May 28, 2019

The Market and Financial Position of Nuclear Resources in Ohio

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

Table of Contents

List of Tables

The Market and Financial Position of Nuclear Resources in Ohio

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

EXECUTIVE SUMMARY: KEY FINDINGS AND CONCLUSIONS

Nuclear Facilities in Ohio Can Easily Cover their Going Forward/Avoidable Costs through 2028 and Should Not Rationally Retire.

Publicly available fuel, capital, and going forward/avoidable cost data indicate Ohio nuclear unit costs, expressed on a $/MWh basis, that range from a low of $31.83/MWh for the Davis Besse 1 facility outside of Toledo to $34.03/MWh for Perry 1 northeast of Cleveland.[1] As single unit reactor sites, the costs of Davis Besse 1 and Perry 1 are nearly 25 percent below the industry average for single unit costs, making these units among the best single unit performers in the U.S. nuclear fleet. The net annual unit operating profits looking into the future on average over the 2019 to 2028 period are $28 million per year ($3.85/MWh) for Davis Besse and $44 million per year ($4.40/MWh) for Perry. Absent any unknown need for major investments or repairs at these units, there is no reason for the Ohio nuclear units to retire as they are profitable on an operating basis including yearly capital expenditures.

---

[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/.

Recent Statements Confirm the Idea Nuclear Facilities in Ohio are Profitable and Will not Retire.

Debt service is a sunk cost which means it must be paid regardless of whether or not generation resources retire or are in commercial operation. Consequently, debt service does not play into whether individual resources are profitable on a going forward basis. Any debt service needs to be maintained as sunk cost, unless the owner of the generation files for bankruptcy protection and the debt can be forgiven in whole or in part.[2] Moreover, as FirstEnergy Solutions emerges from bankruptcy proceedings, it will no longer have the debt service that it once had and has stated that the revised bankruptcy plan just announced April 21, "will significantly strengthen our financial position and allow FES to emerge as a fully integrated independent power producer."[3] Such a statement further supports the idea that the Ohio nuclear units have no intention of retiring if FES is aiming to emerge as an independent power producer.[4]

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

The Ohio nuclear units are operating profitably in covering their going forward and avoidable costs and future capital expenditures. Consequently, 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, payments envisioned to be as much as $300 million in the Ohio House Bill 6 would require rate increases of $2.50/month for residential customers, $20/month for commercial customers, and $250/month

[2] This is especially true in this case for the Davis Besse and Perry nuclear units owned by FirstEnergy Services (FES) which has filed for bankruptcy protection on March 31, 2018.

[3] Jeffery Tomich, "Bankruptcy Won't Shield FirstEnergy from Cleanup Claims", *E&E News Energywire*, April 22, 2019. Available at https://www.eenews.net/energywire/2019/04/22/stories/1060196019.

[4] At the time of this report, FES has announced the retirements of all of its generation resources but for the West Lorain facility which is a gas/oil peaker. One plant alone does not constitute a fully integrated independent power producer which means announced retirements of resources may not actually happen. And given that Davis Besse and Perry are profitable, there is no reason to retire these resources.

for industrial customers.[5] These charges are equivalent to a $2.18/MWh increase in energy prices in Ohio, given historic end-use energy sales.

Out of Market Financial Support for Ohio 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.[6] But the equivalent $2.18/MWh charge to load would nearly eliminate these benefits to Ohio customers. These are additional costs that need not be incurred since the public data indicate that Ohio customers would not receive any corresponding benefit given these nuclear resources would not rationally retire.

PJM's Wholesale Energy and Capacity Markets are not "Broken".

PJM's wholesale energy and capacity markets reflect underlying market conditions including potential slowing or flat load growth, the presence of low-cost Marcellus Shale gas, rapidly improving efficiency and cost profiles for combined cycle gas units, and innovation in bringing an active demand-side into the market. Energy and capacity prices reflect these underlying fundamentals. The PJM market remains highly successful with a healthy reserve margin above the target reserve margin, attracting new entry from new efficient and low-cost resources, improved reliability and relatively low prices that are reflective of underlying economic fundamentals.

---

[5] Ohio House Bill 6, Section 3706.42(B) available at https://www.documentcloud.org/documents/5837536-hb6-00-In.html

[6] 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.

Unit Specific Cost Data and Revenue Projection, not Industry Average Cost Data or Revenues, Show Davis Besse and Perry are Profitable and will Remain so Into the Future.

The forward-looking prices in this market indicate that Ohio nuclear resources will remain profitable on an operating basis, more than covering their going forward costs. The results of this report differ from conclusions reached by the PJM Independent Market Monitor (IMM). This report uses unit specific costs, whose relative accuracy has been verified by examining FirstEnergy financial statements in Securities and Exchange Commission (SEC) filings. In contrast the PJM IMM used industry average costs for single unit nuclear facilities that are much higher than the publicly available unit specific costs for Davis Besse and Perry.

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

I. ECONOMICS OF RETIREMENT AND GO FORWARD DECISIONS FOR NUCLEAR RESOURCES

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 as 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 contributes to covering sunk costs and return on investment. If the resource can cover its going forward/avoidable costs and contribute revenues toward sunk cost recovery and return on investment, then the economically rational choice is 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 as 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 since 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.[7] Moreover, as FirstEnergy Solutions emerges from bankruptcy proceedings, it will no longer have the debt service that it once had and has stated that the revised bankruptcy plan just announced April 21, "will

[7] This is especially true in this case for the Davis Besse and Perry nuclear units owned by FirstEnergy Services (FES) which has filed for bankruptcy protection on March 31, 2018.

significantly strengthen our financial position and allow FES to emerge as a fully integrated independent power producer."[8] Such a statement further supports the idea that the Ohio nuclear units have no intention of retiring if FES is aiming to emerge as an independent power producer.[9]

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 in order to remain in commercial operation and at least cover some part of sunk costs plus a contribution toward desired returns. 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,[10] 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 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 shuts 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 is $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

[8] Jeffery Tomich, "Bankruptcy Won't Shield FirstEnergy from Cleanup Claims", *E&E News Energywire*, April 22, 2019. Available at https://www.eenews.net/energywire/2019/04/22/stories/1060196019.

[9] At the time of this report, FES has announced the retirements of all of its generation resources but for the West Lorain facility which is a gas/oil peaker. One plant alone does not constitute a fully integrated independent power producer which means announced retirements of resources may not actually happen. And given that Davis Besse and Perry are profitable, there is no reason to retire these resources.

[10] *See* Table 8 below.

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.

II. INTRODUCTION AND PURPOSE

Much attention has been given in recent years to the financial condition and viability of the nuclear fleet in US 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 driving down gas prices. At the same time, combined cycle gas heat rate efficiencies have improved while installed costs and going forward costs of combined cycle gas units have declined. The end result is lower gas prices and lower cost, more efficient combined cycle generation has led to these new resources are entering power markets, especially the PJM market. New, lower cost entry combined with the flat demand, are driving wholesale power 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 has 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 have been financially challenging for many nuclear resources, with owners of nuclear units threatening to retire due to these market developments unless they can receive some other form of financial support from states.[11] The provision of financial support has already been provided in Illinois[12] and New Jersey[13] in the PJM region. Financial support has also been provided in New York[14] and recently Connecticut in the ISO New England market.[15]

The rationales for financial support to keep nuclear resources in operation include the arguments that keeping these resources in operation will keep power prices down, will help avoid additional

---

[11] 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/.

[12] 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.

[13] *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. *See also* New Jersey Board of Public Utilities, *Order Determining the Hope Creek, Salem 1, and Salem 2 Nuclear Generators to Receive ZECs* in BPU Docket Nos. EO18080899, E018121337, E018121338, E018121339, April 18, 2019. Available at https://www.state.nj.us/bpu/pdf/boardorders/2019/20190418/4-18-19-9A.pdf.

[14] 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.

[15] 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.

carbon dioxide emissions, and will preserve local job, tax base, and economic benefits. Yet, these rationales are placing the cart before the horse. It is simply asserted by owners and accepted by some policymakers 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, according to the publicly available data this is not true.[16]

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,[17] but also there remains a large segment of the nuclear fleet that has lower going forward costs and are in locations with favorable market designs such as in PJM with robust energy and capacity markets. As it turns out, nuclear resources in Ohio are well positioned in the market, and they are projected to remain profitable on an operating basis as 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, going forward, and projected capital costs and have substantial operating margins to cover any remaining sunk costs plus returns on investment.

The purpose of this analysis to show that Ohio nuclear resources: 1) Historically have been able to cover the 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 ten years are projected to remain profitable with their ability to cover going forward costs. The bottom line: Ohio nuclear resources are not in danger of retiring anytime soon. Retiring such resources would not only be economically irrational, but would financially harm the shareholders of the companies owning these assets.

---

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

[17] 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.

III. ORGANIZATION OF THE ANALYSIS

The overall organization of this analysis is as follows. First, an examination of the underlying costs and historic performance of the Ohio nuclear resources from 2015 through 2018 to provide a snapshot of profitability on a historic basis. This discussion is then followed 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 future. The final stage of the analysis derives the projected profitability on an operating basis for each of the Ohio nuclear resources. Finally, the presentation of the results for projections out to 2028 is 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 IV provides the underlying costs and historic performance of the Ohio 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 going forward costs have declined in recent years showing that Ohio nuclear resources are behaving competitively to remain profitable.

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

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

Section VIII provides broader economic and policy 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 Ohio from enacting a method of financial support as proposed under the Ohio House Bill 6. Section X provides context regarding the cost of carbon dioxide reductions costs. Section X shows that at the margin it is lower cost to let the market work to build new combined cycle gas resources to reduce carbon dioxide emissions by displacing fossil resources based on economics alone. Section XI summarizes and concludes.

IV. 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 Ohio nuclear units. Over 2015-2018 these resources operated at high capacity factors and with low forced outage rates.

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

	Nameplate Capacity (MW)[18]	Summer Net Dependable Capacity (MW)[19]	Capacity Factor (EIA 923)[20]	EFORd[21]
Davis Besse	925.2	894	91.07%	1.18%
Perry	1311.6	1240	88.40%	1.18%

In fact, the PJM nuclear fleet overall operates at a lower forced outage rate than North American nuclear units overall, according to NERC, which reports the average nuclear unit forced outage rate is 2.71 percent.[22]

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

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

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

[20] 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/.

[21] The EFORd is based upon the 4-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.

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

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, which it is currently using to analyze environmental policy outcomes in the power industry.[23]

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

	Fixed O&M (2016$/kW-year)[24]	Fuel Cost (2017$/kW-year)[25]	Annual Capital Cost (2017 $/kW-year)[26]	Fixed O&M plus Fuel Costs ($/MWh)	Fixed O&M + Fuel + Capital ($/MWh)	Fuel Cost ($/MWh)[27]	Fixed O&M Cost ($/MWh)[28]	Capital Costs ($/MWh)[29]
Davis Besse	$169.90	$58.00	$26.00	$28.57	$31.83	$7.27	$21.30	$3.26
Perry	$179.92	$58.00	$26.00	$30.73	$34.08	$7.49	$23.24	$3.36

In addition to the costs reported by government agencies, the Nuclear Energy Institute ("NEI") also reports aggregated costs for nuclear facilities on a $/MWh basis and has breakdowns by multi-

[23] 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 US EIA. https://www.epa.gov/airmarkets/documentation-epas-power-sector-modeling-platform-v6

[24] US EPA, IPM v6, Table 4-47.

[25] 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 2015-2018 was used as shown in **Table 1.**

[26] 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 an additional $35/kW-year to account for major investments that would go into retirement decisions.

[27] Costs in $/MWh are computed using the historic 2015-2018 Capacity factors and nameplate capacity reported in **Table 1.**

[28] *See supra* Note 19.

[29] *See supra* Note 19.

unit versus single unit facilities and wholesale market versus regulated facilities.[30] These are summarized below, in **Table 3** Overall, multi-unit facilities have lower costs than single unit facilities and nuclear resources operating in wholesale markets have lower costs than those operating in regulated paradigms.

Table 3: Nuclear Units Costs in 2017 $/MWh as Reported and Derived from the Nuclear Energy Institute

	Multi-unit Industry Average	Single Unit Industry Average	Derived Wholesale Multi-unit[31]	Derived Wholesale Single Unit
Fixed O&M + Fuel + Capital ($/MWh)	$30.89	$42.67	$28.61	$39.52
Fuel Cost ($/MWh)	$6.44	$6.42	$5.97	$5.95
Fixed O&M Cost ($/MWh)	$18.46	$27.32	$17.10	$25.31
Capital Costs ($/MWh)	$5.99	$8.92	$5.55	$8.26

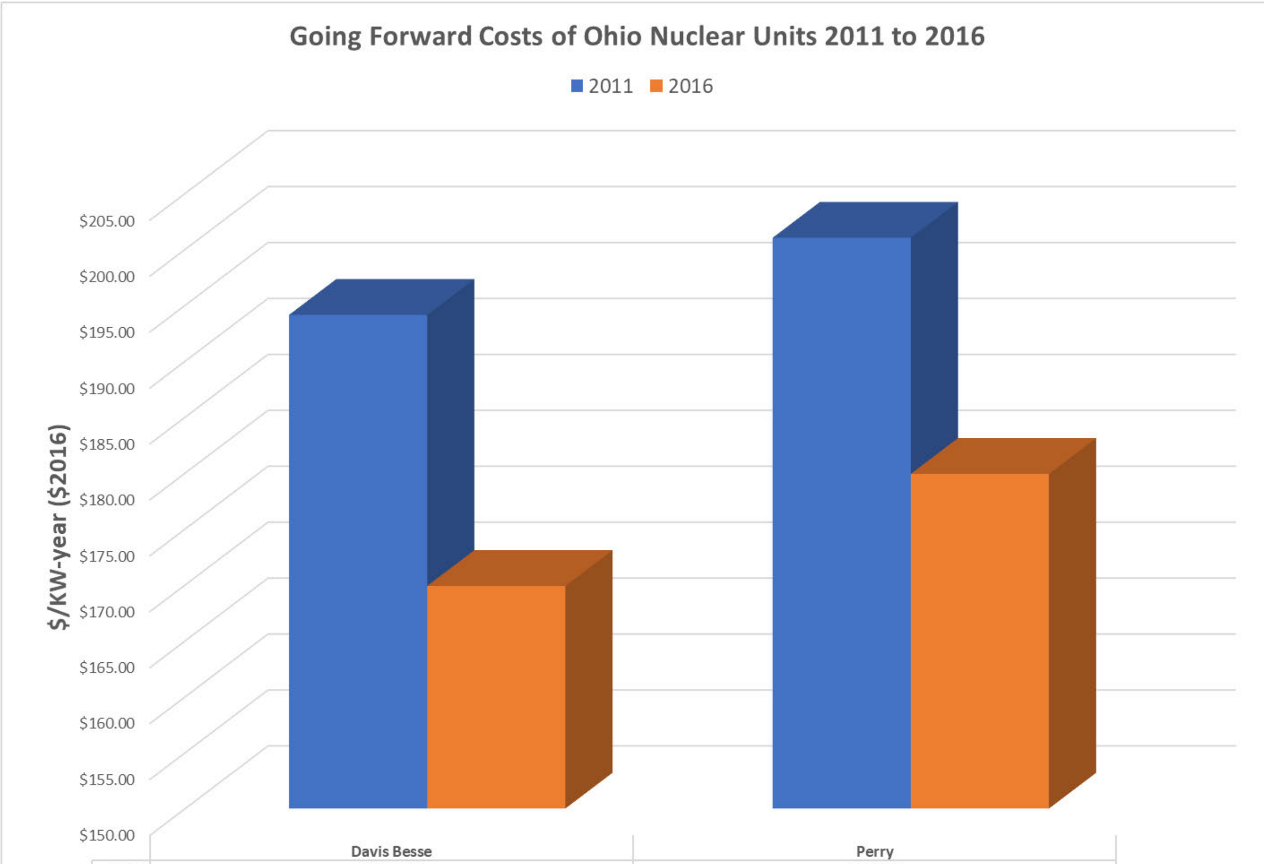
The combined fuel, going forward, and capital costs of the Ohio nuclear resources shown in **Table 2** are below the average costs of single unit nuclear facilities as reported by the Nuclear Energy Institute in **Table 3** by as much as 25 percent despite using fuel cost measures that are conservatively high. Their costs are in line with or just over the average costs for all nuclear units operating in wholesale power markets overall as reported by NEI.[32]

[30] Nuclear Energy Institute ("NEI"), *Nuclear Costs in Context,* October 2018. Available at https://nei.org/CorporateSite/media/filefolder/resources/reports-and-briefs/nuclear-costs-context-201810.pdf.

[31] Derived by adjusting the overall industry average fuel, fixed O&M, and capital cost of $33.50/MWh to the wholesale market cost of $31.03/MWh as reported by NEI. The wholesale costs are 7.38% below the overall industry average. The derived wholesale multi-unit and single unit costs were then calculated by taking the industry average reduction applied to the industry average multi-unit costs and single unit costs assuming they have the same weighting toward the average as the industry-wide average costs.

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

Figure 1: Evolution of Going Forward Costs of Ohio Nuclear Units as Reported in the US EPA IPM Model



	Davis Besse	Perry
2011	$194.13	$201.02
2016	$169.90	$179.92

In fact, over time, the Ohio nuclear resources have seen their going forward costs decline 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 between 10 percent and 12.5 percent for Ohio nuclear resources as shown in **Figure 1**.[33] This trend is consistent with that reported by NEI with cost reduction on average over the entire nuclear fleet of nearly 20 percent.[34]

V. HISTORIC PROFITABILITY

Generators earn net revenues from both 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 Ohio at their specific pricing point.[35] 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. 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 Ohio. Yet, energy prices have bounced back after the low prices observed in 2016 and 2017. Overall, the Perry unit has enjoyed higher energy market prices, on average, than units in the eastern portion of the PJM footprint and higher than the Davis Besse unit further to the west.

Table 4: Annual Average LMPs ($/MWh) at Nuclear Unit Pricing Points 2015-2018[36]

	Davis Besse	Perry
2015	$31.94	$32.77
2016	$27.81	$27.85
2017	$28.85	$29.91
2018	$34.44	$37.24

---

[33] Prior to IPM v6, IPM v5.13 published full nuclear cost data in 2011 dollars. *See* US 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.

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

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

[36] 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.

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 by compensating generators for their ability to be available when PJM needs them for resource adequacy purposes. **Table 5** provides the annualized capacity market revenue earned by each nuclear resource in Ohio clearing the market. Since Perry and Davis Besse are in the ATSI LDA, they receive the same capacity prices.[37]

Table 5: Annualized Capacity Prices ($/MW-day UCAP) for Ohio Nuclear Units 2015-2018[38]

	Davis Besse	Perry
2015	$261.43	$261.43
2016	$214.66	$214.66
2017	$117.61	$117.61
2018	$146.25	$146.25

The combined net revenues from the energy market along with capacity market revenues provides the annual net revenues or operating profits for each of the nuclear units as shown in **Table 6**.

[37] Historically, it is clear these resources cleared in the capacity market. FirstEnergy Solutions has not been as open regarding what specific resources have cleared or not cleared. Yet, clearing of specific nuclear resources can be determined through the use of aggregate offer and clearing data and the posted RPM resource model from PJM along with other public announcements of resources that have not cleared.

[38] 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 2016/2017 price and 214 days in which it earns the 2017/2018 price.

Table 6: Annual Net Revenues ($ millions) from Energy and Capacity Markets for Ohio Nuclear Units 2015-2018 Assuming the Deferral of Capital Expenditures[39]

	Davis Besse	Perry
2015	$116.66	$120.17
2016	$55.67	$69.06
2017	$42.88	$40.47
2018	$111.90	$142.43

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 2015-2018 Assuming the Deferral of Capital Expenditures[40]

	Davis Besse	Perry
2015	$14.78	$12.67
2016	$8.71	$6.63
2017	$5.44	$4.12
2018	$15.16	$13.03

Over the past 4 years, the nuclear resources in Ohio have been profitable on an operating basis.[41] This is even true for the years 2016 and 2017 where energy prices were below $30/MWh, and there was no winter energy price uplift like that experienced in 2015 and 2018. Yet, the revenues

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

[40] 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 2018/2019 BRA.

[41] This assumes the operating costs for the Ohio nuclear units as reported by the US EPA. If the Ohio units had industry average single unit costs, then the Ohio nuclear units would not have been profitable in 2016 and 2017 but would have been profitable in 2015 and 2018. See NEI costs reported in **Table 3**.

provided from the PJM RPM capacity market have more than made up for those energy market prices. In a market environment where energy prices where 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.

VI. PROJECTED ENERGY AND CAPACITY PRICES

Looking for toward future profitability there are already prices posted for PJM RPM auctions through the 2021/2022 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 2021/2022 Delivery Year and then averages of the past four auctions for 2023 to 2028. Using the average over the past four auctions is a conservative look at capacity revenues beyond 2022 as the past two auctions have produced prices that are well above the average used into the future and is used to **not over-state** any potential profitability.

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

	Davis Besse	Perry
2019	$126.80	$126.80
2020	$86.24	$86.24
2021	$132.11	$132.11
2022	$146.02	$146.02
2023	$128.16	$128.16
2024	$128.16	$128.16
2025	$128.16	$128.16
2026	$128.16	$128.16
2027	$128.16	$128.16
2028	$128.16	$128.16

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)[42]

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 10 shows the projected forward energy market prices for the Ohio nuclear units based on the published Western Hub price and adjusted to account for the historic basis differential seen in2018 in the PJM Energy Market.[43] Perry is projected to have a slightly positive basis to Western Hub given its location and changing power flows in PJM in recent years. Davis Besse being further west, is about a $2/MWh negative basis to Western Hub.

While forward energy market prices on from 2022-2027 are below $30/MWh as shown in **Table 10** for Davis Besse, both Davis Besse and Perry are located in constrained locational deliverability areas (LDAs) in the PJM capacity market that have consistently observed prices greater than the RTO price in moving power into Northern Ohio, especially the Cleveland area.

---

[42] 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 number of peak and off-peak hours are about equal.

[43] For this analysis, the historic 2015-2018 basis differential can be derived from PJM LMP data obtained from the Data Miner 2 application. The 2018 basis differential was used as it captures the trend that has taken place over the previous 4 years.

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

	Davis Besse	Perry
2019	$33.91	$36.67
2020	$31.94	$34.70
2021	$30.18	$32.94
2022	$28.99	$31.74
2023	$28.83	$31.59
2024	$28.83	$31.59
2025	$28.95	$31.71
2026	$29.24	$32.00
2027	$29.63	$32.39
2028	$31.20	$33.96

VII. FUTURE OPERATING PROFITABILITY

Going forward Davis Besse and Perry are projected to earn substantial operating margins on a $/MWh basis as shown in **Table 11** from both 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 either of these units.

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

Table 11: Projected Ohio Nuclear Unit Profitability 2019-2028 Accounting for Capital Expenditures ($/MWh)[44]

Margin $/MWh	Davis Besse	Perry
2019	$7.62	$8.17
2020	$3.88	$4.41
2021	$4.12	$4.67
2022	$3.54	$4.09
2023	$2.60	$3.15
2024	$2.60	$3.15
2025	$2.72	$3.27
2026	$3.01	$3.56
2027	$3.41	$3.95
2028	$4.98	$5.52

Table 12 shows the projected annual profitability of the Ohio nuclear fleet over the next 10 years. Davis Besse is projected to have an annual profit of $28 million over ten years while Perry is projected to have annual profits of just over $44 million per year between 2019 and 2028. But at no time over the 10-year period, are these resources losing money. [45]

Table 12: Projected Annual Ohio Nuclear Units Profits ($ millions) 2019-2028 Accounting for Capital Expenditures

Profits ($millions)	Davis Besse	Perry

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

[45] A search of SEC filings and FirstEnergy's Press releases has not turned up any formal announcement regarding whether or not Davis Besse or Perry cleared in the 2018 Base Residual Auction for the 2021/2022 Delivery Year. But whether they cleared or not definitive as to their ability to earn these capacity revenues for the 2020/2022 Delivery Year or beyond. It would appear from public market clearing data and PJM's resources model for the 2021/2022 BRA that FirstEnergy cleared a substantial amount of capacity in the ATSI LDA that has already made retirement announcements and these capacity obligations can be transferred between resources within FirstEnergy.

2019	$56.27	$82.99
2020	$28.63	$44.81
2021	$30.43	$47.45
2022	$26.12	$41.56
2023	$19.22	$32.01
2024	$19.22	$32.01
2025	$20.10	$33.21
2026	$22.25	$36.18
2027	$25.14	$40.15
2028	$36.73	$56.11

A. Differences in Profitability Estimates from the PJM IMM.

In the above presented history and projections, Perry and Davis Besse have been and will continue to be profitable. Yet there are other projections, notably those provided by the Independent Market Monitor for PJM ("PJM IMM") that show Davis Besse and Perry to not be profitable with the implication that these resources would rationally exit the market. The biggest difference in the analysis presented here and the PJM IMM are based on the assumed unit costs.

As noted, the unit costs are specific to the units as estimated for use in the EPA IPM modeling framework and based on historic data. The accuracy of this data has been confirmed by examining FirstEnergy financial disclosures submitted to the United States Securities and Exchange Commission ("SEC"). At the time of FirstEnergy Solutions ("FES") bankruptcy filing in 2018, FES provided an update to their creditors where the costs of the FES nuclear units could be confirmed.[46]

---

[46] FirstEnergy Solutions, "Presentation to the Creditors", March 14, 2018. Available at https://www.sec.gov/Archives/edgar/data/1407703/000119312518104000/d561242dex992.htm. This was attached as Exhibit 99.2 to the 8-K filed April 2, 2018 disclosing their bankruptcy filing on March 31, 2018. Available at https://www.sec.gov/Archives/edgar/data/1407703/000119312518104000/d561242d8k.htm. The average capital and fixed O&M costs for the nuclear fleet is about $196/kW-year consistent with the costs reported for Davis Besse, Perry, and Beaver Valley 1 and 2 in the EPA IPM data.

In contrast, the PJM IMM relied upon industry average single unit costs as provided by NEI and reproduced above in **Table 3**. The differences in costs between the NEI and those costs used for Davis Besse and Perry in **Table 2** above are \$10.84/MWh and \$8.64/MWh respectively. If these additional costs were applied to **Table 11** above, Davis Besse and Perry would not be profitable.[47]

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 Ohio nuclear resources, take on the full operational risk which includes outage risk due to poor maintenance practices, performance risk during emergency

[47] PJM IMM in the *2018 State of the Market Report* Section 5, pp. 351-352.of \$438 million. See 2018 State of the Market Report, Section 5, pages 351-352 for the full discussion. Conversation with the PJM IMM revealed another difference regarding 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.

conditions under PJM's Capacity Performance construct, or simply performance risk during periods of high prices among or 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 as 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 improved markedly across the entire industry exposed to wholesale market competition.[48] 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 Ohio 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. Any further consideration of these risks 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

[48] 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.

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 in House Bill 6 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 nearly 20 years through Ohio's Electric Restructuring Act of 1999.[49]

Such a change in philosophy and shifting of risk would effectively convert the Ohio nuclear resources from merchant resources that take on all the downside AND upside risks of market participation borne by the generation owners, to old-fashioned, regulated, rate-of-return facilities that shift all the down-side risk to Ohio consumers while the shareholder keep all the upside benefits. It would cause rates to rise to the detriment of the competitiveness of Ohio 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 Clean Air Credits ("CAC")[50] or any other out-of-market financial support provides a financial floor, effectively reducing 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 "heads I win, tails you lose" scenario. Or stated another way, ***CACs***

---

[49] This is also known in Ohio as Senate Bill 3. The analysis of this bill is available at https://www.lsc.ohio.gov/documents/gaDocuments/analyses123/99-sb3.pdf.

[50] Ohio House Bill 6, Sec 3706.40 (F) available at https://www.documentcloud.org/documents/5837536-hb6-00-In.html.

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, Ohio risks returning 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 market place to bring innovative, lower cost resources to market that would benefit electricity customers. This can be seen by the displacement of otherwise economic resources from the market and through the reduced prices paid to resources in the market due to the presence of these now subsidized resources.[51]

IX. POTENTIAL RATE INCREASES TO OHIO 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.[52] These benefits come from a region wide commitment and economic dispatch of resources in the PJM Energy Market, joining resource adequacy procurement through the PJM RPM Capacity Market, and region-wide transmission planning. For Ohio consumers, this translates to a savings of approximately $390 million annually.[53]

---

[51] *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.

[52] 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.

[53] This is based upon the average of electricity sales as reported from the US 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 retail sales in Ohio from in 2017 was 137,072,348 MWh.

Total Ohio nuclear energy output from 2015-2017 average just over 17.5 million MWh out of an average of over 120 million MWh of total power output from Ohio resources.[54] Ohio is a net importer of electricity in the PJM market. According to the EIA, average electricity sales to Ohio customers was just over 137 million MWh of energy in 2017.[55]

According to Ohio House Bill 6, a clean energy fund would be established to pay out clean air credits (CACs) to eligible carbon free or low emitting resources that would be priced at $9.25/MWh and adjusted for inflation in future years.[56] The fund would come from fixed monthly charges on residential, commercial and industrial customers and if applied to all electric load in Ohio would collect about $300 million per year.[57] Nuclear resources would be the largest beneficiary of carbon free resources with 14.5 percent of all Ohio generation, and 90 percent of all carbon free generation in the state.[58] The range of costs between what is estimated to be collected of $300 million and what could be paid out in the first year of $185 million is a sizable difference. Still, even at $185 million annually, the erosion of cost savings accruing to Ohio consumers from participating in PJM's markets would be in the range of $1.35/MWh up to $2.18/MWh if the costs were $300 million.

[54] Aggregated Ohio generation is available from US EIA at https://www.eia.gov/electricity/data/state/annual_generation_state.xls for the actual 2015-2017 average was 120,122,540 MWh. Nuclear output comes from EIA Form 923 is 17,549,229 MWh on average from 2015-2018.

[55] US EIA 861 Data for 2017. *See supra* Note 48

[56] Ohio House Bill 6, Section 3706.482 (B)(1).

[57] Ohio House Bill 6, Section 3706.42(B) establishes the rates of $2.50/month per residential customer, $20/month per commercial customer, and $250/month per industrial customer. According to EIA 861 data there were 4,456,979 residential customers in Ohio in 2017, 516,027 commercial customers in Ohio in 2017, and 14, 468 customers in Ohio in 2017. Multiplying these by the rates in House Bill 6 yields $301, 059, 850 dollars per year. If Municipal and cooperative customers are taken out, then the residential customer level is 3,836,899, commercial customer level is 438,720, and Industrial customers count is 12,216 then the fund would only be $257 million per year.

[58] EIA data shows 1,971,087 MWh of wind, solar, and hydro combined in Ohio. So nuclear would account for 90 percent of all carbon free generation in the state in 2017.

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 subsidize to nuclear resources is that they will retire absent the additional financial support and that Ohio 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.[59] 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, Ohio nuclear resources are projected to easily cover their going forward/avoidable costs and earn revenues to contribute toward sunk cost recovery and return on investment even though they have announced they will retire by May 2020 and May 2021. So, the prospect of avoiding an increase in CO_2 emissions due to the "retention" of the Davis Besse and Perry seems assured since they can cover going forward/avoidable costs absent out-of-market financial support such as CACs. Given this, any money spent on out-of-market support would not have any additional 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

[59] 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.

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 6200 Btu/kWh (6.2 mmBtu/MWh) which implies a CO_2 emissions rate of 0.363 tons of CO_2/MWh or about two-thirds lower than a typical coal unit. 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 happens 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 Ohio nuclear units in service, and such payments are not necessary, the implied marginal cost of CO_2 abatement would be $13.46/ton if payments were based on the level of CAC credits to be paid out in the initial year under House Bill 6.[60]

But taking this hypothetical idea that Ohio 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. If those costs are considered in addition to the subsidy payment, the cost of abatement for CO_2 emissions is even larger than the $13.46/ton cited above.

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 because natural gas has 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

[60] This value is calculated by dividing the cost per MWh of the CAC of $9.25 by the marginal unit emissions rate of 0.687 tons per MWh.

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.

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

There are 7,000 MW of future coal retirements and about 8,700 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 as all these fossil units are retiring due to economic factors beyond any desire of need to reduce carbon dioxide emissions. In contrast, if Davis Besse and Perry were to retire, these account for only 2,237 MW of nameplate capacity and operating at their historic capacity factors would have only avoided 12 million tons of carbon dioxide emissions annually,[62] or less than half of those avoided by the retirement of fossil units. In aggregate, emission still decline in PJM in this exchange. And even so, if natural gas combined cycle covers the MWh output of retiring nuclear, their emissions rate would only result in 6.4 million tons per year more emissions.[63] Net emissions are still down nearly 25 million tons, and at a much lower cost to the PJM market and Ohio electricity consumers.

XI. SUMMMARY AND CONCLUSIONS

Out-of-market financial support for nuclear resources in Ohio is not necessary as both Davis Besse and Perry are profitable going forward. Moreover, to support nuclear units that do not need the money in the cause of avoiding carbon dioxide emissions would substantially increase costs for Ohio consumers without providing a new source of, or any increase in, avoided emissions. Finally, even if Davis Besse and Perry were to retire, carbon dioxide emissions would still be declining in PJM overall as the existing economic conditions are resulting in

---

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

[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

economic retirement of high emitting coal and other fossil resources. Overall emissions are still declining when considering all retirements together. Allowing the PJM market to work as it is designed and intended will cost nothing to PJM and Ohio consumers while continuing to drive down net emissions.