



PJM Interconnection Response to the Pennsylvania Public Utility Commission & Ohio Consumers' Counsel Requests to Analyze Certain Impacts of Nuclear Power Plant Retirements

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Summary of Findings

- In response to separate requests from the Pennsylvania Public Utility Commission (PA PUC) and the Ohio Consumers' Counsel (OCC), PJM Interconnection studied cost and emission impacts of potential nuclear power plant retirements in Pennsylvania and Ohio.
- To evaluate these impacts, PJM simulated market results for the year 2023 under various resource mixes, including what exists today, projected conditions for the future and several combinations of potential nuclear unit retirements.
- The PJM base case includes the announced retirements of nuclear units in Pennsylvania and Ohio: Three Mile Island (TMI), Beaver Valley 1 & 2, Davis-Besse and Perry, and also includes new generation with a planned in-service date of 2023 and an executed Interconnection Service Agreement.
- Modeling the base case, considering retirements and new entry, shows that wholesale energy market net-load payments would decrease by \$1.6 billion across the PJM region compared to today's system due to the significant entry of new, efficient resources.
- PJM executed three simulations of the requested nuclear unit retirement scenarios. These scenarios assume the requested combinations of nuclear unit retirements occur and also assume that those generators in the queue that have executed an Interconnection Service Agreement and are planned to come online between 2020 and 2023 would enter the market as scheduled. The results of these simulations for the PJM region, (without including the cost of a possible subsidy) are:
 - Beaver Valley 1 & 2 remain online: \$210 million **decrease** in load payments from the base case
 - Davis-Besse and Perry remain online: \$277 million **decrease** in load payments from the base case
 - Beaver Valley 1 & 2, Davis-Besse, and Perry remain online: \$474 million **decrease** in load payments from the base case
- PJM executed three additional simulations accounting for the same nuclear unit retirement scenarios and included an additional sensitivity assumption regarding the impact of subsidies on new entry. To represent what PJM believes to be the market's likely, long-term reaction to out-of-market subsidies that retain substantial quantities of generation that would have otherwise retired, we discounted by 50 percent the planned natural-gas generation otherwise scheduled to come online between 2020 and 2023. We assumed these projects would be canceled or deferred and in any event, were assumed to not enter the market. The results of these simulations for the PJM region, (again without including the cost of a possible subsidy) are:
 - Beaver Valley 1 & 2 remain online and new entry of natural gas is discounted by 50 percent: \$240 million **increase** in load payments from the base case
 - Davis-Besse and Perry remain online and new entry of natural gas is discounted by 50 percent: \$164 million **increase** in load payments from the base case
 - Beaver Valley 1 & 2, Davis-Besse and Perry remain online and new entry of natural gas is discounted by 50 percent: \$91 million **decrease** in load payments from the base case
- Detailed tables in the report show the changes in emissions for each simulation case.

Background Information

Ohio

On April 22, 2019, the OCC sent a letter to PJM requesting that PJM analyze the following:

1. If the Ohio nuclear power plants Perry and Davis-Besse were permanently shut down, what would be the expected impact on PJM's wholesale capacity and energy market prices?
2. If the Perry and Davis-Besse nuclear power plants were permanently shut down, what would be the expected impact on retail electric prices for Ohio consumers?

Given the limited time to produce the requested analysis, PJM focused on the Energy Market and emissions impacts of the requested study scenarios. PJM also focused on wholesale market impacts of the retirement scenarios rather than retail, given the many assumptions that would be required in order to estimate the impacts on retail electric prices. However, it is reasonable to assume that retail price impacts would follow in the same direction as wholesale market impacts.

Pennsylvania

On April 29, 2019, the PA PUC sent a letter to PJM requesting that PJM analyze the impacts of nuclear generation retirements in Pennsylvania. The letter asked PJM to quantify the impacts of retired nuclear generation on wholesale power prices as well as on emissions – carbon monoxide, lead, ground-level ozone, particulate matter, nitrogen oxide, sulfur dioxide and carbon dioxide.

The PA PUC asked PJM to model the following scenarios using calendar year 2023 as the base year and assuming in the base case that:

1. TMI and Beaver Valley 1 & 2 remain online
2. TMI, Beaver Valley 1 & 2 and the Ohio plants Perry and Davis-Besse remain online

The PA PUC initially requested that PJM provide its analysis by May 17, 2019, if possible. To provide the analysis relatively close to that timeframe, an exhaustive analysis of each market could not be performed. Rather, PJM focused on the Energy Market and emissions impacts associated with the scenarios studied.

On May 8, 2019, Exelon Generation announced that TMI Generating Station Unit 1 would shut down by September 30, 2019. For this study, PJM therefore assumed that TMI would be retired in all scenarios (See Table 1).

PJM's analysis is confined to wholesale power prices and does not consider the added cost to consumers that would result from the imposition of any subsidy or non by-passable charge at the retail level.

Study Assumptions

PJM uses PROMOD software to simulate energy market impacts in future years. The PROMOD production cost simulation tool models an hourly security-constrained generation commitment and dispatch.

For this study, PJM used the input parameters and forecast assumptions from the best-available market-efficiency base case agreed upon by the PJM Transmission Expansion Advisory Committee (TEAC). Details regarding the PJM market efficiency input assumptions can be found in the white paper posted with the materials for the May 2019 TEAC, [Market Efficiency Process Scope and Input Assumptions \(2019 Mid-Cycle Update\)](#).

Nuclear Retirements

PJM considered the following retirement scenarios to evaluate the impacts of the combinations of nuclear unit retirements, as described in the Summary of Findings section:

1. Announced retirements of Beaver Valley 1 & 2 are withdrawn only
2. Announced retirements of Davis-Besse and Perry are withdrawn only
3. Announced retirements of Beaver Valley 1 & 2, Davis-Besse and Perry are withdrawn

PJM executed two sets of these scenarios. The first set of scenarios assumed that all planned new generation capacity (having executed an Interconnection Service Agreement) announced to come online between 2020 and 2023 enters the market as scheduled. In the second set of scenarios, to account for the market's potential reaction to out-of-market subsidies implemented in order to retain nuclear generation that would otherwise retire, PJM assumed that roughly 50 percent of natural gas capacity planned to come online between 2020 and 2023 did not enter the market.

Table 1. Nuclear Units Included in the Study

Name	Area	State	Max. Cap. (MW)
Davis-Besse:1	FirstEnergy ATSI	OH	896
Perry (OH):1	FirstEnergy ATSI	OH	1,247
Beaver Valley:2	Duquesne Light Company	PA	903
Beaver Valley:1	Duquesne Light Company	PA	910

Transmission Upgrades

For each scenario, PJM modeled any new electric transmission system investments necessary to preserve a reliable electric transmission system, given the announced nuclear retirements in Pennsylvania and Ohio. Any such reinforcements were included in all of the scenarios, including those in which the nuclear units were assumed to have retired, as well as those in which the nuclear units were assumed to remain in operation.

Planned Generation

Planned generation in the scenarios was composed of all proposed generating units in the PJM queue with a planned in-service date by 2023 and an executed Interconnection Service Agreement. Pennsylvania nuclear power station TMI was retired in all scenarios. As indicated above, two sets of scenarios were executed for each nuclear unit retirement combination.

The second set of scenarios, in which only half of the planned natural gas units is retained, is informative and based on a credible assumption because it can reasonably be expected that imposing additional out-of-market subsidies to

retain generation that would otherwise retire would have a chilling effect on new investment in the longer term. While PJM believes this is a reasonable expectation, we acknowledge that accurately forecasting how new investment will react to out-of-market intervention is difficult, at best. Therefore, in this report, PJM presents the second set of scenarios as a sensitivity showing the impact of a decrease in new entry by half of what is expected, so that readers of this report may interpolate the effects of various levels of new entry on the overall cost to consumers as well as emissions (see Table 2 and Table 3).

Table 2. Assumed Retirements

2023 Market Efficiency Base Case Retirements	2023 Base Case All Announced PJM Nuclear Retirements Occur (MW)	Beaver Valley 1 & 2 Not Retired (MW)	Davis-Besse + Perry Not Retired (MW)	Beaver Valley 1 & 2 + Davis-Besse + Perry Not Retired (MW)
Retired Coal	11,882	11,882	11,882	11,882
Retired Gas	1,768	1,768	1,768	1,768
Retired Nuclear	5,387	3,575	3,244	1,432
Nuclear not Retired	-	1,812	2,143	3,955

Table 3. Assumed New Generation Additions*

2023 Market Efficiency Base Case Additions	2023 Base Case All ISA Units Included (MW)	Generation Conditions as of End of 2019 (MW)	No Market Reaction (All New Gas Goes In-Service as Scheduled) (MW)	Some Market Reaction (50% Planned Gas Does Not Enter the Market)** (MW)
New Coal	-	-	-	-
New Gas (in-service 2018 and 2019)	11,415	11,415	11,415	11,415
New Gas (in-service 2020 and beyond)	10,514	-	10,514	4,618
Total New Gas	21,929	11,415	21,929	16,033
New Wind	3,235	3,235	3,235	3,235
New Solar	3,933	3,933	3,933	3,933

*PJM assumed status quo for energy efficiency and renewables forecasts.

**Assumption: 50 percent of new entrants do not materialize if nuclear units are kept in service (i.e., 5,896 MW – 50 percent of megawatts – capacity of 10,514 MW ISA units with in-service date of 2020 and beyond).

Simulation Results

Base Case

The PJM base case includes the stated retirements of nuclear units in Pennsylvania and Ohio – TMI, Beaver Valley 1 & 2, Davis-Besse, and Perry and also includes new generation with a planned in-service date of 2023 and an executed Interconnection Service Agreement.

This base case shows that under these conditions, when compared to today's system, wholesale energy market net-load payments would decrease by \$1.6 billion across the PJM region due to the significant quantity of new, more efficient generation that is expected to enter the market. Emissions of carbon dioxide would decrease by

4,300,000 tons, nitrogen oxides would decrease by 37,900 tons, and sulfur dioxide would decrease by 18,200 tons compared to the base case (see Table 4).

The nuclear retirement scenario results are all compared to this base case. If a given nuclear retirement scenario indicates that net-load payments increase compared to the base case, that result could also be articulated as net-load payments would not be expected to decrease as much from today.

Table 4. Simulation Results Base Case

Category	Item	Base Case	End of 2019 Case	Change
Nuclear Unit Status	TMI (PA)	Retired	Retired	
	Beaver Valley 1 & 2 (PA)	Retired	In-Service	
	Perry (OH)	Retired	In-Service	
	Davis-Besse (OH)	Retired	In-Service	
Nuclear Capacity Retired (MW)		3,955	1,432	
Planned New Gas Capacity (MW)		10,514	-	
Delta in Effluent Tons	Ohio CO ₂ (millions)	80.17	74.75	(5.4)
	Ohio SO ₂ (thousands)	87.09	87.85	0.8
	Ohio NO _x (thousands)	48.13	48.18	0.1
	Pennsylvania CO ₂ (millions)	102.24	98.63	(3.6)
	Pennsylvania SO ₂ (thousands)	62.71	71.54	8.8
	Pennsylvania NO _x (thousands)	86.20	108.94	22.7
	PJM CO ₂ (millions)	383.06	387.36	4.3
	PJM SO ₂ (thousands)	284.64	302.89	18.2
	PJM NO _x (thousands)	247.01	284.95	37.9
Delta in Load Payments (\$ millions)	AEP	\$4,409	\$4,653	\$244
	APS	\$1,718	\$1,834	\$116
	FE-ATSI	\$2,316	\$2,435	\$119
	DAY	\$591	\$627	\$36
	DEOK	\$901	\$959	\$58
	DUQ	\$471	\$503	\$31
	METED	\$526	\$565	\$40
	PECO	\$1,396	\$1,494	\$98
	PENELEC	\$579	\$615	\$36
	PLGRP	\$1,364	\$1,474	\$110
	Ohio	\$5,485	\$5,790	\$305
	Pennsylvania	\$5,271	\$5,647	\$375
	PJM	\$26,797	\$28,394	\$1,597
Delta in Load-Weighted LMP (\$/MWh)	AEP	32.39	34.20	\$1.81
	APS	32.84	35.00	\$2.17
	FE-ATSI	33.48	35.20	\$1.72
	DAY	33.10	35.09	\$1.99
	DEOK	32.07	34.13	\$2.07
	DUQ	32.37	34.52	\$2.14
	METED	32.43	34.86	\$2.43
	PECO	32.85	35.15	\$2.31
	PENELEC	32.09	34.15	\$2.06

Category	Item	Base Case	End of 2019 Case	Change
	PLGRP	32.17	34.76	\$2.60
	Ohio	0.00	0.00	\$0.00
	Pennsylvania	0.00	0.00	\$0.00
	PJM	32.88	34.83	\$1.96

First Set of Simulations

The first set of simulations was executed with the assumption that all new gas generators enter the market as scheduled (see Table 5).

Beaver Valley 1 & 2 Retirement Withdrawn

If the stated retirement of Beaver Valley 1 & 2 is withdrawn and the units remain online:

Energy Market Impacts: Results show an annual decrease in net-load payments of \$210 million from the base case for the entire PJM region. Of that decrease, \$45 million would occur in Pennsylvania and \$62 million would occur in Ohio. Said another way, load payments would decrease by an additional \$210 million for the PJM region, \$45 million for Pennsylvania and \$62 million for Ohio from the base case if the Beaver Valley 1 & 2 units are retained and if all anticipated new generation entry into the market occurs as is expected today. This reduction in customer payments, however, is not netted against the cost of a potential subsidy to consumers in a particular state.

Emissions Impact: In Pennsylvania, emissions of carbon dioxide would decrease by 2,100,000 tons, nitrogen oxides would decrease by 2,100 tons, and emissions of sulfur dioxide would decrease by 1,300 tons compared to the base case (or more than they otherwise would if Beaver Valley 1 & 2 retire).

In Ohio, emissions of carbon dioxide would decrease by 1,500,000 tons, nitrogen oxides would decrease by 500 tons, and sulfur dioxide would decrease by 700 tons (see Table 5).

Davis-Besse and Perry Retirements Withdrawn

If the stated retirements of Davis-Besse and Perry are withdrawn and the units remain online:

Energy Market Impacts: Annual load payments would decrease by \$277 million over the base case for the entire PJM region. Of that decrease, \$50 million would occur in Pennsylvania and \$95 million would occur in Ohio. Said another way, load payments would decrease by an additional \$277 million from the base case for the PJM region, \$50 million in Pennsylvania and \$95 million in Ohio if the Davis-Besse and Perry units are retained and if all the anticipated new generation entry into the market occurs as is expected today. This reduction in customer payments, however, is not netted against the cost of a potential subsidy to consumers in a particular state.

Emissions Impact: In Pennsylvania, emissions of carbon dioxide would decrease by 2,300,000 tons, nitrogen oxides would decrease by 2,000 tons and emissions of sulfur dioxide would decrease by 2,000 tons.

In Ohio, emissions of carbon dioxide would decrease by 2,300,000 tons, nitrogen oxides would decrease by 1,700 tons and sulfur dioxide would decrease by 2,600 tons (see Table 5).

Beaver Valley 1 & 2, Davis-Besse and Perry Retirements Withdrawn

If the stated retirements of Beaver Valley 1 & 2, Davis-Besse and Perry are all withdrawn and the units remain online:

Energy Market Impacts: Annual load payments would decrease by \$474 million over the base case for the entire PJM region. Of that annual decrease, \$95 million would occur in Pennsylvania and \$155 million would occur in Ohio. Said another way, load payments would decrease by an additional \$474 million for the PJM region, \$95 million in Pennsylvania and \$155 million in Ohio from the base case if Beaver Valley 1 & 2, Davis-Besse, and Perry are all retained and if all the anticipated new generation entry into the market occurs as is expected today. This reduction in customer payments, however, is not netted against the cost of a potential subsidy to consumers in a particular state.

Emissions Impact: In Pennsylvania, emissions of carbon dioxide would decrease by 4,700,000 tons, nitrogen oxides would decrease by 5,000 tons and emissions of sulfur dioxide would decrease by 3,300 tons.

In Ohio, emissions of carbon dioxide would decrease by 3,700,000 tons, nitrogen oxides would decrease by 2,400 tons and sulfur dioxide would decrease by 3,500 tons (see Table 5).

Table 5. Simulation Results Base Case (No Market Reaction Regarding New Entrants)

Category	Item			
Nuclear Units Status	TMI (PA)	Retired	Retired	Retired
	Beaver Valley 1 & 2 (PA)	In-Service	Retired	In-Service
	Perry (OH)	Retired	In-Service	In-Service
	Davis-Besse (OH)	Retired	In-Service	In-Service
Nuclear Capacity Not Retired (MW)		1,812	2,143	3,955
Planned Gas Capacity Removed (MW)		-	-	-
Delta in Effluent Tons	Ohio CO ₂ (millions)	(1.5)	(2.3)	(3.7)
	Ohio SO ₂ (thousands)	(0.7)	(2.6)	(3.5)
	Ohio NO _x (thousands)	(0.5)	(1.7)	(2.4)
	Pennsylvania CO ₂ (millions)	(2.1)	(2.3)	(4.7)
	Pennsylvania SO ₂ (thousands)	(1.3)	(2.0)	(3.3)
	Pennsylvania NO _x (thousands)	(2.1)	(2.0)	(5.0)
	PJM CO ₂ (millions)	(6.6)	(8.1)	(15.1)
	PJM SO ₂ (thousands)	(2.9)	(5.3)	(8.5)
PJM NO _x (thousands)	(3.7)	(4.8)	(9.7)	
Delta in Load Payments (\$ millions)	AEP	\$(37.85)	\$(52.48)	\$(88.49)
	APS	\$(20.91)	\$(21.71)	\$(42.19)
	FE-ATSI	\$(39.11)	\$(61.93)	\$(99.63)
	DAY	\$(4.20)	\$(6.58)	\$(10.55)
	DEOK	\$(5.69)	\$(8.75)	\$(14.16)
	DUQ	\$(11.77)	\$(8.33)	\$(19.53)
	METED	\$(2)	\$(3)	\$(5)
	PECO	\$(7)	\$(8)	\$(15)
	PENELEC	\$(6)	\$(9)	\$(15)
	PLGRP	\$(6)	\$(7)	\$(14)
	Ohio	\$(62)	\$(95)	\$(155)
	Pennsylvania	\$(45)	\$(50)	\$(95)
	PJM	\$(210)	\$(277)	\$(474)
Delta in Load-Weighted LMP (\$/MWh)	AEP	\$(0.28)	\$(0.39)	\$(0.66)
	APS	\$(0.41)	\$(0.42)	\$(0.79)

Category	Item			
	FE-ATSI	\$(0.57)	\$(0.90)	\$(1.45)
	DAY	\$(0.24)	\$(0.37)	\$(0.60)
	DEOK	\$(0.21)	\$(0.33)	\$(0.54)
	DUQ	\$(0.82)	\$(0.59)	\$(1.37)
	METED	\$(0.16)	\$(0.18)	\$(0.32)
	PECO	\$(0.16)	\$(0.18)	\$(0.35)
	PENELEC	\$(0.33)	\$(0.51)	\$(0.84)
	PLGRP	\$(0.15)	\$(0.16)	\$(0.32)
	Ohio	\$(0.37)	\$(0.57)	\$(0.93)
	Pennsylvania	\$(0.28)	\$(0.31)	\$(0.58)
	PJM	\$(0.26)	\$(0.34)	\$(0.58)

Second Set of Simulations

The second set of simulations was executed assuming that 50 percent of new gas does not enter the market (see Table 6).

Beaver Valley 1 & 2 Retirement Withdrawn and 50 Percent of New Gas Does Not Enter Market

If the stated retirement of Beaver Valley 1 & 2 is withdrawn and the units remain online:

Energy Market Impacts: Results show an annual increase in load payments of \$240 million over the base case for the entire PJM region. Of that increase, \$43 million would occur in Pennsylvania, and \$52 million would occur in Ohio. Said another way, load payments would increase by \$240 million from the base case if the Beaver Valley 1 & 2 units are retained, given the anticipated reduction in new entry that would otherwise occur. The load payment increases would result from higher-cost marginal units setting the zonal locational marginal prices in the absence of expected new entrants we assumed will not enter due to the existence of the subsidies. This increase in customer payments does not include the cost of a potential subsidy to consumers in a particular state — the subsidy would be an additional cost on top of the increase in wholesale energy prices.

Emissions Impact: In Pennsylvania, emissions of carbon dioxide would decrease by 2,800,000 tons, nitrogen oxides would increase by 3,000 tons, and emissions of sulfur dioxide would increase by 1,400 tons. Increases in nitrogen oxides and sulfur dioxide reflect coal generation, which is uneconomic in the base case, being dispatched when less new entry from natural gas occurs.

In Ohio, emissions of carbon dioxide would decrease by 2,200,000 tons, nitrogen oxides would decrease by 300 tons, and sulfur dioxide would decrease by 400 tons (see Table 6).

Davis-Besse and Perry Retirements Withdrawn and 50 Percent of New Gas Does Not Enter Market

If the stated retirements of Davis-Besse and Perry are withdrawn and the units remain online:

Energy Market Impacts: Results show an annual increase in load payments of \$164 million over the base case for the entire PJM marketplace. Of that increase, \$39 million would occur in Pennsylvania, and \$16 million would occur in Ohio. The analysis shows that load payments would increase by \$164 million from the base case if the Davis-Besse and Perry units were retained, given the anticipated reduction in new entry that would otherwise occur. The

load payment increases would result from higher-cost marginal units setting the zonal LMPs in the absence of expected new entrants that we assume will not enter due to the existence of the subsidies. This increase in customer payments does not include the cost of a potential subsidy to consumers in a particular state – the subsidy would be an additional cost on top of the increase in wholesale energy prices.

Emissions Impact: In Pennsylvania, emissions of carbon dioxide would decrease by 3,000,000 tons, nitrogen oxides would increase by 2,700 tons, and emissions of sulfur dioxide would increase by 1,400 tons.

In Ohio, emissions of carbon dioxide would decrease by 2,800,000 tons, nitrogen oxides would decrease by 800 tons and sulfur dioxide would decrease by 1,000 tons (see Table 6).

Beaver Valley 1&2, Davis-Besse and Perry Retirements Withdrawn and 50 Percent of New Gas Does Not Enter Market

If the stated retirements of Beaver Valley 1 & 2, Davis-Besse and Perry are all withdrawn and the units remain online:

Energy Market Impacts: Results show an annual decrease in load payments of \$91 million from the base case for the entire PJM marketplace. Of that annual decrease, \$15 million would occur in Pennsylvania, and \$56 million would occur in Ohio. Said another way, load payments would decrease by an additional \$90 million for the PJM region, \$15 million in Pennsylvania and \$56 million in Ohio from the base case if the Beaver Valley 1 & 2, Davis-Besse and Perry units were retained, even if a reduction in new entry were to occur. This is because the retention of all the nuclear plants and their associated energy production is sufficient to offset the impact of the reduced new entry. This reduction in customer payments, however, is not netted against the cost of a potential subsidy to consumers in a particular state.

Emissions Impact: In Pennsylvania, emissions of carbon dioxide would decrease by 5,500,000 tons, nitrogen oxides would show very little change and emissions of sulfur dioxide would decrease by 300 tons.

In Ohio, emissions of carbon dioxide would decrease by 4,000,000 tons, nitrogen oxides would decrease by 1,400 tons and sulfur dioxide would decrease by 1,800 tons (see Table 6).

Table 6. Simulation Results Base Case (50 Percent of New Entrants Don't Enter Market)

Category	Item			
Nuclear Units Status	TMI (PA)	Retired	Retired	Retired
	Beaver Valley 1 & 2 (PA)	In-Service	Retired	In-Service
	Perry (OH)	Retired	In-Service	In-Service
	Davis-Besse (OH)	Retired	In-Service	In-Service
Nuclear Capacity Not Retired (MW)		1,812	2,143	3,955
Planned Gas Capacity Removed (MW)		5,896	5,896	5,896
Delta in Effluent Tons	Ohio CO ₂ (millions)	(2.2)	(2.8)	(4.0)
	Ohio SO ₂ (thousands)	(0.4)	(1.0)	(1.8)
	Ohio NO _x (thousands)	(0.3)	(0.8)	(1.4)
	Pennsylvania CO ₂ (millions)	(2.8)	(3.0)	(5.5)
	Pennsylvania SO ₂ (thousands)	1.4	1.4	(0.3)



Category	Item			
	Pennsylvania NOx (thousands)	3.0	2.7	0.0
	PJM CO ₂ (millions)	(4.1)	(5.2)	(12.5)
	PJM SO ₂ (thousands)	1.7	0.9	(3.0)
	PJM NOx (thousands)	3.8	2.9	(1.9)
Delta in Load Payments (\$ millions)	AEP	\$45.29	\$27.98	\$(17.17)
	APS	\$15.67	\$14.84	\$(7.94)
	FE-ATSI	\$13.67	\$(10.85)	\$(54.05)
	DAY	\$8.20	\$5.49	\$0.15
	DEOK	\$13.14	\$9.88	\$2.22
	DUQ	\$0.08	\$3.67	\$(9.02)
	METED	\$5	\$5	\$1
	PECO	\$13	\$12	\$3
	PENELEC	\$5	\$2	\$(5)
	PLGRP	\$12	\$11	\$2
	Ohio	\$52	\$16	\$(56)
	Pennsylvania	\$43	\$39	\$(15)
	PJM	\$240	\$164	\$(91)
Delta in Load-Weighted LMP (\$/MWh)	AEP	\$0.34	\$0.21	\$(0.13)
	APS	\$0.27	\$0.28	\$(0.18)
	FE-ATSI	\$0.20	\$(0.16)	\$(0.78)
	DAY	\$0.46	\$0.31	\$0.00
	DEOK	\$0.47	\$0.34	\$0.06
	DUQ	\$0.00	\$0.25	\$(0.63)
	METED	\$0.30	\$0.28	\$0.07
	PECO	\$0.31	\$0.30	\$0.07
	PENELEC	\$0.27	\$0.09	\$(0.28)
	PLGRP	\$0.27	\$0.27	\$0.06
	Ohio	\$0.31	\$0.10	\$(0.33)
	Pennsylvania	\$0.27	\$0.24	\$(0.09)
	PJM	\$0.29	\$0.20	\$(0.11)

Table 7. Summary of all Simulation Results

Category	Item	Scenarios						
		Retired	Retired	Retired	Retired	Retired	Retired	Retired
Nuclear Units Status	TMI (PA)	Retired	Retired	Retired	Retired	Retired	Retired	Retired
	Beaver Valley 1&2 (PA)	In-Service	In-Service	Retired	In-Service	In-Service	Retired	In-Service
	Perry (OH)	In-Service	Retired	In-Service	In-Service	Retired	In-Service	In-Service
	Davis-Besse (OH)	In-Service	Retired	In-Service	In-Service	Retired	In-Service	In-Service
Nuclear Capacity not Retired (MW)		3,955	1,812	2,143	3,955	1,812	2,143	3,955
Planned Gas Capacity Removed (MW)		10,514	-	-	-	5,896	5,896	5,896



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Category	Item	Scenarios						
Delta in Effluent Tons	Ohio CO ₂ (millions)	(5.4)	(1.5)	(2.3)	(3.7)	(2.2)	(2.8)	(4.0)
	Ohio SO ₂ (thousands)	0.8	(0.7)	(2.6)	(3.5)	(0.4)	(1.0)	(1.8)
	Ohio NO _x (thousands)	0.1	(0.5)	(1.7)	(2.4)	(0.3)	(0.8)	(1.4)
	Pennsylvania CO ₂ (millions)	(3.6)	(2.1)	(2.3)	(4.7)	(2.8)	(3.0)	(5.5)
	Pennsylvania SO ₂ (thousands)	8.8	(1.3)	(2.0)	(3.3)	1.4	1.4	(0.3)
	Pennsylvania NO _x (thousands)	22.7	(2.1)	(2.0)	(5.0)	3.0	2.7	0.0
	PJM CO ₂ (millions)	4.3	(6.6)	(8.1)	(15.1)	(4.1)	(5.2)	(12.5)
	PJM SO ₂ (thousands)	18.2	(2.9)	(5.3)	(8.5)	1.7	0.9	(3.0)
	PJM NO _x (thousands)	37.9	(3.7)	(4.8)	(9.7)	3.8	2.9	(1.9)
Delta in Load Payments (\$millions)	AEP	\$244.18	\$(37.85)	\$(52.48)	\$(88.49)	\$45.29	\$27.98	\$(17.17)
	APS	\$115.51	\$(20.91)	\$(21.71)	\$(42.19)	\$15.67	\$14.84	\$(7.94)
	FE-ATSI	\$118.82	\$(39.11)	\$(61.93)	\$(99.63)	\$13.67	\$(10.85)	\$(54.05)
	DAY	\$35.51	\$(4.20)	\$(6.58)	\$(10.55)	\$8.20	\$5.49	\$0.15
	DEOK	\$58.44	\$(5.69)	\$(8.75)	\$(14.16)	\$13.14	\$9.88	\$2.22
	DUQ	\$31.20	\$(11.77)	\$(8.33)	\$(19.53)	\$0.08	\$3.67	\$(9.02)
	METED	\$40	\$(2)	\$(3)	\$(5)	\$5	\$5	\$1
	PECO	\$98	\$(7)	\$(8)	\$(15)	\$13	\$12	\$3
	PENELEC	\$36	\$(6)	\$(9)	\$(15)	\$5	\$2	\$(5)
	PLGRP	\$110	\$(6)	\$(7)	\$(14)	\$12	\$11	\$2
	Ohio	\$305	\$(62)	\$(95)	\$(155)	\$52	\$16	\$(56)
	Pennsylvania	\$375	\$(45)	\$(50)	\$(95)	\$43	\$39	\$(15)
PJM	\$1,597	\$(210)	\$(277)	\$(474)	\$240	\$164	\$(91)	
Delta in Load-Weighted LMP (\$/MWh)	AEP	\$1.81	\$(0.28)	\$(0.39)	\$(0.66)	\$0.34	\$0.21	\$(0.13)
	APS	\$2.17	\$(0.41)	\$(0.42)	\$(0.79)	\$0.27	\$0.28	\$(0.18)
	FE-ATSI	\$1.72	\$(0.57)	\$(0.90)	\$(1.45)	\$0.20	\$(0.16)	\$(0.78)
	DAY	\$1.99	\$(0.24)	\$(0.37)	\$(0.60)	\$0.46	\$0.31	\$0.00
	DEOK	\$2.07	\$(0.21)	\$(0.33)	\$(0.54)	\$0.47	\$0.34	\$0.06
	DUQ	\$2.14	\$(0.82)	\$(0.59)	\$(1.37)	\$0.00	\$0.25	\$(0.63)
	METED	\$2.43	\$(0.16)	\$(0.18)	\$(0.32)	\$0.30	\$0.28	\$0.07
	PECO	\$2.31	\$(0.16)	\$(0.18)	\$(0.35)	\$0.31	\$0.30	\$0.07
	PENELEC	\$2.06	\$(0.33)	\$(0.51)	\$(0.84)	\$0.27	\$0.09	\$(0.28)
	PLGRP	\$2.60	\$(0.15)	\$(0.16)	\$(0.32)	\$0.27	\$0.27	\$0.06
	Ohio	\$1.83	\$(0.37)	\$(0.57)	\$(0.93)	\$0.31	\$0.10	\$(0.33)
	Pennsylvania	\$2.32	\$(0.28)	\$(0.31)	\$(0.58)	\$0.27	\$0.24	\$(0.09)
PJM	\$1.96	\$(0.26)	\$(0.34)	\$(0.58)	\$0.29	\$0.20	\$(0.11)	