April 5, 2019

The Market and Financial Position of Nuclear Resources in Pennsylvania

Paul M. Sotkiewicz, Ph.D., President and Founder
E-CUBED POLICY ASSOCIATES, LLC

The Market and Financial Position of Nuclear Resources in Pennsylvania

Paul M. Sotkiewicz, Ph.D., President and Founder
E-CUBED POLICY ASSOCIATES, LLC

Policymakers throughout the United States are undertaking discussions and impactful decisions about the financial viability of nuclear power plants. Pennsylvania is no different, with Three Mile Island and Beaver Valley both having announced closures and plant owners seeking out of market, ratepayer subsidies enacted by the Pennsylvania General Assembly.

A lynchpin of the nuclear power plant owners' argument is that Pennsylvania's nuclear industry is in financial distress, and deserving of additional economic support from ratepayers. However, based on publicly available data, four of Pennsylvania's five nuclear plants are profitable. As detailed in the *Market and Financial Position of Nuclear Resources in Pennsylvania* report, with the exception of Three Mile Island, all four plants are projected to remain highly profitable through at least 2028.

Pennsylvania's five nuclear plants are comprised of nine reactors. Eight of these nine reactors are making money. The lone exception is the single reactor at Three Mile Island, which is losing money, and projected to continue losing money moving forward if it remains in operation.

This 10-year outlook shows that PA's nuclear power generators are projected to make more than $3.4 billion in profits through 2028. Should TMI continue to operate at a loss for that same 10-year time period, the total industry profits over ten years would be $2.9 billion.

The profit outlook for individual plants is as follows:

- Beaver Valley - $624 million
- Peach Bottom - $633 million
- Limerick - $1.5 billion
- Susquehanna - $631 million
- TMI - -$466 million

These projections indicate that the nuclear industry as a whole is not in financial distress and therefore there is no need to implement state specific market reforms or ratepayer subsidies.

In addition to the profitability of Pennsylvania's nuclear power plants, the structure of our competitive wholesale electricity markets is saving consumers billions of dollars each year. The type of state-by-state, industry-specific subsidies being considered in Pennsylvania would erode those cost savings. The addition of subsidies would burden consumers with additional costs with no benefit, since the nuclear power resources will not rationally retire given the at least 10-year profit projections previously established above.

Not only are competitive markets working for consumers, they are working for power generators in Pennsylvania as well. Many nuclear power resources in Pennsylvania's fleet have generating costs below the national average, operate at high capacity factors, and have seen declining costs in recent years. This is driven by the market structure which requires participants to behave competitively in order to remain profitable.

In conclusion, the proponents of out of market nuclear subsidies point to several arguments in support, including the fact that preventing retirements of nuclear power will keep prices down, will avoid carbon emissions, prevent job losses, and maintain local tax revenue. However, these arguments all accept the presumption that all nuclear plants will close. As demonstrated in this report, that assumption is premature at best, given the financial viability of every nuclear plant in Pennsylvania with the exception of Three Mile Island which is only a small, single reactor.

Table of Contents

List of Tables

The Market and Financial Position of Nuclear Resources in Pennsylvania

Prepared by Paul M. Sotkiewicz, Ph.D.
President and Founder, E-Cubed Policy Associates, LLC

EXECUTIVE SUMMARY: KEY FINDINGS AND CONCLUSIONS

Nuclear Facilities in Pennsylvania Can Easily Cover Their Going Forward/Avoidable Costs through 2028 and Should Not Rationally Retire

Publicly available fuel and going forward/avoidable cost data indicates Pennsylvania nuclear unit costs, expressed on a $/MWh basis, that range from a low of $24.62/MWh for Limerick 1 in the PECO Zone in the EMAAC LDA in eastern Pennsylvania to $30.05/MWh for Beaver Valley 1 in the ATSI LDA in northwest Pennsylvania.[1] Overall, the going forward costs for six of the nine operating nuclear units in Pennsylvania are at or below the industry average, with Three Mile Island 1 and Beaver Valley 1 and 2 having costs well above average. The net annual unit operating profits looking into the future on average over the 2019 to 2028 period are $9.22/MWh, or nearly $73 million per year for a 1000 MW unit operating at a 90 percent capacity factor. Absent any unknown need for major investments or repairs at these units, there is no reason for the Pennsylvania nuclear units, except for Three Mile Island, to retire because they are profitable on an operating basis.

---

[1] For going forward costs see, United States Environmental Protection Agency ("US EPA"), *Documentation for EPA's Power Sector Modeling Platform v6 Using the Integrated Planning Model*, May 2018. Available online at https://www.epa.gov/sites/production/files/2018-08/documents/epa_platform_v6_documentation_-_all_chapters_august_23_2018_updated_table_6-2.pdf. Chapter 4, Generation Resources, Table 4-47 Characteristics of Existing Nuclear Units, available as a spreadsheet at https://www.epa.gov/sites/production/files/2018-05/table_4-47_characteristics_of_existing_nuclear_units_in_epa_platform_v6.xlsx. ("IPM v6 Table 4-47"). For Fuel costs *See also* Sargent & Lundy, *IPM Model – Nuclear Power Plant Costs, Nuclear Power Plant Life Extension Cost Development Methodology-Final*, at 4-6 to 4-7. Available at https://www.epa.gov/sites/production/files/2018-05/documents/attachment_4-1_nuclear_power_plant_life_extension_cost_development_methodology_1.pdf. To derive the cost per MWh, the average capacity factor using output from EIA 923 data from 2015-2018 was used. EIA-923 data can be found at https://www.eia.gov/electricity/data/eia923/.

Out-of-Market Financial Support to Profitable Pennsylvania Nuclear Only Raises Consumer Rates and Increases Nuclear Owner Profits and Does Not Lead to Avoided Emissions.

First, because eight of the nine nuclear units are operating profitably in covering their going forward and avoidable costs, there is no rational economic reason for them to retire. Retiring would lead to losses if there are any sunk costs that have not yet been recovered through the market. And since these profitable nuclear units would not be rationally retiring in any case, there are no additional avoided emissions benefits. However, Tier III Alternative Energy Credit (AEC) payments as envisioned by the Pennsylvania House Nuclear Bailout Bill would lead to rate increases of anywhere from \$3.04/MWh to \$3.95/MWh. Or for a typical household using 1000 kWh/month, the bill would go up \$3.04-\$3.95/month.

Out-of-Market Financial Support for Pennsylvania Nuclear Facilities Would Wipe Out the Cost Savings From Participating in PJM's Markets.

According to PJM, its markets save consumers in the PJM footprint about \$2.3 billion annually. This translates to a savings of approximately \$2.85/MWh, with a PJM administrative cost of \$0.32/MWh, for a cost-benefit ratio of about 8.9-to-1 in 2018.[2] But the potential \$3.04-\$3.95/MWh charge to load for Tier III AECs or similar financial support would more than offset these benefits to Pennsylvania customers. These are just additional costs that need not be incurred because the public data indicates that these costs would simply be additional costs to Pennsylvania customers without any corresponding benefit given these nuclear resources would not rationally retire.

PJM's Wholesale Energy and Capacity Markets Are Not "Broken"

---

[2] PJM Interconnection, LLC, *The Value of Markets*, at 2. Available at https://www.pjm.com/-/media/about-pjm/newsroom/fact-sheets/the-value-of-pjm-markets.ashx. PJM states it saves \$2.3 billion per year due to its operations. With projected PJM total energy of 806,725 GWh as shown in the PJM 2018 Load Forecast Report Data, this comes out to \$2.85/MWh. PJM's administrative cost can be found in the monthly Markets Report presented to the Members Committee. The most recent report can be found at https://pjm.com/-/media/committees-groups/committees/mc/20181022-webinar/20181022-item-07a-markets-report.ashx?la=en.

PJM's wholesale energy and capacity markets reflect underlying market conditions. Whether it is slowing or flat load growth, the presence of low-cost Marcellus Shale gas, rapidly improving efficiency and cost profiles for combined cycle gas units, or innovation in bringing an active demand side into the market, energy and capacity prices reflect these underlying fundamentals. With a healthy reserve margin above the target reserve margin, attracting new entry from new efficient and low-cost resources, and no major reliability events and simply relatively low prices, the PJM market remains highly successful. And the forward-looking prices in this market indicate that Pennsylvania nuclear resources will remain profitable on an operating basis more than covering their going forward costs.

The bottom line is Pennsylvania nuclear resources are profitable on an operating basis and have no incentives to retire for the foreseeable future, and there is no need for additional out-of-market financial support.

I. INTRODUCTION AND PURPOSE

Much attention has been given in recent years to the financial condition and viability of the nuclear fleet in U.S. wholesale power markets. Nuclear resources have lower fuel costs than traditional and new advanced fossil resources, yet they also have extremely high fixed operation and maintenance ("O&M") costs compared to fossil resources and renewable resources. These high fixed costs are considered going forward or avoidable costs and must be incurred to keep the nuclear resource in commercial operation and can only be avoided if the nuclear resource decides to retire. Furthermore, some nuclear resources may have additional investments they must make to make major overhauls or repairs to safely operate and remain in commercial operation.

At the same time, underlying market fundamentals have changed in the last decade. Power demand is growing only slowly in some regions, while in other regions it has been flat or declining. New shale gas fields have ramped up production of low-cost natural gas, and at the same time combined cycle gas efficiencies have increased while installed and fixed, going forward costs of combined cycle gas have declined and these new resources are entering power markets, especially the PJM market and, along with the flat demand, are driving prices lower in an efficient and competitive manner.

An additional layer of complexity and discussion has been introduced as climate change and the need to reduce carbon dioxide emissions to mitigate climate change have entered the calculus. Nuclear resources provide a zero-carbon dioxide source of energy in operation, and there is a strong desire on the part of some state policymakers to advance lower-emitting resources in the absence of concerted action on climate change at the federal level.

The combination of high costs of keeping nuclear resources in commercial operation, along with the competitiveness of new gas technologies and flat or slow demand growth, has been financially challenging for many nuclear resources, with owners of nuclear units threatening to retire resources due to these financial strains unless they can receive some other form of financial support from states.[3] The provision of financial support has already been provided in

Illinois[4] and is undergoing consideration in New Jersey[5] in the PJM region. Financial support has also been provided in New York[6] and recently Connecticut in the ISO New England market.[7]

The rationales for financial support to keep nuclear resources in operation range from the idea that keeping these resources in operation will keep power prices down and will help avoid additional carbon dioxide emissions to local job, tax base and economic considerations. Yet these rationales are placing the cart before the horse. It is simply assumed that the resources receiving the out-of-market financial support would in fact retire and are not financially viable. In almost all cases in the PJM market, this is not true according to the data.[8]

---

[3] For example, see Steve Daniels, "Exelon threatens closure of three more Illinois nukes," *Crain's Chicago Business*, February 12, 2019. Available at https://www.chicagobusiness.com/utilities/exelon-threatens-closure-three-more-illinois-nukes. See also Tom Johnson, "PSEG Affirms It Will Shut Down Nuclear Plants Unless It Gets Big Subsidies," *NJ Spotlight,* October 5, 2018. Available at https://www.njspotlight.com/stories/18/10/04/pseg-affirms-it-will-shut-down-nuclear-plants-unless-it-gets-big-subsidies/.

[4] Illinois General Assembly, Public Act 99-0906 ("Future Energy Jobs Act" or "FEJA"), November 30, 2016, available online at http://www.ilga.gov/legislation/publicacts/99/PDF/099-0906.pdf. The FEJA was signed into law by Governor Bruce Rauner on December 7, 2016.

[5] *See* New Jersey Board of Public Utilities, BPU Docket No. EO18080899 for a discussion of Zero Emissions Credits. Legislative language can be found at https://www.njleg.state.nj.us/2018/Bills/S2500/2313_I1.HTM.

[6] State of New York Public Service Commission, *Order Adopting Clean Energy Standard,* Case 15-E-0302 *Proceeding on Motion of the Commission to Implement a Large-Scale Renewable Program and a Clean Energy Standard* and Case 16-E-0270, *Petition of Constellation Energy Nuclear Group LLC; R.E. Ginna Nuclear Power Plant, LLC; and Nine Mile Point Nuclear Station, LLC to Initiate a Proceeding to Establish the Facility Costs for the R.E. Ginna and Nine Mile Point Nuclear Power Plants*, August 1, 2016. Available at http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7b44C5D5B8-14C3-4F32-8399-F5487D6D8FE8%7d.

[7] Peter Maloney, "Connecticut passes bill to support Dominion's Millstone nuclear plant", *Utility Dive,* October 26, 2017. Available at https://www.utilitydive.com/news/connecticut-passes-bill-to-support-dominions-millstone-nuclear-plant/508280/. See also the discussion of whether the Millstone facility is profitable, Michael Kuser, "Conn. Regulators Signal Support for Millstone," *RTO Insider*, January 22, 2018. The final notice Millstone could receive subsidies was in December 2018. See Stephen Singer, "Connecticut commits to nuclear power, ending debate over Millstone's future," *Hartford Courant,* December 28, 2018. Available at https://www.courant.com/business/hc-biz-millstone-state-auctions-20181228-ikwxhrmvsfa5phpygwnb7vbfcq-story.html.

[8] For example, see *Prepared Comments of Paul M. Sotkiewicz, Ph.D.*, On behalf of the PJM Power Providers Group, *In the Matter of the Implementation of L. 2018, c. 16 Regarding the Establishment of a*

Indeed, there have been some nuclear retirements in other parts of the country outside of RTO markets, many due to other circumstances that would have substantially increased costs,[9] but also there remains a large segment of the nuclear fleet that has lower fixed going forward costs and is in locations with favorable market designs such as in PJM with robust energy and capacity markets. As it turns out, nuclear resources in Pennsylvania are well positioned in the market, and they are projected to remain profitable on an operating basis because they are generally lower cost and/or are well situated in the market to receive higher revenues. That is, these resources can cover their fuel and going forward costs and have substantial operating margins to cover any remaining sunk costs plus returns on investment.

The purpose of this analysis is to show that Pennsylvania nuclear resources: 1) historically have been able to cover the fixed going forward costs and have margins that contribute toward recovery of sunk costs plus a return on investment; and 2) on a going forward basis over the next 10 years are projected to remain profitable with their ability to cover fixed, going forward costs. The bottom line is that Pennsylvania nuclear resources are not in danger of retiring anytime soon, and that retiring such resources would not simply be economically irrational but financially harm the shareholders of the companies owning these assets.

II. ORGANIZATION

The overall organization of this analysis is to examine the underlying costs and historic performance of the Pennsylvania nuclear resources from 2015 through 2018 to provide a snapshot of profitability on a historic basis. This discussion is then followed up by setting the stage for the forward-looking analysis by looking at forward prices for energy and for capacity as a measure of the expected underlying market fundamentals that will drive pricing in the

Zero Emission Certificate Program for Eligible Nuclear Power Plants, BPU Docket No. EO18080899, October 22, 2018.

[9] Crystal River 3 in Florida was undergoing a steam generator retrofit with the containment structure being damaged. See https://www.nrc.gov/info-finder/decommissioning/power-reactor/cr3.html. San Onofre Nuclear Generating Station (SONGS) replacement steam generators had issues after replacement steam generators showed 15,000 tube leaks in 3,000 steam tubes lead to a radioactive release. See Gregory B. Jaczko (5 July 2012). "Letter to The Honorable Dianne Feinstein" (PDF). NRC. Available at https://www.nrc.gov/reading-rm/doc-collections/congress-docs/correspondence/2012/feinstein-07-05-2012.pdf. Fort Calhoun in Nebraska had a series of problems that started with river flooding and a major incident that eventually led to its shutdown.

future. The final stage of the analysis then derives the projected profitability on an operating basis for each of the Pennsylvania nuclear resources. The presentation of the results for projections out to 2028 is then followed by a discussion that places the results of the analysis into a broader economic context on retirement decisions and the role of competitive markets.

Section III provides the underlying costs and historic performance of the Pennsylvania nuclear resources from 2015 through 2018. This section shows that many of the nuclear resources have costs below the national average, and that these resources uniformly have operated at very high capacity factors. Furthermore, this section also demonstrates how fixed, going forward costs have declined in recent years showing that Pennsylvania nuclear resources are behaving competitively to remain profitable.

Section IV provides the historic operating margins for the Pennsylvania nuclear fleet from 2015 through 2018 based on actual historic energy and capacity market prices, as well as the costs shown in Section III. Historically, these resources have operated profitably due to the combination of energy and capacity market revenues.

Section V provides a snapshot of projected energy and capacity prices based on cleared PJM RPM auctions and the forward curves for power at the PJM Western Hub and adjusted for historical basis from PJM Western Hub to each of the nuclear resource generator busses.

Section VI shows the projected operating profitability for each of the Pennsylvania nuclear resources in terms of total dollars and in terms of $/MWh. This section shows that there is no reason for any of these nuclear resources, but for Three Mile Island, to retire based upon known fixed going forward costs.

Sections VII and VIII provide broader economic and policy context for the results shown in the previous sections. Section VII focuses on the economics behind the retirement or go forward decisions faced by generation resources. This section also provides context surrounding the difference between going forward costs and sunk costs which have already been incurred. Section VIII provides context regarding risks and returns in competitive markets in the context of the results.

Section IX provides a brief analysis of the rate impacts in Pennsylvania from enacting a method of financial support such as ZECs based on implemented legislation and rules in Illinois and those under discussion in New Jersey.

III. UNDERLYING COSTS AND HISTORIC PERFORMANCE

The costs and performance of nuclear units is a major determinant of the ultimate competitiveness and profitability of nuclear resources. The more often a resource operates, the more profitable it will be. There are two measures of performance. One is the capacity factor, which is an indicator of how much energy a resource produces relative to its potential output over all hours of the year based on its capacity. The other is the equivalent forced outage rate under demand (EFORd), which is an indicator of how often a resource is unavailable when needed to produce energy. Table 1 shows the capacity, capacity factor and forced outage rates of the Pennsylvania nuclear units. Over 2015-18 these resources operated at high capacity factors and with low forced outage rates.

Table 1: Pennsylvania Nuclear Unit Nameplate Capacity, Capacity Factor (2015-18) and Forced Outage Rate (2015-2018 Average)

	Beaver Valley 1	Beaver Valley 2	Peach Bottom 2	Peach Bottom 3	Limerick 1	Limerick 2	TMI	Susquehanna 1	Susquehanna 2
Nameplate Capacity (MW)[10]	923.4	923.4	1407	1377	1138.5	1138.5	980	1298	1298

[10] Nameplate capacities come from the United States Energy Information Administration (US EIA) Form 860 available at https://www.eia.gov/electricity/data/eia860/. Nameplate capacities were taken from 2017 data.

[11] Summer capacity is also known as summer net dependable capacity and is used in PJM for determining the capacity value of the resource, along with EFORd, to determine capacity market compensation. This data is taken from United States Environmental Protection Agency (US EPA), *Documentation for EPA's Power Sector Modeling Platform v6 Using the Integrated Planning Model*, May 2018 (IPM v6). Available online at https://www.epa.gov/sites/production/files/2018-08/documents/epa_platform_v6_documentation_-_all_chapters_august_23_2018_updated_table_6-2.pdf. Chapter 4, Generation Resources, Table 4-47 Characteristics of Existing Nuclear Units, available as a spreadsheet at https://www.epa.gov/sites/production/files/2018-05/table_4-47_characteristics_of_existing_nuclear_units_in_epa_platform_v6.xlsx. (IPM v6 Table 4-47). The summer net dependable capacity corresponds to data available in the 2017 EIA 860 data.

Summer Capacity (MW)[11]	907	901	1248.4	1245.4	1119.7	1122.1	805	1247	1247
Capacity Factor (EIA 923)[12]	92.87%	91.58%	87.83%	86.58%	96.34%	94.59%	81.13%	88.27%	90.05%
EFORd[13]	1.18%	1.18%	1.18%	1.18%	1.18%	1.18%	1.18%	1.18%	1.18%

In fact, the PJM nuclear fleet overall operates at a lower forced outage rate than nuclear units overall, according to NERC, which reports the average nuclear unit forced outage rate is 2.71 percent.[14]

Another aspect of nuclear competitiveness is measured by fuel costs and fixed O&M or going forward costs of the resources. Obviously, the lower the costs, the more competitive and more profitable the nuclear units will be in the wholesale market. Table 2 shows the fixed O&M and fuel costs as reported by the United States Environmental Protection Agency (U.S. EPA) in its documentation for the Integrated Planning Model, Version 6, it is currently using to analyze environmental policy outcomes in the power industry.[15]

Table 2: Pennsylvania Nuclear Unit Costs from EPA IPM and Annual Energy Outlook From EIA

---

[12] The capacity factor is equal to the potential maximum output over the entire year divided by the actual output for the year. Maximum output for the year is equal to the number of hours in the year (8760 or 8784 for a leap year) multiplied by the EIA 860 nameplate capacity. Net generation for each nuclear unit from 2015 through 2018 comes from the US EIA Form 923 data available at https://www.eia.gov/electricity/data/eia923/.

[13] The EFORd is based upon the four-year average EFORd of all nuclear units in PJM. *See* Monitoring Analytics, Inc, The Independent Market Monitor for PJM (PJM IMM), *2018 State of the Market Report for PJM,* Volume 2 Detailed Analysis, March 8, 2019, (2018 SoM Report) Table 5-31 at 297 for EFORd of 1.4%, 1.9%, 0.6%, 0.8% respectively for 2015 through 2018. Available at http://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2018/2018-som-pjm-sec5.pdf.

[14]North American Electric Reliability Corporation (NERC) Generator attributes Databases System ("GADS") available at https://www.nerc.com/pa/RAPA/gads/Pages/Reports.aspx. The 2013-17 data is available at https://www.nerc.com/pa/RAPA/gads/Reports/Generating%20Unit%20Statistical%20Brochure%204%202013-2017%20-%20All%20Units%20Reporting.xlsx.

[15] US EPA, IPM v6, Table 4-47. According to the IPM documentation the fixed costs reported in Table 4-47 are taken from the Annual Energy Outlook (AEO) published each year by U.S. EIA.

	Beaver Valley 1	Beaver Valley 2	Peach Bottom 2	Peach Bottom 3	Limerick 1	Limerick 2	TMI	Susquehanna 1	Susquehanna 2
Fixed O&M (2016$/kW-year)[16]	$189.90	$181.18	$163.17	$167.33	$152.78	$149.23	$194.30	$149.71	$154.03
Fuel Cost (2017$/kW-year)[17]	$58.00	$58.00	$58.00	$58.00	$58.00	$58.00	$58.00	$58.00	$58.00
Annual Capital Cost (2017 $/kW-year)[18]	$26.00	$26.00	$26.00	$26.00	$26.00	$26.00	$26.00	$26.00	$26.00
Fixed O&M plus Fuel Costs ($/MWh)	$30.05	$28.88	$25.60	$27.03	$24.62	$24.75	$29.25	$25.94	$25.91
Fixed O&M + Fuel + Capital ($/MWh)	$33.67	$33.05	$32.12	$33.14	$28.06	$28.15	$39.16	$30.23	$30.18
Fuel Cost ($/MWh)[19]	$7.03	$7.00	$6.71	$6.96	$6.77	$6.93	$6.72	$7.24	$7.09
Fixed O&M Cost ($/MWh)[20]	$23.02	$21.88	$18.89	$20.07	$17.85	$17.82	$22.53	$18.70	$18.82
Capital Costs ($/MWh)[21]									

[16] U.S. EPA, IPM v6, Table 4-47, except for TMI, which comes from U.S. EPA, *Documentation for EPA Base Case v. 5.13 Using the Integrated Planning Model* (EPA Base Case v. 5.13), Chapter 4 "Generating Resources," Table 4-34, November 2013. Available electronically at https://www.epa.gov/sites/production/files/2015-07/documents/chapter_4_generating_resources_0.pdf. The entire documentation is electronically available at https://www.epa.gov/airmarkets/power-sector-modeling-platform-v513. Costs in the Base Case v. 5.13 are expressed in 2011 dollars, and for TMI these are assumed to be the same in nominal terms.

[17] For Fuel costs *See also* Sargent & Lundy, *IPM Model – Nuclear Power Plant Costs, Nuclear Power Plant Life Extension Cost Development Methodology-Final*, at 4-6 to 4-7. Available at https://www.epa.gov/sites/production/files/2018-05/documents/attachment_4-1_nuclear_power_plant_life_extension_cost_development_methodology_1.pdf. To derive the cost per MWh, the average capacity factor using output from EIA 860 and EIA 923 data from 2015-18 was used as shown in Table 1.

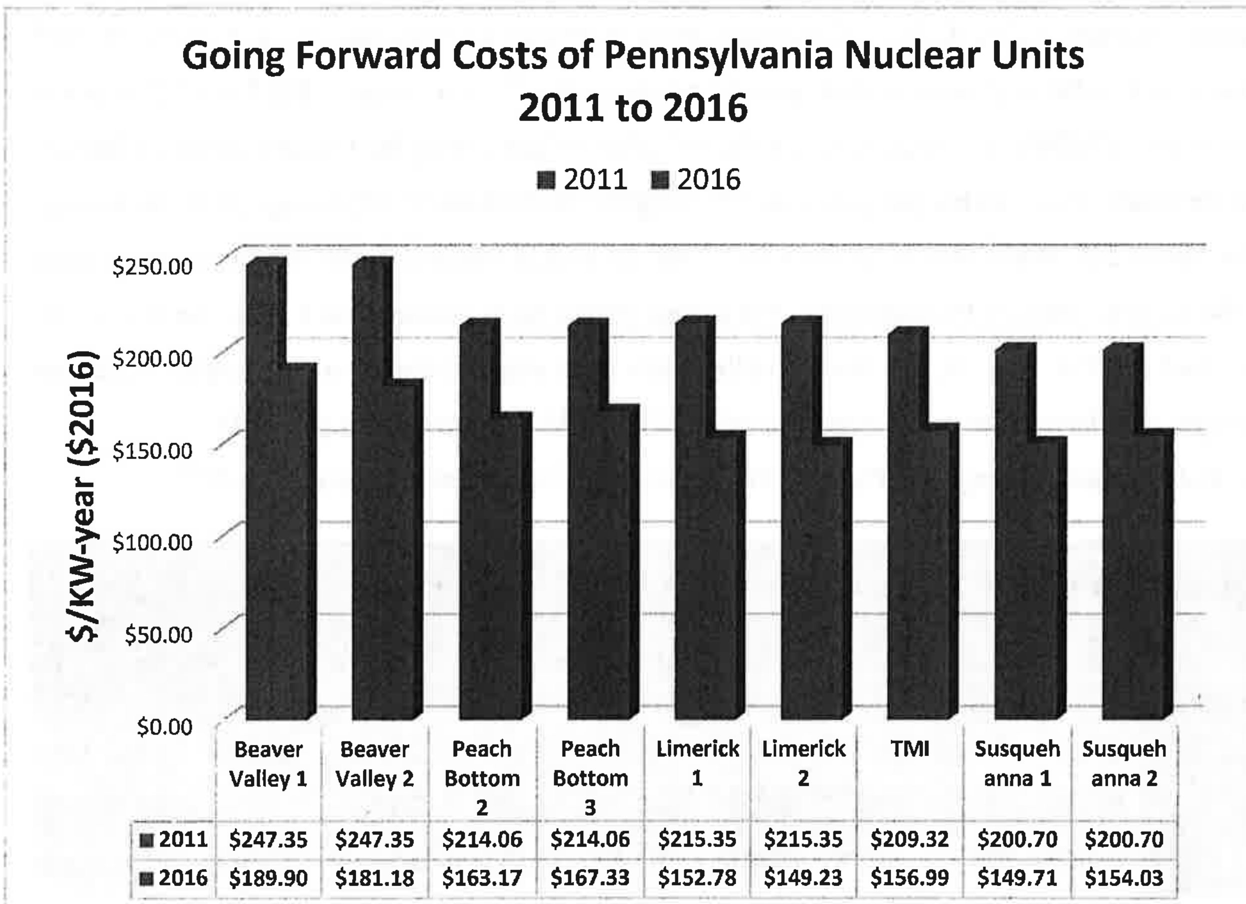
[18] US EIA, *Assumptions to the Annual Energy Outlook 2018, Electricity Market Module,* at 12-13. Available at https://www.eia.gov/outlooks/archive/aeo18/assumptions/pdf/electricity.pdf. This is based upon historical data. EIA also states that it would add $35/kW-year to account for major investments that would go into retirement decisions.

[19] Costs in $/MWh are computed using the historic 2015-18 Capacity factors and nameplate capacity reported in Table 1.

[20] *See supra* Note 19.

For nuclear facilities and in general, the combined fuel and going forward costs of these resources are below the average costs of wholesale market nuclear units as reported by the Nuclear Energy Institute in spite using fuel cost measures that are conservatively high.[24]

Figure 1: Evolution of Going Forward Costs of Pennsylvania Nuclear Units as Reported in the USA IPM Model



	Beaver Valley 1	Beaver Valley 2	Peach Bottom 2	Peach Bottom 3	Limerick 1	Limerick 2	TMI	Susquehanna 1	Susquehanna 2
2011	$247.35	$247.35	$214.06	$214.06	$215.35	$215.35	$209.32	$200.70	$200.70
2016	$189.90	$181.18	$163.17	$167.33	$152.78	$149.23	$156.99	$149.71	$154.03

In fact, over time, the Pennsylvania nuclear resources have seen their going forward costs decline over time as shown by U.S. EPA data in the IPM documentation. In data reported in the 2018 version of IPM, going forward costs have declined on average 25 percent for Pennsylvania nuclear

[24] Nuclear Energy Institute (NEI), *Nuclear Costs in Context,* October 2018 showing for nuclear units operating in wholesale power markets and average going forward cost of $25.29/MWh and fuel costs of $5.74/MWh for a total cost of $31.03/MWh at 2.

resources as shown in **Error! Reference source not found.**, with the exception of TMI.[25] This trend is consistent with that reported by NEI, with cost reduction on average over the entire nuclear fleet of nearly 20 percent.[26]

IV. HISTORIC PROFITABILITY

Generators earn net revenues from operating in the energy market and participating in PJM's capacity market. **Table 4** shows the annual average locational marginal prices (LMPs) for each nuclear unit in Pennsylvania at their specific pricing point.[27] On average in 2015 and 2018, prices were above $30/MWh in large measure due to higher prices during the winter months of January and February, when natural gas prices are often higher. In 2016 and 2017, energy prices on average were below $30/MWh, and on average below the combined fuel and going forward costs of some of the nuclear units in Pennsylvania. Yet energy prices have bounced back after the low prices observed in 2016. Overall, the Beaver Valley units have enjoyed higher energy market prices, on average, than have units in the eastern portion of the PJM footprint starting in 2016.

Table 4: Annual Average LMPs ($/MWh) at Nuclear Unit Pricing Points 2015-18[28]

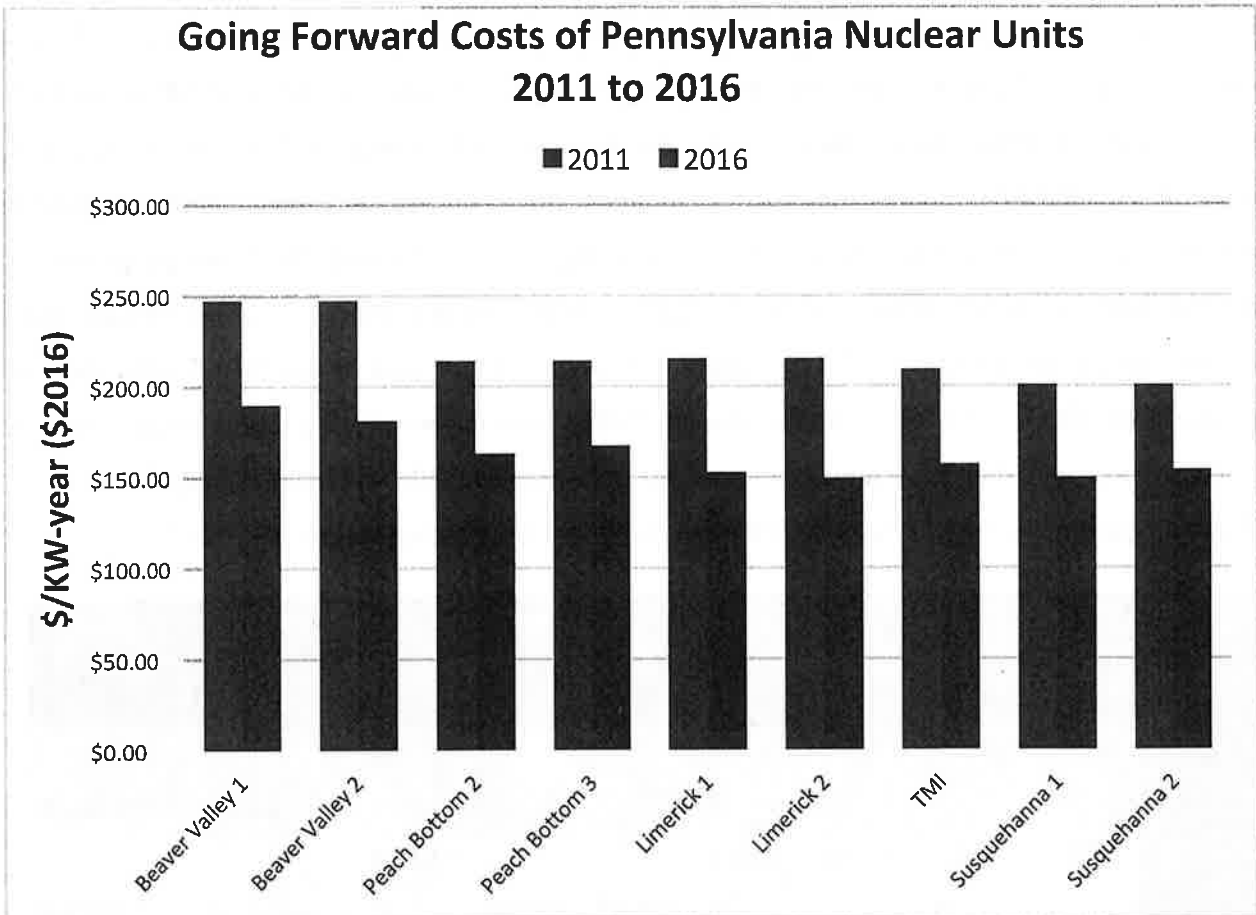
	Beaver Valley 1	Beaver Valley 2	Peach Bottom 2	Peach Bottom 3	Limerick 1	Limerick 2	TMI	Susquehanna 1	Susquehanna 2
2015	$30.35	$30.35	$31.98	$31.98	$32.65	$32.80	$30.94	$32.47	$32.75
2016	$27.08	$27.08	$23.07	$23.05	$23.37	$23.43	$22.95	$23.66	$23.83
2017	$29.13	$29.13	$26.76	$26.76	$26.99	$27.24	$27.12	$27.14	$27.41
2018	$36.35	$36.35	$32.63	$32.63	$33.08	$33.11	$31.76	$32.42	$32.15

[25] *See supra* notes 15 and 16. TMI had no data reported in 2018 in 2016 dollars, so it was adjusted to assume that in nominal terms, the going forward costs for TMI have not changed and remained at $194.30/kW-year. Had it experienced similar cost reduction as others, it would have a going forward cost of $156.99/kW-year.

[26] NEI, *Nuclear Costs in Context,* October 2018 at 3.

[27] In wholesale markets, these pricing points are often referred to as nodes or busses.

[28] The average annual prices are based upon hourly, bus level, day-ahead LMPs that were pulled from the Data Miner 2 application on PJM's website at http://dataminer2.pjm.com/list.



In fact, over time, the Pennsylvania nuclear resources have seen their going forward costs decline over time as shown by U.S. EPA data in the IPM documentation. In data reported in the 2018 version of IPM, going forward costs have declined on average 25 percent for Pennsylvania nuclear resources as shown in Figure 1, with the exception of TMI.[25] This trend is consistent with that reported by NEI, with cost reduction on average over the entire nuclear fleet of nearly 20 percent.[26]

IV. HISTORIC PROFITABILITY

---

[25] *See supra* notes 10 and 11. TMI had no data reported in 2018 in 2016 dollars, so it was adjusted to assume that in nominal terms, the going forward costs for TMI have not changed and remained at $194.30/kW-year. Had it experienced similar cost reduction as others, it would have a going forward cost of $156.99/kW-year.

[26] NEI, *Nuclear Costs in Context,* October 2018 at 3.

Generators earn net revenues from operating in the energy market and participating in PJM's capacity market. **Table 4** shows the annual average locational marginal prices (LMPs) for each nuclear unit in Pennsylvania at their specific pricing point.[27] On average in 2015 and 2018, prices were above $30/MWh in large measure due to higher prices during the winter months of January and February, when natural gas prices are often higher. In 2016 and 2017, energy prices on average were below $30/MWh, and on average below the combined fuel and going forward costs of some of the nuclear units in Pennsylvania. Yet energy prices have bounced back after the low prices observed in 2016. Overall, the Beaver Valley units have enjoyed higher energy market prices, on average, than have units in the eastern portion of the PJM footprint starting in 2016.

Table 4: Annual Average LMPs ($/MWh) at Nuclear Unit Pricing Points 2015-18[28]

	Beaver Valley 1	Beaver Valley 2	Peach Bottom 2	Peach Bottom 3	Limerick 1	Limerick 2	TMI	Susquehanna 1	Susquehanna 2
2015	$30.35	$30.35	$31.98	$31.98	$32.65	$32.80	$30.94	$32.47	$32.75
2016	$27.08	$27.08	$23.07	$23.05	$23.37	$23.43	$22.95	$23.66	$23.83
2017	$29.13	$29.13	$26.76	$26.76	$26.99	$27.24	$27.12	$27.14	$27.41
2018	$36.35	$36.35	$32.63	$32.63	$33.08	$33.11	$31.76	$32.42	$32.15

As part of the PJM market design, the capacity market is designed to compensate generation resources for the ability to provide energy when needed most by the system, usually during summer and winter peak load conditions. These capacity payments are intended to help resources that cannot otherwise cover their going forward costs through net energy market revenues alone to compensate generators for their ability to be available when PJM needs them for resources

[27] In wholesale markets, these pricing points are often referred to as nodes or busses.

[28] The average annual prices are based upon hourly, bus level, day-ahead LMPs that were pulled from the Data Miner 2 application on PJM's website at http://dataminer2.pjm.com/list.

adequacy purposes. **Table 5** provides the annualized capacity market revenue that would have been earned by each nuclear resource in PJM had each resource cleared the market.[29]

Table 5: Annualized Capacity Prices ($/MW-day UCAP) for Pennsylvania Nuclear Units 2015-18[30]

	Beaver Valley 1	Beaver Valley 2	Peach Bottom 2	Peach Bottom 3	Limerick 1	Limerick 2	TMI	Susquehanna 1	Susquehanna 2
2015	$131.86	$131.86	$154.65	$154.65	$154.65	$154.65	$154.65	$154.65	$154.65
2016	$91.07	$91.07	$139.12	$139.12	$139.12	$139.12	$139.12	$139.12	$139.12
2017	$94.92	$94.92	$119.64	$119.64	$119.64	$119.64	$119.64	$119.64	$119.64
2018	$146.25	$146.25	$181.81	$181.81	$181.81	$181.81	$146.25	$146.25	$146.25

The combined net revenues from the energy market, along with capacity market revenues, provide the annual net revenues or operating profits for each of the nuclear units as shown in **Table 6**. Except for Three Mile Island (TMI), all nuclear resources in Pennsylvania were profitable overall during the 2015-18 period.[31]

[29] Three Mile Island did not clear in the 2018-19 Base Residual Auction (BRA) and so would only have earned 2018 capacity revenues through May 31, 2018. See Exelon Corporation, SEC 8-k Filing, August 21, 2015. Available at https://www.sec.gov/Archives/edgar/data/1109357/000119312515299385/d51940d8k.htm

[30] Delivery Year capacity Market prices for each BRA are available at https://pjm.com/-/media/markets-ops/rpm/rpm-auction-info/rpm-auctions-resource-clearing-price-summary.ashx?la=en. These prices were annualized based on the days in each calendar year. For example, for the 2017, there are 151 days in which the resource earns the 2016-17 price and 214 days in which it earns the 2017-18 price.

[31] The costs used for Three Mile Island were assumed to only decline in real terms by about 7%, compared to a 25% decline for the remaining resources on average. If TMI had also experienced similar declines in costs, then it would also have been profitable. See Table 12 below. Moreover, since TMI did not clear in the 2018-19 BRA, its actual profitability would have been different than shown in Table 5.

Table 6: Annual Net Revenues ($ millions) From Energy and Capacity Markets for Pennsylvania Nuclear Units 2015-18 Assuming the Deferral of Capital Expenditures[32]

	Beaver Valley 1	Beaver Valley 2	Peach Bottom 2	Peach Bottom 3	Limerick 1	Limerick 2	TMI	Susquehanna 1	Susquehanna 2
2015	$40.64	$48.01	$100.25	$94.37	$134.91	$138.38	$22.17	$135.26	$133.02
2016	$4.14	$8.53	$5.93	-$13.48	$44.39	$40.39	-$50.47	$40.15	$31.61
2017	$20.40	$25.76	$31.63	$26.27	$68.98	$67.93	-$22.18	$57.64	$55.98
2018	$86.38	$107.93	$122.58	$108.60	$145.01	$124.83	$21.80	$123.65	$120.37

To place the profitability of nuclear resources in the context of margins earned on a MWh-basis, **Table 7** provides the implied margins for every MWh of energy produced over and above the fuel plus going forward costs of each of the units.

Table 7: Implied Margins Over Cost ($/MWh) Earned in PJM's Energy and Capacity Markets 2015-18, Assuming the Deferral of Capital Expenditures[33]

	Beaver Valley 1	Beaver Valley 2	Peach Bottom 2	Peach Bottom 3	Limerick 1	Limerick 2	TMI	Susquehanna 1	Susquehanna 2
2015	$5.58	$6.62	$9.32	$10.37	$13.47	$15.52	$3.36	$12.40	$13.73
2016	$0.56	$1.08	$0.57	-$1.18	$4.79	$3.99	-$7.13	$4.60	$2.97
2017	$2.55	$3.52	$2.80	$2.52	$6.90	$7.94	-$3.23	$5.24	$5.73
2018	$11.61	$14.96	$11.36	$9.97	$15.79	$12.29	$2.97	$12.94	$11.04

Over the past four years, the nuclear resources in Pennsylvania, except for TMI, have been profitable on an operating basis.[34] This is even true for the years 2016 and 2017, where energy

[32] The underlying costs for these net revenues are based on the 2016 costs as reported by the U.S. EPA IPM model and AEO in 2018 and assuming the deferral of capital costs.

[33] These figures are based upon actual monthly MWh of energy output from EIA Form 923 from January 2015 through October 2018. Again, the margin for TMI in 2018 is based on it clearing the 2018-19 BRA.

[34] This assumes the high costs for TMI. If costs had followed the industry trends, then TMI would have been profitable. See Table 13 below.

prices were below $30/MWh for many nuclear units and there was no winter energy price uplift like that experienced in 2015 and 2018. Yet the revenues provided from the PJM RPM capacity market have more than made up for those energy market prices. In a market environment where energy prices were over $30/MWh on average (2015 and 2018), there were more than sufficient revenues to cover going forward costs plus any contribution toward returns and the recovery of any sunk costs.

V. PROJECTED ENERGY AND CAPACITY PRICES

Looking toward future profitability, there are already prices posted for PJM RPM auctions through the 2021-22 Delivery Year. To go out to 2028, the average RPM prices faced by each unit over the past four Base Residual Auctions (BRAs) have been used. Then for each calendar year, the capacity prices have been annualized using the same method as used to compute historic profitability. **Table 8** shows the projected annual capacity market prices using known auction outcome through the 2021-22 Delivery Year and then averages of the past four auctions beyond for 2023 to 2028. Using the average over the past four auctions is a conservative look at capacity revenues beyond 2022 because the past two auctions have produced prices that are well above the average used into the future, and this is used to not overstate any potential profitability.

Table 8: Forward-Looking Capacity Prices ($/MW-day) for Pennsylvania Nuclear Units

	Beaver Valley 1	Beaver Valley 2	Peach Bottom 2	Peach Bottom 3	Limerick 1	Limerick 2	TMI	Susquehanna 1	Susquehanna 2
2019	$126.80	$126.80	$172.34	$172.34	$172.34	$172.34	$134.19	$134.19	$134.19
2020	$86.24	$86.24	$173.59	$173.59	$173.59	$173.59	$98.18	$98.18	$98.18
2021	$132.11	$132.11	$187.15	$187.15	$187.15	$187.15	$128.03	$128.03	$128.03
2022	$146.02	$146.02	$183.91	$183.91	$183.91	$183.91	$138.94	$138.94	$138.94
2023	$128.16	$128.16	$174.70	$174.70	$174.70	$174.70	$122.70	$122.70	$122.70

2024	$128.16	$128.16	$174.70	$174.70	$174.70	$174.70	$122.70	$122.70	$122.70
2025	$128.16	$128.16	$174.70	$174.70	$174.70	$174.70	$122.70	$122.70	$122.70
2026	$128.16	$128.16	$174.70	$174.70	$174.70	$174.70	$122.70	$122.70	$122.70
2027	$128.16	$128.16	$174.70	$174.70	$174.70	$174.70	$122.70	$122.70	$122.70
2028	$128.16	$128.16	$174.70	$174.70	$174.70	$174.70	$122.70	$122.70	$122.70

Forward energy market prices are not available at each generator pricing point/bus, but there is a very well traded and liquid forward market traded through the PJM Western Hub that can be used to develop specific forward prices for each nuclear unit pricing point/bus using the historic trends and basis differential between the PJM Western Hub and each nuclear unit bus. **Table 9** provides the annual average PJM Western Hub forward prices as downloaded from the Intercontinental Exchange (ICE)[35]

Table 9: PJM Western Hub Annual Average Forward Prices ($/MWh)

2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
$35.89	$33.92	$32.16	$30.97	$30.81	$30.81	$30.93	$31.23	$31.62	$33.19

Table 9 shows the projected forward energy market prices based on the published Western Hub price and adjusted to account for the historic basis differential seen from 2015 to 2018 in the PJM Energy Market.[36] With the exception of the Beaver Valley units, all nuclear units in PJM are

[35] Intercontinental Exchange (ICE), Futures Daily Market Report, January 16, 2019, Futures for PJM PJM Western Hub Day-ahead Peak (PJC) and Off-peak (PJD). These reports are available at https://www.theice.com/marketdata/reports/142. Average annual prices were determined by first taking the simple average of the peak and off-peak prices for the month, recognizing that the numbers of peak and off-peak hours are about equal.

[36] For this analysis, the historic 2015-18 basis differential can be derived from PJM LMP data obtained from the Data Miner 2 application. The 2018 basis differential was used because it captures the trend that

projected to see prices that are at a discount to PJM Western Hub. The trend has been toward greater negative basis for the Peach Bottom, Susquehanna, Limerick and TMI units. In contrast, Beaver Valley has seen a positive basis emerge with PJM Western Hub during peak hours and all but disappear when looking at all hours on average.

Table 10: Projected Forward Energy Prices ($/MWh) for Each Nuclear Unit in Pennsylvania

	Beaver Valley 1	Beaver Valley 2	Peach Bottom 2	Peach Bottom 3	Limerick 1	Limerick 2	TMI	Susquehanna 1	Susquehanna 2
2019	$35.78	$35.78	$32.08	$32.08	$32.51	$32.54	$31.20	$31.85	$31.60
2020	$33.81	$33.81	$30.10	$30.10	$30.54	$30.57	$29.22	$29.88	$29.63
2021	$32.05	$32.04	$28.34	$28.34	$28.78	$28.81	$27.46	$28.12	$27.87
2022	$30.85	$30.85	$27.15	$27.15	$27.58	$27.62	$26.27	$26.92	$26.67
2023	$30.70	$30.70	$27.00	$27.00	$27.43	$27.46	$26.12	$26.77	$26.52
2024	$30.70	$30.70	$27.00	$27.00	$27.43	$27.46	$26.12	$26.77	$26.52
2025	$30.82	$30.82	$27.12	$27.12	$27.55	$27.58	$26.24	$26.89	$26.64
2026	$31.11	$31.11	$27.41	$27.41	$27.84	$27.87	$26.53	$27.18	$26.93
2027	$31.50	$31.50	$27.80	$27.80	$28.23	$28.27	$26.92	$27.57	$27.32
2028	$33.07	$33.07	$29.37	$29.37	$29.80	$29.84	$28.49	$29.14	$28.89

has taken place over the previous four years. The basis of the Beaver Valley units has steadily increased going from $-5.46/MWh in 2015 to $-2.15/MWh in 2016 to $-0.60/MWh in 2017 to $-0.10/MWh in 2018. The basis differential for the have remained consistent over the 2015-18 period, except for 2016.

While forward energy market prices beyond 2020 are below $30/MWh, as shown in **Table 10**, the units in question are also located in constrained locational deliverability areas (LDAs) in the PJM capacity market that have consistently observed prices greater than the RTO price, and this is especially true for Limerick and Peach Bottom units that are located in the EMAAC LDA.

VI. FUTURE OPERATING PROFITABILITY

Going forward, all nuclear units, with the exception of Three Mile Island, are projected to earn substantial operating margins on a $/MWh basis, as shown in **Table 11**, from the energy and capacity markets in PJM under the assumptions that there are no more forthcoming reductions in going forward costs as have been observed over time, that unit capacity factor performance remains as it has without any degradation, and there are no major capital investment needs for any of these units.[37]

Any additional reduction in going forward costs along the same trends as shown in **Figure 1** would only succeed in making Pennsylvania nuclear resources more profitable going forward than they are today. On the flip side, any degradation in capacity factor performance would lead to slightly reduced profitability.

Table 11: Projected Pennsylvania Nuclear Unit Profitability 2019-28 Accounting for Capital Expenditures ($/MWh)[38]

Margin	Beaver	Beaver	Peach	Peach	Limerick	Limerick	TMI	Susquehanna	Susquehanna

[37] According to news reports, Beaver Valley 2 was scheduled to do a steam generator and reactor vessel head replacement originally in 2017 (see Rachel Morgan, "Replacement project at Beaver Valley nuke plant set for 2017," *The Times*, September 25, 2013. Available at https://www.timesonline.com/article/20130925/News/309259860). Then just one year later this had been pushed out to 2020 (see "FirstEnergy postpones nuclear plant upgrades," August 12, 2014. Available at https://www.steam-generator.com/firstenergy-postpones-nuclear-plant-upgrades/). Beaver Valley 1 and 2 announced their retirements on March 28, 2018, effective May 31, 2021, and October 31, 2021, respectively. See FirstEnergy Corporation, SEC 8-K Filing, April 5, 2018. Available at https://www.sec.gov/Archives/edgar/data/1031296/000103129618000021/a8-kdated04022018.htm. Thus, beyond 2021, the analysis assumes what the profitability would be if they had cleared.

[38] These are costs and capital expenditures as shown in US EPA IPM 2018 and US EIA AEO 2018.

$/MWh	Valley 1	Valley 2	Bottom 2	Bottom 3	1	2		1	2
2019	$7.64	$8.29	$6.75	$5.97	$11.32	$11.41	- $2.68	$7.31	$6.99
2020	$3.89	$4.52	$4.61	$3.82	$9.17	$9.26	- $6.12	$3.75	$3.47
2021	$4.13	$4.79	$3.49	$2.73	$8.07	$8.17	- $6.79	$3.16	$2.86
2022	$3.55	$4.20	$2.14	$1.37	$6.71	$6.81	- $7.48	$2.52	$2.20
2023	$2.61	$3.27	$2.14	$1.37	$6.72	$6.81	- $7.93	$2.04	$1.73
2024	$2.60	$3.25	$2.12	$1.35	$6.70	$6.79	- $7.94	$2.03	$1.72
2025	$2.73	$3.39	$2.26	$1.49	$6.83	$6.93	- $7.81	$2.16	$1.85
2026	$3.03	$3.68	$2.55	$1.79	$7.13	$7.22	- $7.52	$2.45	$2.14
2027	$3.42	$4.07	$2.94	$2.18	$7.52	$7.61	- $7.13	$2.85	$2.54
2028	$4.97	$5.62	$4.49	$3.73	$9.07	$9.16	- $5.57	$4.40	$4.09

Table 12 shows the projected annual profitability of the Pennsylvania nuclear fleet over the next 10 years. Some units are projected to individually walk away with more than $100 million per year in operating profits in 2019. But at no time over the 10-year period are these resources losing money, except for Three Mile Island.

Table 12: Projected Annual Pennsylvania Nuclear Units Profits ($ millions) 2019-28 Accounting for Capital Expenditures[39]

Profits ($millions)	Beaver Valley 1	Beaver Valley 2	Peach Bottom 2	Peach Bottom 3	Limerick 1	Limerick 2	TMI	Susquehanna 1	Susquehanna 2
2019	$57.36	$61.39	$73.12	$62.37	$108.80	$107.63	- $18.65	$73.33	$71.61
2020	$29.27	$33.59	$50.05	$40.06	$88.32	$87.49	- $42.55	$37.79	$35.67
2021	$31.05	$35.45	$37.83	$28.50	$77.54	$77.03	- $47.30	$31.75	$29.28
2022	$26.65	$31.15	$23.18	$14.30	$64.51	$64.21	- $52.06	$25.27	$22.56
2023	$19.64	$24.20	$23.18	$14.36	$64.53	$64.26	- $55.21	$20.50	$17.76
2024	$19.64	$24.20	$23.18	$14.36	$64.53	$64.26	- $55.21	$20.50	$17.76
2025	$20.54	$25.08	$24.46	$15.60	$65.67	$65.38	- $54.38	$21.70	$18.97
2026	$22.73	$27.24	$27.62	$18.64	$68.47	$68.13	- $52.35	$24.62	$21.96
2027	$25.67	$30.14	$31.86	$22.73	$72.24	$71.82	- $49.63	$28.55	$25.97
2028	$37.47	$41.78	$48.87	$39.14	$87.33	$86.64	- $38.69	$44.32	$42.05

A. The Case of Three Mile Island

In the above presented history and projections, Three Mile Island is not profitable on an operating basis in two of the four previous years (2016 and 2017), and TMI is projected to lose

[39] Total annual profits in 2019 are $614 million, ignoring the losses from TMI. This is larger than the profits shown by the PJM IMM in the 2018 State of the Market Report of $438 million. See 2018 State of the Market Report, Section 5, Pages 351-352, for the full discussion. The reasons for the differences are twofold. First, the costs used in this work differ from the NEI costs used by the IMM and in some cases the NEI costs are lower (such as for Beaver Valley and Peach Bottom) and some for other units NEI costs are higher (such as for Limerick and Susquehanna). The other big difference is the time at which forward curves were pulled for energy prices. The IMM pulled forward prices on January 2, 2016 (See Note 53 Page 351, of the 2018 State of the Market Report). This work pulled prices on January 16, 2016, and the difference in prices between the two weeks is just under $3/MWh for 2019, according to discussions with the IMM. This leads to higher projected revenues in this study. The results remain the same across the two analyses … all the Pennsylvania nuclear units are slated to remain profitable but for TMI.

money from 2019 through 2028 when accounting for capital expenditures.[40] However, the going forward costs for Three Mile Island were assumed to stay constant (in nominal terms) from data published in 2013 because no recent data on unit costs was available from the U.S. EPA IPM modeling documentation. Had Three Mile Island experienced a similar decline in costs to that which the entire nuclear fleet in Pennsylvania experienced, its going forward fixed O&M costs would be $156.99/kW-year rather than the $194.30/kW-year used in the previous analysis.

However, running sensitivities on the going forward costs of Three Mile Island shows it would be projected to operate at a small operating profit going forward only into 2019 as shown in **Table 13** below. Profitability going forward for Three Mile Island is projected to be negative accounting for capital costs as assumed by the U.S. EIA in its AEO study.[41] However, if capital expenditures could be avoided or fixed O&M costs could be brought down, or some combination of both, it is possible that Three Mile Island could do slightly better than breaking even looking into the future. So, even the only single-unit site in Pennsylvania could be profitable in the future with further cost-cutting measures, although not nearly as profitable as the multi-unit sites, if its costs would follow the trend of the rest of the nuclear industry in the commonwealth.

Table 13: Three Mile Island Profitability Sensitivity With Going Forward Costs Following Industry Trends[42]

	Margin $/MWh	Profits ($millions)
2015	$8.61	$56.81
2016	-$1.88	-$13.28
2017	$2.02	$13.84
2018	$8.47	$62.14
2019	$2.57	$17.92

[40] If capital expenditures were not considered, TMI would be profitable in 2019, but not in in 2020 or beyond.

[41] Capital costs for TMI would be $3.66/MWh.

[42] Historic profitability (2015-2018) assumes capital expenditures have been deferred. Future profitability (2019-2028) accounts for capital expenditures.

2020	-$0.87	-$5.98
2021	-$1.54	-$10.73
2022	-$2.22	-$15.50
2023	-$2.68	-$18.65
2024	-$2.69	-$18.65
2025	-$2.56	-$17.82
2026	-$2.27	-$15.79
2027	-$1.88	-$13.06
2028	$3.28	$22.77

B. The Case of Beaver Valley Units 1 and 2

With the announcements of the retirement of Beaver Valley 1 and 2 in March 2018, it is difficult to reconcile these retirements with the economic analysis shown above. But what is known from press reports is that Beaver Valley 2 was to replace the steam generators and the reactor vessel head originally in 2017, then this was pushed back to 2020 and beyond.[43] It is not known with any certainty what the costs of these replacements are, but if FirstEnergy follows the industry trend toward reducing capital expenditures and maintaining the safety and performance of the units as they have while deferring these investments, there is no reason for the Beaver Valley units to retire as shown in **Table 12**, which already accounts for continual capital expenditures.

VII. ECONOMICS OF RETIREMENT AND GO FORWARD DECISIONS

The only metric that can reasonably be measured is whether a nuclear facility will be able to cover its avoidable or going forward costs as shown in the analysis above. The level of profits over and above this are not relevant because the units would remain in commercial operation so long as they can cover their going forward/avoidable costs. Any revenues above and beyond going forward/avoidable costs contribute to covering sunk costs and return on investment. If the resource can cover its going forward/avoidable costs and contribute revenues toward sunk

[43] FirstEnergy Solutions Corporation, 8-k Filing, April 2, 2018, Exhibit 99.2, Presentation to Creditors, March 14, 2018. Available at https://www.sec.gov/Archives/edgar/data/1407703/000119312518104000/d561242dex992.htm. In this filing, FES notes that the steam generator and reactor vessel head replacement had been pushed off beyond 2021. At the time of this presentation, the Beaver Valley retirements had not yet been announced.

cost recovery and return on investment, then it is the economically rational choice to continue to keep the unit in service. There is no need to provide additional out-of-market financial support to keep these resources from retiring because they will not rationally retire.

Going forward or avoidable costs include items such as fixed operating and maintenance costs (fixed O&M) and various other expenses that do not change with unit output, such as labor costs, consumable materials, administrative costs, property taxes and insurance, and other such similar costs that must be incurred in order to keep a generating facility in commercial operation but can be avoided if the facility shuts down. Some capital expenditures that have not yet been incurred but would need to be spent in the future to stay in commercial operation can also be considered going forward or avoidable costs.

Capital or investment costs, once they are incurred, become sunk costs. These costs are considered sunk because they can no longer be avoided … the money has already been spent. Another example of a sunk cost is debt service. Regardless of whether a generation resource remains in commercial operation, the debt service needs to be maintained, unless the resource files for bankruptcy protection and the debt can be forgiven in whole or in part.[44]

In a competitive market environment, the optimal offer in the capacity market is offering at the net going forward/avoidable costs. These costs include items such as fixed O&M, certain administrative overhead costs, property taxes and insurance, and plant labor costs, and they account for net operating profits from the energy market.

A simple example shows why all an existing resource must do is cover its net going forward/avoidable costs. Suppose the generation facility in question has net going forward/avoidable costs of $80/MW-day after accounting for net energy market revenue. If the capacity price is $128/MW-day, as it has been on average in the ATSI LDA over the last four auctions,[45] the generation resource covers its net going forward/avoidable cost and earns $48/MW-day to cover any sunk capital costs, cost of debt financing and a possible return on

[44] This is especially true for the Beaver Valley units owned by FirstEnergy Services (FES), which has filed for bankruptcy protection.

[45] *See* Table 7 above.

investment. In such a case, it pays the generation resource to remain in commercial operation even if it is not earning the returns it would like to receive. What would happen if the generation resource shut down? It could avoid all its going forward/avoidable costs, but then it would also lose the opportunity to earn $48/MW-day to cover its sunk costs plus any return.

For the sake of example, suppose the sunk costs plus a return that the resource wishes to recover as a margin each year are $70/MW-day. If the unit remains in operation, it covers nearly 69 percent of its sunk costs plus return, but if it shuts down, it covers nothing. The economically rational course of action is to remain in commercial operation even if the resource is not earning the returns it wants. Any threat to shut down under conditions such as those in this example is simply not credible because the resource owner would not be carrying out its fiduciary responsibility to its shareholders and would be saddling shareholders with losses they would otherwise not have to bear.

VIII. COMPETITION, RETURNS, AND RISK

A. Rationale for Moving From Cost-of-Service Regulation to Wholesale Market Competition

At a fundamental level, one of the main tenets behind wholesale market restructuring was to shift risk to those parties best able to manage that risk. In the old regulated world, the risk of plant performance and market risks were borne entirely by the captive customers of the regulated utility. Captive customers, being dispersed and not being expert in understanding how to operate such complex facilities, had no way in which to understand the market and operational risks, let alone find ways to manage those risks. And yet the owners of these facilities, regardless of performance, could still earn the regulated returns to capital on those assets. The result of such risks being borne by captive customers, especially with respect to nuclear plant operations, was poor availability and low capacity factor performance to go along with high costs.

All competitive merchant generators face operational and market risks. Operational risks are unit-specific and are related to performance of the resources over time, and with capacity performance in PJM, performance during system emergencies. All merchant generation owners, including the owners of the Pennsylvania nuclear resources, take on the full operational risk, which includes outage risk due to poor maintenance practices, performance risk during emergency conditions under PJM's Capacity Performance construct, or simply performance risk during periods of high prices among other operational risks. Operational risks may also include having to incur additional going forward costs to make unexpected repairs and investments to ensure energy output and meeting all mandated safety requirements. Operational risks can be minimized through following prudent maintenance practices to minimize the probability of unforeseen outages and to maximize revenues from running as often as possible when energy prices are above the marginal fuel cost of operation.

Market risks include changes in supply-demand fundamentals that include technological changes and innovations (for themselves or competitors), changing patterns of demand, and entry or exit decisions of competitors. But operational and market risks should be borne by the merchant generation owners because they are in the best position to manage these risks.

Since the advent of restructuring, with the risks of performance shifted to the owners of these nuclear assets, performance has improved markedly across the entire industry exposed to wholesale market competition.[46] Furthermore, the evidence provided in this analysis based on the capacity factors and forced outage rates in Table 1 and Table 2 and Figure 1 show that the Pennsylvania nuclear resources are already accomplishing this part of risk mitigation and are earning operating profits while doing so.

Given these risks, the cost of capital for each merchant generation resource should already account for such risks and will be reflected in the cost of debt and cost of equity faced by each resource owner. There is no need to consider these risks additionally as an excuse for additional out-of-market financial support. Market investors should have already accounted for these issues in making their investment decisions. Considering these risks beyond what they

---

[46] Davis, Lucas W. and Wolfram, Catherine, "Deregulation, Consolidation, And Efficiency: Evidence from U.S. Nuclear Power," *American Economic Journal: Applied Economics*, Vol. 4, pp. 194-225, 2012. They determine that nuclear units subject to competitive pressures have improved availability and shortened their refueling outage times leading to a 10 percent gain in operating efficiency. See also NEI *Nuclear Costs in Context,* October 2018, at 3.

have already been would amount to double counting and, in essence, require consumers to pay twice for the same thing: once through energy and capacity purchases in the market where consumers have an ability to hedge such costs through various means, and then paying again through out-of-market payments that cannot be avoided or hedged.

B. The Harmful Impacts of Out-of-Market Financial Support for Nuclear Resources

The presence of an additional revenue stream outside the market in the form of out-of-market financial support such as the recently proposed Tier III AECs simply transfers risk from the owners of nuclear assets, who are in the best position to manage those risks, to taxpayers and consumers of power who are least able to manage the risk. In effect, this would lead nuclear resources to be treated as if they were under the old cost-of-service regulatory regime while their market competitors and consumers are exposed to market risks. This effectively reverses the incentives and agreed upon paradigm that has been in place for over 20 years through Pennsylvania's restructuring law.[47] In fact, in the policy declaration of the restructuring law, the following points were made very clear as to why restructuring was being pursued:

> (4) Rates for electricity in this Commonwealth are on average higher than the national average, and significant differences exist among the rates of Pennsylvania electric utilities.
> (5) Competitive market forces are more effective than economic regulation in controlling the cost of generating electricity.
> (6) The cost of electricity is an important factor in decisions made by businesses concerning locating, expanding and retaining facilities in this Commonwealth.
> (7) This Commonwealth must begin the transition from regulation to greater competition in the electricity generation market to benefit all classes of customers and to protect this Commonwealth's ability to compete in the national and international marketplace for industry and jobs.[48]

Such a change in philosophy and shifting of risk would effectively convert the Pennsylvania nuclear resources from merchant resources that take on all the downside AND upside risks of

---

[47] *Electricity Generation Customer Choice and Competition Act*, Effective January 1, 1997. Available at https://www.legis.state.pa.us/WU01/LI/LI/CT/HTM/66/00.028..HTM.

[48] *Id.* Section 2802, Declaration of Policy.

market participation borne by the generation owners, to old-fashioned, regulated, rate-of-return facilities that shift all the downside risk to Pennsylvania consumers while the shareholders keep all the upside benefits. It would cause rates to rise to the detriment of the competitiveness of Pennsylvania businesses.

At least in the "old days" of rate-of-return regulation captive customers could get all the benefits of the upside risk in the form of reduced rates. Ironically, the mere presence of the subsidies in the form of ZECs or other out-of-market financial support provides a financial floor and effectively reduces the downside risk while leaving the merchant generation owner to capture the upside benefits of good market outcomes and superior operational performance. It's a classic head's I win, tails you lose scenario. Or stated another way, ***ZECs socialize the losses from downside risk*** ("Tails, you lose!") ***while privatizing the gains to upside benefits*** ("Heads, I win!").

Even worse, with nuclear resources going back and seeking guaranteed returns should risks run against them, Pennsylvania will return to the "bad old days" of little incentive for maintaining superior performance for their resources. But this return to poor incentives for good performance has negative spillover effects that go beyond these resources. From an overall market efficiency perspective, out-of-market financial support has the effect of pushing out more innovative and efficient resources, thus reducing the overall incentives in the marketplace to bring innovative, lower-cost resources to market that would benefit electricity customers. This can be seen by the displacement of otherwise economical resources from the market and through the reduced prices paid to resources in the market due to the presence of these now subsidized resources.[49]

IX. POTENTIAL RATE INCREASES TO PENNSYLVANIA CONSUMERS

According to PJM, its markets save consumers in the PJM footprint about \$2.3 billion annually. This translates to a savings of approximately \$2.85/MWh with a PJM administrative cost of \$0.32/MWh, for a cost benefit ratio of about 8.9-to-1 in 2018.[50] These benefits come

---

[49] *Initial Brief of the Electric Power Supply Association,* Affidavit of Paul M. Sotkiewicz, Ph.D., in Docket No. EL16-49, ER18-1314-000, ER18-1314-001, EL18-178, October 2, 2018.

from a regionwide commitment and economic dispatch of resources in the PJM Energy Market, joining resource adequacy procurement through the PJM RPM Capacity Market, and regionwide transmission planning. For Pennsylvania consumers, this translates to a savings of approximately $413 million annually.[51]

Total Pennsylvania nuclear energy output from 2015 to 2017 averaged just over 82 million MWh out of an average of over 214 million MWh of total power output from Pennsylvania resources.[52] Clearly, Pennsylvania is a net exporter of electricity in the PJM market. Furthermore, according to the EIA, electricity sales to Pennsylvania customers averaged just under 145 million MWh of energy from 2015 to 2017.[53]

According to the Pennsylvania House version of the nuclear bailout bill,[54] nuclear resources are considered Tier III alternative energy resources and eligible to receive Tier III alternative energy credit (AEC) payments. The nuclear bailout bill also sets a price floor for Tier III AEC payments at 50 percent, and a price cap for Tier III AEC at 65 percent of the Tier I price reported by the Pennsylvania Public Utility Commission (PA PUC) in its 2017 Annual Report on the Alternative Energy Portfolio Standards Act of 2004.[55] In 2017, this price was

---

[50] PJM Interconnection, LLC, *The Value of Markets*, at 2. Available at https://www.pjm.com/-/media/about-pjm/newsroom/fact-sheets/the-value-of-pjm-markets.ashx. PJM states it saves $2.3 billion per year due to its operations. With projected PJM total energy of 806,725 GWh as shown in the PJM 2018 Load Forecast Report Data, this comes out to $2.85/MWh. PJM's administrative cost can be found in the monthly Markets Report presented to the Members Committee. The most recent report can be found at https://pjm.com/-/media/committees-groups/committees/mc/20181022-webinar/20181022-item-07a-markets-report.ashx?la=en.

[51] This is based upon the average of electricity sales as reported from the U.S. EIA on Form 861 available at https://www.eia.gov/electricity/data/eia861/ and aggregated on a state-by-state basis at https://www.eia.gov/electricity/data/state/sales_annual.xlsx. The average sales in Pennsylvania from 2015-17 were 144,887,536 MWh per year.

[52] Aggregated Pennsylvania generation is available from U.S. EIA at https://www.eia.gov/electricity/data/state/annual_generation_state.xls for the actual 2015-2017 average was 214,426,033 MWh. Nuclear output comes from EIA Form 923 is 82, 213,532 MWh on average from 2015-2017.

[53] US EIA 861 Data for 2017. *See supra* Note 51

[54] A version of the bill, released on March 11, 2019, can be found here https://stateimpact.npr.org/pennsylvania/2019/03/11/read-pennsylvania-house-version-of-nuclear-bailout-bill/.

$12.16/MWh.[56] So the associated price cap is $7.90/MWh and the price floor is $6.08/MWh. The range of costs between the price floor and cap is $440.8 million to $572.75 million per year for at least six years as proposed in the bill.[57] Even at the floor price, the cost of this bailout wipes out the entire cost savings accruing to Pennsylvania consumers from participating in PJM's markets. The overall increase in costs on an energy basis is $3.04/MWh to $3.95/MWh.

All the Tier III AEC money would be paid to nuclear resources even though nuclear resources in Pennsylvania are operating profitably in PJM's markets, but for Three Mile Island, and would not rationally retire, so these are simply additional costs to consumers, or profits to the owners of nuclear generation, without any corresponding benefits of avoided emissions.

X. CARBON DIOXIDE EMISSIONS CAN BE AVOIDED OR REDUCED BY LETTING THE PJM MARKET WORK AS INTENDED

One key excuse for providing out-of-market financial support to nuclear resources is that they will retire absent the additional financial support and that Pennsylvania values the avoidance or reduction in carbon dioxide ("CO_2") emissions to combat climate change, and under the implicit assumption no other fossil units are also under financial strain and likely to retire as well.[58] The policy goal of avoiding or reducing CO_2 emissions may be a reasonable and rational policy, but emissions reductions should be done in as cost-effective a manner as possible.

As shown in the analysis above, Pennsylvania nuclear resources, with the potential exception of Three Mile Island, are projected to easily cover their going forward/avoidable costs and earn revenues to contribute toward sunk cost recovery and return on investment, even for the Beaver

[55] Available at www.puc.pa.gov/Electric/pdf/AEPS/AEPS_Ann_Rpt_2017.pdf.

[56] *Id.* at 32, Chart 20.

[57] If an average of 145 million MWh is consumed, half of that, or 72.5 million MWh of Tier III AECs, would need to be purchased. Multiplying this amount by the floor and cap prices provides the range in millions of dollars.

[58] PJM Interconnection, LLC, *Future Generator Deactivations*. Available at https://pjm.com/planning/services-requests/gen-deactivations.aspx. As of the writing of this paper, there are just over 7,000 MW of coal-fired capacity slated to retire, but just over 4,750 MW of pending nuclear retirements, of which Beaver Valley 1 and 2 and Three Mile Island are listed currently.

Valley units that are currently announced as retiring. So, the prospect of avoiding an increase in CO_2 emissions due to the "retention" of the Pennsylvania nuclear resources seems ensured since they can cover going forward/avoidable costs absent out-of-market financial support such as ZECs. Any money spent on out-of-market support would not have any environmental benefit, and the payments would flow only to owners of nuclear resources as increased profits.

A. It Is More Cost Effective to Allow Entry of New Efficient Combined Cycle and Renewable Resources to Reduce Emissions.

It is no secret that new, highly efficient combined cycle natural gas and increasingly cost-competitive renewable resources have been entering the PJM market over the last decade due to a combination of factors. These include: 1) technological innovation in natural gas production in the Marcellus and Utica shale basins that have resulted in extremely low natural gas prices; 2) technological innovation that has increased the heat rate efficiency of combined cycle units that reduce their running costs and emissions profiles; 3) economies of scale in combined cycle and renewable technologies that allow larger, higher capacity machines to be built at the same overall cost and reducing the cost/kW of capacity; and 4) increased experience in bringing these new resources on line reducing installation costs.

These new combined cycle gas units have heat rates as low as 6,200 Btu/kWh (6.2 mmBtu/MWh) which implies a CO_2 emissions rate of .363 tons of CO_2/MWh or about two-thirds lower than a typical coal unit. And these new resources are being built regardless of CO_2 policy or price and consequently emissions reductions from new gas units displacing higher-emitting resources happen at no additional cost. In the language of environmental economics or markets, the marginal cost of abatement is zero.

The marginal CO_2 emissions rate in PJM for 2017 was reported by PJM as being 1,374/MWh (0.687 tons/MWh). The new, efficient combined cycle units are nearly half that rate so that one MWh of new combined cycle gas would displace 0.324 tons of CO_2 at no additional cost since it is cost-effective for these resources to enter the market today.

In contrast, if out-of-market financial support payments were required to keep the Pennsylvania nuclear units in service, and such payments are not necessary, the implied marginal cost of CO_2

abatement would be \$24.01/ton if payments were based on Illinois's policy or \$16.01/ton if based on the New Jersey policy.[59] Clearly this is not as cost-effective as new combined cycle gas at the margin for reducing or avoiding CO_2 emissions.

But taking this hypothetical idea that Pennsylvania nuclear resources are being driven economically from the PJM market absent out-of-market financial support, then they would not even need to incur their avoidable/going forward costs once they retire. Taking Three Mile Island as an example, and depending upon the going forward costs used, the range of abatement costs is from \$56.72/ton to \$64.50/ton, which is three to four times the social cost of carbon of \$16.50 used in Illinois ZEC legislation.[60]

In contrast, new and highly efficient combined cycle gas resources are entering the market without the benefit of out-of-market support due to the fuel efficiency and lower costs. Because of their efficiency and burning a fuel with lower carbon content overall, new-entry combined cycle gas resources are ***more cost effective at the margin*** because their new entry would reduce carbon dioxide emissions by displacing output from more expensive, higher-emitting resources ***without any additional costs*** because these resources will enter the market regardless of any price or value placed on carbon dioxide emissions.

A. Carbon Dioxide Emissions Must Be Viewed Within a Broader Market Context in PJM, Including Retirements of Higher Emitting Resources

As noted above, there are just 7,000 MW of future coal retirements and about 7,700 MW of total fossil fuel retirements in PJM that are pending total. In 2017, these resources accounted for 31.36 million short tons of carbon dioxide emissions.[61] All are slated to retire by June 1, 2022. In an economic sense, these emissions reductions cost nothing beccause all these fossil units are retiring due to economic factors beyond any desire of need to reduce carbon dioxide emissions. In contrast, if Three Mile Island and the Beaver Valley units were to retire, these account for

[59] These values are calculated by dividing the cost per MWh of the ZEC in Illinois or New Jersey and divided by the marginal unit emissions rate of 0.687 tons per MWh.

[60] Future Energy Jobs Act. This value is set at \$16.50/ton and increase each year for 10 years.

[61] United States Environmental Protection Agency (U.S. EPA), *Air Markets Program Database*, available at https://ampd.epa.gov/ampd/.

only 2614 MW of capacity and operating at a 95 percent capacity factor would have only avoided 14.94 million tons of carbon dioxide emissions,[62] or less than half of those avoided by the retirement of fossil units. In aggregate, emissions still decline in PJM in this exchange, albeit not as fast as many might wish. And even so, if natural gas combined cycle covers the MWh output of retiring nuclear, their emissions rate would only result in 7.9 million tons per year more emissions,[63] and net emissions are still down 22.46 million tons, and at a much lower cost to the PJM market and Pennsylvania electricity consumers.

XI. SUMMMARY AND CONCLUSIONS

Out-of-market financial support for nuclear resources in Pennsylvania is not necessary because all existing nuclear units, but for Three Mile Island, are profitable in an operating sense going forward. Moreover, to support nuclear units that do not need the money in the cause of avoiding carbon dioxide emissions would not provide any addition to avoiding emissions but would substantially increase costs for Pennsylvania consumers. Finally, for those nuclear resources that have announced retirements, even if they were to retire, carbon dioxide emissions would still be declining on PJM overall because the economic conditions affecting some nuclear resources are having the same impact on high-emitting coal and other fossil resources and overall emissions are still declining when considering all retirements together. And the additional costs to Pennsylvania customers for the net emissions reductions from letting the PJM market work as it is designed and intended? The cost is nothing except lower overall costs to PJM and Pennsylvania consumers.

---

[62] Based on the 2017 marginal emission rate of 0.687 tons/MWh in PJM.

[63] Based on the latest combined cycle technology and an emission rate of 0.363 tons/MWh