this report. AEC made reasonable assumptions based on our professional experience when estimating these bid prices. These assumptions were necessary because most information related to bids is deemed by PJM and plant owners to be confidential even when aggregated.) Note that while a supply curve would organize these bids by price from lowest to highest, this scatterplot instead organizes the bids (left to right) according to their capacity factor (that is, the share of the year during which the unit operates). A generating unit's capacity factor is a key consideration in its profitability, and therefore its ability to secure capacity market payments. The average capacity factor among PJM's existing gas combined cycle (CC) units in 2017 was 46 percent, but these values range from 1 to 86 percent (see Appendix B). PJM's gas combustion turbine (CT) and coal units had average capacity factors of 10 and 34 percent, respectively.

Overall, within each category of units (organized by gas CC, gas CT, and coal unit, and by age in Figure 2) bid prices tend to be lower for plants that run more (i.e., those that have higher capacity factors). The next sub-sections of this report discuss specific categories of units with bid prices in the "fat market" range between $100 and $140 per MW-day: These are the units that—according to our estimates—received payments in the 2021/22 capacity auction, but would not have with a lower clearing price. Later in this report, we discuss units with bids that were too high to clear at $140 per MW-day. Our analysis includes coal versus gas combined cycle (CC) and combustion turbine (CT) units, proposed versus existing units, units by age, units by capacity factor, units by state, and units in or near EJ communities.

Figure 2. Bid price estimates for fossil fuel plants in PJM's 2021/22 capacity auction



Note: "Admin Clearing Price" refers to PJM's clearing price for the 2021/22 capacity auction; "Base Adjusted" and "Low Adjusted" are the resultant clearing prices of AEC's analysis (described in detail in Appendix A – Capacity Demand: Demand Curve Adjustments "CC" and "CT" refer to gas combined-cycle and gas combustion turbine generating units, respectively; and the years listed in the legend are the age of each unit as of 2018.

Many uneconomic units did not clear in PJM's 2021/22 capacity auction

Table 1 (below) presents the number of units, and their associated MW of capacity, that—as estimated by AEC—are too high to clear at PJM's $140 per MW-day clearing price, could clear at that price but not at our adjusted clearing prices, or would clear even with our adjustments. In the actual 2021/22 PJM capacity auction, 22.9 GW of capacity (12.3 percent of offered capacity) failed to clear.[1] The bids submitted by generation owners are proprietary: only PJM's smoothed supply curve is made publicly available,[2] which does not show which units bid at what prices.

Using our estimated bids, 147 units amounting to 28.5 GW of capacity (15.3 percent of the total offered) failed to clear at PJM's $140 per MW-day clearing price. These are units that PJM does not require to meet customer electric demand. Ninety-nine of these unnecessary units are proposed (not yet constructed): 37 gas CC units and 62 gas CT units.[3] The remaining units that failed to clear in our analysis based on PJM's $140 per MW-day clearing price were 18 existing gas CCs with an average age of 2 years and 30 existing coal units with an average age of 48 years.

Overall, age and capacity factors are important determinants of our estimated bid prices. In Figure 2 (above), coal units (in red) with lower capacity factors have higher estimated bid prices. Around or below a 10 percent capacity factor, most coal units do not clear at PJM's $140 per MW-day clearing price. (And below a 30 percent capacity factor, most coal units do not clear at our adjusted capacity price.) The effects of age on bid price can be observed more clearly in the gas CC units in Figure 2 above (shown as circles with age indicated by color): The oldest CCs have very low capacity factors and relatively high estimated bid prices but still clear in our adjusted market. CCs that are between 6 and 40 years old have higher capacity factors and lower bid prices. Younger CCs have higher bid prices due to our assumption that these units must still consider the levelized capital costs of their construction in their bid prices in the same way that proposed plants do (see Appendix B).

Adjusting the 2021/22 auction results in 77 fossil fuel units that would no longer clear

AEC's analysis suggests that 77 gas- and coal-fired generating units existing or planned in PJM, would have cleared using PJM's actual clearing price, but would not clear using our adjusted clearing prices. These generating units are beneficiaries of a "fat market" (see Figure 1 and Figure 2 above) or a market with an overestimated reliability requirement, demand curve, and clearing price. To the extent that PJM's clearing price is, in fact, higher than the level needed to procure the needed capacity, then consumers lose out by having to pay unnecessary charges on their electric bills. These 77 units represented 35.5 GW of capacity for which PJM electric utility customers would have paid $2 billion in 2021/22.[4]

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[1] PJM. 2018. "2021/2022 RPM Base Residual Auction Results." Available at: https://www.pjm.com/-/media/markets-ops/rpm/rpm-auction-info/2021-2022/2021-2022-base-residual-auction-report.ashx p.15

[2] PJM. 2019. "2021/2022 Supply Curves for Base Residual Auction." Available at: https://www.pjm.com/-/media/markets-ops/rpm/rpm-auction-info/2021-2022/2021-2022-bra-supply-curves.ashx

[3] Although AEC estimated bids for proposed units as of 2018, not all of them necessarily offered into the 2021/22 capacity auction.

[4] To calculate the cost to electric utility customers of $2 billion in 2021/22, AEC multiplied the 2021/22 administrative clearing price for each Locational Deliverability Area (LDA) by the total capacity of the uneconomic units in each LDA (i.e., 35.5 GW or 35,500 MW) and the number of days in a year (i.e., 365 days).

Table 1. Comparison of bid price estimates to clearing prices for PJM's 2021/22 Auction

Adjustments to Clearing Prices	Existing Units	Proposed Units	Total	Existing Units *(MW)*	Proposed Units *(MW)*	Total *(MW)*
Total coal and gas units						
BID > Admin Clearing Price	48	99	147	13,950	14,508	28,457
BASE Adjusted < BID <= Admin Clearing Price	**41**	**20**	**61**	**17,705**	**9,391**	**27,096**
LOW Adjusted < BID <= BASE Adjusted	**10**	**6**	**16**	**5,749**	**2,623**	**8,372**
$0/MW-Day <= BID <= LOW Adjusted	124	1	125	40,483	485	40,968
BID < $0/MW-Day	101	0	101	20,774	0	20,774
TOTAL	**324**	**126**	**450**	**98,661**	**27,007**	**125,668**
Gas combined cycle (CC) units						
Adjustments to Clearing Prices	**Existing Units**	**Proposed Units**	**Total**	**Existing Units *(MW)***	**Proposed Units *(MW)***	**Total *(MW)***
BID > Admin Clearing Price	18	37	55	5,043	13,265	18,307
BASE Adjusted < BID <= Admin Clearing Price	**12**	**20**	**32**	**3,181**	**9,391**	**12,573**
LOW Adjusted < BID <= BASE Adjusted	**0**	**6**	**6**	**0**	**2,623**	**2,623**
$0/MW-Day <= BID <= LOW Adjusted	56	1	57	5,570	485	6,055
BID < $0/MW-Day	98	0	98	18,562	0	18,562
TOTAL	**184**	**64**	**248**	**32,356**	**25,764**	**58,120**
Gas combuston turbine (CT) units						
Adjustments to Clearing Prices	**Existing Units**	**Proposed Units**	**Total**	**Existing Units *(MW)***	**Proposed Units *(MW)***	**Total *(MW)***
BID > Admin Clearing Price	0	62	62	0	1,243	1,243
BASE Adjusted < BID <= Admin Clearing Price	**1**	**0**	**1**	**0**	**0**	**0**
LOW Adjusted < BID <= BASE Adjusted	**5**	**0**	**5**	**903**	**0**	**903**
$0/MW-Day <= BID <= LOW Adjusted	32	0	32	8,092	0	8,092
BID < $0/MW-Day	0	0	0	0	0	0
TOTAL	**38**	**62**	**100**	**8,994**	**1,243**	**10,237**
Coal units						
Adjustments to Clearing Prices	**Existing Units**	**Proposed Units**	**Total**	**Existing Units *(MW)***	**Proposed Units *(MW)***	**Total *(MW)***
BID > Admin Clearing Price	30	0	30	8,907	0	8,907
BASE Adjusted < BID <= Admin Clearing Price	**28**	**0**	**28**	**14,518**	**0**	**14,518**
LOW Adjusted < BID <= BASE Adjusted	**5**	**0**	**5**	**4,782**	**0**	**4,782**
$0/MW-Day <= BID <= LOW Adjusted	36	0	36	26,822	0	26,822
BID < $0/MW-Day	3	0	3	2,212	0	2,212
TOTAL	**102**	**0**	**102**	**57,240**	**0**	**57,240**

But this $2 billion would not be the only savings from cutting out the fat in the market: all cleared capacity resources would receive a lower per MW-day payment based on the lower capacity price. AEC estimates that the 2021/22 capacity auction resulted in a payout to power plant owners of approximately $9.9 billion compared to our estimated $5.6 billion payout based on AEC's adjusted clearing prices. This difference would amount to a total cost savings of $4.3 billion or $67 per customer on average.[5]

Of these fat-market beneficiaries, 38 are gas CCs, 6 are gas CTs, and 33 are coal units (Table 1 above). Twenty-six are proposed units (all gas CCs); the rest are existing units.

Fat-market benefits are robust to changes in our modeling assumptions

Because of the proprietary nature of PJM's power plants capacity auction bids, AEC estimated all of the bid prices used in this report, and we do not report our estimates by unit. Our calculations were based on a number of potentially critical assumptions including capacity prices, cost of capital, power plant efficiency, and the treatment of construction capital costs. Overall, we found our analysis to be robust to changes in the values assigned to these underlying assumptions (see Table 2 below and Appendix B).

We examined the sensitivity of our central case to variations in several assumptions with the following results:

- **Central case:** 77 units with bids in the fat market range (capacity factors taken from 2017 plant data, weighted average cost of capital (WACC) 7.5 percent; fuel efficiency (heat rate) taken from Lazard and EIA; and new build capital cost recovery set at five years (see Appendix B for more details),
- **Sensitivity 1 – More optimistic capacity factors:** Resulted in 72 units in the fat market range,
- **Sensitivity 2 – Lower and higher WACC:** Resulted in 93 and 48 units in the fat market range, respectively; with the WACC of 9 percent many units' bids rose into the uneconomic zone,
- **Sensitivity 3 – Lower and higher fuel efficiency (heat rate):** Resulted in 85 and 71 units in the fat market range, and
- **Sensitivity 4 – Shorter and longer new build capital cost recovery:** Resulted in 61 and 72 units in the fat market range.

All of these sensitivity analyses showed numerous generating units and megawatts with estimated bid prices between $140 and $100 per MW-day. In some case, changes in our assumptions resulted in units moving from "fat market" to "uneconomic;" that is, to bid prices higher than PJM's $140 per MW-day.

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[5] To calculate the capacity market payout, AEC multiplied the 2021/22 administrative clearing price for each Locational Deliverability Area (LDA) by the total cleared capacity of each LDA (from AEC's analysis in Appendix A – Capacity Demand: Demand Curve Adjustments, which is different from the analysis described in Appendix B – Capacity Supply: Bid Estimates) and the number of days in a year (i.e., 365 days). The customer cost savings estimate makes the simplifying assumption that the payout costs would be spread evenly across all customer classes. This cost savings is calculated by dividing the difference between the estimated payout for the actual 2021/22 auction and AEC's adjusted 2021/22 auction by the number of customers in PJM (i.e., 65 million).

Table 2. Sensitivity analysis

Central Results/Assumptions	Total Units	Total Capacity *(MW)*	Sensitivity: Heat Rates *10% lower*	Total Units	Total Capacity *(MW)*
High Bid Prices	147	28,457	High Bid Prices	107	11,612
Fat Market Bid Prices	**77**	**35,469**	**Fat Market Bid Prices**	**85**	**33,938**
Cleared Bid Prices	226	61,742	Cleared Bid Prices	258	80,119
Sensitivity: Capacity Factor *Coal = 50%; Gas CC = 80%; Gas CT = 10%*	**Total Units**	**Total Capacity *(MW)***	**Sensitivity: Heat Rates** *10% higher*	**Total Units**	**Total Capacity *(MW)***
High Bid Prices	137	26,777	High Bid Prices	181	47,800
Fat Market Bid Prices	**72**	**25,792**	**Fat Market Bid Prices**	**71**	**34,660**
Cleared Bid Prices	241	73,100	Cleared Bid Prices	198	43,208
Sensitivity: Capital Costs *WACC = 6%*	**Total Units**	**Total Capacity *(MW)***	**Sensitivity: Capital Costs** *New build cost recovery for 2 years*	**Total Units**	**Total Capacity *(MW)***
High Bid Prices	111	15,166	High Bid Prices	151	30,402
Fat Market Bid Prices	**93**	**40,041**	**Fat Market Bid Prices**	**61**	**31,002**
Cleared Bid Prices	246	70,461	Cleared Bid Prices	238	64,264
Sensitivity: Capital Costs *WACC = 9%*	**Total Units**	**Total Capacity *(MW)***	**Sensitivity: Capital Costs** *New build cost recovery for 8 years*	**Total Units**	**Total Capacity *(MW)***
High Bid Prices	177	41,853	High Bid Prices	165	33,328
Fat Market Bid Prices	**48**	**22,558**	**Fat Market Bid Prices**	**72**	**33,667**
Cleared Bid Prices	225	61,257	Cleared Bid Prices	213	58,673

IV. Unnecessary Power Plants are Running in EJ Communities

Roughly 6,700 out of PJM's more than 15,500 census tracts[6] are EJ communities (using the Commonwealth of Pennsylvania definition[7]): 20 percent or more of the population lives at or below the federal poverty line, or 30 percent or more of the population identifies as a race other than white. Using this definition, about 40 percent of PJM's population resides in EJ communities. EJ communities have: a higher share of residents with underlying health issues—like asthma—that can be exacerbated by air pollution;[8] are subject to historical economic and pollical oppression that has placed control of facilities are cited in or near to them out of their hands;[9] and a large proportion of households facing higher "energy burdens" than their richer and whiter neighbors.[10] (A household's energy burden is the percentage of its income spent on energy.) According to recent research from the University of Washington and Stanford University, nationwide and in the PJM region, low-income Black people face the highest risk of death from power plants' fine particulate emissions.[11]

While data were not available specific to PJM, Figure 3 (below) shows disparities in energy burdens across the United States as a whole in terms of the share of households with severe energy burdens of 10 percent or more of their income paid in energy costs; 13 percent of total households pay more than 10 percent of their income on energy. Eleven percent of white households pay 10 percent or more; 21 percent of Black households pay 10 percent or more.

The median energy burden of a U.S. household is roughly 3 percent (half of all households pay more than 3 percent, half pay less than 3 percent). For comparison, 40 percent of low-income households and 47 percent of low-income elderly households have an energy burden greater than 10 percent.

[6] Census tracts vary greatly in land area because they are defined as small statistical subdivisions that are updated approximately every 10 years. These subdivisions generally have a population size between 1,200 and 8,000 people. See: https://www.census.gov/programs-surveys/geography/about/glossary.html#par_textimage_13

[7] See Appendix C for more detail regarding EJ categorization.

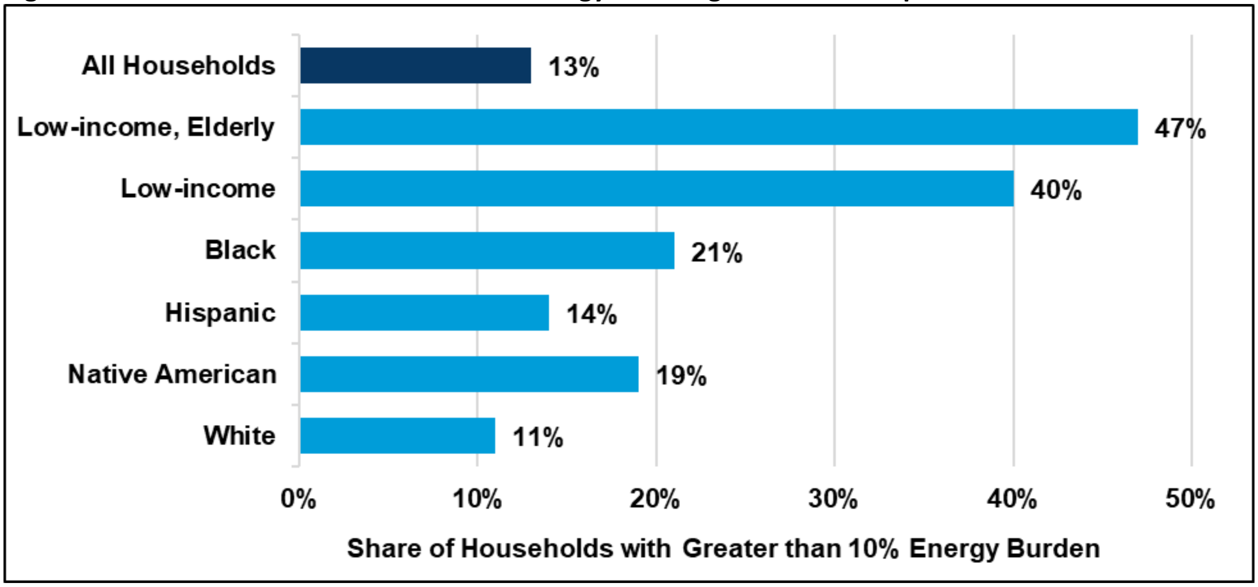
[8] (1) Mikati, I., Benson, A.F., Luben, T. J. Sacks, J.D, and Richmond-Bryant, J. 2018. "Disparities in Distribution of Particulate Matter EmissionSources by Race and Poverty Status." American Journal of Public Health, 108, 480-485. https://doi.org/10.2105/AJPH.2017.304297; (2) Miranda, L. M., Edwards, S. E., Keating, M. H., and Paul, C. J. 2011. "Making the Environmental Justice Grade: The Relative Burden of Air Pollution Exposure in the United States." International Journal of Environmental Research and Public Health, 8(6),1755-1771. https://doi.org/10.3390/ijerph8061755

[9] 1) Bullard, R. D., Mohaj, P., Saha, R., and Wright, B. 2008. "ToxicWastes and Race at Twenty: Why Race Still Matters After All These Years." Environmental Law, 38(2), 371-411. Available at: https://www.jstor.org/stable/43267204; (2) Banzhaf, S., Ma, L., and Timmins, C. 2019. "Environmental Justice: The Economics of Race, Place, and Pollution." Journal of Economic Perspectives, 33 (1), 185-208. Available at: https://www.aeaweb.org/articles?id=10.1257/jep.33.1.185

[10] Drehobl, Ariel, et al. September 2020. *How High Are Household Energy Burdens?* ACEEE. Available at: https://www.aceee.org/sites/default/files/pdfs/u2006.pdf

[11] Thind, M. P. S., Tessum, C. W., Azevedo, I. L., and Marshall, J. D. 2019. "Fine Particulate Air Pollution from Electricity Generation in the US: Health Impacts by Race, Income, and Geography." *Environmental Science and Technology*, 53, 23, 14010–14019. https://doi.org/10.1021/acs.est.9b02527

Figure 3. Share of U.S. households with an energy burden greater than 10 percent



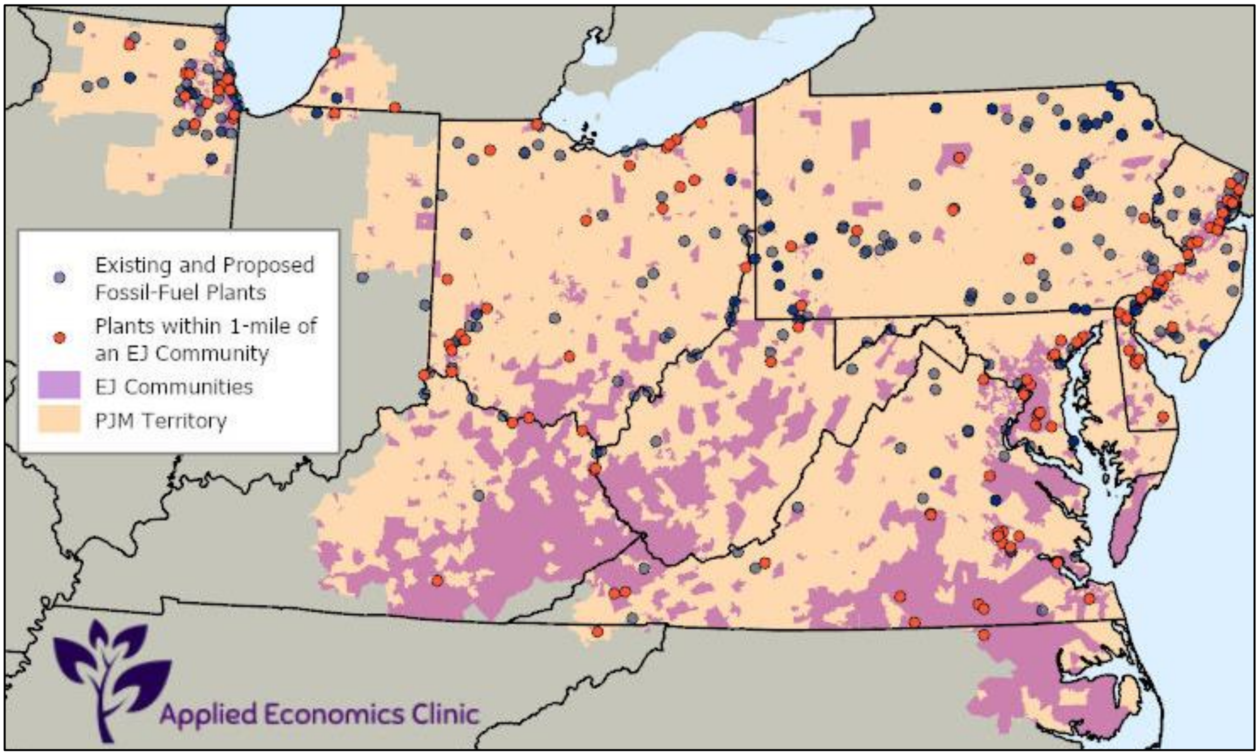
Source: Drehobl, Ariel, et al. September 2020. How High Are Household Energy Burdens? ACEEE. Available at: https://www.aceee.org/sites/default/files/pdfs/u2006.pdf

Potential EJ implications are often examined based on a 1-mile radius around a polluting facility.[12] For example, the U.S. Environmental Protection Agency's (U.S. EPA) Environmental Justice Mapping and Screening Tool (EJSCREEN)[13] sets 1-mile as the default radius for EJ assessment. (Of course, some air and water pollutants could have wider ranging effects beyond one mile.) Figure 4 (below) is a map of PJM with EJ communities marked in magenta along with gas- and coal-fired power plants depicted as orange circles if they are within one mile of an EJ community and blue if they are not (see Appendix C for a description of AEC's mapping analysis). Half of PJM's gas- and coal-fired power plants are located within 1 mile of an EJ community.

[12] Chakraborty, J. and Maantay, J. A. 2011. "Chapter 5: Proximity Analysis for Exposure Assessment in Environmental Health Justice Research." *Geospatial Analysis of Environmental Health*. Available at: https://www.lehman.edu/academics/eggs/documents/2011_GeospatialAnalysis_ChakrabortyMaantay.pdf

[13] U.S. EPA. 2019. *EJSCREEN Technical Documentation*. Available at: https://www.epa.gov/sites/default/files/2017-09/documents/2017_ejscreen_technical_document.pdf

Figure 4. EJ communities and fossil fuel power plants in PJM



More than half of PJM's gas- and coal-fired units are within 1 mile of EJ communities

The location of existing and proposed fossil fuel plants matters because EJ communities are already disproportionately exposed to local air pollution and the impacts of climate change.[14] Historically, polluting facilities like landfills and industrial plants have been sited in EJ communities.[15] For example, almost 80 percent of municipal solid waste incinerators nationwide, and the majority of landfills and burn facilities, are in EJ communities.[16] Increased exposure to air pollutants from these facilities puts these communities at higher risk for several health conditions like respiratory and cardiovascular disease, as well as preterm

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[14] Mikati, I., Benson, A.F., Luben, T. J. Sacks, J.D, and Richmond-Bryant, J. 2018. "Disparities in Distribution of Particulate Matter Emission Sources by Race and Poverty Status." *American Journal of Public Health, 108*, 480-485. https://doi.org/10.2105/AJPH.2017.304297

[15] (1) Bullard, R. D., Mohaj, P., Saha, R., and Wright, B. 2008. "Toxic Wastes and Race at Twenty: Why Race Still Matters After All These Years." Environmental Law, 38(2), 371-411. Available at: https://www.jstor.org/stable/43267204; (2) Banzhaf, S., Ma, L., and Timmins, C. 2019. "Environmental Justice: The Economics of Race, Place, and Pollution." Journal of Economic Perspectives, 33 (1), 185-208. Available at: https://www.aeaweb.org/articles?id=10.1257/jep.33.1.185

[16] (1) Skelton, R. and Miller, V. March 17, 2016. "The Environmental Justice Movement." Natural Resource Defense Council. Available at: https://www.nrdc.org/stories/environmental-justice-movement; (2) Yang, C. May 14, 2021. "Q&A: Addressing the Environmental Justice Implications of Waste." Environmental and Energy Study Institute. Available at: https://www.eesi.org/articles/view/qa-addressing-the-environmental-justice-implications-of-waste

births, low birth weights and infant mortality.[17]

Polluting power plants in PJM follow this same pattern:

- More than half of PJM's existing and proposed gas- and coal-fired generating units are located within 1 mile of an EJ community: that's 547 gas units and 88 coal units. Almost four-fifths of PJM's gas and coal units are located within 5 miles of an EJ community.
- Of all new gas units proposed in PJM, roughly half are located within 5 miles of an EJ community and 20 percent are located within 1 mile of an EJ community; 15 percent are directly within an EJ community.
- Overall, more than 80 percent of PJM's existing gas- and coal-fired generating units are within 5 miles of an EJ community (see Table 3). For example, the Vicinity Energy gas plant, located in New Jersey, is located within an EJ community and within 1 mile of ten K-12 schools (see Section II above for a map of the EJ community surrounding the Vicinity Energy gas plant in Trenton, New Jersey).

Polluting facilities, like gas- and coal-fired plants, are located within or close to EJ communities as a result of racial segregation in housing and zoning policies that favor non-BIPOC, high-income individuals. BIPOC and low-income communities are more often re-zoned as industrial areas, rather than residential areas, which allows industry to be placed in these same neighborhoods, driving down property values and often displacing residents. Moreover, housing segregation through government spending in the development of suburban areas, barriers to mortgage insurance for Black individuals in integrated areas, and redlining[18] all contribute to the increased proximity of environmental hazards to EJ communities.[19]

[17] Miranda, L. M., Edwards, S. E., Keating, M. H., and Paul, C. J. 2011. "Making the Environmental Justice Grade: The Relative Burden of Air Pollution Exposure in the United States." International Journal of Environmental Research and Public Health, 8(6),1755-1771. https://doi.org/10.3390/ijerph8061755.

[18] Redlining is the practice of separating out areas with high Black populations and deterring mortgage lenders from serving these areas. This results in low-investment in these neighborhoods compared to predominantly white areas. The term comes from marking these areas with red ink on a map. Source: Perry, A. M., and Harshbarger, D. 2019. "America's formerly redlined neighborhoods have changed, and so must solutions to rectify them." Brookings Institute. Available at: https://www.brookings.edu/research/americas-formerly-redlines-areas-changed-so-must-solutions/

[19] U.S. Commission on Civil Rights. October 2003. "Chapter 2: What is Environmental Justice?" *Not in My Backyard: Executive Order 12,898 and Title VI as Tools for Achieving Environmental Justice.* Available at: https://www.usccr.gov/files/pubs/envjust/ch2.htm

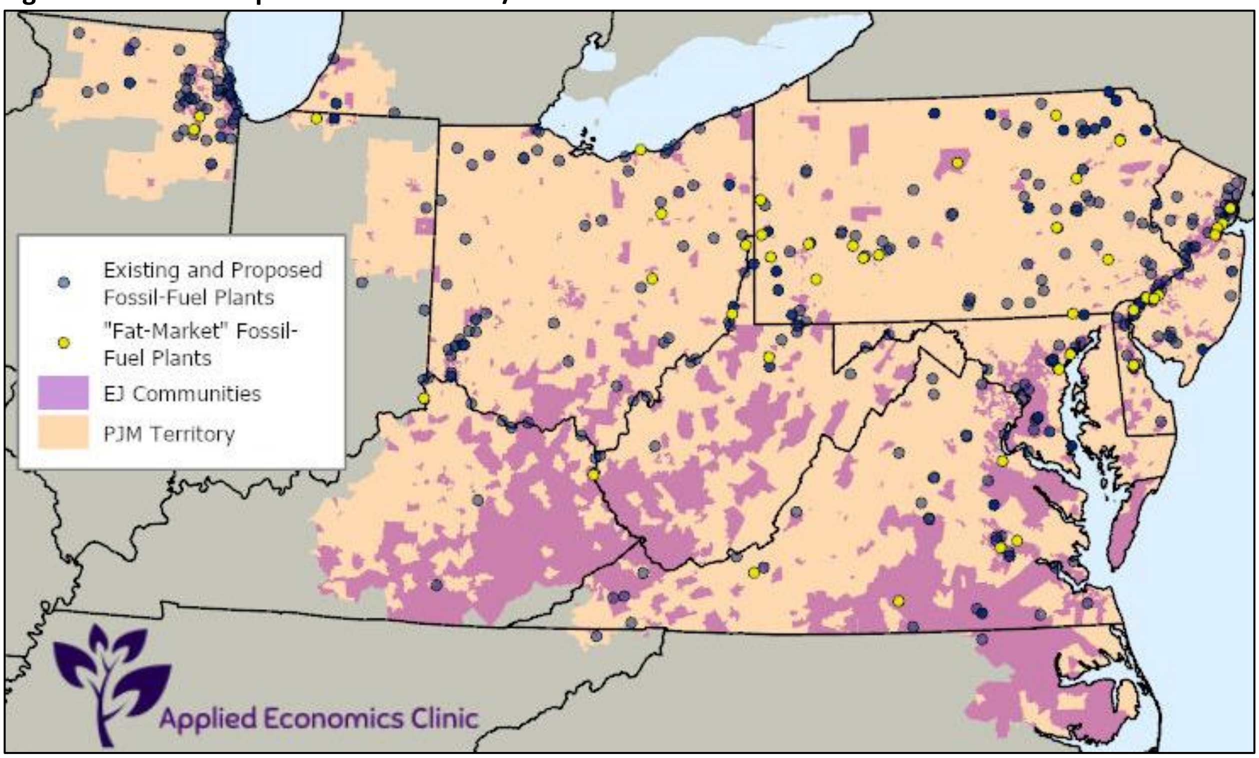
Table 3. Proximity to EJ communities for gas- and coal-fired generating units in PJM

Total coal and gas units			
Proximity to an EJ Community	**Number of Units**	**Percentage of Units**	**Combined Capacity (MW)**
Within a community	396	33%	45,631
Less than 1-mile	635	54%	78,583
Less than 5-miles	918	78%	119,684
Total units	1,183	100%	172,191
Existing coal and gas units			
Proximity to an EJ Community	**Number of Units**	**Percentage of Units**	**Combined Capacity (MW)**
Within a community	376	36%	38,241
Less than 1-mile	609	58%	68,820
Less than 5-miles	851	81%	101,764
Total existing units	1,050	100%	144,901
Proposed gas units			
Proximity to an EJ Community	**Number of Units**	**Percentage of Units**	**Combined Capacity (MW)**
Within a community	20	15%	7,390
Less than 1-mile	26	20%	9,763
Less than 5-miles	67	50%	17,921
Total proposed units	133	100%	27,291

Many power plants benefitting from the fat-market are located in or near EJ communities

Section III of this report analyzed 450 gas- and coal-fired generating units in PJM, of which 77 had bid prices lower than the actual 2021/22 clearing prices but higher than our adjusted clearing prices. Of these 77 "fat-market beneficiaries" (shown in Figure 5 in yellow), 33 units (43 percent) are within 1 mile of an EJ community and 48 units (62 percent) are within 5 miles of an EJ community. These are units that would not receive the capacity market revenue that allows them to continue operating if it were not for PJM's overestimated clearing price.

Figure 5. Fat-market plants in PJM's 2021/22 Auction



Of the fat-market beneficiaries located within 1 mile of an EJ community: 6 are not yet constructed; 13 are existing gas-fired units; 14 are existing coal-fired units (see Table 4 below). Capacity payments received by fat-market beneficiaries are an important factor in both keeping existing power plants running in EJ communities in the PJM region and in the economics of plants planned for construction in these communities.

Table 4. EJ analysis of fat-market units in PJM by type

Total coal and gas units			
Proximity to an EJ Community	**Existing Units**	**Proposed Units**	**Total Units**
Within a community	13	4	17
Less than 1-mile	27	6	33
Less than 5-miles	38	10	48
Total units	51	26	77
Gas units			
Proximity to an EJ Community	**Existing Units**	**Proposed Units**	**Total Units**
Within a community	9	4	13
Less than 1-mile	13	6	19
Less than 5-miles	16	10	26
Total units	18	26	44
Coal units			
Proximity to an EJ Community	**Existing Units**	**Proposed Units**	**Total Units**
Within a community	4	0	4
Less than 1-mile	14	0	14
Less than 5-miles	22	0	22
Total units	33	0	33

PJM’s 77 fat-market beneficiaries are located in ten states. In seven of these states (Delaware, Illinois, Kentucky, Maryland, New Jersey, Ohio, and Virginia) every single fat-market unit is located within 5 miles of an EJ community; in Delaware, Illinois, and Kentucky, every fat-market unit is within 1 mile of an EJ community (see Table 5). Indiana, Pennsylvania, and West Virginia are the exceptions; still, Pennsylvania houses 8 fat-market units that are within 5 miles of an EJ community.

Table 5. EJ analysis of fat-market units in PJM by state

Total coal and gas units											
Proximity to an EJ Community	**DE**	**IL**	**IN**	**KY**	**MD**	**NJ**	**OH**	**PA**	**VA**	**WV**	**Total Units**
Within a community	1	0	0	1	0	7	2	3	3	0	17
Less than 1-mile	2	2	0	2	0	12	8	3	3	1	33
Less than 5-miles	2	2	0	2	3	13	11	8	6	1	48
Total units	2	2	5	2	3	13	11	31	6	2	77
Existing coal and gas units											
Proximity to an EJ Community	**DE**	**IL**	**IN**	**KY**	**MD**	**NJ**	**OH**	**PA**	**VA**	**WV**	**Total Units**
Within a community	1	0	0	1	0	6	2	1	2	0	13
Less than 1-mile	2	2	0	2	0	9	8	1	2	1	27
Less than 5-miles	2	2	0	2	3	10	11	2	5	1	38
Total existing units	2	2	2	2	3	10	11	12	5	2	51
Proposed gas units											
Proximity to an EJ Community	**DE**	**IL**	**IN**	**KY**	**MD**	**NJ**	**OH**	**PA**	**VA**	**WV**	**Total Units**
Within a community	0	0	0	0	0	1	0	2	1	0	4
Less than 1-mile	0	0	0	0	0	3	0	2	1	0	6
Less than 5-miles	0	0	0	0	0	3	0	6	1	0	10
Total proposed units	0	0	3	0	0	3	0	19	1	0	26

Even without a fat market, some power plants are uneconomic and should be retired or never built

PJM does not reveal which 22.9 MW of generating units bid in at too high of a price to receive capacity payments (that is, above $140 per MW-day) in its 2021/22 capacity market, but AEC's analysis provides a window. Similar to the actual market results, AEC modeling found 28.5 MW that appear to require too much from the capacity market to clear, even with the fat market in place:

- More than half (83) of the 147 high-bid-price existing and proposed units are located within 5 miles of an EJ community; more than one-quarter (43) are within 1 mile of an EJ community; more than one-fifth (35) are located directly within an EJ community, in close proximity to homes, schools, parks, playgrounds, and healthcare facilities (see Table 6).
- Existing and proposed units that are already uneconomic in PJM's capacity auction and located close to EJ communities are primarily in Maryland, Ohio, Pennsylvania, and Virginia, with some in Delaware, Illinois, Kentucky, Michigan, New Jersey, and West Virginia. Among the 26 total existing units within 1 mile of an EJ community across the PJM region, 10 are in Virginia (see Table 7).

- 17 of these units within 1 mile of an EJ community have not yet been built but appear to be too expensive to clear in the capacity market. Proposed units that were sited within 5 miles of an EJ community are concentrated in Pennsylvania.

Table 6. EJ analysis high bid price units in PJM by type

Total coal and gas units			
Proximity to an EJ Community	**Existing Units**	**Proposed Units**	**Total Units**
Within a community	21	14	35
Less than 1-mile	26	17	43
Less than 5-miles	34	49	83
Total units	48	99	147
Gas units			
Proximity to an EJ Community	**Existing Units**	**Proposed Units**	**Total Units**
Within a community	8	14	22
Less than 1-mile	8	17	25
Less than 5-miles	15	49	64
Total units	18	99	117
Coal units			
Proximity to an EJ Community	**Existing Units**	**Proposed Units**	**Total Units**
Within a community	13	0	13
Less than 1-mile	18	0	18
Less than 5-miles	19	0	19
Total units	30	0	30

Table 7. EJ analysis of high bid price units in PJM by state

Total coal and gas units												
Proximity to an EJ Community	**DE**	**IL**	**IN**	**KY**	**MD**	**MI**	**NJ**	**OH**	**PA**	**VA**	**WV**	**Total Units**
Within a community	3	1	0	2	11	0	0	4	0	12	2	35
Less than 1-mile	3	2	0	2	11	3	0	6	0	14	2	43
Less than 5-miles	3	4	0	2	12	3	2	13	20	16	8	83
Total units	3	4	2	2	20	3	4	16	66	16	11	147
Existing coal and gas units												
Proximity to an EJ Community	**DE**	**IL**	**IN**	**KY**	**MD**	**MI**	**NJ**	**OH**	**PA**	**VA**	**WV**	**Total Units**
Within a community	3	1	0	2	5	0	0	2	0	8	0	21
Less than 1-mile	3	2	0	2	5	0	0	4	0	10	0	26
Less than 5-miles	3	4	0	2	6	0	0	7	2	10	0	34
Total existing units	3	4	2	2	9	0	1	10	4	10	3	48
Proposed gas units												
Proximity to an EJ Community	**DE**	**IL**	**IN**	**KY**	**MD**	**MI**	**NJ**	**OH**	**PA**	**VA**	**WV**	**Total Units**
Within a community	0	0	0	0	6	0	0	2	0	4	2	14
Less than 1-mile	0	0	0	0	6	3	0	2	0	4	2	17
Less than 5-miles	0	0	0	0	6	3	2	6	18	6	8	49
Total proposed units	0	0	0	0	11	3	3	6	62	6	8	99

V. Conclusions and Recommendations

AEC's examination of over-procurement in PJM's 2021/22 capacity auction found coal and gas generating units were paid to stay online in readiness to supply electricity, even though they were not needed for reliability:

- 35 gigawatts (GW) of unnecessary capacity from 77 existing and proposed gas- and coal-fired generating units cleared only because of PJM's fat market; for reference, 164 total GW cleared in PJM's 2021/22 capacity auction.
- Fat-market capacity bought in PJM's 2021/22 auction cost customers $4.3 billion dollars in extra cost, about $67 a year on the average customer bill.
- Of the 1,050 existing coal and gas generating units in the PJM region, 851 units (81 percent) are within 5 miles of an EJ community. The majority—609 units (58 percent)—are within 1 mile of an EJ community. More than one-third—376 units (36 percent)—are sited within an EJ community.
- Of the 77 existing and proposed gas- and coal-fired units receiving capacity payments only because of PJM's fat-market over-procurement, 48 units (62 percent) are within 5 miles of an EJ community; 33 units (43 percent) are within 1 mile.
- Of the fat-market beneficiary units located within 1 mile of an EJ community, 6 are proposed gas units (for which capacity payments are an important step toward receiving financing to begin construction); 13 are existing gas-fired units; and 14 are existing coal-fired units.
- In Maryland, New Jersey, Ohio, and Virginia, every single gas and coal unit benefitting from 2021/22 fat-market capacity payments in PJM is located within 5 miles of an EJ community. In Delaware, Illinois, and Kentucky every fat-market unit is within 1 mile of an EJ community.
- Among the 147 existing and proposed units with capacity that is too expensive to clear even with the fat market in place, more than half (83) are located within 5 miles of an EJ community; more than one-quarter (43) are within 1 mile of an EJ community; more than one-fifth (35 units) are located directly within an EJ community.
- Existing and proposed units that are already uneconomic in PJM's capacity auction and located close to EJ communities are primarily in Maryland, Ohio, Pennsylvania, and Virginia, with some in Delaware, Illinois, Kentucky, Michigan, New Jersey, and West Virginia. Among the 26 total existing units within 1 mile of an EJ community across the PJM region, 10 are in Virginia.

Over-procurement of capacity has important real-world impacts that could be resolved by taking a different approach to estimating future customer demand and capacity market design.

We offer the following recommendations developed in the course of our analysis:

1. PJM should reconsider its methodology for forecasting three-year ahead demand; the current methodology appears to result in a consistent overestimate year after year.

2. PJM should reconsider its methodology for designing a capacity demand curve, including comparison of its methods to those used in other regional electric grid operating systems. Small adjustments in the shape and slope of the demand curve have big impacts on the clearing price.

3. PJM should provide additional opportunities for a wider and more diverse set of stakeholder comment and third-party review of its proposed demand curve before holding every auction. Assessment by a larger set of experts may improve the accuracy of the demand curve, permit consideration of more diverse technical, social and environmental factors in the design of a final demand curve, and provide Federal Energy Regulatory Commission (FERC) with more comprehensive input and guidance in their assessment of auction processes.

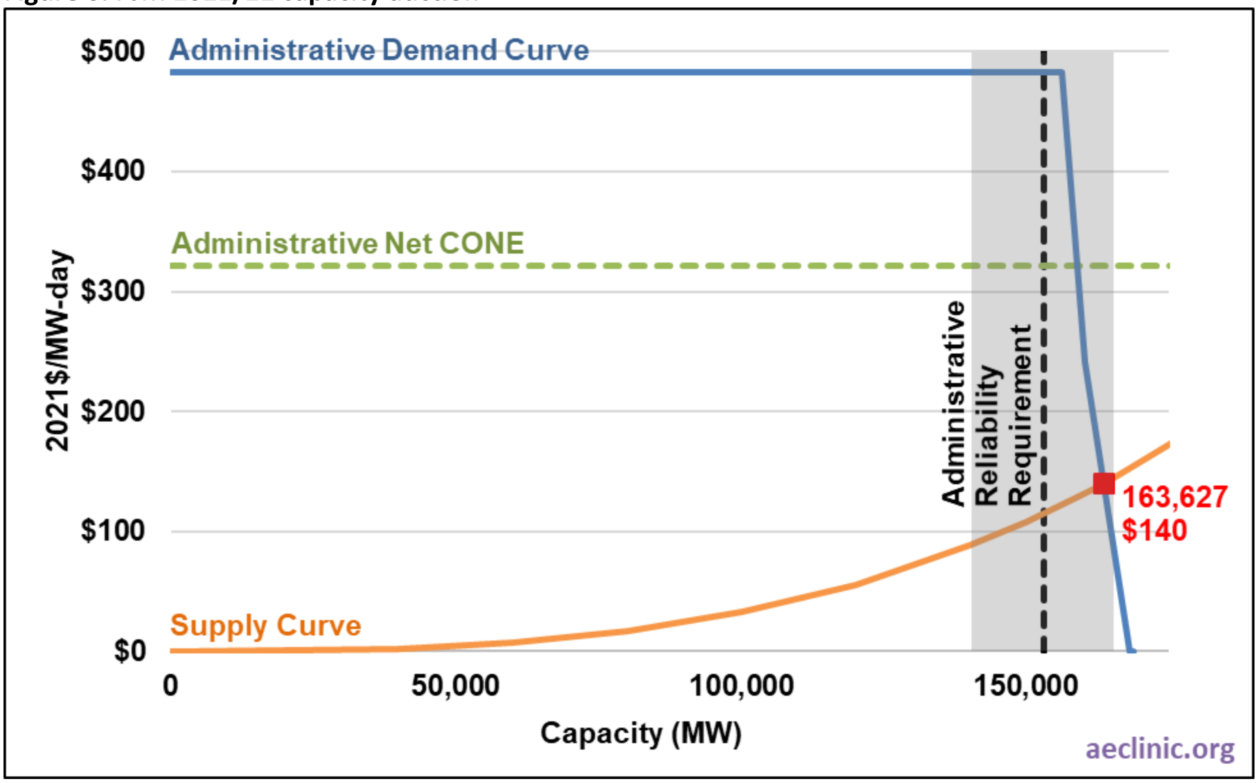
4. PJM along with state and local governments should take steps to include the voices and concerns of power plant host communities—and especially EJ communities—when considering changes to their market design. For the best decision-making, it is not possible to subsume the full range of power plants' impacts in market prices. Environmental and social impacts have a role to play in equitable and reliable power supply.

Appendix A – Capacity Demand: Demand Curve Adjustments

In response to concerns that PJM's overestimate of peak demand may have negative effects on EJ communities,[20] AEC developed an alternative peak demand curve that would better reflect both PJM's reliability needs and the cost of building new units. Because data related to PJM's bids and supply curves are not made publicly available, we made several simplifying assumptions and examined the sensitivity of our results to changes in underlying assumptions.

This analysis of PJM's Reliability Pricing Model—or capacity auction—relies on a series of adjustments made to the 2021/22 auction (conducted in 2018), shown for the PJM regional transmission organization (RTO) as a whole in Figure 6.[21,22]

Figure 6. PJM 2021/22 capacity auction



The red square in Figure 6 is the intersection of supply (the supply curve of unit bids) and demand (PJM's administrative demand curve). That intersection point determines the amount of capacity needed for reliability (163,627 MW) and the "clearing price" that selected plants receive for their capacity ($140 per

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[20] (1) Roberts, C. March 16, 2020. "PJM's Costly Capacity Cushion." *Sierra Club.* Available at: https://www.sierraclub.org/articles/2020/03/pjm-excess-capacity-cost; (2) Roberts, C., Eric, G. et al. May 5, 2021. "Public Interest Entities Other Users Group--Environmental Advocates." *Presentation for PJM Board of Managers.* Available at: https://www.pjm.com/-/media/committees-groups/user-groups/pieoug/2021/20210505/202[…]nterest-entities-other-users-group-environmental-advocates.ashx

[21] PJM. "Capacity Market (RPM)." Available at: https://www.pjm.com/markets-and-operations/rpm.aspx

[22] All dollar values presented in 2021 dollars, converted (when necessary) using the CPI-U.

MW-day). (For historical clearing prices, Net CONE[23] values, and reliability requirements see Appendix D – Additional Historical Data.)

Following James F. Wilson's 2016 and 2020 analyses of over-procurement of capacity resources in PJM, we refer to PJM's own estimates of Net CONE, reliability requirement, and the derivative demand curve (as used in the PJM capacity auction) as "administrative".[24] In Figure 6 (above), PJM constructs its administrative demand curve using its 2021/22 planning parameters, including the administrative Net CONE and reliability requirement.[25] PJM calculates the initial flat section of its demand curve as 1.5 times the administrative Net CONE.[26] The supply curve is constructed using PJM's supply curves from the 2021-2022 Base Residual Auction, which are approximated and smoothed versions of the actual supply curves.[27]

The grey section in Figure 6 is shown in greater detail in Figure 7 and subsequent graphs in this report. In the 2021/22 capacity auction, PJM estimated its reliability requirement (forecasted peak plus a 9 percent contingency known as the Forecast Pool Requirement[28]) at 153,161 MW and Net CONE as $322 per MW-day. The intersection of administrative demand and the actual supply curve determine the amount of capacity that cleared in the auction (163,627 MW) and the "clearing price" (or the price of the most expensive cleared, or marginal, resource: $140 per MW-day).

[23] Net CONE (or "Net Cost of New Entry") represents the first-year capacity revenue that a new resource would need after accounting for revenues in the energy and ancillary service markets.

[24] Wilson, JF. February 2020. *Over-Procurement of Generating Capacity in PJM: Causes and Consequences*. Wilson Energy Economics. p.3. Available at: https://www.powermag.com/wp-content/uploads/2020/03/wilson-overprocurement-of-capacity-in-pjm.pdf

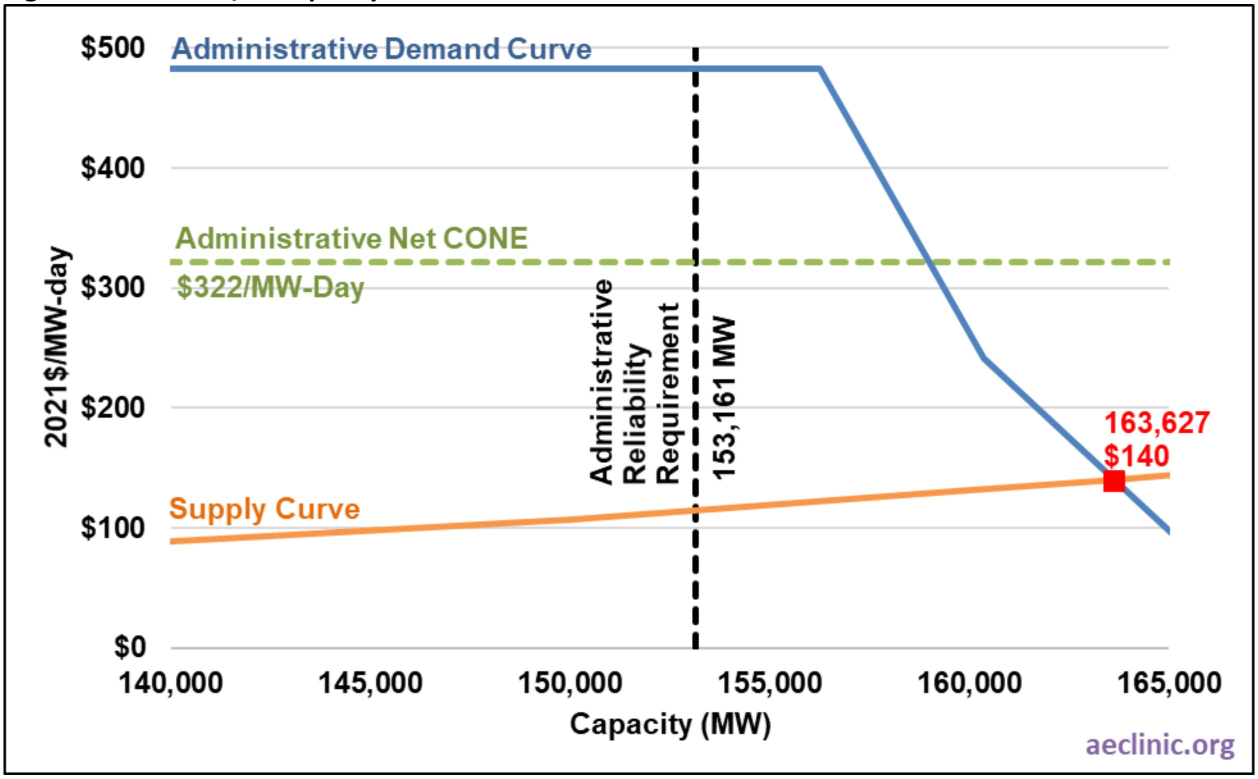
[25] PJM. 2018. "2021-2022 RPM Base Residual Auction Planning Parameters." Planning Period Parameters for Base Residual Auction. Available at: https://www.pjm.com/markets-and-operations/rpm.aspx

[26] Ibid.

[27] PJM. 2019. "2021-2022 Base Residual Auction Supply Curves." Available at: https://www.pjm.com/-/media/markets-ops/rpm/rpm-auction-info/2021-2022/2021-2022-bra-supply-curves.ashx

[28] The Forecast Pool Requirement (FPR) is calculated based on the Installed Reserve Margin (IRM) and Pool-Wide Average Equivalent Demand Forced Outage Rate (EFORd), using the following formula: FPR = (1 + IRM) * (1 – Average EFORd). In the 2021-2022 auction, the IRM was equal to 15.8 percent and the Average EFORd was equal to 5.89 percent. Source: PJM. 2018. "2021-2022 RPM Base Residual Auction Planning Parameters." Planning Period Parameters for Base Residual Auction. Available at: https://www.pjm.com/markets-and-operations/rpm.aspx

Figure 7. PJM 2021/22 capacity auction: detail view



Adjusting the Reliability Requirement

For the 2021/22 capacity auction (which took place in 2018), PJM based its forecast of 2021 peak demand on a forecast of customer demand conducted in 2018 (see Figure 8), predicting that peak load in 2021 would be 152,363 MW (red line in Figure 8, which shows the forecast of peak used in each annual capacity auction).[29] PJM's forecast conducted in 2021 predicts lower customer peak demand: 149,224 MW (see the blue line in Figure 8, which shows much lower demand forecasts in the actual auction year than in the three-year ahead forecast).[30] Actual recorded peaks (after the fact and adjusted for weather[31]) are lower still (black line in Figure 8). PJM has over-estimated peak load and the capacity required for reliability in every capacity auction it has conducted; the average over-estimate (compared to actual peak) has been 8 percent; between 2019 and 2020 the average over-estimate was 5 percent.[32]

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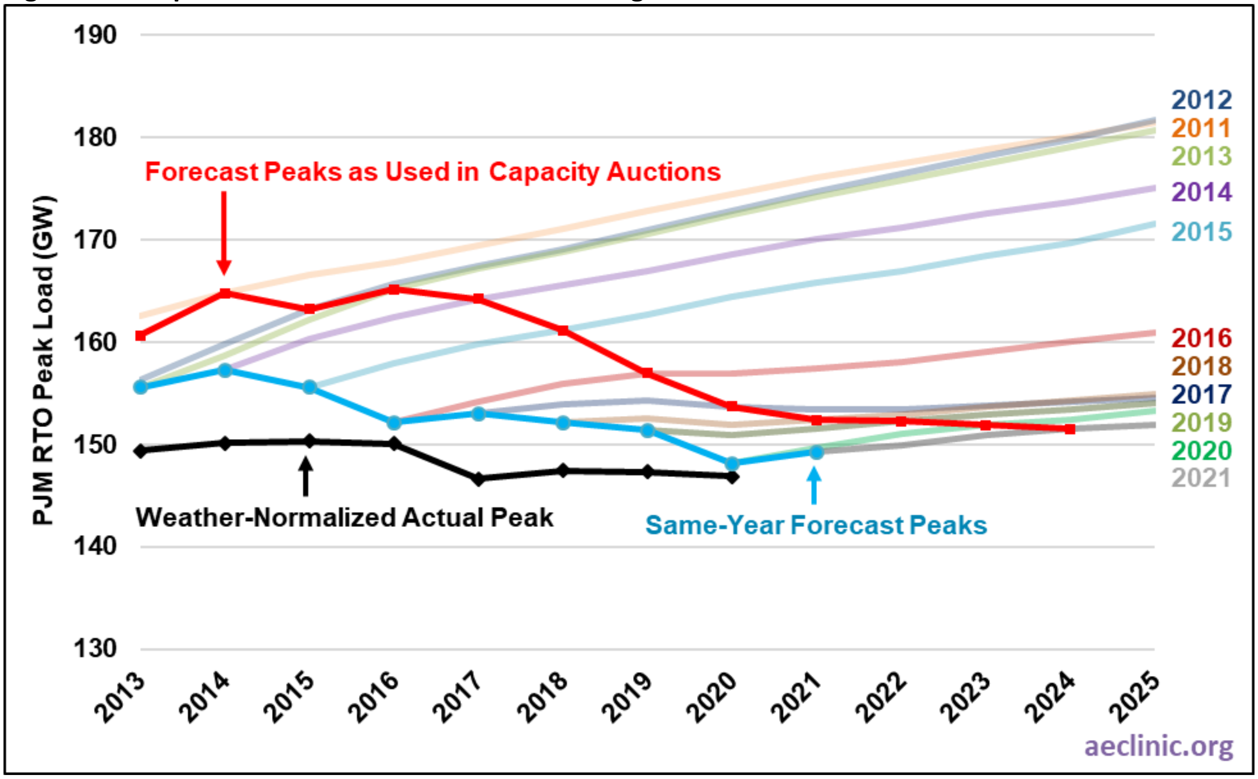
[29] PJM. January 2018. *PJM Load Forecast Report Data*. Available at: https://www.pjm.com/library/reports-notices

[30] PJM. January 2021. *PJM Load Forecast Report Data*. Available at: https://www.pjm.com/library/reports-notices

[31] Weather normalization regresses "seasonal daily peak load on non-holiday weekdays against weather" to create a weather standard. The intent is to indicate the long-term trend of each zone's seasonal coincident and noncoincident peak loads. Reynolds, J. November 15, 2017. "Weather Normalization of Peak Load". PJM Load Analysis Subcommittee.P.2. Available at: https://www.pjm.com/-/media/committees-groups/subcommittees/las/20171115/20171115-item-06-weather-normalization-method.ashx

[32] Wilson, JF. February 2020. *Over-Procurement of Generating Capacity in PJM: Causes and Consequences*. Wilson Energy Economics. p.5. Available at: https://www.powermag.com/wp-content/uploads/2020/03/wilson-overprocurement-of-capacity-in-pjm.pdf

Figure 8. PJM peak load as forecasted in 2012 through 2021



Sources: 1) PJM. January 2010. PJM Load Forecast Report. Table B-10. p.53. Available at: https://www.nrc.gov/docs/ML1005/ML100540735.pdf; 2) PJM. January 2011. PJM Load Forecast Report. Table B-10. p.54. Available at: https://www.pjm.com/-/media/library/reports-notices/load-forecast/2011-pjm-load-report.ashx?la=en; 3) PJM. January 2012. PJM Load Forecast Report. Table B-10. p.60. Available at: https://www.pjm.com/-/media/library/reports-notices/load-forecast/2012-pjm-load-report.ashx; 4) PJM. January 2013. PJM Load Forecast Report. Table B-10. p.66. Available at: https://www.pjm.com/-/media/library/reports-notices/load-forecast/2013-load-forecast-report.ashx?la=en; 5) PJM. January 2014. PJM Load Forecast Report. Table B-10. p.70. Available at: https://www.pjm.com/-/media/library/reports-notices/load-forecast/2014-load-forecast-report.ashx?la=en; 6) PJM. January 2015-2021. PJM Load Forecast Report Data. Available at: https://www.pjm.com/library/reports-notices; 7) Wilson, JF. February 2020. Over-Procurement of Generating Capacity in PJM: Causes and Consequences. Wilson Energy Economics. p.5. Available at: https://www.powermag.com/wp-content/uploads/2020/03/wilson-overprocurement-of-capacity-in-pjm.pdf.

If it were to under-estimate peak load, PJM then would seek to procure additional capacity in one of its three Incremental Auctions (used to “true up” capacity amounts closer to the real-time capacity needs).[33] In principal, the excess capacity could also be sold off to other RTOs (meaning that these units would still receive capacity payments). Electric customers pay for all cleared plants, which receive the capacity price multiplied by the number of MWs each plant cleared in the auction.

To adjust for these repeated over-estimates, AEC reduced the reliability requirement by 8,000 MW (or 5 percent of the administrative amount, based on overestimates in 2019 and 2020; see Figure 10 below). A lower reliability requirement means that less capacity clears in the auction, reducing costs for consumers. If a same-year forecast suggested that more capacity would be needed, under-procurement could be

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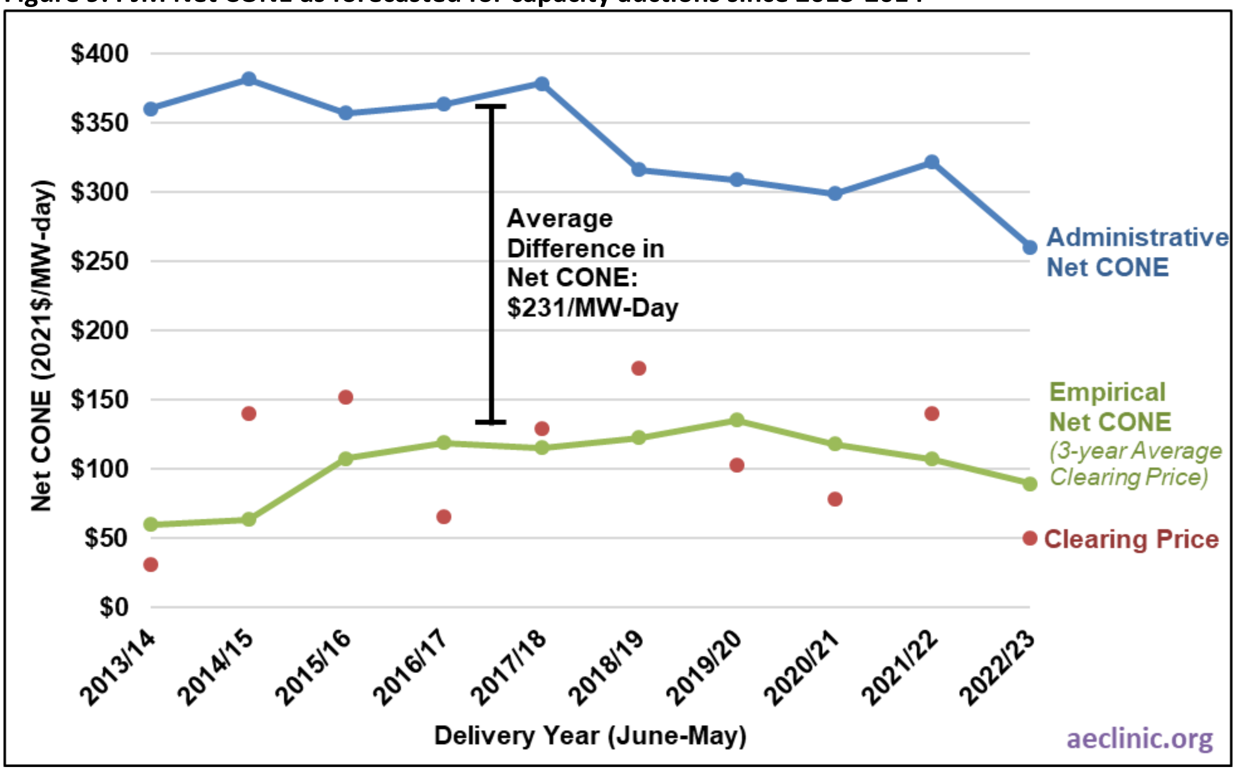
[33] PJM. January 2019. *RPM Incremental Auction FAQs*. Available at: https://www.pjm.com/-/media/markets-ops/rpm/rpm-auction-info/rpm-incremental-auction-faqs.ashx

resolved in an Incremental Auction used to true up over or under-estimates of capacity needs. PJM's first and third 2021/22 incremental capacity auctions resulted in a decrease in the reliability required, forcing PJM to sell off capacity to purchasers outside of the region. In contrast, PJM's second incremental auction for 2021/22 resulted in an increase in the reliability required, forcing PJM to buy additional capacity.

Adjusting Net CONE

According to Wilson's 2020 analysis on the over-procurement of capacity, the Net CONE (or Cost of New Entry) should be close to the clearing price if the administrative demand curve prices and quantities are set properly.[34] PJM has also over-estimated Net CONE in every capacity auction that it has conducted (see Figure 9). The $322 per MW-day administrative Net CONE used in the 2021/22 capacity auction is 230 percent higher than the clearing price and 310 percent higher than a three-year running average of auction clearing prices (green line in Figure 9, called "Empirical" following Wilson (2020)).

Figure 9. PJM Net CONE as forecasted for capacity auctions since 2013-2014



Sources: 1) PJM. 2013-2021. "BRA Resource Clearing Results". Planning Period Parameters for Base Residual Auction. Available at: https://www.pjm.com/markets-and-operations/rpm.aspx; 2) PJM. 2013-2021. "RPM Base Residual Auction Planning Parameters". Base Residual Auction: Results. Available at: https://www.pjm.com/markets-and-operations/rpm.aspx; 3) PJM. July 2020. Resource Clearing Prices Summary [Excel File]. Available at: https://www.pjm.com/-/media/markets-ops/rpm/rpm-auction-info/rpm-auctions-resource-clearing-price-summary.ashx.

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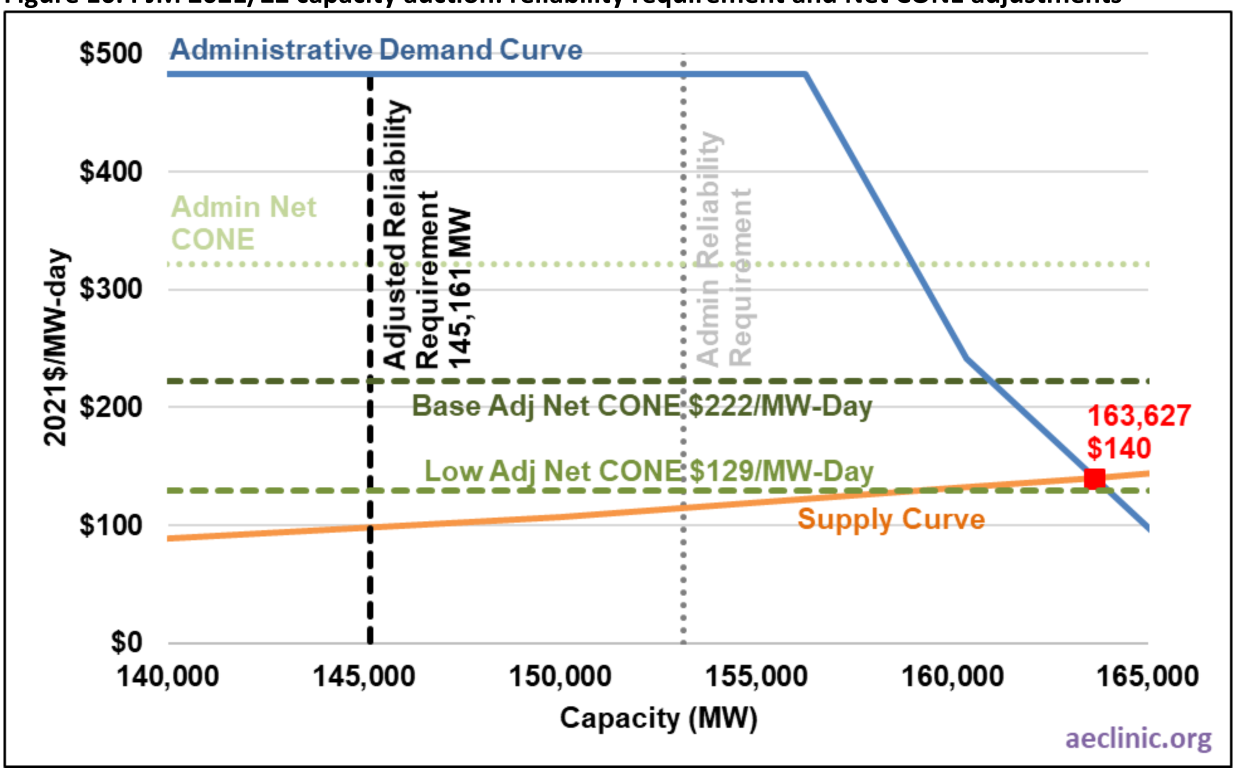
[34] Wilson, JF. February 2020. *Over-Procurement of Generating Capacity in PJM: Causes and Consequences*. Wilson Energy Economics. p.3. Available at: https://www.powermag.com/wp-content/uploads/2020/03/wilson-overprocurement-of-capacity-in-pjm.pdf

Net CONE represents the cost to add new capacity to the grid. To correct for PJM's repeated over-estimates of this cost, AEC examined two adjustments for Net CONE following Brattle Group (2018) (see Figure 10):[35]

- **Base Adjusted Net CONE ($222 per MW-day):** Based on Net CONE for a gas-fired combustion turbine (CT)—the current reference technology used by PJM in developing its demand curve. This adjustment represents a 25 to 42 percent decrease from PJM's 2021/22 administrative Net CONE, primarily driven by economies of scale on larger CTs, reduced federal taxes, and lower cost of capital.
- **Low Adjusted Net CONE ($129 per MW-day):** Based on Net CONE for a gas-fired combined-cycle unit (CC)—the dominant technology of new generation in PJM for more than 15 years. This adjustment represents a 44 to 76 percent decrease from PJM's 2021/22 administrative Net CONE, primarily driven by the much higher energy and ancillary services revenues of CCs with only slightly higher plant costs than those of CTs.[36]

Figure 10. PJM 2021/22 capacity auction: reliability requirement and Net CONE adjustments



[35] Newell, S.A. et al. April 2018. *Fourth Review of PJM's Variable Resource Requirement Curve*. The Brattle Group. Prepared for PJM. Adjusted for inflation. p.30. Available at: https://www.pjm.com/-/media/library/reports-notices/reliability-pricing-model/20180425-pjm-2018-variable-resource-requirement-curve-study.ashx

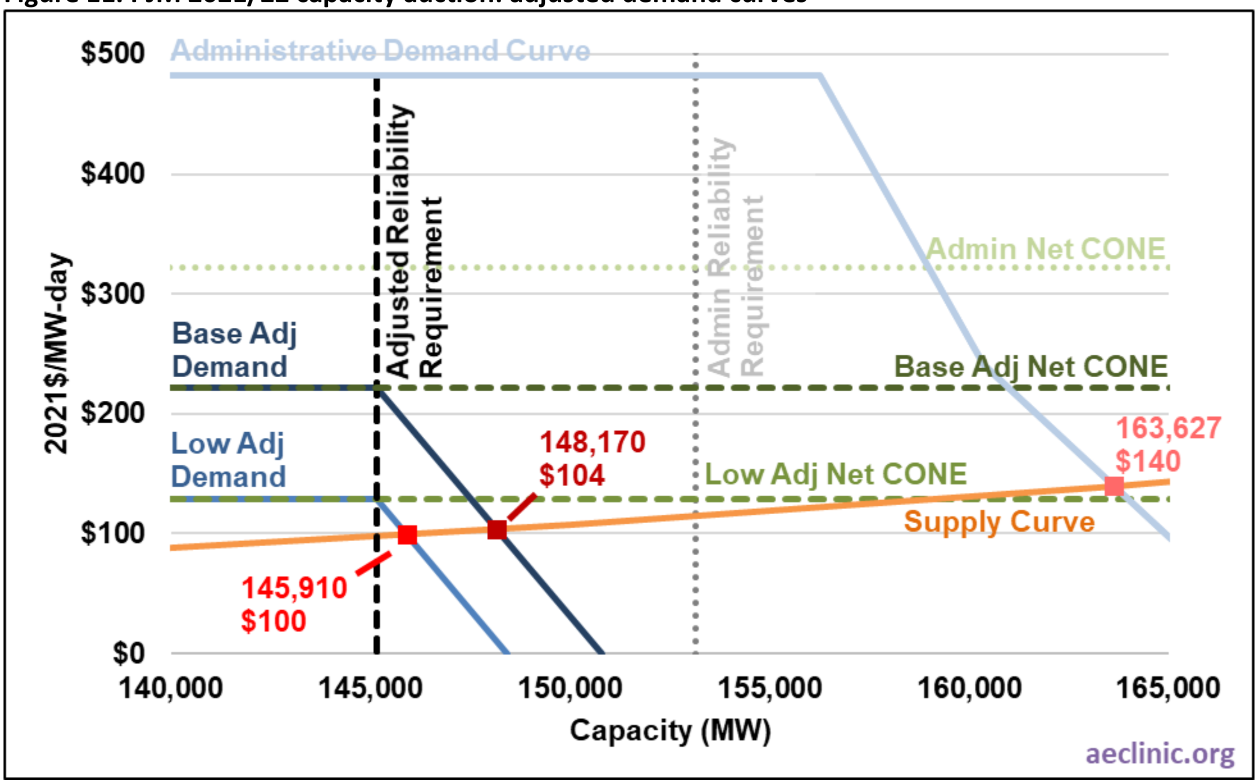
[36] "The updated estimate of Net CONE for CC plants—the dominant technology of new generation in PJM for more than fifteen years—is 44-76% lower than PJM's 2021/22 Net CONE parameters, and 25-63% below our updated CT Net CONE estimates, depending on location. CCs are more economic because their much higher net E&AS revenues more than offset slightly higher plant costs on a per-kW basis." Newell, S.A. et al. April 2018. *Fourth Review of PJM's Variable Resource Requirement Curve*. The Brattle Group. Prepared for PJM. Adjusted for inflation. p.30. Available at: https://www.pjm.com/-/media/library/reports-notices/reliability-pricing-model/20180425-pjm-2018-variable-resource-requirement-curve-study.ashx p.iii

A lower reliability requirement may also result in less capacity clearing in the auction, lowering costs for consumers. Again, if the same-year forecast suggested that more capacity was needed, that under-procurement could be resolved in an Incremental Auction.

Adjusted Demand Curves

Based on these adjustments, we constructed two new demand curves, both based on the 8,000 MW reduction to PJM's administrative reliability requirement (see the blue base adjusted demand and low adjusted demand curves in Figure 11). Our adjusted demand curves follow the base and low adjusted Net CONE values (we do not follow PJM's practice of raising the demand curve to 1.5 times the Net CONE[37]) until the reliability requirement capacity level and then decline at the average slope of that same section of the administrative demand curve to reach $0 per MW-day.

Figure 11. PJM 2021/22 capacity auction: adjusted demand curves



Based on these adjusted demand curves:

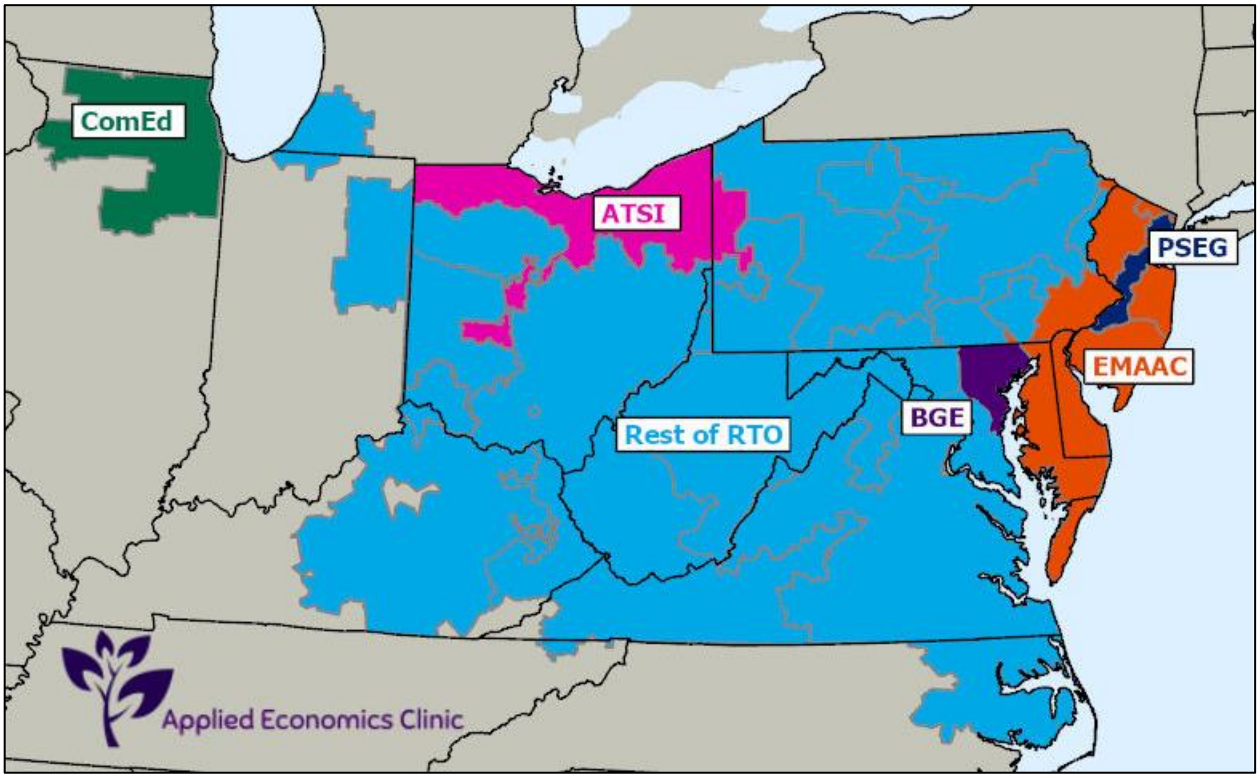
- **Base adjusted auction result** would clear at 148,170 MW and $104 per MW-day.
- **Low adjusted auction result** would clear at 145,910 MW and $100 per MW-day.
- For comparison, the **actual 2021/22 PJM auction** cleared at 163,627 MW and $140 per MW-day.

[37] This modeling choice makes our adjusted PJM demand curve more similar to that of ISO-New England, which does scale its Net CONE by a factor of 1.6 but also adjusts the relevant projection of the demand curve such that it passes through the intersection of the (unscaled) Net CONE and reliability requirement.

Results for Zonal Auctions

In addition and simultaneous to its RTO-wide capacity auction, PJM's calculations include zone-specific analysis; some zones have higher clearing prices than the RTO as a whole, reflecting transmission constraints. In the 2021/22 auction, five Locational Deliverability Areas (LDAs) cleared at higher prices than the rest of the RTO: ATSI, BGE, ComEd, EMAAC, and PSEG (see map in Figure 12).

Figure 12. PJM by LDA for the 2021/22 capacity auction



Sources: (1) PJM. n.d. "Transmission Zones." Available at: https://www.pjm.com/library/maps.aspx; (2) EnergyWatch. 2018. "PJM Capacity Prices Nearly Double in Most Territories." Available at: https://energywatch-inc.com/pjm-capacity-prices-nearly-double/

AEC made the same reliability requirement and Net CONE adjustment by zone as with the RTO: reliability requirements were reduced by 5 percent, Net CONE was calculated based on Brattle Group 2018, and adjusted demand curves followed Net CONE until the reliability requirement and decreased to $0 per MW-day at the slope of the administrative demand curve thereafter (see Table 8). AEC utilized the unaltered, LDA-specific supply curves from PJM's 2021/22 Base Residual Auction for this analysis.

Table 8. PJM reliability requirement and Net CONE by LDA for the 2021/22 capacity auction

Locational Deliverability Area (LDA)	Admin Reliability Requirement *(MW)*	Admin Net CONE *(2021$/MW-Day)*	Adjusted Reliability Requirement *(MW)*	BASE Adjusted Net CONE *(2021$/MW-Day)*	LOW Adjusted Net CONE *(2021$/MW-Day)*
RTO	153,161	$322	145,161	$222	$129
EMAAC	35,994	$314	34,114	$234	$164
BGE	7,910	$244	7,497	$145	$92
ComEd	26,112	$344	24,748	$240	$142
ATSI	15,598	$307	14,783	$204	$95
PSEG	11,501	$331	10,900	$251	$187

Sources: (1) PJM. 2018. "2021-2022 RPM Base Residual Auction Planning Parameters." Planning Period Parameters for Base Residual Auction. Available at: https://www.pjm.com/markets-and-operations/rpm.aspx; (2) Newell, S.A. et al. April 2018. Fourth Review of PJM's Variable Resource Requirement Curve. The Brattle Group. Prepared for PJM. Adjusted for inflation. p.30. Available at: https://www.pjm.com/-/media/library/reports-notices/reliability-pricing-model/20180425-pjm-2018-variable-resource-requirement-curve-study.ashx

Table 9 presents actual and adjusted clearing prices by LDA for PJM's 2021/22 capacity auction. After adjustments were made to the Net CONE and reliability requirement, four out of the five other LDAs have higher clearing prices than the rest of RTO. One of the LDAs, ATSI, has a lower clearing price than the rest of RTO, which is likely due to the shape of its supply curve. When a supply curve is steeper—which was the case for ATSI—any small change in the demand curve to the left (lower demand) or right (higher demand) result in relatively large changes in the clearing price. In practice, LDAs would only break out from the rest of RTO if they resulted in a higher clearing price. Since the ATSI adjusted clearing prices are lower than RTO—as shown in Table 9—AEC assigned the RTO adjusted clearing prices to ATSI in its analysis.

Table 9. PJM clearing price by LDA for the 2021/22 capacity auction

Locational Deliverability Area (LDA)	2021/22 Auction Clearing Price *(2021$/MW-Day)*	BASE Adjusted Clearing Price *(2021$/MW-Day)*	LOW Adjusted Clearing Price *(2021$/MW-Day)*
RTO	$140	$104	$100
EMAAC	$166	$105	$100
BGE	$200	$123	$114
ComEd	$195	$130	$123
ATSI*	$172	$86	$73
PSEG	$204	$119	$112

**For this analysis, AEC set the ATSI adjusted clearing prices equal to the RTO adjusted clearing prices of $104 and $100 per MW-day, respectively.*

Source: PJM. 2018. "2021/2022 Base Residual Auction Results." Available at: https://www.pjm.com/markets-and-operations/rpm.aspx

The Latest PJM Capacity Auction: 2022/23

Close to the completion of this analysis, PJM released the results of its 2022/23 capacity auction (see Figure 13)—which was conducted 2 years late due to the lack of FERC-approved auction rules.[38] (Normally, PJM's capacity auctions are conducted three years in advance (e.g., 2018 for 2021/22) but this latest auction was only one year in advance (2021 for 2022/23).) For the 2022/23 auction, both the reliability requirement and administrative Net CONE were lower, resulting in a lower demand curve.[39] Bid prices and the supply curve that they generate were also lower.[40,41]

Cleared capacity in the 2022/23 auction fell by almost 20,000 MW from the previous auction year to 143,477 MW, and the clearing price fell to one-third of its previous value at $50 per MW-day. Various drivers could have played a role in creating these differences between PJM's last two capacity auctions, including:

- The **timing of the auction**—the 2022/23 auction was held only a year prior to the delivery year as opposed to the usual three years, which likely provided PJM with a more accurate forecast of peak demand: a lower reliability requirement, lower demand curve and, as a result, a lower clearing price.
- The auction was held during the **ongoing COVID-19 pandemic**, which has reduced annual and peak electric demand throughout the United States: PJM's reliability requirement was 153,161 MW for its 2021/22 auction and 132,257 MW for its 2022/23 auction, a decline of roughly 14 percent.
- Uncertainty and challenges related to FERC's changes to PJM's **minimum offer price rule (MOPR)** could have affected these differences in capacity bid prices, although the rationales (and even direction) of bidders' adjustments are likely diverse and complex.[42]
- Dominion Energy Virginia's selection of the Fixed Resource Requirement (FRR) for capacity year 2022/23 will subtract over 18 GW from the capacity market accounting for 13 percent of the cleared capacity in the 2022/23 auction. With the FRR option, generators can meet PJM's resource adequacy requirements by committing to acquire enough capacity to meet its load forecast plus a reserve margin for at least five years.[43]

Overall, the unique circumstances and timing of PJM's 2022/23 capacity auction had the result of removing

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[38] Walton, R. November 18, 2019. "Generators call on PJM to expedite delayed capacity auction, once new rules are set". Utility Dive. Available at: https://www.utilitydive.com/news/generators-call-on-pjm-to-expedite-delayed-capacity-auction-once-new-rules/567510/

[39] PJM. 2021. "2022/2023 RPM Base Residual Auction Planning Parameters." Planning Period Parameters for Base Residual Auction. Available at: https://www.pjm.com/markets-and-operations/rpm.aspx

[40] PJM. 2021. "2022/2023 Base Residual Auction Results." Available at: https://www.pjm.com/markets-and-operations/rpm.aspx

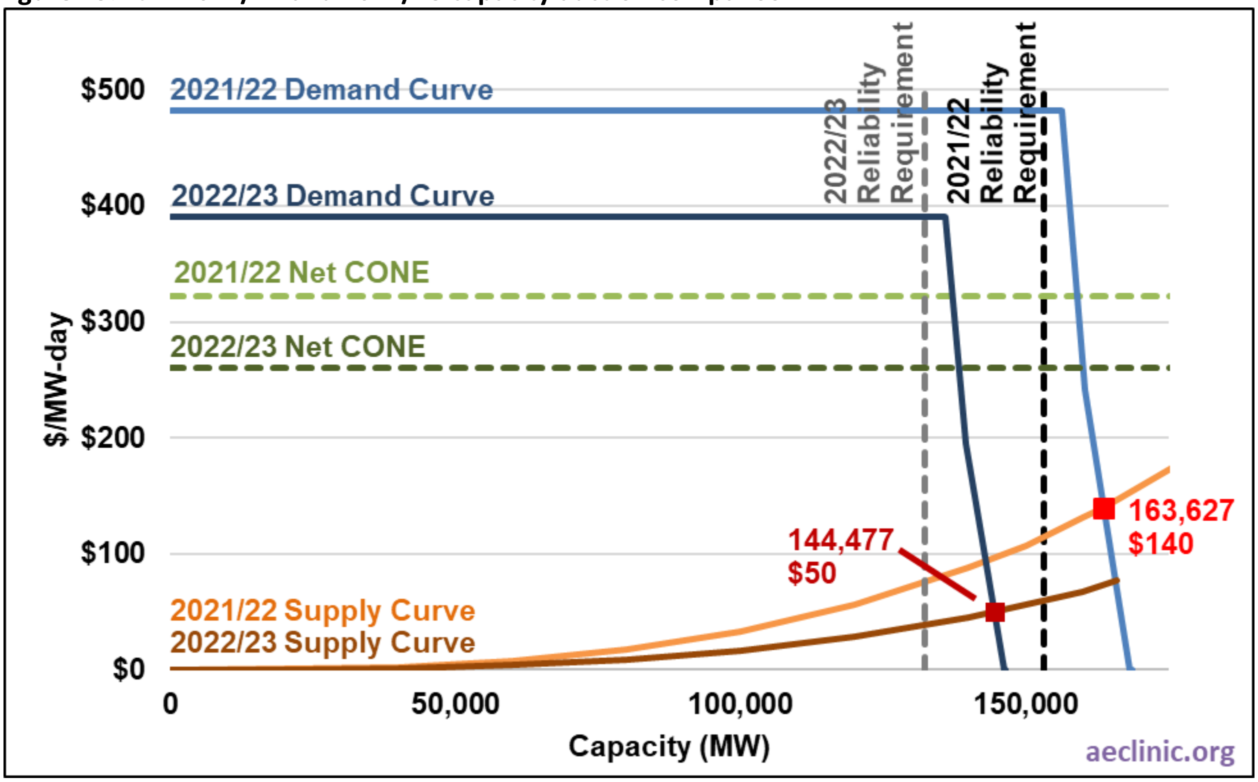
[41] PJM. 2021. "2022/2023 Base Residual Auction Supply Curves." Available at: https://www.pjm.com/-/media/markets-ops/rpm/rpm-auction-info/2022-2023/2022-2023-bra-supply-curves.ashx

[42] Morehouse, C. 29 April, 2021. "PJM proposes to end FERC MOPR policy that raised prices for state-subsidized resources". *Utility Dive.* Available at: https://www.utilitydive.com/news/pjm-proposes-to-end-ferc-mopr-policy-that-raised-prices-for-state-subsidize/599248/

[43] Heidorn, R. Jr. 5 May, 2021. "Dominion Opts out of PJM Capacity Auction". *RTO Insider.* Available at: https://www.rtoinsider.com/articles/20192-dominion-opts-out-of-pjm-capacity-auction

much of the fat from the market and drastically lowering the clearing price. While the 2021/22 auction cleared at $140 per MW-day, the 2022/23 auction cleared at $50 per MW-day (see Figure 13).

Figure 13. PJM 2021/22 and 2022/23 capacity auction comparison

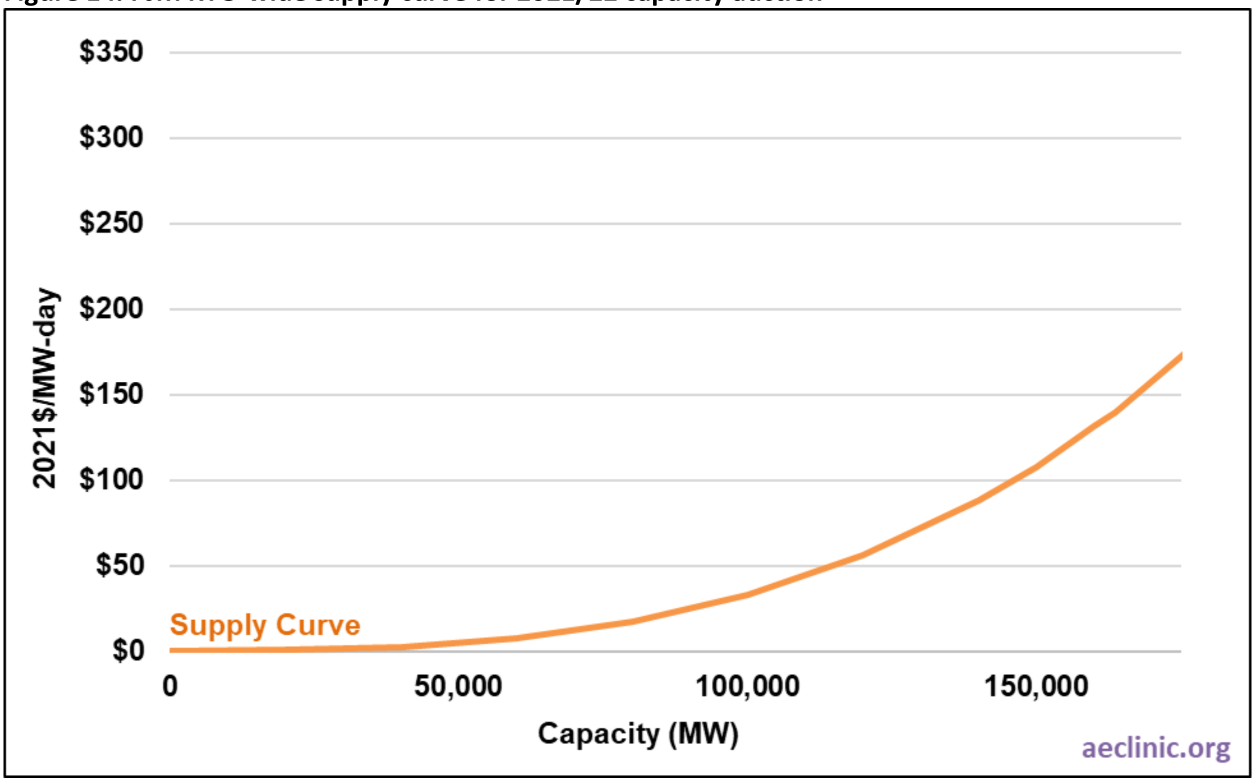


Note: PJM's capacity auctions assume dollar values to be in the same year as the auction's delivery year (i.e., 2021 dollars for the 2021/22 auction and 2022 dollars for the 2022/23 auction). For the purposes of this graph, we make a simplifying assumption and treat 2021$ and 2022$ as equivalent in real terms.

Appendix B – Capacity Supply: Bid Estimates

Power plant owners bid into PJM's capacity auction by offering the amount of capacity they can provide at times of peak demand and the price (in dollars per MW-day) that they require to remain at readiness to supply power when called upon. Bid prices should represent the cost to operate the plant less the other (non-capacity) revenues that the plant owner expects to collect. Subtracting expected non-capacity revenues from costs results in the "missing money" needed to stay in operation. Generators' actual bids are not made available to the public but aggregated bids can be observed in the PJM supply curve, in which all bids are put in order of their $ per MW cost (see Figure 14).

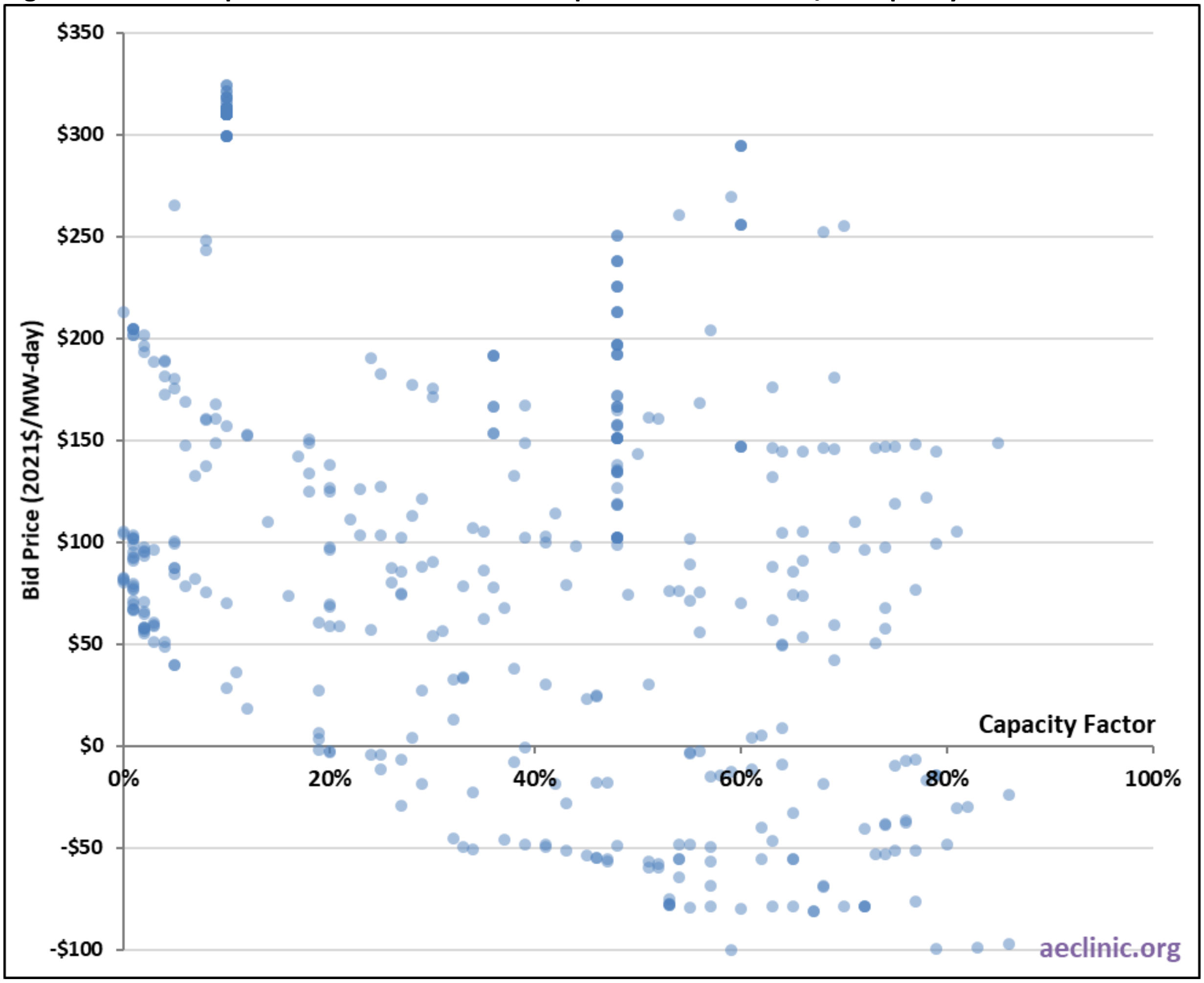
Figure 14. PJM RTO-wide supply curve for 2021/22 capacity auction



Note: The supply curve for 2021/22 auction shown above was converted from 2018$ to 2021$. Source: PJM. "2021-2022 Base Residual Auction Supply Curves." Available at: https://www.pjm.com/-/media/markets-ops/rpm/rpm-auction-info/2021-2022/2021-2022-bra-supply-curves.ashx.

AEC estimated 2021/22 bid prices using approximated costs and revenues for each gas- or coal-fired generating unit operating in PJM in 2017 along with each new unit expected to be in operation by 2021 (450 existing and proposed units in total). Costs less revenues for the generating unit as a whole are divided by the MW capacity of the unit and 365 to arrive at a $ per MW-day value (see Figure 15).

Figure 15. AEC bid price estimates for fossil fuel plants in PJM's 2021/22 capacity auction



Estimating Unit Costs

A unit's total cost to run is determined by its fuel costs, incremental capital costs, variable, and fixed operations and maintenance costs. All cost and revenue estimates used in this analysis are based on data for 2017 (or the next closest available year) presented in 2021 dollars. Fuel cost is calculated using each unit's fuel consumption in MMBtu and heat rates[44] to account for fuel use and prices[45] found in data from EIA. Gas units were given assumed heat rates based on their age in 2018 and technology type (see Table 10).

[44] U.S. EIA. 2018. "Form EIA-923 detailed data with previous form data (EIA-906/920)" 2017 Generator Data. Available at: https://www.eia.gov/electricity/data/eia923/

[45] *Source for gas plants:* U.S. EIA. 2020. "Table 7.20: Average cost of natural gas delivered for electricity generation by state." Electric Power Annual. Available at: https://www.eia.gov/electricity/annual/; *Source for coal plants:* U.S. EIA. 2020. "Average sales price: Open market and captive sales price by state." Annual Coal Report. Table 33. Available at: https://www.eia.gov/coal/data.php#prices

Table 10. Assumed Heat Rate for Select Technologies (MMBtu/MWh)

Assumed Heat Rate (MMBtu/MWh)	Gas-Fired Combined Cycle	Gas-Fired Combustion Turbine
pre-1990	9.00	12.00
1990-1999	8.00	11.00
2000-2009	7.30	10.50
2010-2018	6.85	10.00
post-2018	6.40	9.00

Note: This analysis assumes that gas-fired steam turbines and gas-fired internal combustion engines have heat rates equivalent to those listed above for gas-fired combustion turbines.
Sources: Lazard. November 2017. Lazard's Levelized Cost of Energy Analysis. Available at: https://www.lazard.com/media/450337/lazard-levelized-cost-of-energy-version-110.pdf; EIA. April 15, 2021. Newer-technology natural gas-fired generators are utilized more than older units in PJM. Available at: https://www.eia.gov/todayinenergy/detail.php?id=47556; EIA. February 12, 2019. Power blocks in natural gas-fired combined-cycle plants are getting bigger. Available at: https://www.eia.gov/todayinenergy/detail.php?id=38312; EIA. February 2021. Electricity Market Module. Available at: https://www.eia.gov/outlooks/aeo/assumptions/pdf/electricity.pdf

Each unit was given a state-specific fuel price, which was then multiplied by its own fuel usage to calculate fuel cost. For coal units specifically, if an error occurs in calculating fuel costs, AEC determined each unit's fuel cost by dividing the average state coal price[46] by the average heat content.[47]

AEC estimated annualized ongoing[48] and new[49] capital costs. At the time of the 2021/22 auction, per the PJM tariff, capacity owners were permitted to include only incremental capital costs in their bids or a few years of a set maximum offer cap that was based on the net cost of new entry (net CONE) of a reference CT.[50] For the purposes of this analysis we estimate capital costs with the following simplified method:[51] if a unit was 5 years of age or less at the time of the 2021/22 auction held in 2018 (including proposed units), it was assumed to only have new capital costs—which were calculated by multiplying the upfront capital costs of the appropriate technology/fuel type (e.g., Gas CT, Gas CC, etc.) by a capital recovery factor of 8.47 percent. This factor is based on an assumed weighted average cost of capital (WACC) of 7.5 percent[52] and

[46] U.S. EIA. 2020. "Average sales price: Open market and captive sales price by state." Annual Coal Report. Table 33. Available at: https://www.eia.gov/coal/data.php#prices
[47] U.S. EIA. 2018. "Form EIA-923 detailed data with previous form data (EIA-906/920)" 2017 Generator Data. Available at: https://www.eia.gov/electricity/data/eia923/
[48] U.S. EIA. December 2019. "Generating Unit Annual Capital and Life Extension Costs Analysis." Available at: https://www.eia.gov/analysis/studies/powerplants/generationcost/pdf/full_report.pdf
[49] U.S. EIA. 2016. *Capital Cost and Performance Characteristic Estimates for Utility Scale Electric Power Generating Technologies*. Available at: https://www.eia.gov/analysis/studies/powerplants/capitalcost/archive/2016/pdf/capcost_assumption.pdf. p. 41
[50] (1) Monitoring Analytics, LLC. August 2018. "Analysis of the 2021/2022 RPM Base Residual Auction: Revised." Available at: https://www.monitoringanalytics.com/reports/Reports/2018/IMM_Analysis_of_the_20212022_RPM_BRA_Revised_20180824.pdf
(2) Personal communication with Dr. Joseph Bowring, President of Monitoring Analytics, LLC in October 2021.
[51] The actual method is complex and—according to the market monitor—may not have been followed correctly in the 2021/22 capacity auction.
[52] Newell, S.A. et al. April 2018. *Fourth Review of PJM's Variable Resource Requirement Curve*. The Brattle Group. Prepared for PJM.

the economic life for a new gas plant of 30 years.[53] All units older than 5 years of age were assigned ongoing capital costs for the appropriate technology/fuel type (e.g., Gas CT, Gas CC, Coal, etc.) from EIA's 2019 *Generating Unit Annual Capital and Life Extension Costs Analysis*, converted to 2021 dollars.

For each technology type included in the analysis, both fixed and variable operations and maintenance costs were taken from EIA's 2016 *Capital Cost and Performance Characteristic Estimates for Utility Scale Electric Power Generating Technologies*.[54]

Finally, all cost categories (as listed above) receive a 10 percent adder based on PJM's Open Access Transmission Tariff[55] and are summed to estimate total costs of operation.

Estimating Unit Revenues

To estimate total revenues by unit, AEC summed energy and ancillary services revenue for each unit. For energy services revenue, AEC used 2017 on-peak, day ahead, load-weighted average zonal locational marginal prices (LMPs)[56] scaled against the average LMP for all of PJM. If a unit's capacity factor is less than 50 percent, we assumed the on-peak zonal price (units operating less than half the time are likely operating most often at times of peak demand). However, if the capacity factor for a unit is above 50 percent, we selected the average price for the RTO (these units operate both at peak and off-peak times). For ancillary revenue, AEC used the revenue price given by PJM[57], and calculated total revenue as a function of unit generation.

"Missing Money"

Capacity auction bids are the difference between estimated costs and estimated energy and ancillary revenues. PJM's supply curve for the 2021/22 auction ranges above the actual clearing price of $140 per MW-day. Like all bid information, the highest bid value is proprietary and not shared by PJM.[58] However, AEC estimated capacity bids to range from -$101 to $324 per MW-day.

Adjusted for inflation. p.18. Available at: https://www.pjm.com/-/media/library/reports-notices/reliability-pricing-model/20180425-pjm-2018-variable-resource-requirement-curve-study.ashx

[53] U.S. EIA. December 2019. "Generating Unit Annual Capital and Life Extension Costs Analysis." Available at: https://www.eia.gov/analysis/studies/powerplants/generationcost/pdf/full_report.pdf

[54] U.S. EIA. 2016. *Capital Cost and Performance Characteristic Estimates for Utility Scale Electric Power Generating Technologies*. Available at: https://www.eia.gov/analysis/studies/powerplants/capitalcost/archive/2016/pdf/capcost_assumption.pdf. p. 41

[55] PJM. *Open Access Transmission Tariff. Attachment DD, Section 6.* Available at: https://pjm.com/directory/merged-tariffs/oatt.pdf. PDF p. 4338.

[56] PJM Hourly Real-Time and Day-Ahead Monthly LMPs. 2017. Available at: https://dataminer2.pjm.com/feed/rt_da_monthly_lmps.

[57] Ancillary Revenues: PJM. 2019. "2019 State of the Market." Table 10-4. Available at: https://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2019/2019-som-pjm-sec10.pdf

[58] PJM. "2021-2022 Base Residual Auction Supply Curves." Available at: https://www.pjm.com/-/media/markets-ops/rpm/rpm-auction-info/2021-2022/2021-2022-bra-supply-curves.ashx.

Exclusions and Caveats

Excluded Units: 450 of PJM's 1,193 gas- and coal-fired generating units from EIA's 2017 data sources are represented in this analysis, excluding a total of 743 units. The following types of units were excluded:

- those recorded by EIA as having zero or negative generation in 2017 (598 units),
- those with a capacity factor greater than 100 percent (5 units) in 2017,
- those burning waste fuels (15 units), and
- 238 combined heat and power (CHP) units (or an additional 125 units that were not already excluded).

Capacity Factors: Capacity factors for proposed gas units were estimated as:

- Proposed gas combined-cycle generators: The average capacity factor for combined cycle plants in our data sample by LDA, except for BGE, which was assigned the RTO average (48 percent) due to insufficient data in that zone.
- Proposed gas steam turbine, gas combustion turbines, and gas internal combustion engines: the average capacity factor of 10 percent from Lazard 14.0.[59]

Data and Dollar Years: The 2021/22 capacity auction took place in 2018. Data used in this analysis were either 2017 data or (for variable and fixed operation and maintenance costs, capital costs) the closest available data year. All dollar values were adjusted to 2021 dollars using the Bureau of Labor Statistics' Consumers Price Index.[60]

[59] Lazard. October 2020. "Lazard's Levelized Cost of Energy Analysis-Version 14.0". Available at: https://www.lazard.com/media/451419/lazards-levelized-cost-of-energy-version-140.pdf
[60] U.S. Bureau of Labor Statistics. 2021. Consumer Price Index for All Urban Consumers (CPI-U). Available at: https://data.bls.gov/cgi-bin/surveymost

Sensitivity Analyses

Table 11. Central results and sensitivity analyses for capacity factor and WACC

Central Results/Assumptions	Existing Units	Proposed Units	Total	Existing Units *(MW)*	Proposed Units *(MW)*	Total *(MW)*
BID > Admin Clearing Price	48	99	147	13,950	14,508	28,457
BASE Adjusted < BID <= Admin Clearing Price	**41**	**20**	**61**	**17,705**	**9,391**	**27,096**
LOW Adjusted < BID <= BASE Adjusted	**10**	**6**	**16**	**5,749**	**2,623**	**8,372**
$0/MW-Day <= BID <= LOW Adjusted	124	1	125	40,483	485	40,968
BID < $0/MW-Day	101	0	101	20,774	0	20,774
TOTAL	**324**	**126**	**450**	**98,661**	**27,007**	**125,668**

Sensitivity: Capacity Factor *Coal = 50%; Gas CC = 80%; Gas CT = 10%*	Existing Units	Proposed Units	Total	Existing Units *(MW)*	Proposed Units *(MW)*	Total *(MW)*
BID > Admin Clearing Price	34	103	137	11,124	15,653	26,777
BASE Adjusted < BID <= Admin Clearing Price	**45**	**15**	**60**	**14,025**	**6,824**	**20,849**
LOW Adjusted < BID <= BASE Adjusted	**12**	**0**	**12**	**4,943**	**0**	**4,943**
$0/MW-Day <= BID <= LOW Adjusted	171	8	179	52,881	4,530	57,411
BID < $0/MW-Day	62	0	62	15,689	0	15,689
TOTAL	**324**	**126**	**450**	**98,661**	**27,007**	**125,668**

Sensitivity: Capital Costs *WACC = 6%*	Existing Units	Proposed Units	Total	Existing Units *(MW)*	Proposed Units *(MW)*	Total *(MW)*
BID > Admin Clearing Price	38	73	111	10,677	4,490	15,166
BASE Adjusted < BID <= Admin Clearing Price	**40**	**41**	**81**	**17,823**	**14,303**	**32,127**
LOW Adjusted < BID <= BASE Adjusted	**10**	**2**	**12**	**5,749**	**2,165**	**7,914**
$0/MW-Day <= BID <= LOW Adjusted	135	10	145	43,638	6,049	49,687
BID < $0/MW-Day	101	0	101	20,774	0	20,774
TOTAL	**324**	**126**	**450**	**98,661**	**27,007**	**125,668**

Sensitivity: Capital Costs *WACC = 9%*	Existing Units	Proposed Units	Total	Existing Units *(MW)*	Proposed Units *(MW)*	Total *(MW)*
BID > Admin Clearing Price	51	126	177	14,846	27,007	41,853
BASE Adjusted < BID <= Admin Clearing Price	**38**	**0**	**38**	**16,808**	**0**	**16,808**
LOW Adjusted < BID <= BASE Adjusted	**10**	**0**	**10**	**5,749**	**0**	**5,749**
$0/MW-Day <= BID <= LOW Adjusted	124	0	124	40,483	0	40,483
BID < $0/MW-Day	101	0	101	20,774	0	20,774
TOTAL	**324**	**126**	**450**	**98,661**	**27,007**	**125,668**

Table 12. Sensitivity analyses for heat rates and new build cost recovery

Sensitivity: Heat Rates *10% lower*	Existing Units	Proposed Units	Total	Existing Units *(MW)*	Proposed Units *(MW)*	Total *(MW)*
BID > Admin Clearing Price	30	77	107	6,065	5,547	11,612
BASE Adjusted < BID <= Admin Clearing Price	**35**	**43**	**78**	**13,702**	**17,477**	**31,179**
LOW Adjusted < BID <= BASE Adjusted	**7**	**0**	**7**	**2,759**	**0**	**2,759**
$0/MW-Day <= BID <= LOW Adjusted	141	6	147	54,146	3,983	58,129
BID < $0/MW-Day	111	0	111	21,989	0	21,989
TOTAL	**324**	**126**	**450**	**98,661**	**27,007**	**125,668**

Sensitivity: Heat Rates *10% higher*	Existing Units	Proposed Units	Total	Existing Units *(MW)*	Proposed Units *(MW)*	Total *(MW)*
BID > Admin Clearing Price	62	119	181	24,132	23,668	47,800
BASE Adjusted < BID <= Admin Clearing Price	**53**	**7**	**60**	**26,346**	**3,339**	**29,685**
LOW Adjusted < BID <= BASE Adjusted	**11**	**0**	**11**	**4,976**	**0**	**4,976**
$0/MW-Day <= BID <= LOW Adjusted	133	0	133	29,500	0	29,500
BID < $0/MW-Day	65	0	65	13,707	0	13,707
TOTAL	**324**	**126**	**450**	**98,661**	**27,007**	**125,668**

Sensitivity: Capital Costs *New build cost recovery for 2 years*	Existing Units	Proposed Units	Total	Existing Units *(MW)*	Proposed Units *(MW)*	Total *(MW)*
BID > Admin Clearing Price	44	107	151	13,227	17,175	30,402
BASE Adjusted < BID <= Admin Clearing Price	**32**	**18**	**50**	**15,420**	**8,807**	**24,228**
LOW Adjusted < BID <= BASE Adjusted	**10**	**1**	**11**	**5,749**	**1,025**	**6,774**
$0/MW-Day <= BID <= LOW Adjusted	128	0	128	41,205	0	41,205
BID < $0/MW-Day	110	0	110	23,059	0	23,059
TOTAL	**324**	**126**	**450**	**98,661**	**27,007**	**125,668**

Sensitivity: Capital Costs *New build cost recovery for 8 years*	Existing Units	Proposed Units	Total	Existing Units *(MW)*	Proposed Units *(MW)*	Total *(MW)*
BID > Admin Clearing Price	58	107	165	16,153	17,175	33,328
BASE Adjusted < BID <= Admin Clearing Price	**43**	**18**	**61**	**18,086**	**8,807**	**26,893**
LOW Adjusted < BID <= BASE Adjusted	**10**	**1**	**11**	**5,749**	**1,025**	**6,774**
$0/MW-Day <= BID <= LOW Adjusted	123	0	123	39,676	0	39,676
BID < $0/MW-Day	90	0	90	18,997	0	18,997
TOTAL	**324**	**126**	**450**	**98,661**	**27,007**	**125,668**

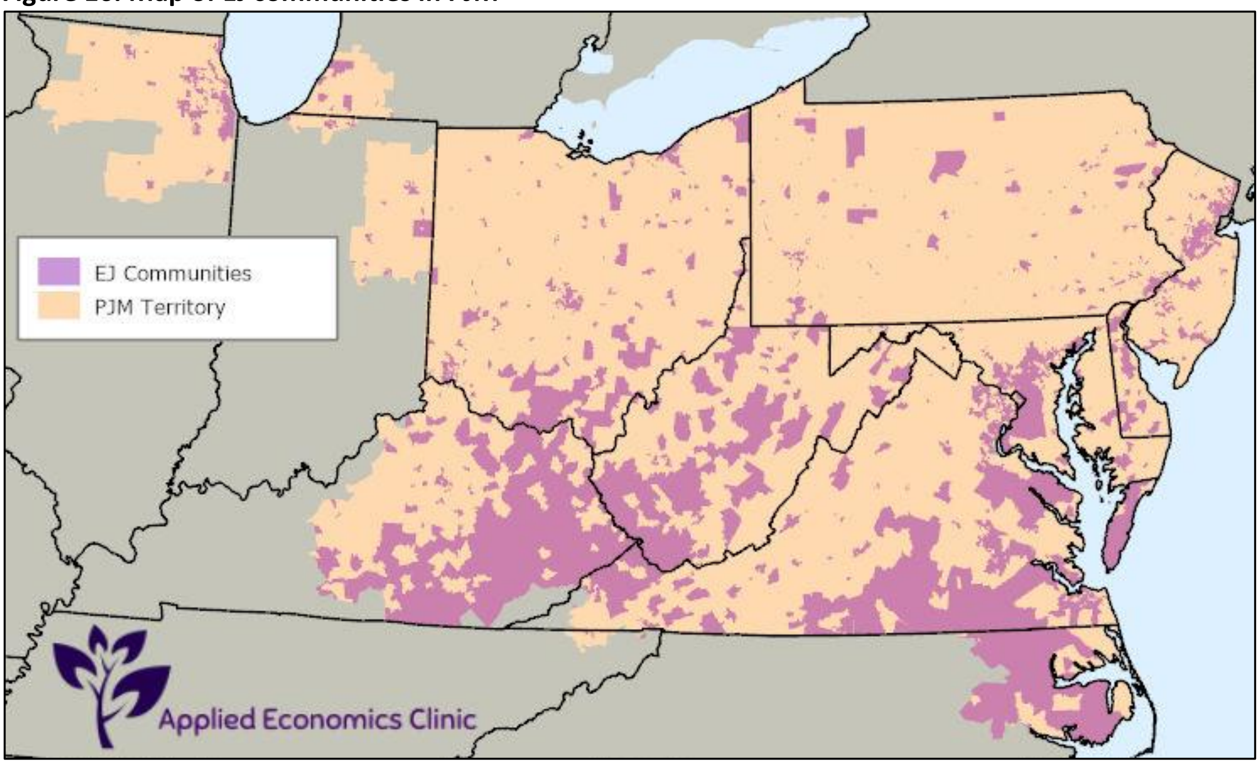
Appendix C – EJ Mapping

Definitions of EJ communities vary, with some states creating their own definition using a range of different demographic criteria that are typically based on race/ethnicity, income, and/or language. For consistency, AEC identified EJ communities in PJM by applying Pennsylvania's EJ definition to U.S. Census tracts in all PJM states. In this analysis, communities qualify as EJ if they meet at least one of the following criteria:

- 20 percent or more of the population lives at or below the federal poverty line; and/or
- 30 percent or more of the population identifies as a race other than white. [61]

Figure 16 displays all of the EJ census tracts in PJM (in purple) based on this definition.

Figure 16. Map of EJ communities in PJM



To draw this map and perform the EJ and other spatial analysis in this report, AEC created a GIS layer for EJ communities using data on income and race from the U.S. Census' 2019 ACS 5-year estimates[62] and identifying tracts that meet either of the criteria above.

Using GIS software, the locations of existing and proposed fossil fuel plants were mapped based on the

[61] PA DEP. n.d. "PA Environmental Justice Areas." Available at: https://www.dep.pa.gov/PublicParticipation/OfficeofEnvironmentalJustice/Pages/PA-Environmental-Justice-Areas.aspx
[62] U.S. Census. 2019. *ACS 5-Year Estimated Detailed Tables [Tables: B02001, S1701]*.

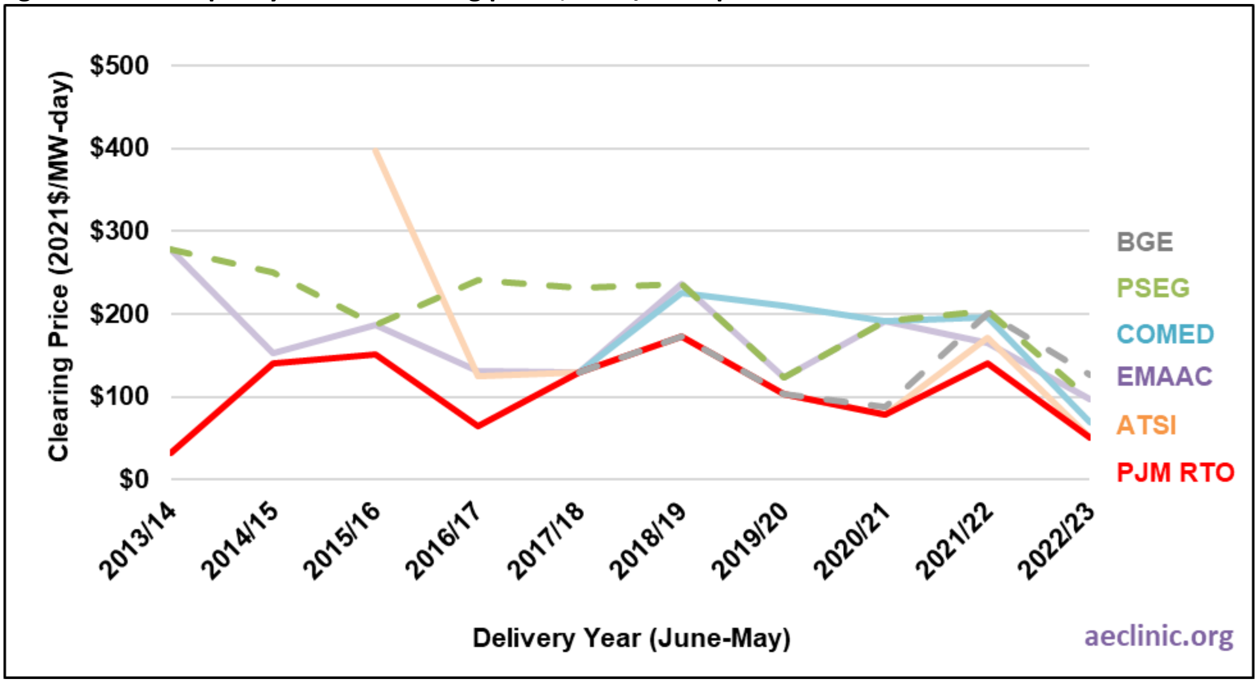
coordinates listed in EIA data.[63] PJM's 1,193 gas- and coal-fired generating units in 2017 account for 383 power plants. (Some plants contain several units.) Out of the 383 proposed and existing gas- and coal-fired plants in PJM, 5 plants (i.e., 10 units) were not included in this EJ analysis because the EIA-provided coordinates placed them (erroneously) outside of PJM boundaries.

For each plant, the distance to the nearest EJ community was calculated.[64] Using these distances, AEC calculated the number and capacity of generators located inside EJ communities and within particular distance bands. For the close-up look at Vicinity Energy, a gas-fired power plant in New Jersey, in Section II the number of schools within one-mile of the plant was also calculated using GIS data.[65]

[63] U.S. EIA. 2017. "Form EIA-860 Data: Plants and Operable Generators." Available at: https://www.eia.gov/electricity/data/eia860/
[64] Due to the large area and multiple states that PJM includes, the projected coordinate system used in the GIS software was NAD 1983 UTM Zone 17N, which is located roughly in the center of PJM.
[65] Shapefiles for K-12 schools were sourced from: (1) Commonwealth of Pennsylvania. 2017. Public and private education institutions 2017. Available at: https://data.pa.gov/K-12-Education/Public-and-Private-Education-Institutions-2017-Cur/a5nq-sy2w; (2) NJGIN Open Data. 2019. School point locations of NJ (public, private, and charter). Available at: https://njogis-newjersey.opendata.arcgis.com/datasets/newjersey::school-point-locations-of-nj-public-private-and-charter/about

Appendix D – Additional Historical Data[66]

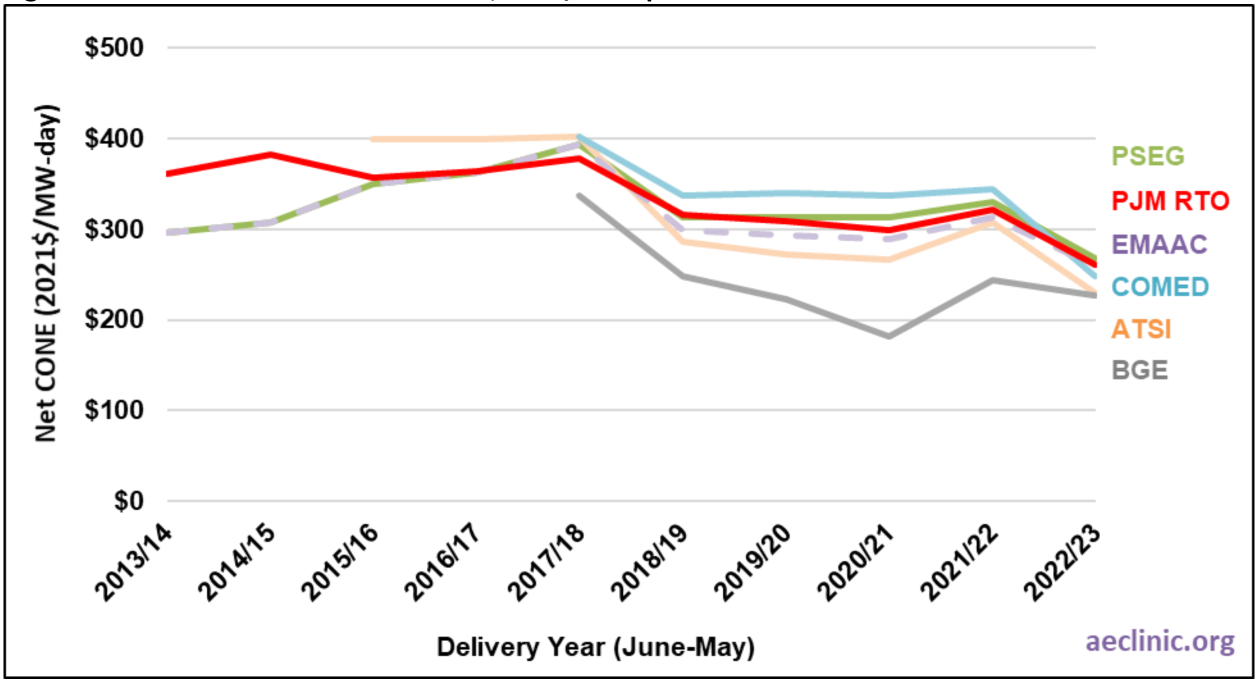
Figure 17. PJM capacity auction clearing prices, 2013/14 to present



Sources: PJM. 2013-2021. "Base Residual Auction Results." Available at: https://www.pjm.com/markets-and-operations/rpm.aspx

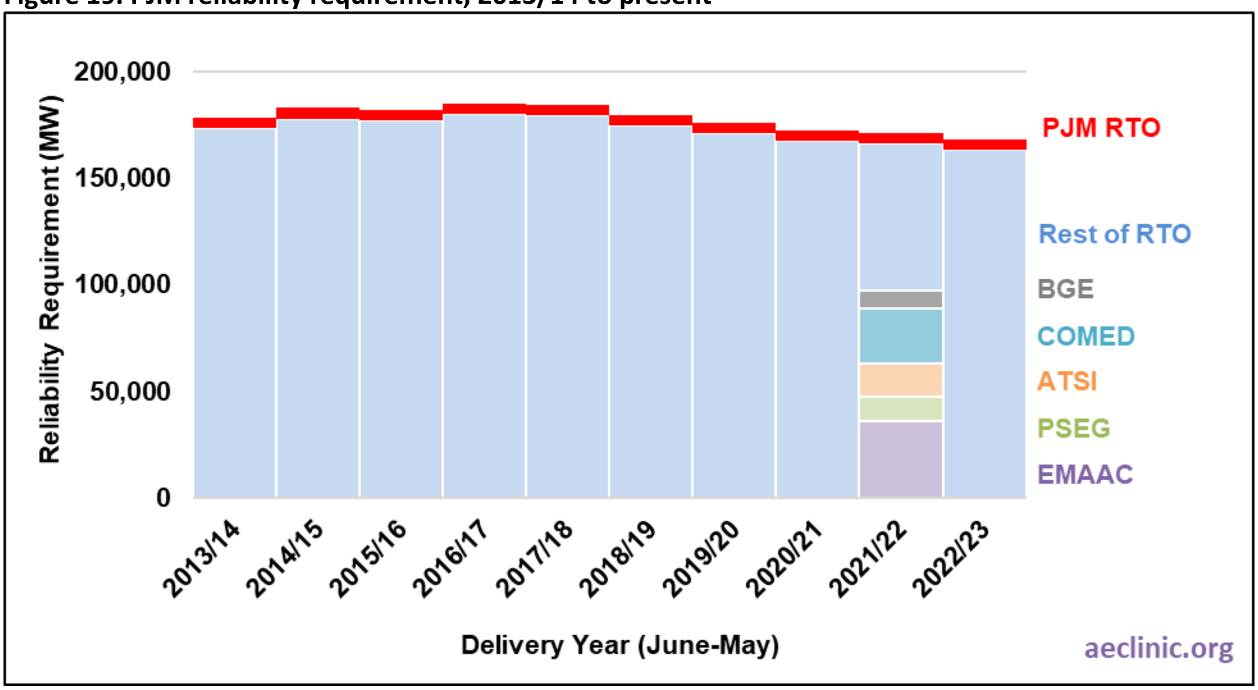
[66] PJM's capacity auctions assume dollar values to be in the same year as the auction's delivery year (i.e., 2021 dollars for the 2021/22 auction and 2022 dollars for the 2022/23 auction). Dollar values from the 2013/14 through 2020/21 auctions are presented in 2021$, converted (when necessary) using the CPI-U. For the purposes of these graphs, we make a simplifying assumption and treat 2021$ and 2022$ as equivalent in real terms.

Figure 18. PJM administrative Net CONE, 2013/14 to present



Sources: PJM. 2013-2021. "Planning Period Parameters for Base Residual Auction." Available at: https://www.pjm.com/markets-and-operations/rpm.aspx

Figure 19. PJM reliability requirement, 2013/14 to present



Sources: PJM. 2013-2021. "Planning Period Parameters for Base Residual Auction." Available at: https://www.pjm.com/markets-and-operations/rpm.aspx

Appendix E – Section II Citations

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