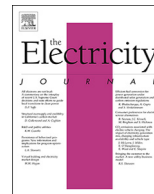




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Impacts of the retirement of the Beaver Valley and Three Mile Island nuclear power plants on capacity and energy prices in Pennsylvania

Seth Blumsack

Energy Policy and Economics, John and Willie Leone Family Department of Energy and Mineral Engineering, Pennsylvania State University, State College, PA, United States

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ABSTRACT

Low electric energy prices in the PJM market are financially threatening some of Pennsylvania's nuclear power plants. An analysis of capacity and energy markets with and without two of Pennsylvania's most economically threatened nuclear power stations suggests that the retirement of these plants will not materially raise energy costs for Pennsylvania ratepayers. In the near term, the pace of investment in efficient generation capacity will be the more important factor affecting the state's electricity costs.

1. Introduction

As the cost of natural gas has fallen, clearing prices in wholesale power markets in many portions of the U.S. have declined, putting some plants in difficult financial situations and forcing a number of retirements. A recent report from the PJM Independent Market Monitor has identified four nuclear power plants in particular that are financially threatened by sustained low clearing prices for electric energy.¹ The PJM market, however, generally has adequate capacity, with recent capacity auctions clearing at quantities above PJM's installed capacity margins.

This paper summarizes analysis of the potential impacts of nuclear power plant retirement decisions in Pennsylvania on prevailing capacity and energy prices in markets run by the PJM Interconnection, with specific attention to impacts on energy bills paid by Pennsylvania ratepayers. The specific nuclear retirements modeled in this analysis include Units 1 and 2 at the Beaver Valley nuclear station outside of Pittsburgh (1834 MW capacity total) and the one remaining operational unit at the Three Mile Island nuclear station near Harrisburg (803 MW capacity). These two plants represent 27% of the nuclear generation capacity in Pennsylvania, and 6% of total electric generation capacity in Pennsylvania. The owners of Three Mile Island have already announced that the plant will retire from service in 2019 after failing to clear the PJM capacity auction (base residual auction, or BRA) for the 2020/21 delivery year.² While Beaver Valley has not announced any firm plans to retire

(and the plant has continued to clear in the PJM BRA through the 2020/21 delivery year), it is viewed as under a greater economic threat than other nuclear power plants in Pennsylvania because of its location in a less-constrained portion of the PJM grid where energy prices are generally lower. It is worth noting that FirstEnergy, the owner of the Beaver Valley plant, has announced plans to either sell or retire the plant.³ Pennsylvania's other nuclear power plants (Limerick, Peach Bottom, and Susquehanna) are under the same economic pressures as Beaver Valley and Three Mile Island, but the owners of those plants have not given any public indication of intentions to take the plants out of service.

A basic principle of economics is that when supply is removed from the market, prices will rise. Indeed, holding all other changes in the PJM generation mix constant the retirement of nuclear power supplies would be expected to increase market prices in PJM. A recent study modeling nuclear retirements concluded that if all five nuclear power stations in Pennsylvania were to retire simultaneously, capacity and energy prices in Pennsylvania would increase by an average of \$4.78 per MWh because not all lost capacity would be economically replaced.⁴ A follow-on analysis concluded that announced nuclear plant retirements in Ohio and Pennsylvania would increase costs to Pennsylvania ratepayers by \$285 million.⁵ The analysis in this report also finds that capacity and energy prices would increase only in the case where Beaver Valley and Three Mile Island were to shut down without replacement. The reality in the PJM market, however, is that gas-fired

E-mail address: sethb@psu.edu.

¹ Monitoring Analytics, "2017 State of the Market Report," available at http://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2017.shtml.

² "Exelon to Retire Three Mile Island Generating Station in 2019," Exelon Corporation press release, May 30 2017.

³ "Beaver Valley hangs in the balance of nuclear subsidy efforts in two states," *Pittsburgh Post-Gazette*, March 6, 2017.

⁴ This is the finding of Mark Berkman and Dean Murphy, "Pennsylvania Nuclear Power Plants' Contribution to the State Economy," December 2016. The analysis in the Brattle report appears to combine the capacity and energy market impacts into a single electricity cost increase figure.

⁵ Mark Berkman and Dean Murphy, "Impacts of Announced Nuclear Retirements in Ohio and Pennsylvania," April 2018.

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generation capacity is expanding at the same time that nuclear capacity faces economic challenges. The net impact on electricity costs in Pennsylvania thus depends on the pace at which gas-fired capacity enters the market as nuclear capacity is exiting the market. While future market outcomes are uncertain, this paper illustrates the impacts of different gas generation build scenarios on ameliorating the impacts of nuclear retirements.

The present paper provides an analysis of the impacts of the Beaver Valley and Three Mile Island retirements on market outcomes in the PJM base residual auction and the real-time energy market, using capacity and energy market models that are non-proprietary and data that is entirely within the public domain. This analysis comes to a different conclusion than does previous work regarding the market price impacts of nuclear retirements in Pennsylvania. Specifically, this study concludes that because the PJM market as a whole is so long on other low-cost generating resources, even the retirement of two large nuclear generating stations in Pennsylvania is unlikely to have a material impact on electricity costs. Instead, this analysis concludes that the pace of new gas-generation investment is a much more important determinant of energy and capacity market outcomes in the near term.

The modeling approach taken here is to simulate market-clearing outcomes in the base residual auction and real-time energy market with and without the Beaver Valley and Three Mile Island power stations under different scenarios for the coincident expansion of the gas-fired generation fleet in Pennsylvania. The approach taken here is different from some other models such as ReEDS or Xpand in being more scenario-based, but the scenarios defined here represent a reasonable range of outcomes. The aggressive gas expansion scenarios are consistent with the pattern of recent gas generation investment in the PJM region.

This paper's discussion is limited to modeled outcomes in the PJM base residual auction and energy markets. It does not address any environmental or fuel-security implications associated with a shift in the PJM generation mix,⁶ nor to quantify specific implications of nuclear retirements or increased activity in the natural gas market for Pennsylvania's economy or state government revenues.

2. Capacity market modeling and impacts of nuclear power plant retirement

The modeling approach taken here is to build a representative capacity supply curve using three different base residual auction clearings, and then to simulate nuclear retirements and new gas generation additions as shifts in different parts of the supply curve. This simulated capacity supply curve is then cleared against the variable resource requirement (VRR) curve for each base residual auction to determine the RTO-wide capacity price. Such an approach is taken here because data on unit-specific clearing in the capacity market is not made public, so it is not possible to build a capacity supply curve using unit-specific information.

The capacity supply curve is built using several pieces of public information that determine the overall shape of the supply curve. The method is illustrated using the 2018/19 base residual auction supply curve shown in Fig. 1. The information used to build the capacity

⁶ If nuclear capacity, which is carbon-free, is replaced with inframarginal natural gas capacity, then a reasonable expectation is that overall annual carbon dioxide emissions in PJM might increase. This is the finding of the Berkman and Murphy study cited above, as well as James Richards and Wesley Cole, "Assessing the impact of nuclear retirements on the U.S. power sector," *Electricity Journal*, 30:9 (2017). The carbon impact, however, will depend on a number of factors, including transmission constraints, dispatch protocols and other generation investments aside from natural gas. See Chen-Hao Tsai and Gurcan Gulen, "Are zero emission credits the right rationale for saving economically challenged U.S. nuclear plants?" *Electricity Journal* 30:6 (2017), which suggests a lower overall carbon impact than Berkman and Murphy.

supply curve for each year is taken from PJM's report on each base residual auction⁷ and the Independent Market Monitor analysis of each base residual auction where available.⁸

- The amount of capacity offered into the base residual auction at \$35/MW-day or less (point a in Fig. 1); this analysis assumes that the supply curve is an upward sloping line between the origin and this point.
- The clearing price and quantity based on a sensitivity where 6000 MW is added from the bottom of the supply curve (point b in Fig. 1).
- The prevailing clearing price and quantity (point c in Fig. 1).
- The clearing price and quantity based on a sensitivity where 6000 MW is removed from the bottom of the supply curve (point d in Fig. 1).
- The maximum supply offer submitted into the base residual auction (point e in Fig. 1).

The capacity market model in Fig. 1 is developed for three delivery years (2018/19, 2019/20, and 2020/21), and is used to model the impact of nuclear retirements and gas-fired capacity additions on the clearing price and clearing quantity in for each of the three delivery years.⁹ In these simulations both Beaver Valley and Three Mile Island are assumed to retire simultaneously. The gas-fired generation scenarios examined in this report are:

- A scenario where Beaver Valley and Three Mile Island retire and are not replaced by any new capacity. This is consistent with recent analysis from the Brattle Group, but with fewer gross nuclear power plant retirements.¹⁰
- A scenario where Beaver Valley and Three Mile Island retire and are replaced by an equal amount of gas-fired generation capacity offering into the base residual auction. The net new gas capacity that clears the base residual auction is assumed to submit offers of \$50-70/MW-day into the base residual auction.
- A scenario where Beaver Valley and Three Mile Island retire and are replaced by an equal amount of gas-fired generation capacity plus 6000 additional MW of gas-fired capacity offering into the base residual auction. The net new gas capacity that clears the base residual auction is assumed to submit offers of \$50-70/MW-day into the base residual auction.

Not all gas generation capacity is assumed to clear the base residual auction. The fraction of new gas capacity that does not clear is calculated based on the fraction of new capacity not clearing the base residual auction that is published in PJM's annual capacity market

⁷ These are available for each delivery year at <http://pjm.com/markets-and-operations/rpm.aspx>.

⁸ The IMM report for the 2018/19 delivery year, "Analysis of the 2018/19 Base Residual Auction," is available at http://monitoringanalytics.com/reports/Reports/2016/IMM_Analysis_of_the_20182019_RPM_Base_Residual_Auction_20160706.pdf.

⁹ As this analysis was being completed, the base residual auction for delivery year 2021/22 was completed, with some zones clearing at substantially higher prices than in the previous two capacity auctions, and new gas generation capacity offered into the auction was also lower than in previous capacity auctions. The outcome here is a natural market reaction to low prices for both energy and capacity. It is difficult to evaluate how the retirement of Beaver Valley and Three Mile Island would have affected capacity outcomes for the 2021/22 delivery year, since neither appears to have cleared for that particular delivery year.

¹⁰ The Brattle Group's 2016 modeling of nuclear retirements in Pennsylvania concludes that approximately 75% of lost nuclear capacity would be replaced with a mix of new generation and avoided retirements. This is roughly equivalent to Beaver Valley and Three Mile Island being retired without replacement.

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