SII-ZECJ-ENV-0002

THE IMPACT OF NUCLEAR GENERATION RETIREMENTS ON EMISSIONS AND FUEL DIVERSITY IN NEW JERSEY

PSEG SERVICES CORPORATION

September 2020

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LICENSE AGREEMENT

The methodology, analysis, and findings expressed in this Report relate solely to the consideration of the retirement of the Hope Creek, Salem 1, and/or Salem 2 nuclear generating resources, are current as of September 2020 and, where applicable, incorporate underlying market data as of April 28, 2020. They were prepared by PA Consulting Group, Inc. ("PA") at the request of the PSEG Services Corporation ("PSEG") as part of PSEG's application to the New Jersey Board of Public Utilities ("BPU") for Zero Emission Certificates ("ZEC") for Hope Creek, Salem 1, and/or Salem 2. The use of this Report for any other purpose or in any other context is prohibited, and PA is not responsible for any loss or damage to any third party as a result of their use or reliance (direct or otherwise) on PA's analysis and this Report.

GLOSSARY

- **AURORA:** Computer-based chronological dispatch simulation model used to project electric generator dispatch and wholesale power prices.
- **Bcfd:** Billion cubic feet per day, a rate measure of natural gas.
- **BPU:** New Jersey Board of Public Utilities.
- **CEMS:** Continuous Emission Monitoring Systems, refers to data on emissions by generating resources reported to the EPA and made publicly available in EPA datasets.
- **CO_2:** Carbon dioxide, the primary greenhouse gas emitted through burning fossil fuels (such as coal and natural gas) to generate electricity.
- **COD:** Commercial online date.
- **Delivery Year:** In this study, a 12-month period covering the months of June through May.
- **Eastern Interconnect:** A major alternating current electric grid covering much of the eastern US and parts of Canada. In this Report, the Eastern Interconnect refers only to the US portion of the grid.
- **eGRID:** Emissions & Generation Resource Integrated Database, an EPA dataset on generation, fuel consumption, and environmental characteristics of generating resources located in the US.
- **EIA:** US Energy Information Administration.
- **EMAAC:** The Eastern Mid-Atlantic Area Council Region, a transmission zone encompassing the eastern portion of the MAAC Region of PJM.
- **Energy Master Plan:** A periodic document issued by the State of New Jersey reflecting state energy policy regarding the production, distribution, consumption, and conservation of energy.
- **EPA:** US Environmental Protection Agency.
- **FERC:** US Federal Energy Regulatory Commission.
- **GHG:** Greenhouse gas.
- **GPCM®:** Computer-based natural gas price forecasting system that models natural gas production, existing pipeline flows and constraints, new pipeline construction, and natural gas demand from the power sector and residential, commercial, and industrial sectors for the entire United States.
- **HEDD:** High Electric Demand Day, the day in the Study Period with the highest projected PJM-wide peak demand.
- **Henry Hub:** A pricing point for natural gas, located in Louisiana. The settlement prices at Henry Hub are used as benchmarks for the entire North American natural gas market.
- **Hg:** Mercury, a naturally occurring toxic pollutant.
- **lb:** Pound.
- **LMP:** Locational marginal price, measured in $/MWh, gives market participants a signal of the price of energy at every location on the electric system. LMP in PJM (including the MAAC Region) reflects the costs of energy, congestion, and marginal losses.
- **MAAC Region:** The Mid-Atlantic Area Council Region, a transmission region within PJM that encompasses all or parts of Delaware, DC, Maryland, New Jersey, and Pennsylvania.
- **MATS:** Mercury and Air Toxics Standards, refers to compliance reports and accompanying emission data submitted by generating resources to the EPA to demonstrate compliance with the Mercury and Air Toxics rule.

- **MISO:** The Midcontinent Independent System Operator, a Regional Transmission Organization encompassing all or parts of 14 Midwestern, Great Plains, and Southern US states.
- **MMBtu:** Million British Thermal Units, a measure of energy content.
- **MMWG:** Multiregional Modeling Working Group, a North American Electric Reliability Corporation working group tasked with electric system reliability modeling.
- **Modeled Pollutants:** The range of pollutants modeled in PA's analysis - CO_2, NOx, SO_2, Hg, PM_{10}, and $PM_{2.5}$.
- **NEB:** Canada's National Energy Board.
- **NOx:** Nitrogen oxides, primarily nitric oxide and nitrogen dioxide - air pollutants emitted through burning fossil fuels such as coal and natural gas to generate power.
- **NYISO:** The New York Independent System Operator, a Regional Transmission Organization encompassing the State of New York.
- **Peak Winter Day:** The day in the coldest winter months (i.e., December through February) during the Study Period with the highest projected peak demand.
- **PJM:** PJM Interconnection, L.L.C., a Regional Transmission Organization ("RTO") encompassing all or parts of 13 Mid-Atlantic, Midwestern, and Southern US states and the District of Columbia.
- **PJM & NYISO States:** The 14 US states and the District of Columbia that lie entirely within the PJM or NYISO market footprints – District of Columbia, Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, North Carolina, New Jersey, New York, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia.
- **PM_{10}:** Particulate matter with diameter less than or equal to 10 micrometers (i.e., coarse PM). PM_{10} is an air pollutant typically caused by incomplete combustion as well as atmospheric chemical reactions of chemicals such as SO_2 and NOx.
- **$PM_{2.5}$:** Particulate matter with diameter less than or equal to 2.5 micrometers (i.e., fine PM). $PM_{2.5}$ is an air pollutant typically caused by incomplete combustion as well as atmospheric chemical reactions of chemicals such as SO_2 and NOx. $PM_{2.5}$ emissions this analysis reflect those directly emitted and may be conservative based on what may form based on chemical reactions.
- **Reserve Margin:** In an electric system, the amount of excess firm resource capacity compared with peak demand.
- **RGGI:** The Regional Greenhouse Gas Initiative, an electric power sector-specific GHG emission cap-and-trade program comprised of ten participating Northeastern and Mid-Atlantic States. Virginia would be the eleventh participating state.
- **RPS:** Renewable Portfolio Standard.
- **RTO:** Regional Transmission Organization, an electric power transmission system operator that coordinates, controls, and monitors a single- or multi-state electric grid, including operating of wholesale markets for electricity products such as energy, capacity, and ancillary services.
- **SMOKE:** Sparse Matrix Operator Kernel, an air emissions modeling system used by the EPA. In this report, SMOKE refers to the emissions input data used by the EPA in its SMOKE modeling.
- **SO_2:** Sulfur dioxide, an air pollutant emitted through the combustion of sulfur in fuel (primarily coal) used by electric generators and industrial facilities.
- **Study Period:** In this analysis, the three-year period is defined as the period from June 1, 2022, through May 31, 2025.
- **Ton:** Short ton, equivalent to 2,000 lbs.
- **TM3:** Texas Eastern Transmission ("TETCO") M3, a major trading hub for natural gas delivery.

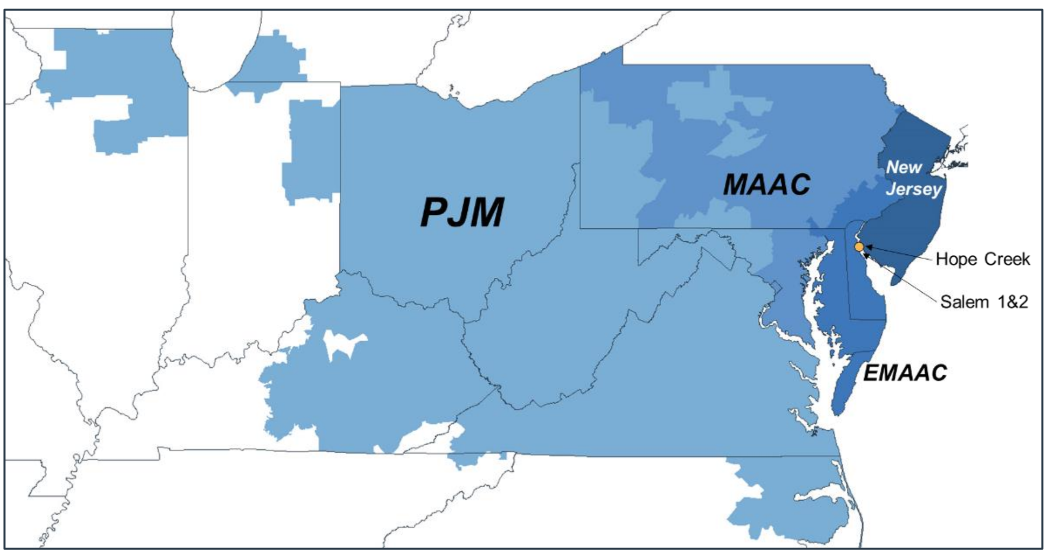
- **TZ6:** Transcontinental Gas Pipeline (“Transco”) Zone 6, a major trading hub for natural gas delivery.
- **TRI:** Toxic Release Inventory, an EPA dataset that tracks emissions of various toxic pollutants.
- **Typical Summer Day:** The day during the summer months (June through August 2021) with peak demand representative of average daily peak demand across those months.
- **ZEC:** Zero Emission Certificate or Zero Emission Credit, a policy mechanism enacted in Illinois, New Jersey, and New York to provide financial support for non-energy attributes of nuclear generation.

1 INTRODUCTION

On May 23, 2018, the State of New Jersey enacted "An Act concerning nuclear energy, and supplementing Title 48 of the Revised Statutes" (P.L.2018, c.16 (C.48:3-87.3 to 48:3-87.7)), referred to in this Report as the "ZEC Act."[1] The ZEC Act directs the New Jersey BPU to create a program to determine both the eligibility of nuclear generating resources for ZECs as well as eligible resources' ranking for selection to receive ZECs. As part of the determination process, the owner of a nuclear generation unit is required to make certain demonstrations including—but not limited to—the adverse impact that retirement of the unit would have on air quality or other attributes of environmental quality in New Jersey as well as fuel diversity and resilience contributions to the electric grid.

The PSEG Services Corporation ("PSEG") initially engaged PA Consulting Group ("PA") in 2018 to conduct an independent evaluation of projected emissions and fuel diversity impacts of the retirement of several nuclear generating resources located in the State of New Jersey that are owned wholly or partially by PSEG. The initial analysis was part of PSEG's first ZEC application before the New Jersey Board of Public Utilities. All three units (Hope Creek and Salem Harbor 1 & 2) were awarded ZEC Certificates in April 2019, covering the time period from June 2019 to May 2022. The analysis in this report pertains to PSEG's second ZEC application, which will address the time period from June 2022 to May 2025. See Figure 1-1 for the location of these generators within PJM and the broader electricity region and Table 1-1 for a more detailed description of the generation units.

Figure 1-1: Location of the PSEG Nuclear Generating Resources[2]



[1] Please see the Glossary for acronym and key term definitions.

[2] New Jersey falls entirely within the EMAAC transmission zone.

Table 1-1: PSEG Nuclear Generating Resources[3]

Facility	Tech. Type	Fuel Type	COD	Nameplate Capacity	Transmission Zone	State
Hope Creek	Boiling Water Reactor	Nuclear	1986	1,291 MW	EMAAC	NJ
Salem 1	Pressurized Water Reactor	Nuclear	1977	1,170 MW	EMAAC	NJ
Salem 2	Pressurized Water Reactor	Nuclear	1981	1,170 MW	EMAAC	NJ

In this independent evaluation, PA seeks to answer two primary questions:

- How would the retirement of the Hope Creek, Salem 1, and Salem 2 nuclear generating units impact electric power generation emissions in the State of New Jersey and the surrounding electricity region?
- How would the retirement of the Hope Creek, Salem 1, and Salem 2 nuclear generating units impact fuel diversity and grid resilience in New Jersey and the surrounding electricity region?

To evaluate these questions, PA conducted a forward-looking analysis over the three-year period between June 2022 and May 2025 (the "Study Period") that assessed the emissions and fuel diversity impacts of retiring one or more of these nuclear generating resources. Specifically, PA modeled the electric system within the Eastern Interconnect under three Cases: (i) a "Base Case" that represents PA's independent view of the Eastern Interconnect, including the continued operation of Hope Creek, Salem 1, and Salem 2; (ii) a "Full Retirement Case" that assumes Hope Creek, Salem 1, and Salem 2 do not operate during the Study Period, and (iii) a "Hope Creek Retirement Case" that assumes Hope Creek does not operate during the Study Period. PA compared the results of the Full Retirement Case and Hope Creek Retirement Case against the Base Case to assess the impacts of the nuclear units' retirements.

As described in the remainder of this report, PA's results clearly demonstrate that emissions of harmful pollutants from the electric power sector would increase considerably over the three-year Study Period if these nuclear generating units were to retire. As demonstrated in Figure 1-2 and Table 1-2, the retirement of Hope Creek, Salem 1, and Salem 2 would lead to significant increases in emissions within the greater New Jersey region.

[3] PSEG fully owns Hope Creek, and has a ~57% ownership stake in Salem 1 and Salem 2.

Figure 1-2: Increase in State-Level Emissions Across Study Period – Full Retirement Case[4,5]

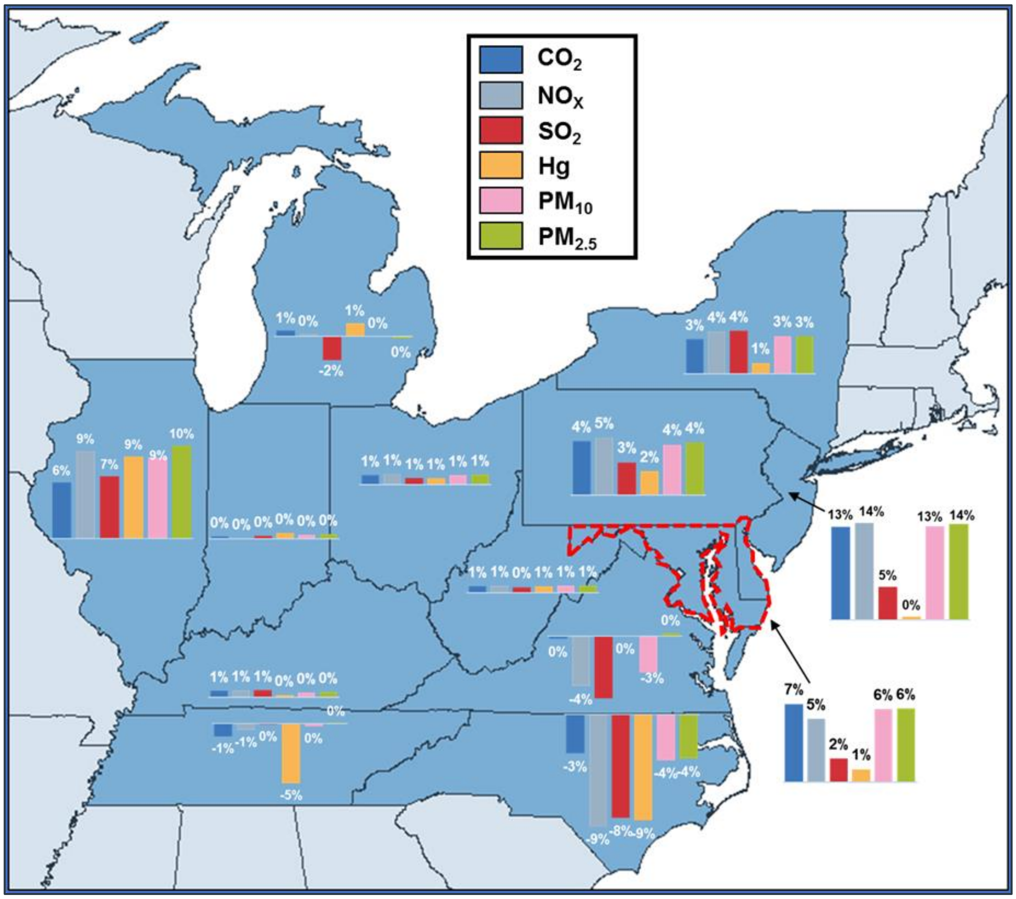


Table 1-2: Increase in Emissions Across Study Period – Full Retirement Case

Geography	CO_2 ('000 short tons)	NOx (short tons)	SO_2 (short tons)	Hg (lbs)	PM10 (short tons)	PM2.5 (short tons)
New Jersey	8,892	2,074	202	0.2	547	526
MAAC	26,053	8,999	4,851	8.3	1,808	1,649

Harmful emissions are also projected to occur if only one of the PSEG nuclear units retires. As demonstrated in Figure 1-3 and Table 1-3, the retirement of Hope Creek alone would also lead to increases in emissions within the greater New Jersey region.

[4] PA's electricity system modeling included the entire Eastern Interconnect. While aggregate emissions across the Eastern Interconnect of all pollutants increased under the Full Retirement Case, re-dispatch of the entire Eastern Interconnect under the Full Retirement Case (compared to the Base Case) did yield emission declines in certain sub-regions. For example, in Michigan, the decline in 3 of the 6 pollutants under the Full Retirement Case was driven by changes to dispatch within the MISO (rather than PJM) portion of the state.

[5] The region encompassed by the purple dashed line includes Maryland, Delaware, and the District of Columbia.

Figure 1-3: Increase in State-Level Emissions Across Study Period – Hope Creek Retirement Case

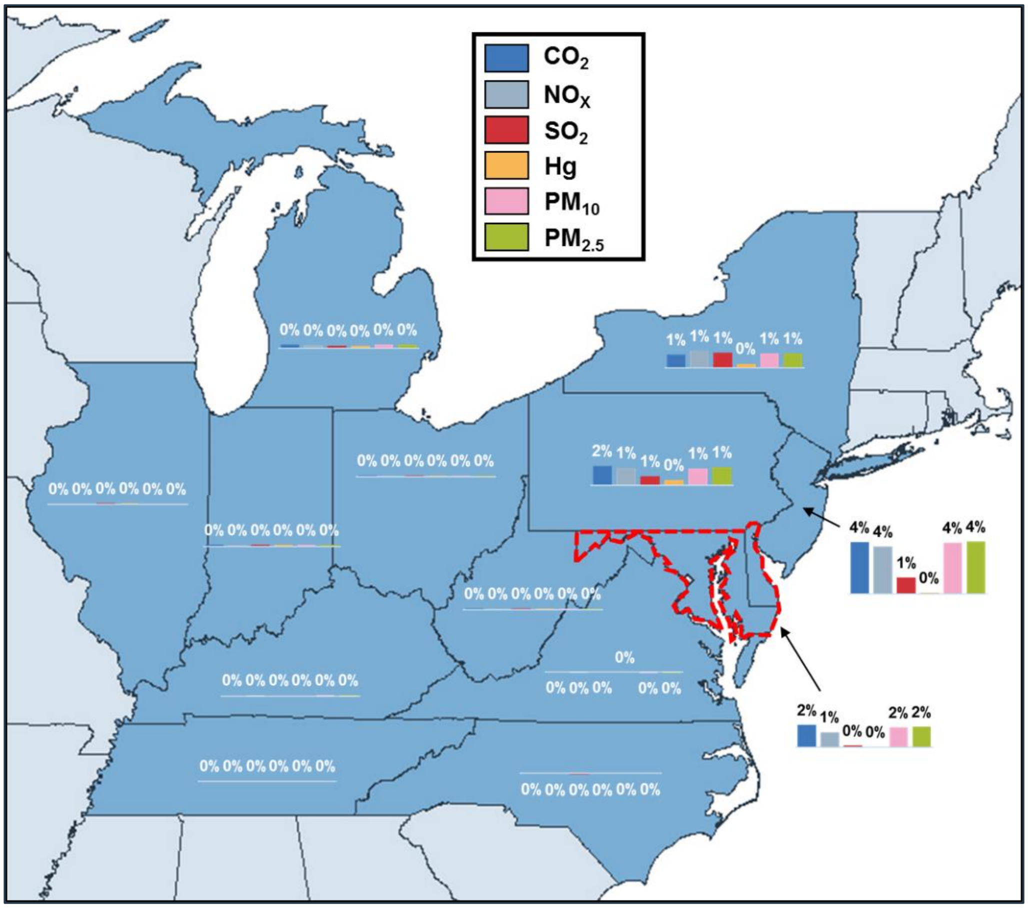


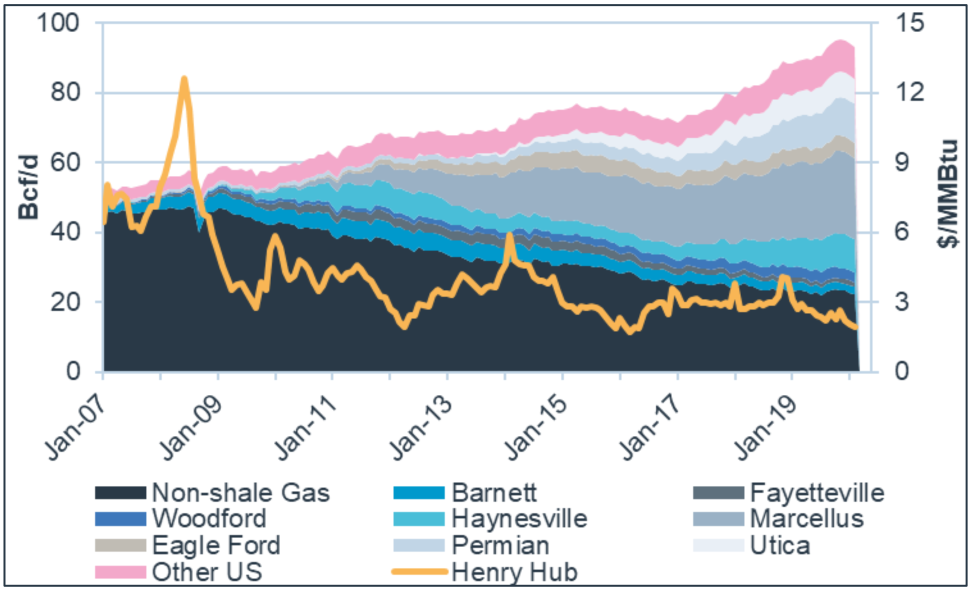
Table 1-3: Increase in Emissions Across Study Period – Hope Creek Retirement Case

Geography	CO_2 ('000 short tons)	NOx (short tons)	SO_2 (short tons)	Hg (lbs)	PM10 (short tons)	PM2.5 (short tons)
New Jersey	2,779	567	57	0.0	168	162
MAAC	8,435	2,512	1,173	1.4	557	517

2 BACKGROUND AND KEY QUESTIONS

In recent years, sustained low natural gas pricing resulting from the shale revolution (see Figure 2-1 for an overview of US shale dry gas production and Henry Hub pricing), an increasing share of natural gas-fired generating capacity and the limited compensation for carbon-free attributes has put downward pressure on wholesale power pricing throughout the United States. This dynamic has narrowed operating margins and created significant economic challenges for baseload nuclear generating resources operating in deregulated wholesale power markets, including PJM and, by extension, the State of New Jersey.

Figure 2-1: Lower 48 Dry Gas Production (Bcfd) vs. Henry Hub Natural Gas Prices ($/MMBtu)[6]



While deregulated wholesale electric markets were introduced, in part, to encourage resource competition to ensure a more cost-effective generation mix and lower electricity costs to consumers, policymakers have grown concerned at the environmental, reliability, resilience, and economic implications of allowing zero-emission generating resources to retire due to low wholesale power prices when these attributes are not fully valued within the current market construct. In turn, policymakers in several states have implemented or proposed programs that seek to compensate zero-emission generating resources for their beneficial non-energy attributes. For example:

- In New York, the August 2016 *Order Adopting a Clean Energy Standard* established payment of ZECs for generation from three upstate nuclear generating resources.
- In Illinois, legislation (SB-2814) signed into law in December 2016 commenced a ZEC program for two of the nuclear generating plants in that state.
- In Connecticut, legislation (SB-1501) signed into law in October 2017 established a clean energy procurement through which two nuclear generation facilities (in Connecticut and New Hampshire) successfully secured long-term power supply contracts.

The State of New Jersey similarly recognizes the value of zero emitting resources and, on May 23, 2018, enacted the ZEC Act. The ZEC Act directs the New Jersey BPU to create a program to determine both the eligibility of nuclear generating resources for ZECs as well as eligible resources' ranking for selection to receive ZECs.

[6] As of July 2020. Source: EIA and NYMEX ClearPort.

The ZEC program enabled under the ZEC Act is consistent with recent energy policy in New Jersey, which has sought to reduce emissions from the electric power sector while ensuring a reliable and resilient electric system. For example:

- Legislation (P.L.1999, c.23 (C.48:3-49 et seq.)) enacted in 1999 that restructured the electric power sector and established the state's first Renewable Portfolio Standard stated that "it is the policy of this State to:…provide diversity in the supply of electric power throughout this State." New Jersey has since adopted an RPS target of 50% by 2030 (signed into law in 2018).
- In 2007, New Jersey enacted the Global Warming Response Act (P.L.2007, c.112 (C.26:2C-37 et seq.), which established a target for the state to reduce GHG emissions to 80% below 2006 levels by 2050.
- New Jersey's October 2008 Energy Master Plan stated that "[t]he State also recognizes that the diversification of the State's fuel portfolio can increase reliability, and encourage competition, which may help stabilize energy prices in New Jersey,"[7] while the December 2015 New Jersey Energy Master Plan Update stated that "[t]he state sees nuclear power as an important element of a diverse resource portfolio."[8]
- A series of executive orders in 2018 (EO 8) and 2019 (EO 92) established offshore wind procurement goals of 3,500 MW by 2030 and 7,500 MW by 2035, with the orders highlighting the emissions free and reliability benefits of offshore wind as key motivators for these actions.
- More recently, the 2019 New Jersey Energy Master Plan calls for 100% carbon-neutral electricity generation by 2050.
  - The Energy Master Plan is a strategic document that guides executive orders, sets goals to be pursued by New Jersey public agencies (e.g., "explore regulatory authority to achieve 100% clean energy by 2050," "coordinate permitting and siting processes for renewable energy development") through studies and the development of new regulations, and sets priorities for the legislature; however, it does not by itself include legally enforceable requirements (e.g., non-compliance penalties).
  - The Energy Master Plan is informed by an Integrated Energy Plan modeling exercise, whereby the costs of achieving New Jersey's 100% clean energy by 2050 goal are compared across seven scenarios (relative to a business-as-usual reference case). Only one scenario (Variation 5) forces the state's nuclear generators to retire by the end of the study period. This model run was nearly $8 billion per year more expensive than the "least cost" scenario by 2050.[9] Thus, the plan suggests that the state's nuclear facilities are critical to achieving its clean energy goals in a cost-efficient manner.
- In 2018, Governor Phil Murphy issued EO 7, calling for New Jersey to re-join RGGI (thereby subjecting the state to a declining regional cap on carbon emissions from large power generators). The DEP subsequently adopted rules allowing for the state's re-entry, and New Jersey participated in its first auction since 2012 earlier this year.[10]

In the ZEC Act, the New Jersey Legislature pointed to several benefits of nuclear generating resources to the electric power system and the State as well as risks if nuclear generating resources were to retire. Summarizing their findings and intent, the Legislature stated that:

- "Nuclear power generation is a critical component of the State's clean energy portfolio because nuclear power plants do not emit carbon dioxide, other greenhouse gases, or other pollutants; in addition, nuclear power is an important element of a diverse energy generation portfolio that currently meets approximately 40 percent of New Jersey's electric power needs"; and

[7] Page 81.
[8] Page 20.
[9] Pages 275-276, 281
[10] New Jersey was a founding member of RGGI in 2005; however, Governor Chris Christie withdrew the state from the program in 2012, beginning an eight year hiatus.

- "A program that recognizes and compensates nuclear energy generators in a manner similar to other non-emitting energy generation resources to the extent required to prevent the loss of nuclear energy…could, in the absence of equally or more cost-effective clean energy alternatives, further the State's interest in environmental protection and maintaining a diverse mix of energy sources."

In order to be deemed eligible, a power plant had to 1) be licensed by the U.S Nuclear Regulatory Commission ("NRC") through 2030, 2) demonstrate a significant and material contribution to New Jersey air quality, 3) demonstrate anticipated plant shutdown within three years due to its financial situation, 4) certify that the plant doesn't received external subsidies, and 5) submit an application fee.

2.1 THE IMPORTANCE OF FUEL DIVERSITY

Twin goals for any electricity system are to provide (i) reliable electricity at (ii) the least cost to consumers. Operators recognize that it is not practical to protect the grid against every possible disruption. These disruptions can include weather events, such as hurricanes, that can damage or strain the physical capabilities of the electricity system; upstream shocks that impact fuel pricing or availability, particularly for natural gas that is not stored on-site; or policy and regulatory shocks that may disproportionately impact one fuel or technology. For this reason, electricity system planners strive for a grid that is resilient to any potential disruption.

A primary contributor to electric system resilience is the diversification of fuels and technologies used to generate electricity. There is no single "perfect" fuel upon which to rely for a reliable and resilient electricity system, and preferences can vary widely by state and by region. Rather, a diversity of fuels and generation technologies helps the system maintain reliability and quickly bounce back after low-probability, high-impact events by allowing operators to maximize the benefits of each individual fuel type and technology while offsetting the drawbacks of each. As a fuel with unique reliability benefits and clean attributes, nuclear generation plays an important and unique role in this diverse generation mix. Table 2-1 provides a qualitative assessment of some of these critical attributes provided by each fuel type.

Table 2-1: Qualitative Comparison of Grid Reliability and Resilience Attributes by Fuel Type[11]

Attribute	Nuclear	Coal	Natural Gas	Other Fuel Oils	Wind and Solar	Demand Response
Price Stability	✓	✓			✓	
Environmental	✓				✓	✓
Dispatchability	✓	✓	✓	✓		✓
Inertia	✓	✓	✓	✓	✓[a]	
Contingency Reserves		✓	✓	✓		✓
Reactive Power	✓	✓	✓	✓		
Black Start			✓	✓		
On-Site Fuel Supply	✓	✓		✓[b]		
Reduced Exposure to Single Point of Disruption	✓	✓			✓	✓

Fuel diversity benefits are frequently cited when promoting policies such as RPS (including New Jersey's RPS, as discussed above) that advance a specific fuel or technology type whose benefits are not recognized or are underpriced by wholesale electricity markets. For instance, the Council of State Governments has noted that one of the main objectives of state RPS is "to diversify the state's electricity supply,"[12] and most states allow a variety of renewable energy technologies (e.g., wind, solar, biomass, waste-to-energy, etc.) to qualify for renewable energy credits. Similarly, the U.S. Department of Energy has identified that "a

[11] Notes: (a) Wind only (b) Often limited.

[12] Source: The Council of State Governments, Overview of State Renewable Portfolio Standards, December 2008.

diverse portfolio of generation resources and well-planned transmission investments are critical to meeting regional reliability objectives."[13]

As coal-fired power generation resources continue to retire across Northeast and Mid-Atlantic states, dependence on natural gas in these regions has increased significantly. However, as discussed in more detail below, weather events and other disruptions have highlighted the consequences associated with existing constraints on the natural gas pipeline network. Over the past decade, developers have proposed a series of pipeline projects intended to ease these constraints; however, mounting civil opposition to greenfield pipelines—combined with states setting more aggressive decarbonization goals in recent years—has led to a challenging permitting environment for such projects, leading to substantial delays, cost overruns, and (in some cases) cancellations. Most recently, Dominion Energy and Duke Energy cancelled the Atlantic Sunrise pipeline in July 2020 (with the project originally announced in 2014) that would have moved gas between West Virginia and North Carolina via Virginia as long delays, increasing costs, and uncertain legal outcomes introduced significant risk. Other recent cancellations (e.g., Williams' Constitution Pipeline in New York) and ongoing delays indicate that pipeline constraints may continue to continue and drive occasionally very high power prices, bolstering the case for a more diversified power generation mix.

These arguments acknowledge that there is an inherent benefit to diversity, regardless of specific fuel supply. One recent example that demonstrated (i) several potential shortcomings of individual fuel types as well as (ii) the resilience benefits of fuel diversity to the electricity system overall was the Polar Vortex of January 2014.

Case Study: Polar Vortex

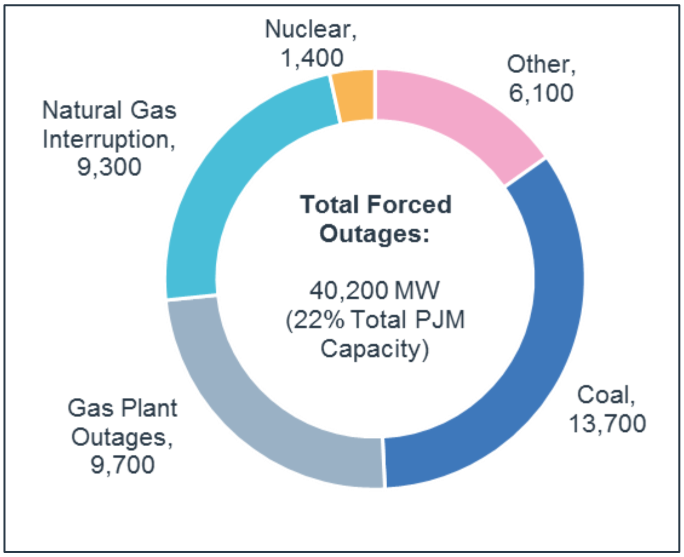
The 2014 Polar Vortex was an abnormally cold weather event that impacted most of the eastern and central United States. It was most severe January 6-8, when record-low temperatures contributed to PJM's all-time winter peak demand of 141.9 GW. Although the PJM region is summer-peaking, the multiple low-probability, high-impact disruptions challenged the reliability of the electricity system and significantly increased wholesale electricity prices.

The extremely cold winter weather contributed directly to high demand for both electricity and natural gas. Natural gas is used by power generators to generate electricity as well as by residential customers for their heating needs. Residential heating demand often has priority on local natural gas distribution systems, meaning the cold weather contributed to natural gas unavailability and price volatility, particularly in eastern PJM, New York and New England. Fuel unavailability also extended to coal plants, several of which reported frozen coal piles as the reason for their outage.

In PJM, over 40 GW, or 22 percent, of generation capacity was out of service during the most critical hour on January 7, 2014, an outcome driven by equipment and fuel supply issues at coal and natural gas generators. Crucially, nearly all nuclear capacity remained online, as shown in Figure 2-2. This allowed system operators to maintain continuous uninterrupted supply of electricity without any load shedding or blackouts. However, tight supply conditions driven by coal and natural gas outages caused abnormally high pricing during this period, and a greater reliance on natural gas or coal in PJM would likely have exacerbated these observed conditions.

[13] Source: U.S. Department of Energy, *Staff Report to the Secretary on Electricity Markets and Reliability*, August 2017, available at: https://www.energy.gov/sites/prod/files/2017/08/f36/Staff%20Report%20on%20Electricity%20Markets%20and%20Reliability_0.pdf

Figure 2-2: PJM Outages (MW) by Primary Fuel, January 7, 2014, 7:00 pm[14]



Beyond maintaining system reliability, fuel diversity also contributes to lower market power prices by reducing the system's reliance on fuels that may temporarily be very expensive (typically natural gas or fuel oils). These high prices for natural gas can reflect temporal mismatches between supply and demand, rather than fundamental drivers of production or consumption. Instead, they can reflect limited storage capability or constraints on pipelines. A more diverse fuel mix can reduce the instances and severity that these temporarily high prices may have on the system.

Within PJM, points on the eastern seaboard, including New Jersey, saw far higher natural gas prices than points further west, closer to production sources. These high natural gas prices resulted in power prices over $1,000/MWh, or $1/kWh, within many hours. Without the added fuel diversity provided by New Jersey's nuclear fleet, reliability would have been further stressed in January 2014 and costs to serve load would have likely risen significantly.

2.2 KEY QUESTIONS

In light of the energy policy goals and legislative intent reflected in the ZEC Act, as well as the recognized importance of fuel diversity to the reliability and resilience of the electric system, this Report discusses PA's evaluation of the projected emissions and fuel diversity impacts of the retirement of the Hope Creek, Salem 1, and/or Salem 2 nuclear generating resources, all located in the State of New Jersey and owned wholly or partially by PSEG.

Specifically, PA's independent evaluation seeks to answer two primary questions:

- How would the retirement of the Hope Creek, Salem 1, and Salem 2 nuclear generating units impact electric power generation emissions in the State of New Jersey and the surrounding electricity region?
- How would the retirement of the Hope Creek, Salem 1, and Salem 2 nuclear generating units impact fuel diversity and grid resilience in New Jersey and the surrounding electricity region?

The remainder of this Report is divided into four primary sections that describe (i) PA's methodology; (ii) the Base Case emissions results, (iii) the emissions scenario case results; and (iv) the fuel diversity scenario case results.

[14] Source: PJM, available at https://www.pjm.com/~/media/library/reports-notices/weather-related/20140509-analysis-of-operational-events-and-market-impacts-during-the-jan-2014-cold-weather-events.ashx

3 METHODOLOGICAL OVERVIEW

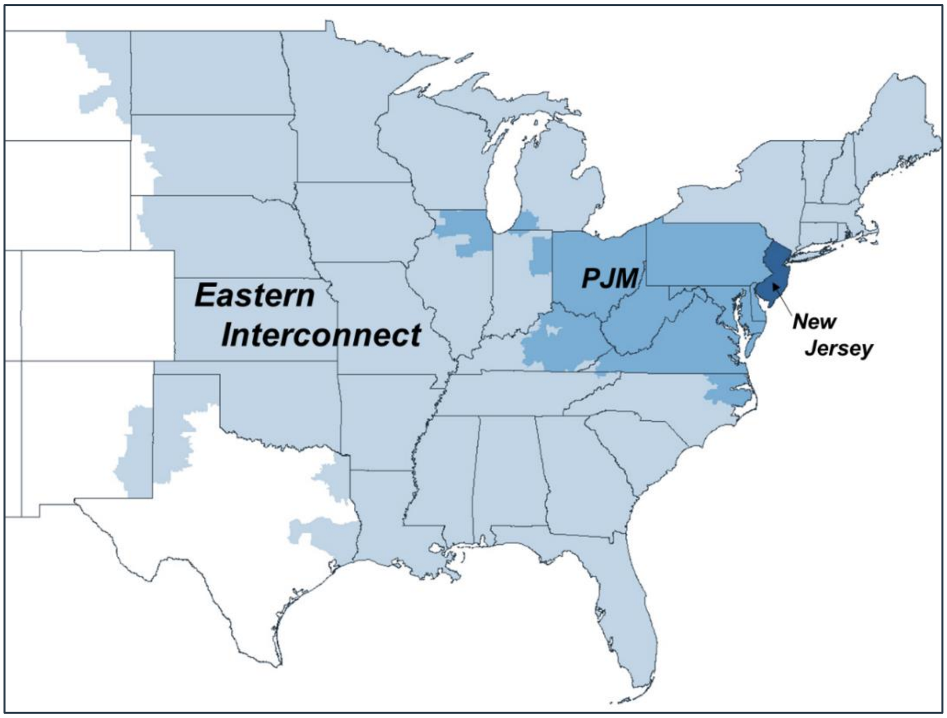
This section describes (i) the electric power system and natural gas system modeling approach used by PA in this analysis, including the process PA used to develop generating unit-level emission rate assumptions used in its electric power system modeling; and (ii) the modeling cases performed by PA to evaluate the impact of nuclear generating resource retirements on electric power sector emissions and fuel diversity.

3.1 MODELING APPROACH

Modeling Process

To evaluate the power sector emissions and fuel diversity impacts of nuclear generating resource retirements, PA used its proprietary electricity market modeling process. The core of PA's modeling process uses an industry standard chronological dispatch simulation model (AURORA) to simulate the hourly operations of the Eastern Interconnect which includes the PJM power market.[15] The AURORA model is widely used by electric utilities, power market regulators, independent system operators, and other market consultants. This model enables PA to project hourly power prices, energy flows, and the operating profiles of the electric generating resources (including dispatch, fuel consumption, and emissions)—in this case, the Eastern Interconnect. See Figure 3-1 for a map of the Eastern Interconnect as well as relevant jurisdictions within the Eastern Interconnect.

Figure 3-1: Modeled Eastern Interconnect Electricity Region[16]



The AURORA model allows for different levels of energy flow assumption detail. The less granular level of detail is known as "zonal" modeling, which reflects aggregate transmission flows and constraints among transmission zones in each electricity region. The more granular level of detail is known as "nodal" modeling, which economically dispatches generating units considering the impact that localized transmission constraints and losses have on nodal LMPs. These differences in LMPs may result in "out of merit" generating unit dispatch to meet demand. Because nodal modeling dispatches based on individual nodal prices, it captures generating unit-specific impacts on the electricity system (e.g., transmission congestion resulting in changes to the regional generation mix).

PA's analysis employed the AURORA Nodal Model configuration. The nodal model is underpinned by the transmission load flow produced by MMWG that incorporates the electrical properties and flow limitations (i.e., constraints) of the Eastern Interconnect bus-level transmission system.

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15 AURORA is a product of Energy Exemplar

16 The entire State of New Jersey is located within the PJM power market.

To forecast the long-term wholesale natural gas prices that PA used in AURORA, PA used the GPCM® Natural Gas Market Forecasting System™. GPCM models natural gas production, existing pipeline flows and constraints, new pipeline construction, and natural gas demand from the power sector and residential, commercial, and industrial sectors for the entire United States. PA used GPCM to develop a long-term forecast of both Henry Hub natural gas prices and the prices of regional natural gas pricing hubs applicable across the Eastern Interconnect. GPCM is used across the energy industry, including by government agencies such as the US FERC and Canadian NEB, as well as independent system operators such as MISO. PA also used GPCM to evaluate how changes in natural gas generation impact the natural gas markets within the scenario cases (i.e., due to the changes in natural gas consumption).

In modeling the PJM market, PA relied on the 2020 PJM Load Forecast Report, applying downward adjustments to the net peak demand forecast based on PJM's subsequent Update of COVID-19 Load Impacts analysis released in June 2020. Relative to the 2020 PJM Load Forecast Report, PJM's latest update forecasts 0.9% lower peak demand (and 1.7% lower load) in 2020, tightening to 0.3% lower peak demand (and 0.6% lower load) by 2023.

Emission Rate Inputs

In using the AURORA model to evaluate power sector emission impacts, PA developed generating unit-level operating assumptions, including emission rates (i.e., lbs or tons of emissions per MMBtu of fuel consumed) based on historical emissions data. These unit-level emission rates ultimately drive total emissions from each generating unit calculated in the AURORA based on each unit's dispatch, fuel consumption, and installed emissions reduction controls.

PA developed emission rate assumptions for the following pollutants: CO_2, NOx, SO_2, Hg, PM10, and PM2.5 (collectively, the "Modeled Pollutants"). The historical data sources PA used to establish unit-level emission rate assumptions for each pollutant are outlined in Table 3-1 below.

Table 3-1: Emission Rate Data Sources

Pollutant	Historical Data Source
CO_2	• US EPA CEMS
NOx	• US EPA CEMS
SO_2	• US EPA CEMS
Hg	• US EPA TRI or MATS (depending on fuel type) to establish aggregate annual Hg emissions from each unit. • US EPA eGRID to establish aggregate annual fuel consumption by each unit.
PM10	• US EPA SMOKE to establish aggregate annual PM10 emissions from each unit. • US EPA eGRID to establish aggregate annual fuel consumption by each unit.
PM2.5	• US EPA SMOKE to establish aggregate annual PM2.5 emissions from each unit. • US EPA eGRID to establish aggregate annual fuel consumption by each unit.

Note that recent historical emissions data were not universally available for all generating units. For any unit that did not have recent historical emissions data reported, PA used a class average emission rate based on the fuel type and technology type of the generating unit, as well as installed emission control(s). Additionally, PA evaluated how unit-level emissions control systems employed at each facility impacts emissions rates.

New Jersey Policy and Regulatory Assumptions

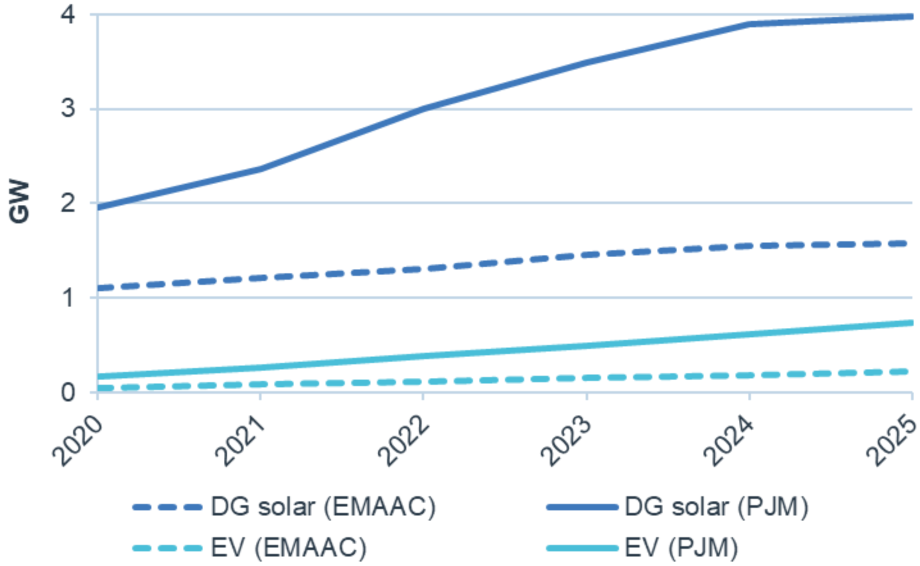
New Jersey has an expansive policy environment and strong decarbonization goals, as discussed briefly in Section 2 and reflected in the state's ZEC program. PA examined each of these policies—from enforceable RPS and carbon cap-and-trade programs to the state's goals and strategies—to inform PA's Base Case inputs into AURORA, including renewable capacity builds, pace of thermal generator retirements, and carbon prices. Key assumptions for New Jersey include the following:

- PA assumes that New Jersey will meet its 50% by 2030 RPS on schedule, primarily through utility-scale solar and offshore wind capacity additions. PA assumes a relatively steady buildout of these resources over the next decade. In total, PA forecasts the entry of approximately 12,800 MW of utility-scale solar, 3,200 MW of onshore wind, and 1,100 MW of offshore wind across PJM from 2020 through 2025 in order to satisfy PJM states' collective RPS requirements (as RECs are tradable throughout PJM). As part of this build-out, PA forecasts approximately 1,100 MW of utility-scale solar, 110 MW of onshore wind, and 1,100 MW of offshore wind will be added in New Jersey.

- PA assumes that New Jersey will remain in RGGI over the study period, thereby subjecting fossil fuel-fired generators to rising carbon emissions prices (in turn determined via a declining cap on allowable emissions). RGGI's 2017 Model Rule calls for emission reductions during the 2021-2030 period (i.e., covering the study period of this analysis), yielding a total 30% reduction between 2020 and 2030 allowable emissions. PA assumes that allowances prices will rise from $6.00/short ton in 2021 to $7.86/short ton in 2025.
- PA assumes that the only offshore wind facility in New Jersey to be enter service by 2025 is Ocean Wind (1,100 MW nameplate capacity), coming online in late 2024. While New Jersey's offshore wind policies (established via executive order) set goals of 3.5 GW by 2030 and 7.5 GW by 2035, the vast majority of this capacity is likely to reach commercial operation in the late 2020s and 2030s. For example, New Jersey's next offshore wind procurement requires the selected projects to come online by 2027 (i.e., past the Study Period, which ends in May 2025).
- While a suite of other policies affects distributed solar, energy efficiency, electrification, and demand response, these variables are all captured as part of the 2020 PJM Load Forecast Report.
  - PA did not make any adjustments to PJM's forecast (outside of applying downward adjustments to account for COVID-19 as discussed above), which projects COVID-adjusted net peak demand in New Jersey to rise approximately 1.0% annually on average from 2020 through 2025 (with load growth at 1.5% on an annual average basis).
  - PJM applies downward adjustments to its peak demand forecast according to growth in distributed solar generation (i.e., solar resources that do not bid into PJM's markets). PJM analyzes historical data (in part from its proprietary Generation Attribute Tracking System subsidiary) in order to isolate the relationship between load and DG solar; this relationship is then used to estimate and apply the DG solar impact to PJM's peak demand forecast. See Figure 3-2 for PJM's estimate of the peak load impact from DG solar through PA's study period across both PJM and EMAAC.[17]
  - PJM also applies downward adjustments to its peak demand forecast according to growth in electric vehicle adoption and expected changes in usage patterns (e.g., switching from Level 1 to Level 2 chargers over time, shifting the frequency with which electric vehicles are charged during the peak hour). PJM based its forecast on the Energy Information Administration's Annual Energy Outlook (which provides plug-in electric vehicle sales projections by census division), applying a set of assumptions to convert sales to net peak demand impact. See Figure 3-2 for PJM's estimate of the peak load impact from EVs through PA's study period across both PJM and EMAAC.[18]
  - PA determined that PJM's adjustments to its peak demand forecast (to account for distributed generation, electric vehicles, etc.) represent the best available information at the system level, and therefore PA elected to not make material modifications (other than accounting for COVID-19).
- New Jersey also has longer-term goals set via the Global Warming Response Act and the state's Energy Master Plan, such as achieving 100% clean energy by 2050. However, beyond the above policies, impacts from any potential additional actions needed to work towards these goals are likely to be felt beyond PA's study period (ending in May 2025 for this analysis). Thus, PA does not assume the introduction of new policies and regulations beyond those discussed above.

[17] Source: "2020 Load Forecast Supplement," January 2020, PJM. Page 18.
[18] Source: "2020 Load Forecast Supplement," January 2020, PJM. Page 20.

Figure 3-2: DG and EV Adjustments to July Peak Load (PJM)[19]



Modeling Outputs

For each case that PA modeled (see Section 3.2 below), PA forecasted monthly and annual emissions of each of the Modeled Pollutants from June 2022 through May 2025 (the "Study Period"). Annual emissions were measured by PJM's Delivery Year (defined as June through May) rather than calendar year (i.e., January through December). PA also reported daily emissions of the Modeled Pollutants for the Typical Summer Demand Day, HEDD, and Peak Winter Day, all of which take place in calendar year 2022.

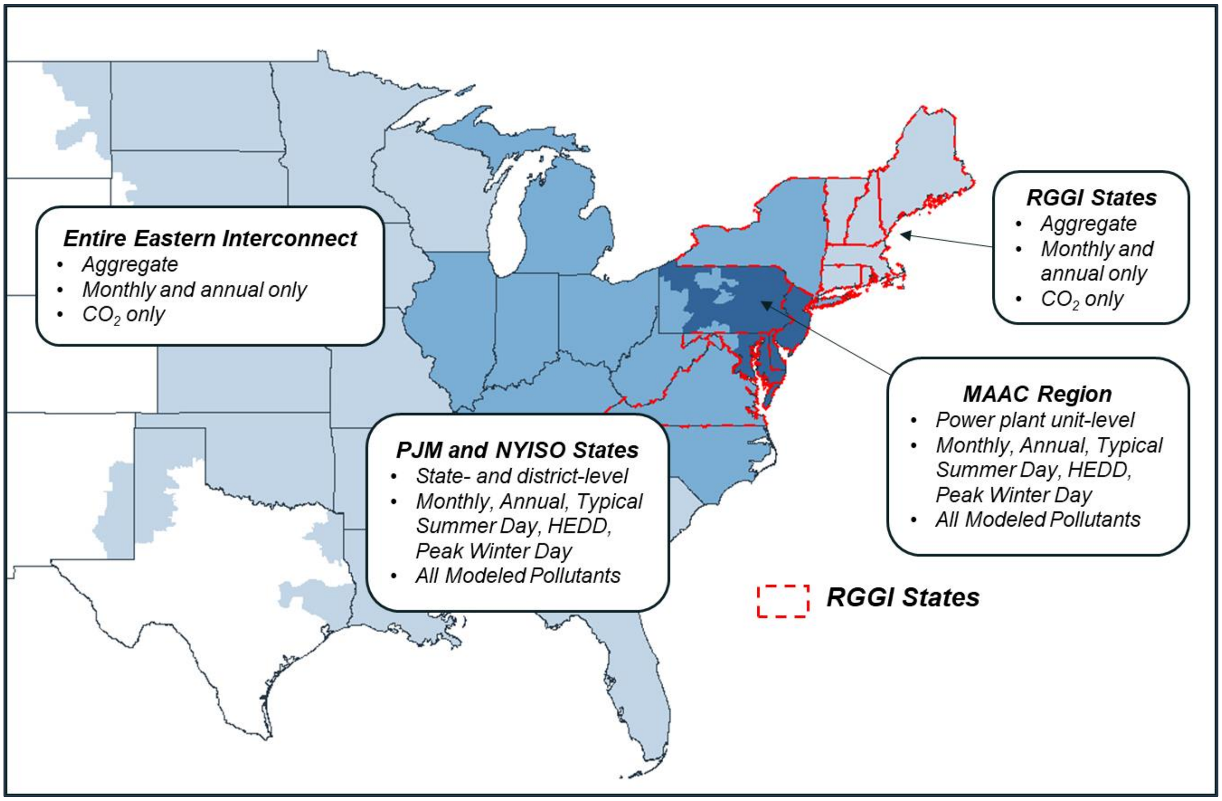
PA reported different levels of aggregation of emission data based on the pollutant, time horizon, and geographic scope being considered:

- Across the MAAC Region of the PJM power market (which contains the entire State of New Jersey), PA forecasted unit-specific monthly, annual, Typical Summer Day, HEDD, and Peak Winter Day emissions of each of the Modeled Pollutants.
- For each of the 14 states and the District of Columbia either partially or completely within the PJM and NYISO power market footprints (the "PJM & NYISO States"), PA forecasted aggregated monthly, annual, Typical Summer Day, HEDD, and Peak Winter Day emissions of each of the Modeled Pollutants. Although New York is part of a separate power market (NYISO) than PJM, there are significant electricity exports from PJM to NYISO, and supply mix changes within PJM (including New Jersey) can have a significant impact on generator dispatch and emissions within NYISO. Additionally, New York is located within close geographical proximity to New Jersey, and generator emissions from New York can impact air quality within New Jersey.
- Because CO_2 is a global pollutant, and because electric sector CO_2 emissions in many Northeast and Mid-Atlantic states are monitored and controlled under the RGGI program, PA forecasted aggregated monthly and annual CO_2 emissions across the entire RGGI footprint and Eastern Interconnect.

See Figure 3-3 for a map of emission modeling outputs by pollutant, time horizon, and geographic scope.

[19] Source: "PJM Load Forecast Report," January 2020, PJM. Tables B-8a and B-8b.

Figure 3-3: Emission Modeling Outputs by Pollutant, Time Horizon, and Geographic Scope[20]



3.2 CASES ANALYZED

PA modeled the Eastern Interconnect under three primary Cases. These Cases are a Base Case that represents PA's independent view of the Eastern Interconnect (including the continued operation of Hope Creek, Salem 1, and Salem 2) as well as two other Cases to compare against the Base Case. Aside from the assumption differences noted below, PA kept assumptions consistent across the Cases (e.g., natural gas prices, coal prices, additions and retirements, etc.) to facilitate comparisons. PA modeled each Case over the same three-delivery year Study Period (June 2022 through May 2025).

- **Base Case:** The Base Case represents PA's current view of the Eastern Interconnect and its component power markets. Notably, PA assumes that the Hope Creek, Salem 1, and Salem 2 nuclear generating resources do not retire (and remain operational) during the Study Period.
- **Full Retirement Case:** This Case represents the Base Case world but assumes that the Hope Creek, Salem 1, and Salem 2 nuclear generating resources do not operate during the Study Period. Comparing this Case against the Base Case estimates the impacts to electric sector emissions and fuel diversity associated with the retirement of all three nuclear generating resources.
- **Hope Creek Retirement Case:** This Case represents the Base Case world but assumes that the Hope Creek nuclear generating resource does not operate during the Study Period (while assuming that the Salem 1 and Salem 2 nuclear generating resources remain operational). Due to the similar capacity and electrical location of each of Hope Creek, Salem 1, and Salem 2, this Case serves as a proxy for retiring *any* of these three nuclear generating resources. As such, comparing this Case against the Base Case estimates the impacts to electric sector emissions and fuel diversity associated with the retirement of Hope Creek, Salem 1, or Salem 2.

[20] The entire State of New Jersey is located within the MAAC Region of the PJM power market. New Jersey is also part of the RGGI program, with Virginia entering in 2021.

4 BASE CASE EMISSIONS RESULTS

This section describes the electric power sector Base Case emission results of the Modeled Pollutants, which served as the reference case to compare the two scenario cases within Section 5 of this report. This section outlines the aggregate emissions in the MAAC region, state-wide emission for all states within the PJM footprint, and CO_2 emissions across the RGGI and Eastern Interconnect footprints.

4.1 BASE CASE EMISSIONS RESULTS

Power sector emissions of the Modeled Pollutants within the MAAC region, over several time horizons, are shown in Table 4-1. As demonstrated in the table, emissions of all Modeled Pollutants decline over the Study Period, largely as a result of retirements of legacy coal-, oil-, and natural gas-fired generators. Reflecting the large share of coal-fired generation retirements compared to other fuel types, SO_2 and Hg emissions see the largest reductions over the Study Period, declining by 18.4% and 20.8%, respectively.

Table 4-1 also shows emissions of the Modeled Pollutants on the Typical Summer Day, HEDD, and Peak Winter Day. As expected, emissions of all Modeled Pollutants are highest on the HEDD, when the electric system relies most heavily on less-efficient and higher-emitting peaking generators. Emissions of certain pollutants (e.g., CO_2) are higher on the Typical Summer Day than the Peak Winter Day, reflecting higher peak demand and greater reliance on natural gas-fired generation on the Typical Summer Day. However, emissions of other pollutants (e.g., SO_2) are higher on the Peak Winter Day than the Typical Summer Day, reflecting constrained natural gas supply on the Peak Winter Day due to competing demand from heating and a greater reliance on coal- and oil-fired generation to meet electricity demand.

Table 4-1: MAAC Region Aggregate Emissions – Base Case

Time Period	CO_2 (‘000 short tons)	NOx (short tons)	SO_2 (short tons)	Hg (lbs)	PM10 (short tons)	PM2.5 (short tons)
Study Period Total	366,843	130,382	163,523	385	28,444	24,595
2022/23 DY	125,029	46,215	60,382	144	9,871	8,479
2023/24 DY	121,183	42,904	53,874	128	9,321	8,079
2024/25 DY	120,631	41,263	49,267	114	9,252	8,036
Typical Summer Day	401	151	193	0	32	28
HEDD	522	202	254	0	42	36
Peak Winter Day	386	156	228	0	33	27

Table 4-2 shows aggregate power sector emissions of the Modeled Pollutants over the Study Period for each of the PJM & NYISO States. For additional detail on aggregate power sector CO_2 emissions in New Jersey in the year 2023, please see Table A-1 in Appendix A.

Reflecting the relative size of its fossil generating fleet and lower share of coal-fired generation compared to other PJM states, New Jersey ranks amongst the lowest state across all Modeled Pollutants in total emissions. Additionally, despite its relatively large installed capacity, New York is a relatively low emitting state due to its heavier reliance on nuclear, renewables (including hydro), and lack of coal-fired generation. Maryland and Delaware have relatively low aggregate emissions, reflecting both the amount of installed capacity in those jurisdictions and the relative efficiency and emissions intensity of the generating fleet.

However, Pennsylvania is among the top five largest emitters of all Modeled Pollutants except Hg (ranking seventh). Further west, Ohio and Indiana also rank among the largest emitters, with Indiana the highest aggregate emitter of all Modeled Pollutants and Ohio being the second largest emitter of all Modeled Pollutants. This reflects both the overall size of the fossil generating fleet in these states as well as their reliance on less-efficient and higher-emitting generating technologies (primarily coal).

Table 4-2: State-Level Aggregate Emissions – Base Case (Study Period)

State	CO_2 ('000 short tons)	NOx (short tons)	SO_2 (short tons)	Hg (lbs)	PM10 (short tons)	PM2.5 (short tons)
DC	270	134	3	0	34	33
DE	12,467	3,667	3,726	14	845	735
IL	105,803	37,018	60,276	367	7,728	6,601
IN	259,963	169,016	200,886	888	34,595	28,425
KY	211,782	141,302	149,638	782	18,687	14,531
MD	54,478	15,944	29,796	175	4,030	3,793
MI	168,152	83,746	51,703	536	7,331	6,022
NC	144,253	84,527	62,350	445	11,904	11,059
NJ	67,587	15,190	4,337	41	4,139	3,888
NY	117,349	41,608	29,534	81	7,644	7,192
OH	240,614	125,024	254,834	840	24,080	19,888
PA	306,663	134,827	159,259	367	24,731	20,636
TN	93,251	29,822	34,501	201	9,828	9,146
VA	114,230	40,840	7,471	82	8,108	6,605
WV	196,992	162,885	136,329	969	19,898	16,658

Table 4-3 shows power sector emissions of the Modeled Pollutants on the Typical Summer Day for each of the PJM & NYISO States. The relative amount of emissions of each of the Modeled Pollutants from each state on the Typical Summer Day are relatively consistent with the relative scale of emissions from each state over the entire Study Period.

Table 4-3: State-Level Aggregate Emissions – Base Case (Typical Summer Day)

State	CO_2 ('000 short tons)	NOx (short tons)	SO_2 (short tons)	Hg (lbs)	PM10 (short tons)	PM2.5 (short tons)
DC	0.3	0.2	0.0	0.0	0.0	0.0
DE	12.9	3.9	3.6	0.0	0.9	0.8
IL	144.8	53.2	73.8	0.5	10.1	9.1
IN	331.2	211.4	267.9	1.1	43.5	35.7
KY	258.0	187.0	198.0	1.0	22.9	17.8
MD	61.5	18.7	41.6	0.2	4.8	4.4
MI	202.3	105.9	74.6	0.7	9.8	7.5
NC	192.3	122.9	94.2	0.6	15.7	14.6
NJ	72.3	16.1	5.2	0.0	4.4	4.1
NY	122.1	42.9	28.8	0.1	7.9	7.4
OH	249.3	137.6	276.8	0.9	24.6	20.3
PA	330.7	152.0	175.1	0.4	27.5	22.7
TN	108.1	45.7	39.7	0.2	11.1	10.5
VA	140.8	51.1	11.9	0.1	10.8	8.5
WV	227.4	174.6	151.3	1.1	20.8	17.4

Table 4-4 shows power sector emissions of the Modeled Pollutants on the HEDD for each of the PJM & NYISO States. Similar to the power sector emissions on a Typical Summer Day case, the relative scale of emissions of each of the Modeled Pollutants from each state on the HEDD are in line with the relative scale of emissions from each state over the entire Study Period.

Table 4-4: State-Level Aggregate Emissions – Base Case (HEDD)

State	CO_2 ('000 short tons)	NOx (short tons)	SO_2 (short tons)	Hg (lbs)	PM10 (short tons)	PM2.5 (short tons)
DC	0.4	0.2	0.0	0.0	0.0	0.0
DE	20.2	6.1	5.7	0.0	1.4	1.2
IL	199.8	77.8	90.9	0.5	14.1	12.6
IN	356.3	226.5	283.7	1.2	46.6	38.3
KY	275.8	199.0	203.2	1.0	24.2	18.9
MD	89.7	29.2	59.2	0.3	7.0	6.5
MI	218.8	118.4	91.0	0.7	10.8	8.3
NC	238.4	151.8	112.4	0.7	19.4	18.0
NJ	102.7	24.9	7.1	0.0	6.5	6.1
NY	186.7	91.1	52.8	0.1	12.6	11.8
OH	283.6	164.2	302.9	1.0	28.4	23.8
PA	399.1	189.1	219.1	0.5	33.4	27.5
TN	113.6	52.9	42.8	0.2	12.0	11.3
VA	176.9	70.5	17.1	0.2	15.0	11.9
WV	247.6	188.2	160.5	1.2	22.6	19.0

Table 4-5 shows power sector emissions of the Modeled Pollutants on the Peak Winter Day for each of the PJM & NYISO States. The relative scale of emissions in most states on the Peak Winter Day compared to the overall Study Period is also relatively similar.

Table 4-5: State-Level Aggregate Emissions – Base Case (Peak Winter Day)

State	CO_2 ('000 short tons)	NOx (short tons)	SO_2 (short tons)	Hg (lbs)	PM10 (short tons)	PM2.5 (short tons)
DC	0.2	0.1	0.0	0.0	0.0	0.0
DE	10.1	3.0	3.6	0.0	0.7	0.6
IL	168.3	75.1	172.5	0.9	14.3	10.3
IN	339.6	221.9	307.4	1.2	45.4	37.2
KY	253.6	191.5	215.4	1.0	23.2	17.9
MD	55.2	17.4	41.9	0.2	4.4	4.1
MI	204.9	112.5	77.3	0.8	9.8	7.0
NC	141.8	89.3	67.7	0.5	11.8	10.9
NJ	52.8	13.4	5.8	0.0	3.2	2.9
NY	110.6	40.2	27.7	0.1	7.1	6.7
OH	284.6	158.6	328.7	1.0	31.7	25.8
PA	351.8	170.0	215.7	0.5	30.5	24.8
TN	89.6	23.9	36.5	0.2	9.3	8.7
VA	101.5	40.8	11.0	0.1	7.8	5.9
WV	247.6	191.3	164.8	1.2	22.8	19.1

Table 4-6 shows aggregate power sector CO_2 emissions over each of the delivery years comprising the Study Period for the RGGI states and entire Eastern Interconnect. In both regions, CO_2 emissions decline from 2022/23 to 2024/25, largely reflecting legacy generating resource retirements and the addition of newer and more efficient natural gas-fired and renewable generating resources.

Table 4-6: Aggregate CO_2 Emissions – Base Case ('000 short tons)

Time Period	RGGI[21]	Eastern Interconnect
Study Period Total	495,437	3,566,386
2022/23 DY	171,052	1,213,596
2023/24 DY	165,088	1,194,182
2024/25 DY	159,296	1,158,608

[21] New Jersey joined RGGI in 2020, Virginia will join in 2021

5 EMISSIONS SCENARIO CASE RESULTS

This section summarizes the changes to electric power sector emissions of the Modeled Pollutants under the Full Retirement Case (i.e., the retirement of Hope Creek, Salem 1, and Salem 2), and the Hope Creek Retirement Case (i.e., the retirement of Hope Creek) in comparison to the Base Case. Both cases demonstrate considerable increases in emissions due to the retirement of the nuclear units with the largest impacts being observed in the greater New Jersey region of PJM (i.e., the MAAC region of PJM, which includes New Jersey).

5.1 FULL RETIREMENT CASE EMISSIONS RESULTS

To answer the question, "***How would the retirement of the Hope Creek, Salem 1, and Salem 2 nuclear generating units impact electric power generation emissions in the State of New Jersey and the surrounding electricity region during the June 2022 – May 2025 timeframe?***", PA compared the results of the Full Retirement Case with the Base Case. The Full Retirement Case uses the same assumptions as the Base Case, but Hope Creek, Salem 1, and Salem 2 nuclear generating resources do not operate during the Study Period.

This Case demonstrates that emissions of the Modeled Pollutants increase significantly with the retirement of these three nuclear generating resources.

- Over the Study Period, emissions of all Modeled Pollutants increase by 2.1% to 7.1% in the MAAC Region. NOx and SO_2 emissions increase by nearly 9,000 and 5,000 tons respectively, while PM10 and PM2.5 emissions increase by over 1,600 tons each. Hg emissions increase by over 8 lbs.
- Emission impacts are most pronounced in the Mid-Atlantic states, particularly Pennsylvania and New Jersey, as well as in North Carolina and Illinois. In Pennsylvania alone, CO_2 emissions are up by nearly 14 million tons, while NOx and SO_2 increase by over 6,000 and 4,000 tons respectively, and PM10 and PM2.5 increase by nearly 1,000 tons. Due to typical air flow patterns, New Jersey is downwind and impacted by these emissions. In New Jersey, CO_2 emissions increase by nearly 9 million tons, NOx emissions increase by over 2,000 tons, SO_2 emissions increase by over 200 tons, and PM10 and PM2.5 emissions increase by over 500 tons each.
- Illinois and North Carolina saw a large increase and decrease in emissions respectively as a result of changes in coal- and natural gas-fired unit dispatch patterns taking place throughout PJM and the entire eastern interconnect.
- CO_2 emissions increase significantly across the RGGI footprint (over 18 million tons) and the Eastern Interconnect (nearly 30 million tons).

Across the MAAC Region, emissions of all Modeled Pollutants increase over all considered time horizons under the Full Retirement Case. See Table 5-1. Emissions of CO_2, NOx, PM10, and PM2.5 all increase by over 6.0% over the Study Period, while emissions of SO_2 increase by 3.0% and emissions of Hg increase by 2.1%. Emission changes are generally more pronounced in 2023/24 than in 2024/25. The only exceptions are SO_2 and NOx, which see increasing emissions in 2024/25 despite over 3 GW of coal fired capacity retiring every year on average between 2022 and 2025. This is most likely due to the tightening of reserve margin[22] across PJM, including the MAAC Region, which drives increased dispatch of coal-fired generating resources that consume coal with relatively high sulfur content.

[22] Reserve margin is the amount of surplus generating capacity available above peak demand.

Table 5-1: Increase in MAAC Region Aggregate Emissions – Full Retirement Case

Time Period	CO_2 ('000 short tons)	NOx (short tons)	SO_2 (short tons)	Hg (lbs)	PM10 (short tons)	PM2.5 (short tons)
Study Period Total	26,053.3 (7.1%)	8,998.7 (6.9%)	4,850.9 (3.0%)	8.3 (2.1%)	1,808.5 (6.4%)	1,649.0 (6.7%)
2022/23 DY	8,556.2 (6.8%)	2,722.2 (5.9%)	1,707.8 (2.8%)	2.9 (2.0%)	591.3 (6.0%)	539.1 (6.4%)
2023/24 DY	8,805.6 (7.3%)	3,090.2 (7.2%)	1,435.8 (2.7%)	2.9 (2.2%)	614.7 (6.6%)	561.8 (7.0%)
2024/25 DY	8,691.5 (7.2%)	3,186.3 (7.7%)	1,707.2 (3.5%)	2.5 (2.2%)	602.4 (6.5%)	548.2 (6.8%)
Typical Summer Day	28.9 (7.2%)	8.7 (5.8%)	3.6 (1.9%)	0.0 (2.1%)	2.1 (6.5%)	1.9 (6.8%)
HEDD	27.6 (5.3%)	26.0 (12.9%)	20.2 (8.0%)	0.0 (6.3%)	2.7 (6.5%)	2.2 (6.3%)
Peak Winter Day	20.4 (5.3%)	6.0 (3.9%)	6.2 (2.7%)	0.0 (2.4%)	1.4 (4.3%)	1.2 (4.5%)

The emission changes resulting from the retirement of Hope Creek, Salem 1, and Salem 2 are concentrated in New Jersey and the Mid-Atlantic states surrounding New Jersey, in addition to Illinois and North Carolina. Figure 5-1 shows the aggregate state-level emission changes (in percentage terms) under the Full Retirement Case across the PJM & NYISO States, and Table 5-2 shows aggregate state-level emissions in both absolute and percentage terms. Emissions changes are more muted in states that are electrically more distant from New Jersey, with the exception of North Carolina and Illinois. For additional detail on power sector CO_2 emission changes in New Jersey in the year 2023, please see Table A-1 in Appendix A.

Figure 5-1: Increase in State-Level Emissions Across Study Period – Full Retirement Case

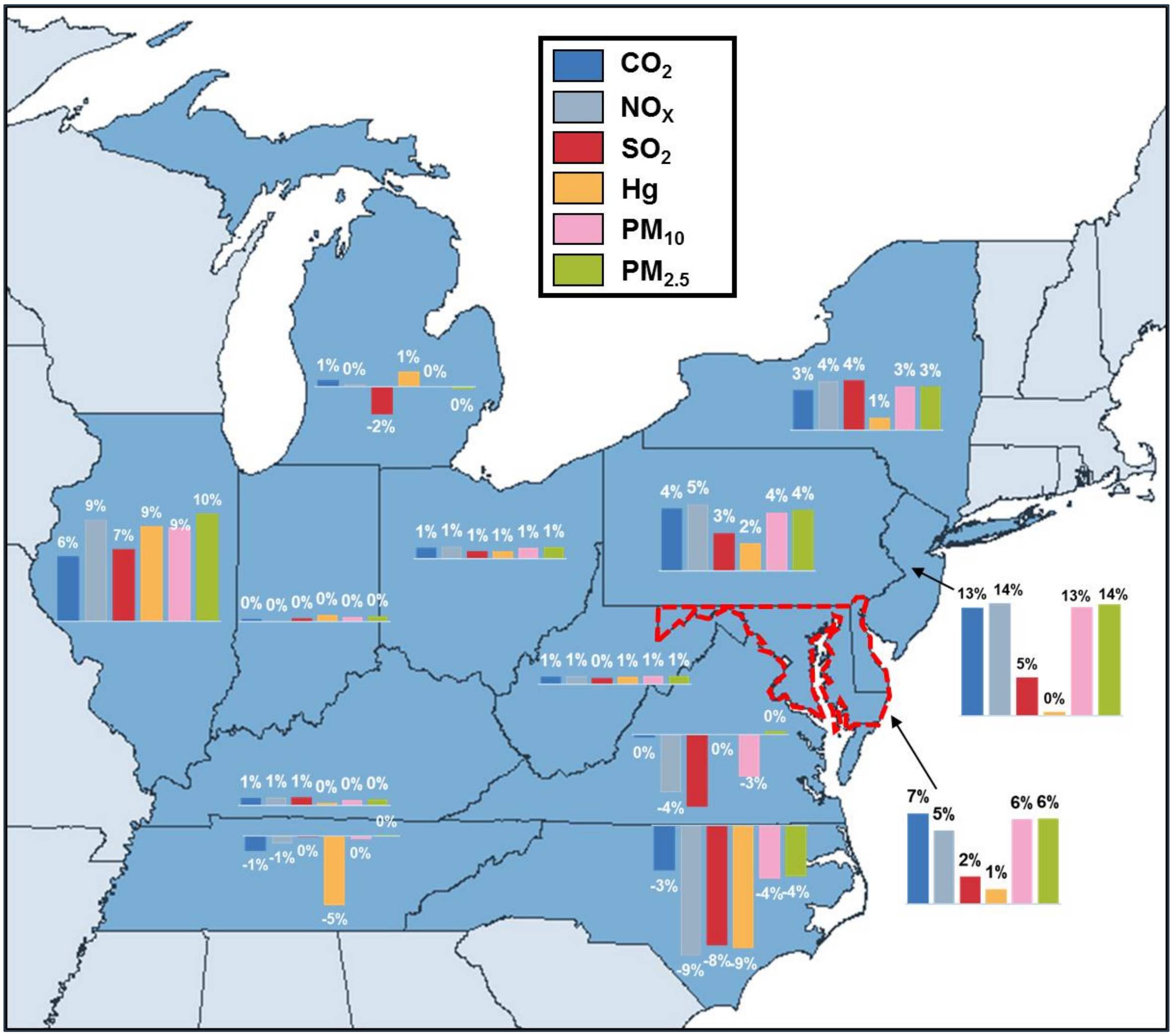


Table 5-2: Change in State-Level Emissions Across Study Period – Full Retirement Case

State	CO2 ('000 short tons)	NOx (short tons)	SO_2 (short tons)	Hg (lbs)	PM10 (short tons)	PM2.5 (short tons)
IL	6,386.7 (6.0%)	3,492.9 (9.4%)	4,031.6 (6.7%)	32.4 (8.8%)	673.6 (8.7%)	659.4 (10.0%)
IN	412.0 (0.2%)	29.3 (0.0%)	479.4 (0.2%)	4.4 (0.5%)	112.6 (0.3%)	108.2 (0.4%)
KY	1,181.4 (0.6%)	838.4 (0.6%)	894.1 (0.6%)	1.6 (0.2%)	74.3 (0.4%)	66.2 (0.5%)
MD+DE+DC	4,446.3 (6.6%)	1,064.5 (5.4%)	659.8 (2.0%)	2.2 (1.2%)	301.4 (6.1%)	281.7 (6.2%)
MI	923.3 (0.5%)	208.0 (0.2%)	-1,163.4 (-2.3%)	6.6 (1.2%)	3.7 (0.1%)	-12.0 (-0.2%)
NC	-4,591.2 (-3.2%)	-7,766.0 (-9.2%)	-5,272.6 (-8.5%)	-38.6 (-8.7%)	-444.7 (-3.7%)	-397.2 (-3.6%)
NJ	8,892.1 (13.2%)	2,073.7 (13.7%)	201.5 (4.6%)	0.2 (0.5%)	547.2 (13.2%)	526.4 (13.5%)
NY	3,418.6 (2.9%)	1,482.0 (3.6%)	1,075.2 (3.6%)	0.8 (0.9%)	244.4 (3.2%)	229.6 (3.2%)
OH	1,960.6 (0.8%)	1,126.9 (0.9%)	1,457.2 (0.6%)	4.7 (0.6%)	198.1 (0.8%)	174.2 (0.9%)
PA	13,605.3 (4.4%)	6,375.5 (4.7%)	4,283.8 (2.7%)	7.2 (2.0%)	1,024.5 (4.1%)	895.0 (4.3%)
TN	-965.8 (-1.0%)	-156.7 (-0.5%)	-17.5 (-0.1%)	-9.7 (-4.8%)	-20.6 (-0.2%)	6.7 (0.1%)
VA	-272.8 (-0.2%)	-1,671.9 (-4.1%)	-384.7 (-5.1%)	0.0 (0.0%)	-241.5 (-3.0%)	15.2 (0.2%)
WV	1,032.5 (0.5%)	957.4 (0.6%)	623.0 (0.5%)	5.2 (0.5%)	116.9 (0.6%)	100.6 (0.6%)

New Jersey shows higher aggregate CO_2, NOx, PM10, and PM2.5 emission changes than Delaware, the District of Columbia, and Maryland combined, but lower levels of SO_2 and Hg changes On an absolute basis, Pennsylvania sees the highest level of emission increases for 5 out of 6 Modeled Pollutants, with only Illinois having a higher emission change on an absolute basis for Hg.. Figure 5-2 shows the aggregate state-level emission changes (in absolute and percentage terms) under the Full Retirement Case for New Jersey and nearby Mid-Atlantic States over the entire Study Period.

Figure 5-2: Increase in NJ, PA, and MD+DE+DC Emissions Across Study Period – Full Retirement Case

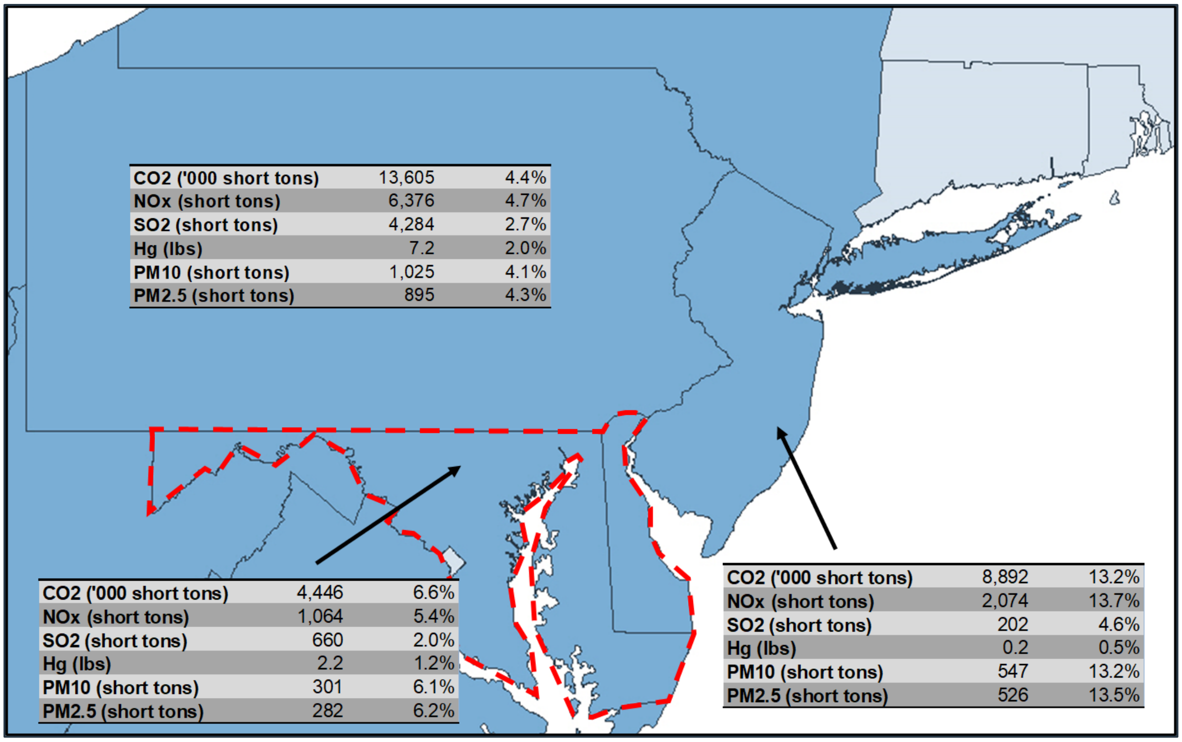


Table 5-3 shows the aggregate CO_2 emission changes under the Full Retirement Case across the RGGI footprint and entire Eastern Interconnect over the Study Period. CO_2 emissions increase by over 18 million tons (or 3.7%) across the RGGI footprint, and nearly 30 million tons (or 0.8%) across the Eastern Interconnect (including RGGI).

Table 5-3: Increase in Aggregate CO_2 Emissions – Full Retirement Case ('000 short tons)

Time Period	RGGI	Eastern Interconnect
Study Period Total	3.7%	0.8%
2022/23 DY	3.9%	0.5%
2023/24 DY	3.7%	0.7%
2024/25 DY	3.6%	1.3%

5.2 HOPE CREEK RETIREMENT CASE EMISSIONS RESULTS

To answer the question, "***How would the retirement of the Hope Creek nuclear generating units impact electric power generation emissions in the State of New Jersey and the surrounding electricity region over the June 2022 – May 2025 timeframe?***", PA compared the results of the Hope Creek Retirement Case with the Base Case. The Hope Creek Retirement Case represents the Base Case world, but where the Hope Creek nuclear generator does not operate during the Study Period. Note that this Case assumes that the Salem 1 and Salem 2 nuclear generators remain operational.

This Case also demonstrates that emissions of the Modeled Pollutants increase modestly with the retirement of only the Hope Creek nuclear generator. As expected, the emission changes under the Hope Creek Retirement Case are not as considerable as the changes under the Full Retirement Case due to the smaller change in operational nuclear generation capacity. However, the emission changes under the Hope Creek Retirement Case are still material.

- Over the Study Period, emissions of all Modeled Pollutants increase by 0.4% to 2.3% in the MAAC Region. NOx and SO_2 emissions increase by 2,500 and 1,200 tons respectively, while PM10 and PM2.5 emissions increase by over 500 tons each. Hg emissions increase by 1.4 lbs.
- Similar to the Full Retirement Case, emission impacts are most pronounced in the Mid-Atlantic states, particularly New Jersey and Pennsylvania. In Pennsylvania alone, NOx and SO_2 emissions increase by 1,800 and 1,100 tons respectively, PM10 and PM2.5 emissions increase by nearly 300 tons each, and Hg emissions increase by nearly 2 lbs.
- CO_2 emissions increase modestly across the RGGI footprint (nearly 6 million tons) and the Eastern Interconnect (nearly 13 million tons).

Under the Hope Creek Retirement Case, emissions of all Modeled Pollutants increase across the MAAC Region for all considered time horizons. See Table 5-4. Emissions of CO2, NOx, PM10 and PM2.5 increase by about 2.0% over the Study Period, while emissions of the SO2 increases by about 1.0% over the Study Period.

Table 5-4: Increase in MAAC Region Aggregate Emissions – Hope Creek Retirement Case

Time Period	CO2 ('000 short tons)	NOx (short tons)	SO_2 (short tons)	Hg (lbs)	PM10 (short tons)	PM2.5 (short tons)
Study Period Total	8,435.5 (2.3%)	2,511.9 (1.9%)	1,172.8 (0.7%)	1.4 (0.4%)	556.9 (2.0%)	516.6 (2.1%)
2022/23 DY	2,645.1 (2.1%)	730.5 (1.6%)	329.6 (0.5%)	0.4 (0.3%)	172.4 (1.7%)	160.9 (1.9%)
2023/24 DY	2,831.2 (2.3%)	832.4 (1.9%)	324.0 (0.6%)	0.4 (0.3%)	187.8 (2.0%)	174.6 (2.2%)
2024/25 DY	2,959.2 (2.5%)	949.0 (2.3%)	519.3 (1.1%)	0.6 (0.5%)	196.8 (2.1%)	181.1 (2.3%)
Typical Summer Day	8.7 (2.2%)	2.4 (1.6%)	0.2 (0.1%)	0.0 (-0.3%)	0.6 (1.7%)	0.5 (1.9%)
HEDD	8.3 (1.6%)	6.3 (3.1%)	0.5 (0.2%)	0.0 (0.6%)	0.6 (1.3%)	0.5 (1.5%)
Peak Winter Day	6.1 (1.6%)	2.0 (1.3%)	1.8 (0.8%)	0.0 (0.9%)	0.5 (1.4%)	0.4 (1.5%)

Similar to the Full Retirement Case, the most consequential emission changes if Hope Creek was to retire are concentrated in New Jersey and the Mid-Atlantic states surrounding New Jersey. Figure 5-3 shows the aggregate state-level emission changes (in percentage terms) under the Hope Creek Retirement Case across the PJM & NYISO States, and Table 5-5 shows aggregate state-level emissions in both absolute and percentage terms. For additional detail on power sector CO_2 emission changes in New Jersey in the year 2023, please see Table A-1 in Appendix A.

Figure 5-3: Increase in State-Level Emissions Across Study Period – Hope Creek Retirement Case

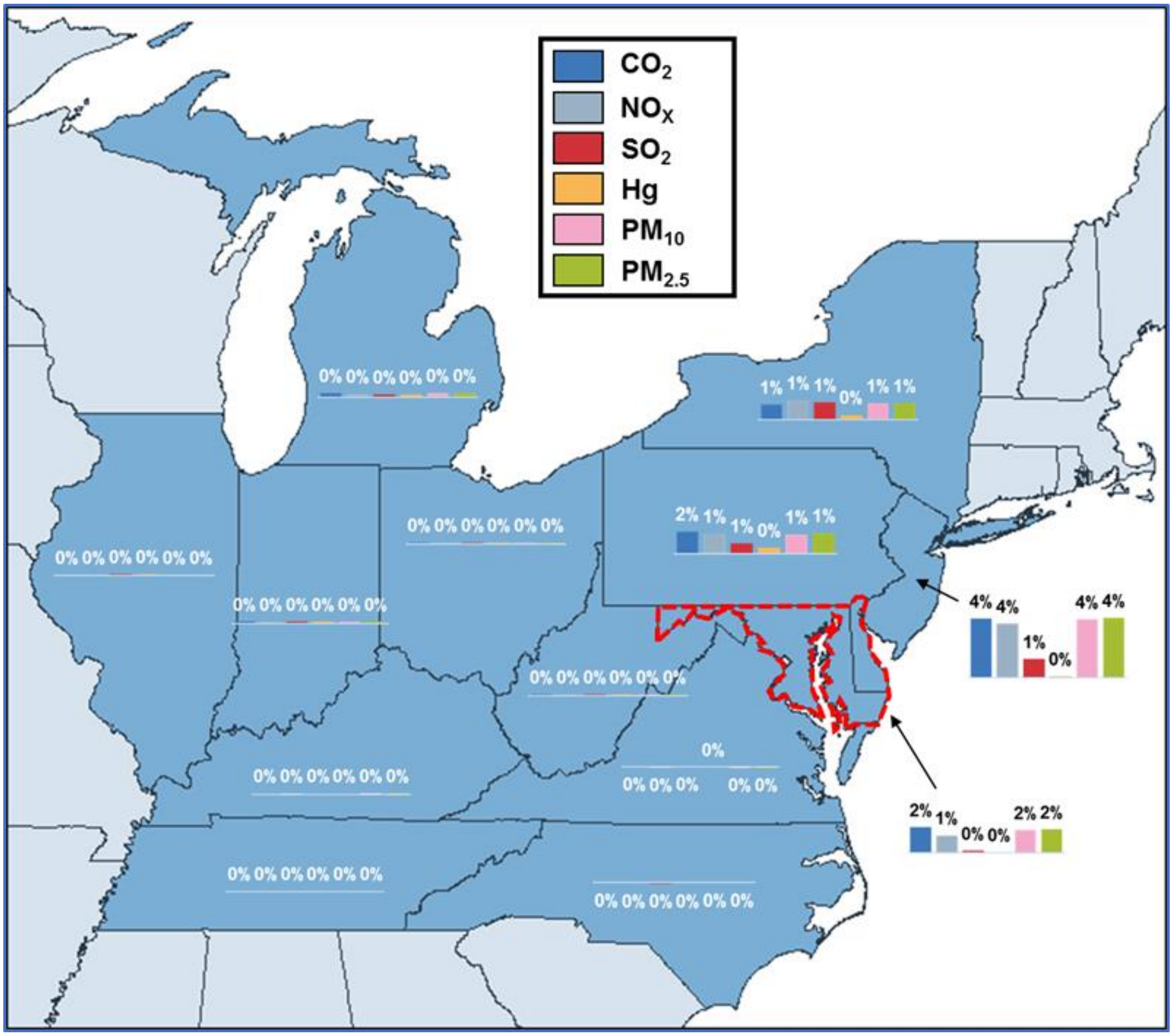


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Table 5-5: Change in State-Level Emissions Across Study Period – Hope Creek Retirement Case

State	CO_2 (‘000 short tons)	NOx (short tons)	SO_2 (short tons)	Hg (lbs)	PM10 (short tons)	PM2.5 (short tons)
IL	49.1 (0.0%)	21.1 (0.1%)	55.1 (0.1%)	0.3 (0.1%)	4.2 (0.1%)	2.8 (0.0%)
IN	361.8 (0.1%)	227.4 (0.1%)	280.3 (0.1%)	1.0 (0.1%)	47.2 (0.1%)	40.0 (0.1%)
KY	194.7 (0.1%)	142.8 (0.1%)	136.8 (0.1%)	0.7 (0.1%)	17.7 (0.1%)	14.6 (0.1%)
MD+DE+DC	1,196.0 (1.8%)	241.8 (1.2%)	44.8 (0.1%)	0.1 (0.0%)	78.7 (1.6%)	74.6 (1.6%)
MI	492.6 (0.3%)	209.3 (0.2%)	99.4 (0.2%)	1.0 (0.2%)	22.5 (0.3%)	19.6 (0.3%)
NC	-23.0 (0.0%)	-52.3 (-0.1%)	-50.6 (-0.1%)	-0.3 (-0.1%)	-3.1 (0.0%)	-2.8 (0.0%)
NJ	2,779.3 (4.1%)	567.5 (3.7%)	56.6 (1.3%)	0.0 (0.1%)	168.1 (4.1%)	161.6 (4.2%)
NY	1,250.8 (1.1%)	557.8 (1.3%)	353.4 (1.2%)	0.3 (0.3%)	88.5 (1.2%)	83.3 (1.2%)
OH	265.7 (0.1%)	114.9 (0.1%)	300.7 (0.1%)	1.0 (0.1%)	26.8 (0.1%)	21.7 (0.1%)
PA	4,677.0 (1.5%)	1,828.1 (1.4%)	1,136.6 (0.7%)	1.6 (0.4%)	325.4 (1.3%)	293.3 (1.4%)
TN	52.3 (0.1%)	12.7 (0.0%)	15.9 (0.0%)	0.1 (0.0%)	5.1 (0.1%)	4.8 (0.1%)
VA	-13.7 (0.0%)	-34.8 (-0.1%)	-1.6 (0.0%)	0.0 (0.0%)	-7.5 (-0.1%)	-5.0 (-0.1%)
WV	142.1 (0.1%)	157.6 (0.1%)	104.9 (0.1%)	0.8 (0.1%)	17.9 (0.1%)	14.8 (0.1%)

On an absolute basis, Pennsylvania has the highest level of emission increases for all Modeled Pollutants, with New Jersey being second highest for CO_2, PM_{10}, and $PM_{2.5}$, and third highest for NOx (after Pennsylvania and then DC Maryland and Delaware combined). Figure 5-4 shows the aggregate state-level emission changes (in absolute terms) under the Hope Creek Retirement Case for New Jersey and nearby Mid-Atlantic States over the entire Study Period.

Figure 5-4: Increase in NJ, PA, and MD+DE+DC Emissions Across Study Period – Hope Creek Retirement Case

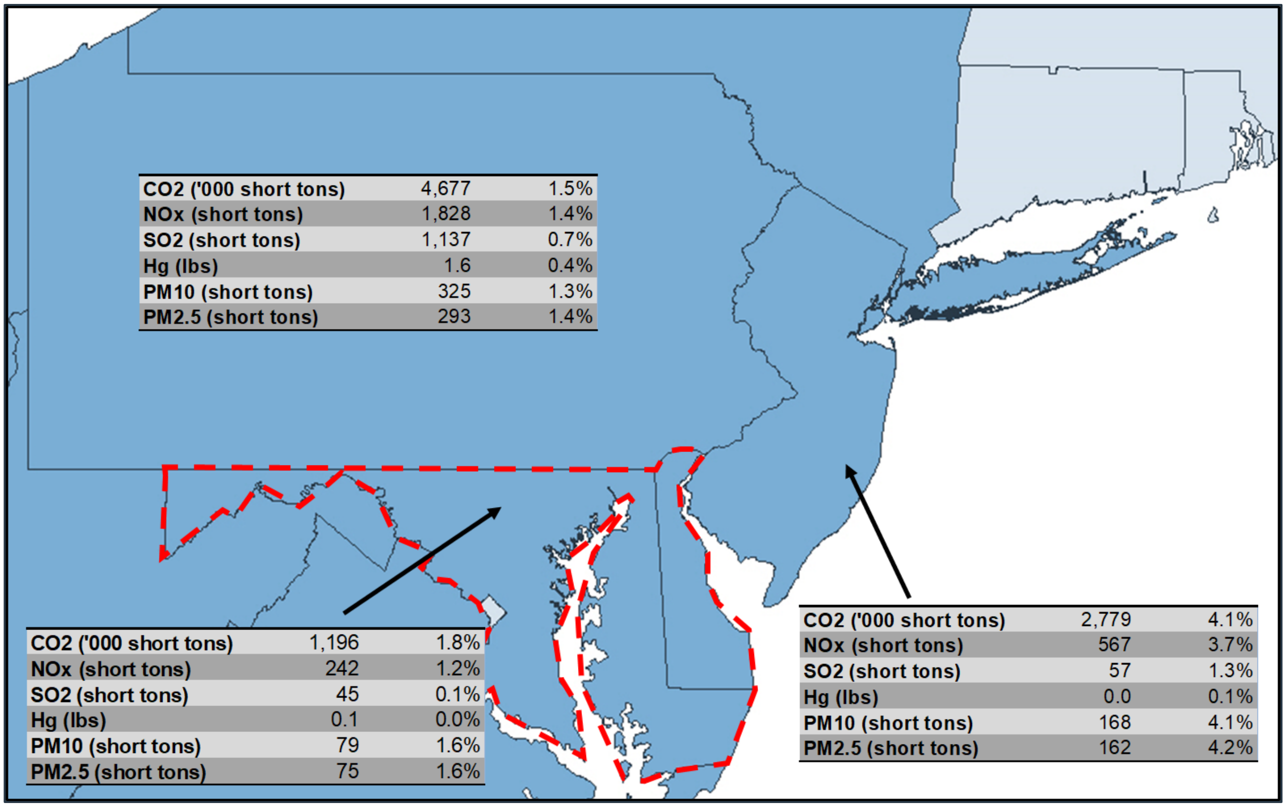


Table 5-6 shows the aggregate CO_2 emission changes under the Hope Creek Retirement Case across the RGGI footprint and the entire Eastern Interconnect over the Study Period. CO_2 emissions increase by nearly 6 million tons (or 1.2%) across the RGGI footprint, and nearly 13 million tons (or 0.4%) across the Eastern Interconnect (including RGGI).

Table 5-6: Increase in Aggregate CO_2 Emissions – Hope Creek Retirement Case ('000 short tons)

Time Period	RGGI	Eastern Interconnect
Study Period Total	1.2%	0.4%
2022/23 DY	1.1%	0.3%
2023/24 DY	1.2%	0.4%
2024/25 DY	1.3%	0.4%

6 FUEL DIVERSITY SCENARIO CASE RESULTS

Because there is no single “perfect” fuel upon which to rely for a reliable and resilient electricity system, a primary contributor to electric system resilience is the diversification of fuels and technologies used to generate electricity. A diversity of fuels and generation technologies helps maintain system reliability and quickly bounce back after low-probability, high-impact events by allowing operators to maximize the benefits of each individual fuel type and technology while offsetting the drawbacks of each. Fuel diversity also helps reduce the impact of such low-probability, high-impact events on the prices of fuel used to generate electricity. Put another way, overreliance on a single fuel or technology places the electricity system at increased risk of higher prices and more frequent and sustained outages.

This section summarizes the impacts to fuel diversity under the Full Retirement Case (i.e. the retirement of Hope Creek, Salem 1, and Salem 2), and the Hope Creek Retirement Case (i.e. only the retirement of Hope Creek). Specifically, this section examines the impact on the electricity generation mix in New Jersey and MAAC, associated impacts to power sector fuel consumption, and the high-level impact to natural gas prices.

Both cases demonstrate considerable impacts to fuel diversity due to the retirement of the nuclear units, with the largest impacts being observed in the greater New Jersey region. Notably, the electric system in the greater New Jersey region becomes more heavily dependent on natural gas and coal with the retirement of the nuclear units, as well as generation imports (primarily fired by natural gas and coal) from elsewhere in PJM and neighbouring electricity regions. This raises concerns about the future resilience of the electricity system in and around New Jersey. As demonstrated during the Polar Vortex, natural gas supply in the power sector is vulnerable to competition from higher priority heating demand, and natural gas-fired generators do not have material on-site fuel storage capability that could ensure fuel supply during constrained periods. While coal-fired generators typically have more robust on-site fuel storage capability, these generators are sometimes vulnerable to frozen or flooded coal piles during extreme weather events. Additionally, while PA did not specifically model electric transmission vulnerabilities, greater reliance on electricity imports could make the electricity system in the greater New Jersey region more vulnerable to outages if key transmission infrastructure were to fail, particularly if those failures were combined with periods of constrained natural gas or coal supply.

This reduction in fuel diversity stemming from the retirement of the nuclear units would also have a detrimental impact on costs to consumers. Due to the increase in natural gas and coal consumption for power generation, natural gas prices in the greater New Jersey area would increase across the Study Period, with particular spikes in pricing on cold winter days. Furthermore, during the summer months, the reduction in low marginal cost baseload nuclear generation would drive the dispatch of more expensive and less efficient generation to meet demand. While it is likely that pricing would be somewhat elevated in all seasons if the nuclear units were to retire, the impact would be exacerbated during hot summer months when supply conditions are tighter and the electricity system relies on dispatch of costlier generators in a higher frequency of hours. These detrimental impacts could be avoided or mitigated by maintaining a diverse generation mix featuring reliable and low marginal cost resources like nuclear generators.

6.1 FULL RETIREMENT CASE FUEL DIVERSITY RESULTS

To answer the question, “***How would the retirement of the Hope Creek, Salem 1, and Salem 2 nuclear generating units impact fuel diversity and grid resilience in New Jersey and the surrounding electricity region?***”, PA compared the results of the Full Retirement Case with the Base Case. The Full Retirement Case uses the same assumptions as the Base Case, but Hope Creek, Salem 1, and Salem 2 nuclear generating resources do not operate during the Study Period.

This Case demonstrates that, in comparison to the Base Case, fuel diversity and grid resilience in MAAC would decrease significantly over the Study Period with the retirement of these three nuclear generating resources.

- Increased coal- and natural gas-fired generation in MAAC replace more than 67% of the 80.6 TWh of nuclear generation lost due to full retirement across the Study Period, with the remaining 33% coming from outside of MAAC. Coal- and natural gas-fired generation are collectively 9.1% higher in the MAAC region across the Study Period, and 7% higher on the Peak Winter Day. The combined coal and natural gas share of MAAC-wide generation climbs from 63.2% to 70.9% of total generation across the Study Period.
- Consumption of natural gas and coal for power generation rises significantly. Total natural gas consumption is 10.2% higher than Base Case, while coal consumption rises by 2.3% across the Study Period. On the Peak Winter Day, natural gas consumption is 7.8% higher than under Base Case projections.
- Increased power sector natural gas consumption leads to higher natural gas prices across the major trading hubs in and around New Jersey (TM3, TZ6 NY, and TZ6 non-NY) on an annual average basis, and particularly higher natural gas prices during winter months.

Across MAAC, coal- and natural gas-fired generation are higher under the Full Retirement Case. Table 6-1 shows projected coal- and natural gas-fired generation compared with the Base Case. Collectively, coal and natural gas-fired generation are 9.1% higher under the Full Retirement Case, an increase that is fairly consistent across the delivery years of the Study Period. For additional detail on coal- and natural gas-fired generation in New Jersey in the year 2023 under the Full Retirement Case, please see Table A-2 in Appendix A.

Table 6-1: Increase in Coal- and Natural Gas-fired Generation in MAAC – Full Retirement Case

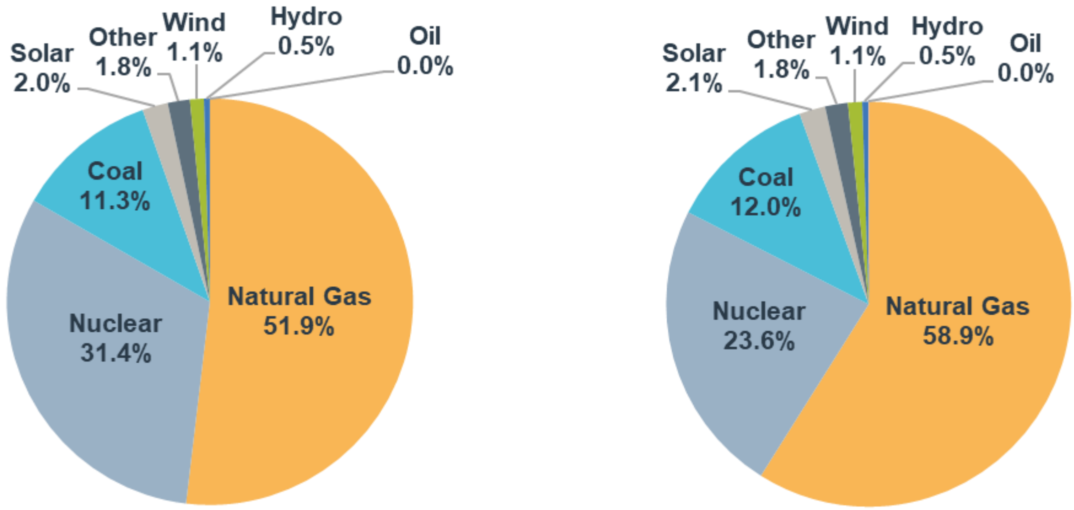
Time Period	Generation (GWh)
Study Period Total	54,405 (9.1%)
2022/23 DY	17,985 (9.0%)
2023/24 DY	18,466 (9.3%)
2024/25 DY	17,953 (8.9%)
Typical Summer Day	58.0 (9.1%)
HEDD	40.1 (4.8%)
Peak Winter Day	41.4 (7.0%)

The MAAC region is of particular importance, as the region both includes and surrounds New Jersey. To the extent that there is increased generation from natural gas and coal, it will lead to higher emissions impacting the air quality of New Jersey. Indeed, the retirement of Hope Creek, Salem 1, and Salem 2 leads to a significant increase in the share of MAAC electricity generated by coal and natural gas. The retirement of Hope Creek, Salem 1, and Salem 2 reduces MAAC-wide nuclear generation during the Study Period by roughly 8%. Natural gas- and coal-fired generation within MAAC replace most of that lost nuclear generation, with the remainder comprised of generation (primarily natural gas- and coal-fired) from elsewhere in PJM and neighboring electricity regions.[23] Coal- and natural gas-fired generation comprise a little more than 70% of aggregate Study Period generation in MAAC under the Full Retirement Case, with natural gas alone comprising more than half of MAAC-wide generation. See Figure 6-1.

[23] Note that PA focused its emissions and fuel diversity impacts analysis on New Jersey and the MAAC Region, as power sector emissions from this area would have the greatest impact on air quality in New Jersey due to the geographic proximity of source generators.

Figure 6-1: MAAC Generation (MWh) – (Across Study Period)

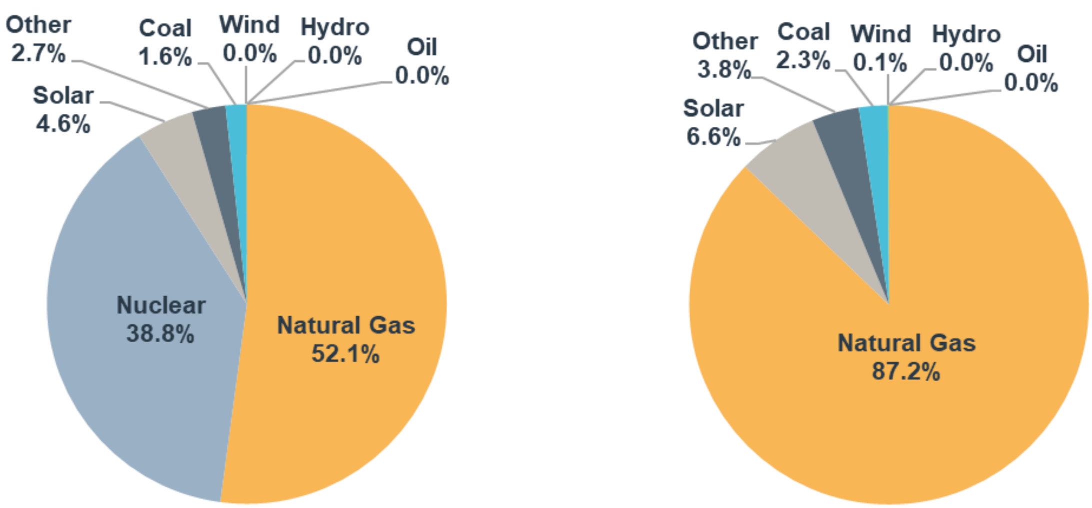
Base Case | **Full Retirement Case**



Within New Jersey, the retirement of Hope Creek, Salem 1, and Salem 2 eliminates nuclear generation from the State. This lost nuclear generation is replaced almost entirely by electricity imports (primarily natural gas- and coal-fired) from elsewhere in PJM and neighboring electricity regions, as well as increased natural gas-fired generation within New Jersey. Natural gas-fired generation comprises about 87% of aggregate Study Period generation in New Jersey under the Full Retirement Case. See Figure 6-2.

Figure 6-2: New Jersey Generation (MWh) - (Across Study Period)

Base Case | **Full Retirement Case**



Under the Full Retirement Case, the increase in coal- and natural gas-fired generation leads to significantly higher natural gas and coal consumption in MAAC compared with the Base Case, with natural gas consumption particularly higher on the Typical Summer Day. Over the Study Period, retirement of Hope Creek, Salem 1, and Salem 2 leads to an additional 388.9 million MMBtu (10.2%) of natural gas consumption for power, along with an additional 26.1 million MMBtu (2.3%) of coal consumption. These increases are roughly balanced across the three delivery years of the Study Period. Projected Typical Summer Day consumption under the Full Retirement Case shows a spike in power sector natural gas consumption, with consumption 10.3% higher than under the Base Case.

Table 6-2: Increase in Coal and Natural Gas Consumption in MAAC – Full Retirement Case

Time Period	Natural Gas (MMBtu)	Coal (MMBtu)
Study Period Total	388,941,595 (10.2%)	26,073,533 (2.3%)
2022/23 DY	124,986,745 (9.9%)	10,818,974 (2.6%)
2023/24 DY	133,192,700 (10.5%)	7,541,900 (2.0%)
2024/25 DY	130,762,149 (10.0%)	7,712,659 (2.2%)
Typical Summer Day	416,641 (10.3%)	39,245 (2.9%)
HEDD	331,327 (6.3%)	42,603 (2.3%)
Peak Winter Day	265,475 (7.8%)	44,959 (2.8%)

Higher natural gas demand under the Full Retirement Case leads to higher natural gas prices across the major trading hubs in and around New Jersey (TM3, TZ6 NY, and TZ6 non-NY) on an annual average basis. The largest increases occur on the weather-normalized Peak Winter Day when power sector natural gas consumption competes with high heating demand. It is important to recognize that to the extent that one was to observe an extreme winter event—such as the 2014 Polar Vortex (as described in Section 2.1 of this report) or 2018 Bombogenesis—we would expect significantly higher pricing than a weather-normalized Peak Winter Day due to the retirement of the nuclear units (an extreme event was winter day was not model as part of this analysis).

6.2 HOPE CREEK RETIREMENT CASE EMISSIONS RESULTS

To answer the question, "***How would the retirement of the Hope Creek nuclear generating units impact fuel diversity and grid resilience in New Jersey and the surrounding electricity region?***", PA compared the results of the Hope Creek Retirement Case with the Base Case. The Hope Creek Retirement Case represents the Base Case world, but where the Hope Creek nuclear generator does not operate during the Study Period. Note that this Case assumes that the Salem 1 and Salem 2 nuclear generators remain operational.

This Case demonstrates that fuel diversity and grid resilience would decrease with the retirement of the Hope Creek nuclear generating facility. The changes are not as considerable as than the changes under the Full Retirement Case due to the smaller loss of nuclear generation. However, the Hope Creek Retirement Case still yields a material loss of fuel diversity and grid resilience.

- Increased coal- and natural gas-fired generation within MAAC replace roughly 67% of the approximately 27.6 TWh of nuclear generation lost due to the Hope Creek retirement across the Study Period, with the remainder coming from outside of MAAC. Coal- and natural gas-fired generation are 3.1% higher in the MAAC region across the Study Period, and 1.8% higher on the Peak Winter Day. The combined coal and natural gas share of the MAAC-wide generation mix climbs from 63.2% to 65.8% across the Study Period.
- Consumption of natural gas and coal for power generation rises. Total natural gas consumption is 3.4% higher than Base Case, while coal consumption rises by 0.5% across the Study Period. On the Peak Winter Day, natural gas consumption is 2.3% higher than under Base Case projections.
- Increased power sector natural gas consumption leads to higher natural gas prices across TM3, TZ6 NY, and TZ6 non-NY on an annual average basis, and particularly higher natural gas prices during winter months.

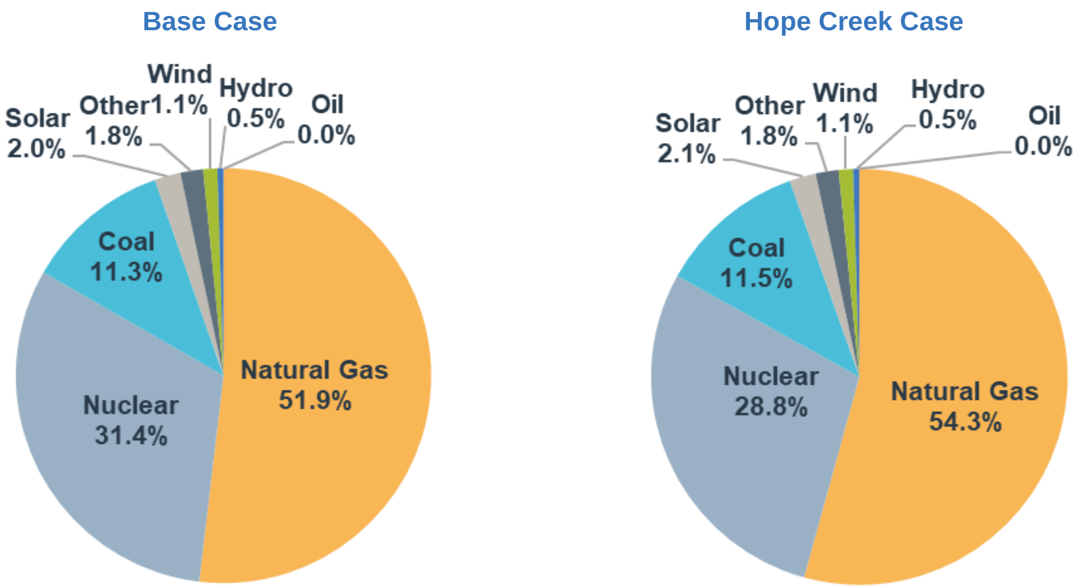
Across MAAC, coal- and natural gas-fired generation are higher under the Hope Creek Retirement Case. Table 6-3 shows projected coal- and natural gas-fired generation compared with the Base Case. Collectively, coal- and natural gas-fired generation are 3.1% higher under the Hope Creek Retirement Case, an increase that is fairly consistent across the three delivery years of the Study Period. For additional detail on coal- and natural gas-fired generation in New Jersey in the year 2023 under the Hope Creek Retirement Case, please see Table A-2 in Appendix A.

Table 6-3: Increase in Coal- and Natural Gas-fired Generation in MAAC – Hope Creek Retirement Case

Time Period	Generation (GWh)
Study Period Total	18,589 (3.1%)
2022/23 DY	5,890 (2.9%)
2023/24 DY	6,299 (3.2%)
2024/25 DY	6,399 (3.2%)
Typical Summer Day	19.7 (3.1%)
HEDD	14.0 (1.7%)
Peak Winter Day	10.9 (1.8%)

The MAAC region is of particular importance, as the region both includes and surrounds New Jersey. To the extent that there is increased generation from natural gas and coal, it will lead to higher emissions impacting the air quality of New Jersey. Indeed, the retirement of Hope Creek leads to an increase in the share of MAAC electricity generated by coal and natural gas. MAAC-wide nuclear generation during the Study Period decreases by roughly 2.6%. Natural gas and coal in MAAC replace most of that lost generation, with the remainder comprised of generation (primarily natural gas- and coal-fired) from elsewhere in PJM and neighboring electricity regions. With the retirement of Hope Creek, coal- and natural gas-fired generation comprise nearly 66% of aggregate Study Period generation in MAAC, with natural gas-fired generation comprising 54.3% of MAAC-wide generation. See Figure 6-3.

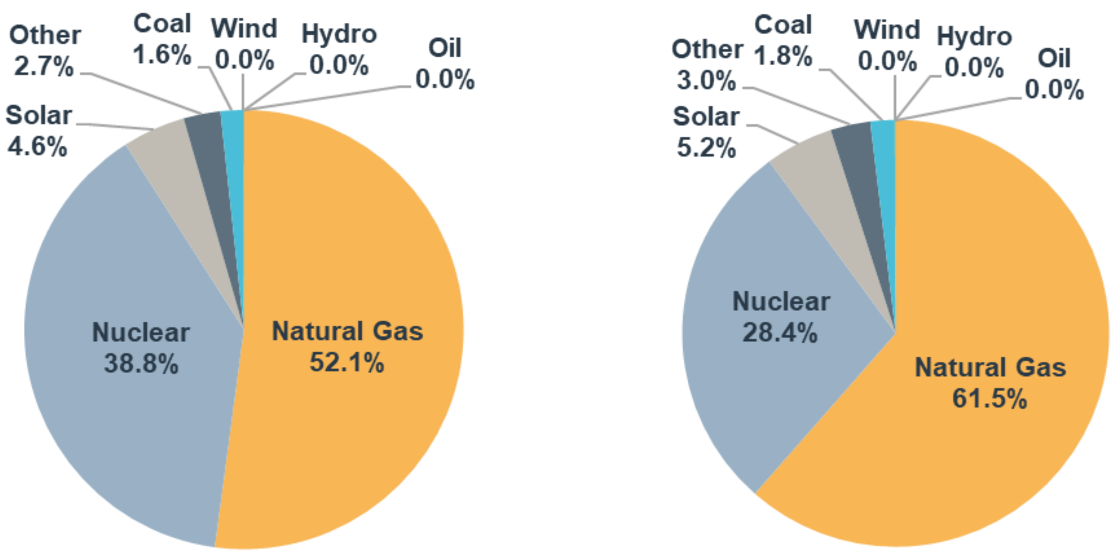
Figure 6-3: MAAC Generation (MWh) - (Across Study Period)



Within New Jersey, the retirement of Hope Creek reduces nuclear generation in the State by little over 10%. This lost nuclear generation is replaced almost entirely by electricity imports (primarily natural gas- and coal-fired) from elsewhere in PJM and neighboring electricity regions, as well as increased natural gas-fired generation within New Jersey. Natural gas-fired generation comprises over 60% of aggregate Study Period generation in New Jersey under the Hope Creek Retirement Case.

Figure 6-4: New Jersey Generation (MWh) - (Across Study Period)

Base Case | **Hope Creek Case**



Under the Hope Creek Retirement Case, the increase in coal- and natural gas-fired generation leads to an increase in natural gas and coal consumption in MAAC compared with the Base Case. Over the Study Period, retirement of Hope Creek leads to an additional 131.6 million MMBtu (3.4%) of natural gas consumption for power, along with an additional 5.6 million MMBtu (0.5%) of coal consumption. These increases are roughly balanced across the three delivery years of the Study Period. Projected Typical Summer Day consumption under the Hope Creek Retirement Case shows a spike in power sector natural gas consumption, with consumption 3.7% higher than under the Base Case.

Table 6-4: Increase in Coal and Natural Gas Consumption in MAAC – Hope Creek Retirement Case

Time Period	Natural Gas (MMBtu)	Coal (MMBtu)
Study Period Total	131,644,920 (3.4%)	5,590,304 (0.5%)
2022/23 DY	41,437,133 (3.3%)	1,770,610 (0.4%)
2023/24 DY	44,819,641 (3.5%)	1,476,028 (0.4%)
2024/25 DY	45,388,146 (3.5%)	2,343,666 (0.7%)
Typical Summer Day	151,525 (3.7%)	-2,940 (-0.2%)
HEDD	127,504 (2.4%)	5,806 (0.3%)
Peak Winter Day	76,880 (2.3%)	15,129 (0.9%)

Higher natural gas demand under the Hope Creek Retirement Case leads to higher natural gas prices across TM3, TZ6 NY, and TZ6 non-NY on an annual average basis. The largest increases occur on the weather-normalized Peak Winter Day when power sector natural gas consumption competes with high heating demand. As noted above in Section 6.1, PA expects extreme winter events to yield even higher price spikes than those on a weather-normalized Peak Winter Day.

7 SUMMARY OF ANALYSIS

As recent wholesale power market dynamics have narrowed operating margins and created significant economic challenges for baseload nuclear generators operating in deregulated wholesale power markets across the United States, policymakers have grown concerned by the environmental, reliability, resilience, and economic implications of retiring zero-emission generating resources. In New Jersey, decades of energy policy measures have been aimed at achieving New Jersey's goals of reducing emissions from the electric power sector while ensuring a reliable and resilient electric system. Furthermore, after enactment of policy measures to support nuclear generation in New York, Illinois, and Connecticut, New Jersey enacted the ZEC Act to create a mechanism to support for qualified nuclear generating resources in order to avoid harmful impacts to power sector emissions and fuel diversity if economically challenged nuclear generators were to retire.

This independent Report by PA demonstrates that power sector emissions would materially increase in the near future if the Hope Creek, Salem 1, and/or Salem 2 nuclear generators were to retire, which could have serious human and environmental health impacts. If Hope Creek were to retire, CO_2 emissions from New Jersey generators alone would increase by nearly 2.7 million tons (or 4.1%) from June 2022 through May 2025. For context, this CO_2 emission impact is roughly equivalent to having over 170,000 additional passenger vehicles per year driving in New Jersey over the same timeframe. If Hope Creek, Salem 1, and Salem 2 were to retire, CO_2 emissions from New Jersey generators would increase by nearly 9 million tons (or 13.2%) over the same timeframe, roughly equivalent to having over 590,000 additional passenger vehicles per year driving in New Jersey.

However, power sector emissions would also increase outside of New Jersey, if these nuclear generators were to retire. Because CO_2 is a global pollutant, CO_2 emission changes over these broader geographic footprints that stem from the retirement of Hope Creek, Salem 1, and/or Salem 2 would directly impact New Jersey. If Hope Creek were to retire, CO_2 emissions from generators across the RGGI footprint would increase by nearly 5.8 million tons (or 1.2%) from June 2022 through May 2025, roughly equivalent to adding over 380,000 passenger vehicles per year over the same timeframe. Across the entire Eastern Interconnect, CO_2 emissions from generators would increase by 13.0 million tons (or 0.4%), roughly equivalent to adding over 850,000 passenger vehicles per year. If Hope Creek, Salem 1, and Salem 2 were to retire, CO_2 emissions from generators across the RGGI footprint would increase by 18.4 million tons (or 3.7%) from June 2022 through May 2025, roughly equivalent to adding nearly 1.21 million passenger vehicles per year over the same timeframe. Across the entire Eastern Interconnect, CO_2 emissions from generators would increase by over 29 million tons (or 0.8%), roughly equivalent to adding over 1.86 million passenger vehicles per year.

Power sector emissions of more localized pollutants would also increase if these nuclear generators were to retire. If Hope Creek were to retire, emissions of NOx and SO_2 in the MAAC Region would increase by 2.5 million and 1.2 million tons respectively (corresponding to 1.9% and 0.7%) from June 2022 through May 2025. If all three nuclear generators were to retire, emissions of NOx and SO_2 in the MAAC Region would increase by nearly 9 million and 5 million tons respectively (or 6.9% and 3.0%) over the same timeframe. Similarly, if Hope Creek were to retire, Hg emissions in the MAAC Region would increase by 1.4 lbs (or 0.4%) while PM10 and PM2.5 emissions would increase by approximately 560 tons (or 2.0%) and 517 tons (or 2.1%), respectively. If all three nuclear generators were to retire, emissions of Hg would increase by over 8 lbs (or 2.1%) while PM10 and PM2.5 emissions would increase by 1.8 million and 1.6 million tons respectively (corresponding to 6.4% and 6.7%).

Moreover, PA's analysis indicates that the retirement of these nuclear generation units would lead to significant fuel diversity consequences in the greater New Jersey region, increasing MAAC dependence on natural gas and coal and driving up costs for those fuels during peak winter demand events. Specifically, if Hope Creek alone were to retire, coal- and natural gas-fired generation would increase by 3.1% across the MAAC region, and 1.8% on the Peak Winter Day. The combined coal and natural gas share of MAAC-wide generation would climb from 63.2% (the Base Case assumption) to 65.8%. Natural gas prices across TM3, TZ6 NY, and TZ6 non-NY would also be higher on a weather normalized Peak Winter Day. If Hope Creek, Salem 1, and Salem 2 were to retire, coal- and natural gas-fired generation would increase by 9.1% across the MAAC region, and 7.0% on the Peak Winter Day. The combined coal and natural gas share of MAAC-wide generation would climb to 70.9%. Natural gas prices across TM3, TZ6 NY, and TZ6 non-NY would also be higher on a weather normalized Peak Winter Day. These dynamics threaten both grid reliability as well as delivering energy at reasonable costs to consumers.

Additionally, the retirement of Hope Creek alone would lead to an increase in electricity imports (primarily natural gas- and coal-fired) from elsewhere in PJM and neighboring electricity regions as well as increased natural gas-fired generation within New Jersey. Natural gas-fired generation comprises approximately two-thirds of aggregate Study Period generation in New Jersey under the Hope Creek Retirement Case.

A APPENDIX

This section provides additional New Jersey state-level detail on emission and fuel diversity impacts under the three Cases in the year 2023.

Table A-1: New Jersey Aggregate CO_2 Emissions (Year 2023)

Case	CO_2 Emissions ('000 short tons)	CO_2 Emissions Increase from Base Case ('000 short tons)
Base Case	22,766.9	N/A
Full Retirement Case	25,800.7	3,033.8 (13.3%)
Hope Creek Retirement Case	23,687.2	920.3 (4.0%)

Table A-2: Coal- and Natural Gas-fired Generation in New Jersey (Year 2023)

Case	Coal Generation (GWh)	Natural Gas Generation (GWh)
Full Retirement Case	1,536	46,846
Hope Creek Retirement Case	1,536	42,143

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