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

LAW DEPARTMENT OF PSEG SERVICES CORPORATION

December 2018

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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 December 2018 and, where applicable, incorporate underlying market data as of June 27, 2018. They were prepared by PA Consulting Group, Inc. ("PA") at the request of the Law Department of 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^{xmp}:** 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 emitted through the combustion of sulfur in fuel (primarily coal) used by electric generators and industrial facilities.
- **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, PM10, and PM2.5.
- **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:** Pennsylvania-New Jersey-Maryland Interconnection, a Regional Transmission Organization ("RTO") encompassing all or part of 14 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.
- **PM10:** Particulate matter with diameter less than or equal to 10 micrometers (i.e., coarse PM). PM10 is an air pollutant typically caused by incomplete combustion as well as atmospheric chemical reactions of chemicals such as SO_2 and NOx.
- **PM2.5:** Particulate matter with diameter less than or equal to 2.5 micrometers (i.e., fine PM). PM2.5 is an air pollutant typically caused by incomplete combustion as well as atmospheric chemical reactions of chemicals such as SO_2 and NOx.
- **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 nine participating Northeastern and Mid-Atlantic States. New Jersey would be the tenth participating state.
- **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:** Sulphur 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 covering June 1, 2019, through May 31, 2022.
- **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 Law Department of PSEG Services Corporation ("PSEG") engaged PA Consulting Group ("PA") 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. 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]

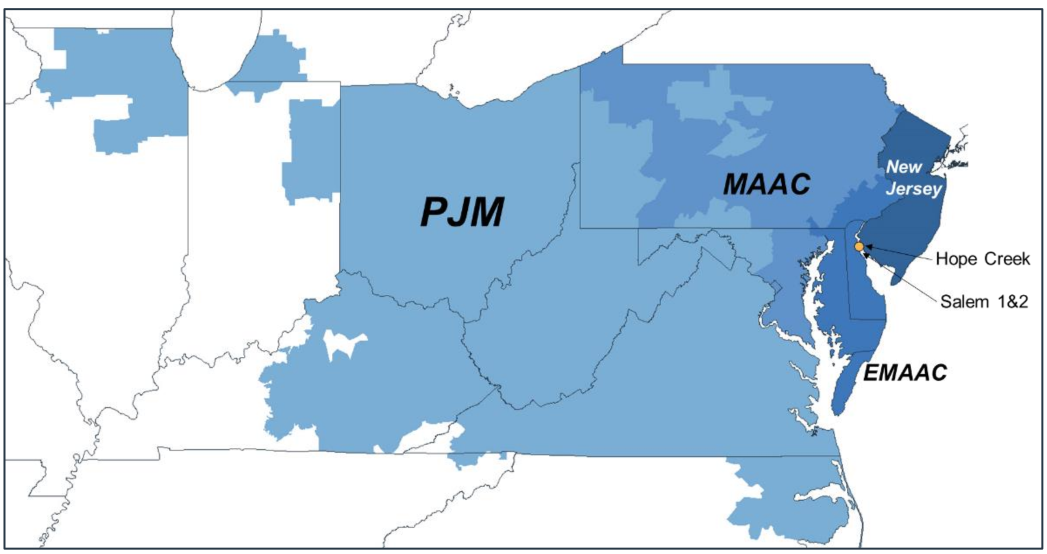


Table 1-1: PSEG Nuclear Generating Resources[3]

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

[1] Please see the Glossary for acronym and key term definitions.
[2] New Jersey falls entirely within the EMAAC transmission zone.
[3] PSEG has a 100% ownership stake in Hope Creek, and a ~57% ownership stake in Salem 1 and Salem 2.

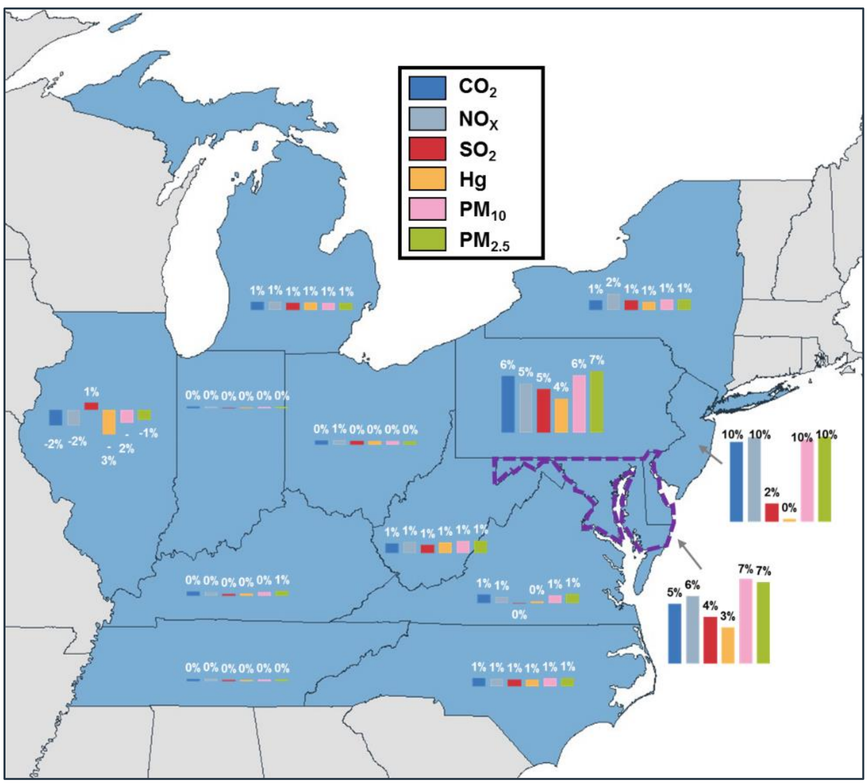
In this independent evaluation, PA sought to answer two primary questions:

- 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 three years (June 2019 to May 2022) 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 significantly 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.

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



[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 Illinois, the decline in 5 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.

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	6,416	1,648	147	0.2	386	372
MAAC	29,339	11,238	11,738	26.4	2,587	2,228

The same general trend in harmful emissions is 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 significant increases in emissions within the greater New Jersey region.

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

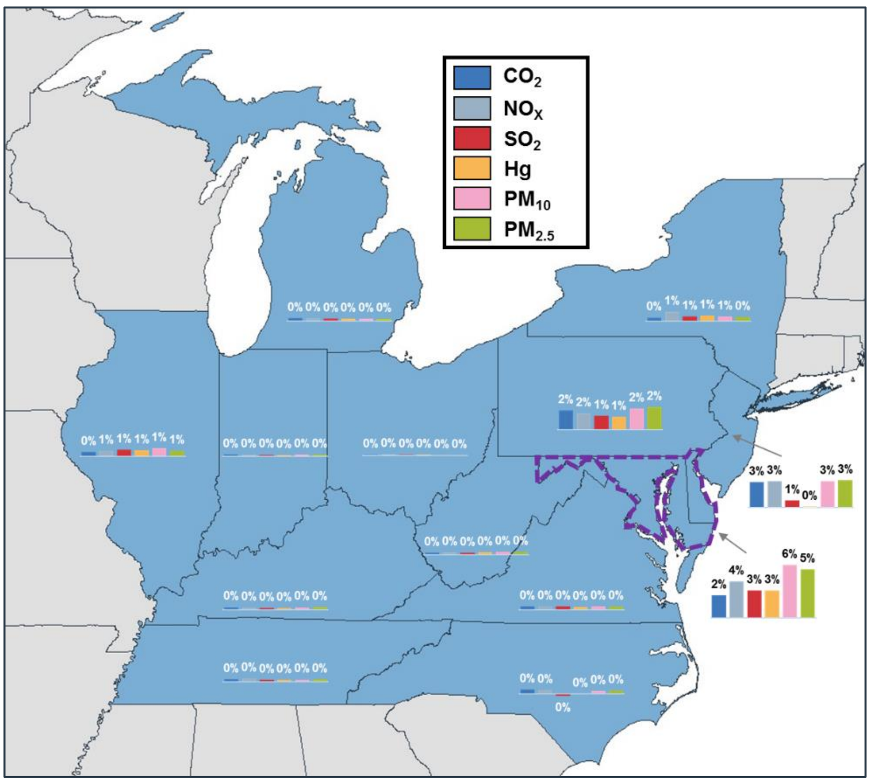


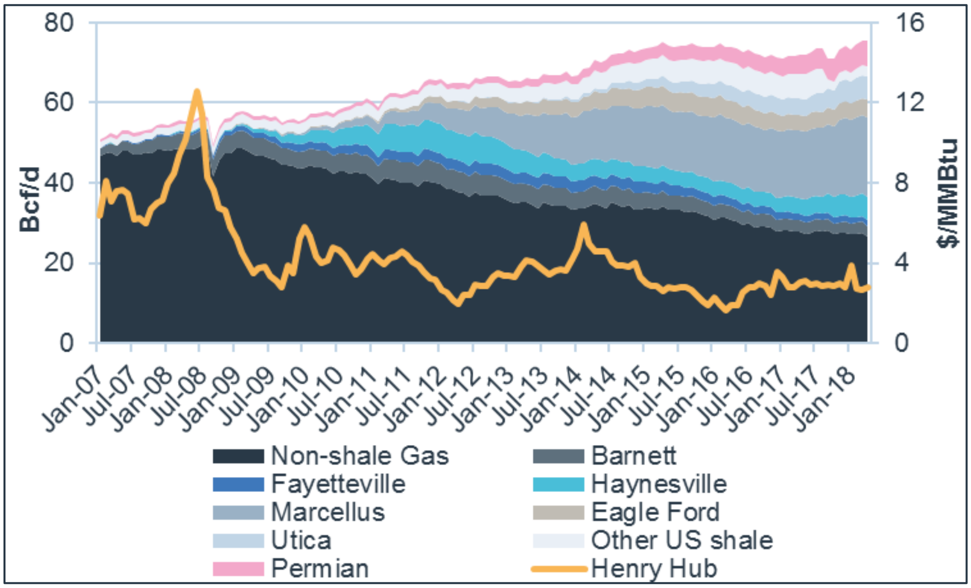
Table 1-3: Increase in Emissions Across Study Period – Hope Creek Retirement Case

Geography	CO_2 ('000 short tons)	NOx (short tons)	SO_2 (short tons)	Hg (lbs)	PM10 (short tons)	PM2.5 (short tons)
New Jersey	1,875	468	54	0.1	113	109
MAAC	10,173	4,275	4,731	14.2	1,138	960

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) and an increasing share of natural gas-fired generating capacity 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)[5]



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 potential environmental, reliability, resilience, and economic implications of retiring zero-emission generating resources due to low wholesale power prices. 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. 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 nuclear generating resources in that state. In Connecticut, legislation (SB-1501) signed into law in October 2017 will allow Millstone to bid into a state-led clean energy procurement to secure a long-term power supply contract.

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. On August 29, 2018, the BPU issued an Order launching a proceeding (Docket No. EO18080899) to create and administer the ZEC program and application process.

[5] As of May 5, 2018. 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. Legislation (P.L.1999, c.23 (C.48:3-49 et seq.) enacted in 1999 that restructured the electric power sector and establishing the state's first Renewable Portfolio Standard stated that "it is the policy of this State to:…[p]rovide diversity in the supply of electric power throughout this State." 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,"[6] 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."[7]

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
- "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."

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.

[6] Page 81.
[7] Page 20.

Table 2-1: Qualitative Comparison of Grid Reliability and Resilience Attributes by Fuel Type[8]

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	✓	✓			✓	✓

Motivations for fuel diversity are frequently raised 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,"[9] 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 diverse portfolio of generation resources and well-planned transmission investments are critical to meeting regional reliability objectives."[10]

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

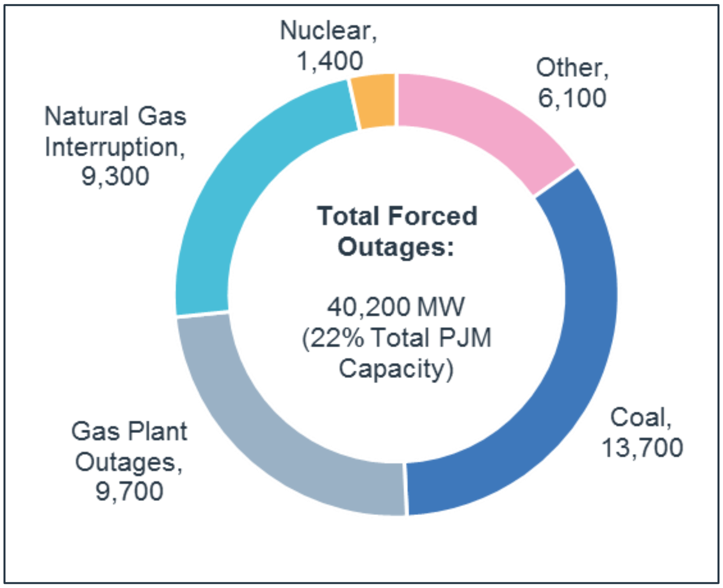
The 2014 Polar Vortex was an abnormally cold weather event that impacted most of the eastern and central United States. It was most severe January 6-8, when record-low temperatures contributed to PJM's all-time winter peak demand of 141.9 GW. Although the PJM region is summer-peaking, the multiple low-probability,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

[8] Notes: (a) Wind only (b) Often limited.
[9] Source: The Council of State Governments, Overview of State Renewable Portfolio Standards, December 2008.
[10] 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

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.

Figure 2-2: PJM Outages (MW) by Primary Fuel, January 7, 2014, 7:00 pm[11]



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.

[11] 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

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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.

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3 METHODOLOGICAL OVERVIEW

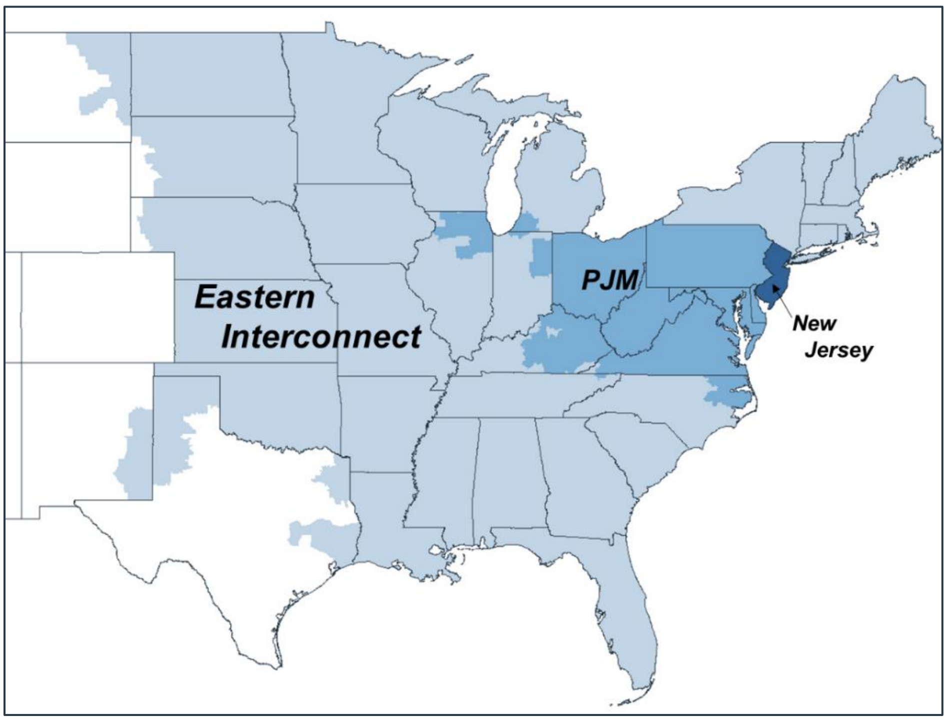
This section describes (i) the electric power system and natural gas system modeling approach used by PA in this analysis, including the process PA used to develop generating unit-level emission rate assumptions used in its electric power system modeling; and (ii) the modeling cases performed by PA to 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^{xmp}) to simulate the hourly operations of the Eastern Interconnect which includes the PJM power market.[12] The AURORA^{xmp} 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, the development of new electric generating resources, the retirement of existing electric generating resources, 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[13]



The AURORA^{xmp} 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^{xmp} 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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[12] AURORA^{xmp} is a product of EPIS, LLC.

[13] The entire State of New Jersey is located within the PJM power market.

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To forecast the long-term wholesale natural gas prices that PA used in AURORA^{xmp}, 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).

Emission Rate Inputs

In using the AURORA^{xmp} 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^{xmp} 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.

Modeling Outputs

For each case that PA modeled (see Section 3.2 below), PA reported monthly and annual emissions of each of the Modeled Pollutants from June 2019 through May 2022 (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 2021.

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 reported 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 reported aggregated monthly, annual, Typical Summer Day, HEDD,

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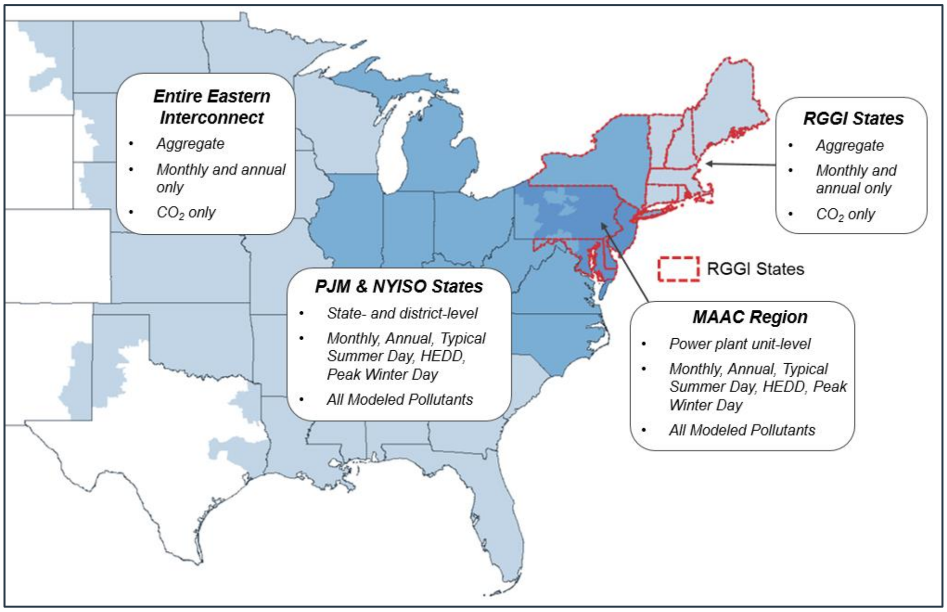
and Peak Winter Day emissions of each of the Modeled Pollutants. Although New York is part of a separate power market (NYISO) than PJM, there are significant electricity exports from PJM to NYISO, and supply mix changes within PJM (including New Jersey) can have a significant impact on generator dispatch 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 reported aggregated monthly and annual CO_2 emissions across the entire RGGI footprint and Eastern Interconnect.

See Figure 3-2 for a map of emission modeling outputs by pollutant, time horizon, and geographic scope.

Figure 3-2: Emission Modeling Outputs by Pollutant, Time Horizon, and Geographic Scope[14]



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 2019 through May 2022).

- **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, but assumes 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 either Hope Creek, Salem 1, or Salem 2.

[14] The entire State of New Jersey is located within the MAAC Region of the PJM power market. While New Jersey is currently not part of the RGGI program, PA's analysis assumes the state will rejoin RGGI in 2020. When reporting emission changes within the RGGI footprint across the Study Period, the change in New Jersey emissions is included with the RGGI values.

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 11.6% and 8.9%, respectively. Note that the study also assumes the retirement of over 5 GW of announced nuclear retirements including Oyster Creek 1, Davis-Besse, Three-Mile Island, Perry 1, and Beaver Valley 1 & 2.

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 and NOx) 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	404,351	160,389	225,290	574	34,155	28,180
2019/20 DY	137,108	55,576	79,980	201	11,889	9,776
2020/21 DY	133,656	52,960	74,620	191	11,312	9,328
2021/22 DY	133,587	51,853	70,690	183	10,953	9,076
Typical Summer Day	420	165	220	1	34	28
HEDD	563	236	285	1	46	39
Peak Winter Day	366	157	254	1	35	28

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 2020, please see Table A-1 in Appendix A.

Reflecting the relative size of its thermal generating fleet and lower share of coal-fired generation compared to other PJM and NYISO States, New Jersey ranks among the lowest states across all Modeled Pollutants. Additionally, despite its relatively large installed capacity, New York is a relatively low emitting state among the PJM & NYISO States due to its heavier reliance on natural gas-fired generation than coal-fired generation. Maryland, Delaware, and the District of Columbia also 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 eighth). Further west, Ohio and Indiana also rank among the largest emitters, with Indiana the highest aggregate emitter of all Modeled Pollutants and Ohio ranking among the top four largest emitters of all Modeled Pollutants. This reflects both the overall size of the generating fleet in these states as well as their reliance on less-efficient and higher-emitting generating technologies (primarily coal).

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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	171	39	2	0	2	2
DE	13,805	4,623	4,359	15	934	811
IL	148,974	57,988	119,087	635	9,558	7,288
IN	337,324	225,188	303,977	1,149	44,204	35,736
KY	252,326	185,166	217,407	1,006	22,419	17,254
MD	69,608	27,886	56,756	229	6,682	6,000
MI	199,715	116,417	80,748	755	9,504	6,639
NC	171,946	105,940	79,714	557	14,028	13,022
NJ	67,005	16,252	6,727	45	3,925	3,646
NY	112,983	53,050	53,670	90	7,525	6,744
OH	286,137	174,080	281,401	1,116	34,712	28,573
PA	326,461	154,507	196,533	523	27,744	21,903
TN	99,356	30,628	35,495	284	10,597	9,469
VA	131,918	51,105	62,191	194	11,782	9,059
WV	232,763	181,791	157,042	1,138	21,392	17,850

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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 scale 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	0.2	0.1	0.0	0.0	0.0	0.0
DE	17.9	6.1	4.7	0.0	1.2	1.1
IL	153.3	59.2	121.9	0.7	10.7	8.1
IN	344.4	228.0	289.9	1.1	44.5	36.2
KY	250.8	182.0	202.9	1.0	22.0	17.1
MD	68.1	22.8	43.0	0.2	5.4	5.0
MI	203.4	116.4	76.0	0.8	9.4	6.7
NC	196.8	123.7	95.2	0.7	16.3	15.1
NJ	74.2	17.7	6.8	0.0	4.4	4.1
NY	110.9	45.2	38.8	0.1	6.9	6.5
OH	283.7	172.6	264.1	1.1	34.2	28.4
PA	336.6	163.0	206.3	0.5	28.7	22.7
TN	98.5	30.7	33.7	0.3	10.3	9.3
VA	136.1	51.5	64.5	0.2	12.1	9.4
WV	224.1	173.1	150.1	1.1	20.3	17.0

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Table 4-4 shows power sector emissions of the Modeled Pollutants on the HEDD for each of the PJM & NYISO States. The relative scale of emissions in certain states on the HEDD compared to the overall Study Period is notably different. For example, Illinois, Michigan, and New York rank higher for emissions of several pollutants on the HEDD than the overall 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	0.2	0.1	0.0	0.0	0.0	0.0
DE	24.4	9.1	8.3	0.0	1.7	1.5
IL	267.9	110.7	150.4	0.8	17.8	14.4
IN	404.5	267.0	334.7	1.3	52.8	42.9
KY	299.1	215.3	235.5	1.1	26.0	20.1
MD	116.1	46.7	73.9	0.3	9.6	8.9
MI	273.1	172.5	117.1	0.9	14.2	10.4
NC	247.5	155.8	115.7	0.8	20.3	18.9
NJ	105.7	34.3	8.2	0.0	6.7	6.3
NY	191.5	118.1	77.7	0.1	13.1	12.0
OH	342.4	216.2	309.6	1.3	40.9	34.1
PA	400.6	194.9	236.9	0.6	33.9	27.0
TN	125.1	50.9	42.5	0.3	13.3	12.0
VA	191.5	79.7	71.8	0.2	18.3	14.2
WV	267.8	200.9	173.3	1.3	24.0	20.2

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 certain states on the Peak Winter Day compared to the overall Study Period is notably different. For example, Illinois, Pennsylvania, and West Virginia rank higher for emissions of several pollutants on the Peak Winter Day than the overall Study Period.

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	0.1	0.0	0.0	0.0	0.0	0.0
DE	10.3	3.5	3.8	0.0	0.7	0.6
IL	193.3	77.7	157.5	0.9	14.0	10.3
IN	327.3	218.1	309.9	1.2	44.1	35.3
KY	254.1	189.9	230.5	1.1	23.2	17.7
MD	57.0	26.8	57.9	0.2	6.7	5.9
MI	197.4	113.4	76.1	0.8	8.9	5.9
NC	132.6	82.8	61.9	0.4	10.9	10.0
NJ	43.8	12.5	7.2	0.0	2.5	2.3
NY	100.0	49.1	51.1	0.1	6.7	6.0
OH	293.2	181.5	302.1	1.2	35.6	29.0
PA	331.5	160.8	227.0	0.6	30.0	23.3
TN	99.3	28.0	37.3	0.3	10.7	9.5
VA	104.4	44.5	65.8	0.2	9.9	7.4
WV	262.7	202.8	174.0	1.3	23.9	19.9

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 2019/20 to 2020/21, largely reflecting legacy generating resource retirements and the addition of newer and more efficient natural gas-fired and renewable generating resources. However, CO_2 emissions increase slightly from 2020/21 to 2021/22, reflecting load growth and significant retirement of nuclear generating resources, both of which make the electric system more reliant on higher-emitting fossil generation.

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

Time Period	RGGI	Eastern Interconnect
Study Period Total	410,300	4,166,557
2019/20 DY	138,491	1,398,686
2020/21 DY	135,206	1,382,563
2021/22 DY	136,603	1,385,308

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). Both cases demonstrate significant 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).

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?***", 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 4.6% to 7.9% in the MAAC Region. NOx and SO_2 emissions increase by over 11,000 tons each, while PM10 and PM2.5 emissions increase by over 2,000 tons each. Hg emissions increase by over 26 lbs.
- Emission impacts are most pronounced in the Mid-Atlantic states, particularly Pennsylvania and New Jersey. In Pennsylvania alone, NOx emissions increase by over 8,000 tons, SO2 emissions increase by over 9,000 tons, and PM10 and PM2.5 emissions increase by over 1,000 tons. Hg emissions in Pennsylvania increase by nearly 20 lbs.
- CO_2 emissions increase significantly across the RGGI footprint (nearly 13 million tons) and the Eastern Interconnect (nearly 38 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 7.0% over the Study Period, while emissions of SO_2 increase by 5.2% and emissions of Hg increase by 4.6%. Reflecting the improving efficiency and reducing emission intensity of the MAAC generating fleet over the Study Period, emission changes are generally more pronounced in 2019/20 than 2021/22. The exception to this trend is SO_2, which sees more pronounced emission changes in 2021/22 than 2019/20 or 2020/21. This is largely due to significant generating resource retirements (including nearly 3 GW of nuclear generation resource retirements; specifically, the Perry 1 and Beaver Valley 1 & 2 nuclear units) in 2021/22 that tighten the reserve margin[15] across PJM, including the MAAC Region, which drives increased dispatch of coal-fired generating resources that consume coal with relatively high sulphur content.

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

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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	29,338.6 (7.3%)	11,238.5 (7.0%)	11,737.6 (5.2%)	26.4 (4.6%)	2,586.6 (7.6%)	2,228.1 (7.9%)
2019/20 DY	10,186.8 (7.4%)	4,094.8 (7.4%)	3,597.6 (4.5%)	10.0 (5.0%)	929.5 (7.8%)	795.7 (8.1%)
2020/21 DY	9,709.7 (7.3%)	3,695.6 (7.0%)	3,660.3 (4.9%)	8.6 (4.5%)	855.6 (7.6%)	742.3 (8.0%)
2021/22 DY	9,442.1 (7.1%)	3,448.2 (6.6%)	4,479.7 (6.3%)	7.8 (4.3%)	801.5 (7.3%)	690.1 (7.6%)
Typical Summer Day	27.6 (6.6%)	10.8 (6.5%)	6.5 (3.0%)	0.0 (4.0%)	2.5 (7.3%)	2.1 (7.4%)
HEDD	21.7 (3.9%)	18.3 (7.8%)	26.0 (9.1%)	0.0 (6.0%)	2.6 (5.7%)	2.1 (5.4%)
Peak Winter Day	24.2 (6.6%)	5.9 (3.8%)	8.8 (3.4%)	0.0 (3.9%)	2.2 (6.4%)	1.9 (6.8%)

The most impactful emission changes resulting from the retirement of Hope Creek, Salem 1, and Salem 2 are concentrated in New Jersey as well as the Mid-Atlantic states surrounding New Jersey. 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 volumetric and percentage terms. Emissions changes are more muted in states that are electrically more distant from New Jersey. For additional detail on power sector CO_2 emission changes in New Jersey in the year 2020, please see Table A-1 in Appendix A.

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

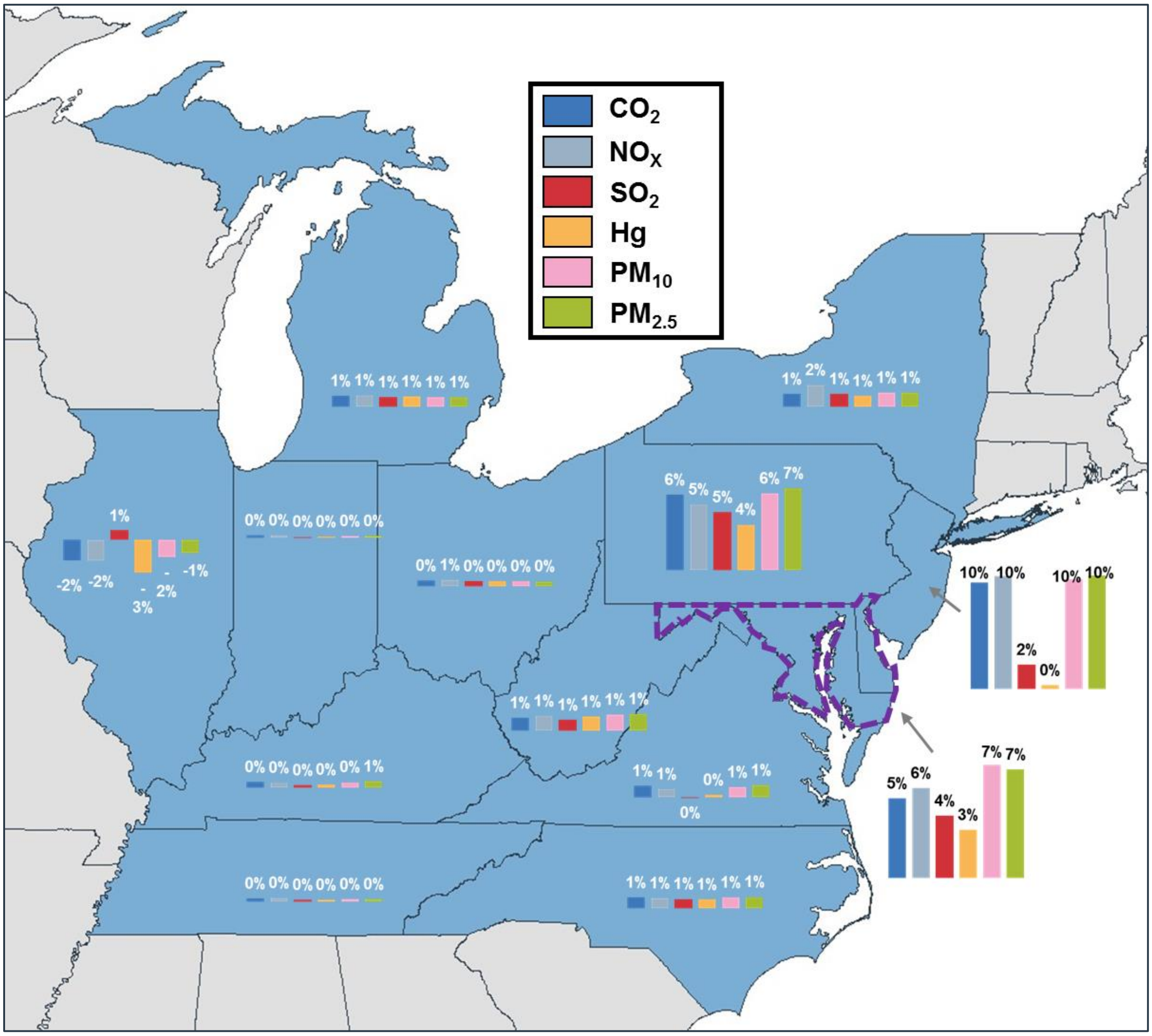


Table 5-2: Increase in State-Level Emissions Across Study Period – Full Retirement Case

State	CO_2 ('000 short tons)	NOx (short tons)	SO_2 (short tons)	Hg (lbs)	PM10 (short tons)	PM2.5 (short tons)
IL	-3,015.2 (-2.0%)	-1,225.6 (-2.1%)	1,133.4 (1.0%)	-20.5 (-3.2%)	-163.4 (-1.7%)	-98.9 (-1.4%)
IN	638.8 (0.2%)	508.7 (0.2%)	235.9 (0.1%)	1.1 (0.1%)	72.0 (0.2%)	62.5 (0.2%)
KY	1,183.1 (0.5%)	787.8 (0.4%)	509.4 (0.2%)	2.7 (0.3%)	102.6 (0.5%)	88.9 (0.5%)
MD+DE+DC	4,337.5 (5.2%)	1,903.9 (5.8%)	2,479.3 (4.1%)	7.6 (3.1%)	559.9 (7.3%)	482.5 (7.1%)
MI	1,848.1 (0.9%)	1,122.9 (1.0%)	630.2 (0.8%)	6.6 (0.9%)	74.6 (0.8%)	53.6 (0.8%)
NC	1,583.8 (0.9%)	904.0 (0.9%)	616.3 (0.8%)	4.3 (0.8%)	129.8 (0.9%)	121.5 (0.9%)
NJ	6,416.2 (9.6%)	1,648.2 (10.1%)	146.9 (2.2%)	0.2 (0.4%)	385.9 (9.8%)	371.8 (10.2%)
NY	1,195.6 (1.1%)	945.8 (1.8%)	562.9 (1.0%)	0.8 (0.9%)	89.1 (1.2%)	78.9 (1.2%)
OH	1,352.6 (0.5%)	909.9 (0.5%)	1,238.0 (0.4%)	5.0 (0.5%)	144.9 (0.4%)	117.0 (0.4%)
PA	20,018.0 (6.1%)	8,297.4 (5.4%)	9,266.8 (4.7%)	19.4 (3.7%)	1,732.1 (6.2%)	1,456.8 (6.7%)
TN	262.9 (0.3%)	103.2 (0.3%)	53.2 (0.1%)	0.5 (0.2%)	24.1 (0.2%)	21.7 (0.2%)
VA	1,842.1 (1.4%)	501.5 (1.0%)	-3.8 (-0.0%)	0.5 (0.3%)	147.4 (1.3%)	131.3 (1.4%)
WV	2,471.5 (1.1%)	2,174.9 (1.2%)	1,446.6 (0.9%)	13.2 (1.2%)	278.9 (1.3%)	242.4 (1.4%)

On a volumetric basis, Pennsylvania sees the highest level of emission changes for all Modeled Pollutants. New Jersey shows higher aggregate CO_2 emission changes than Delaware, the District of Columbia, and Maryland combined, but lower levels of NOx, SO_2, Hg, PM10, and PM2.5 changes. This reflects the greater reliance on cleaner-burning natural gas-fired generating resources in New Jersey than Delaware, the District of Columbia, and Maryland (combined). Figure 5-2 shows the aggregate state-level emission changes (in volumetric 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

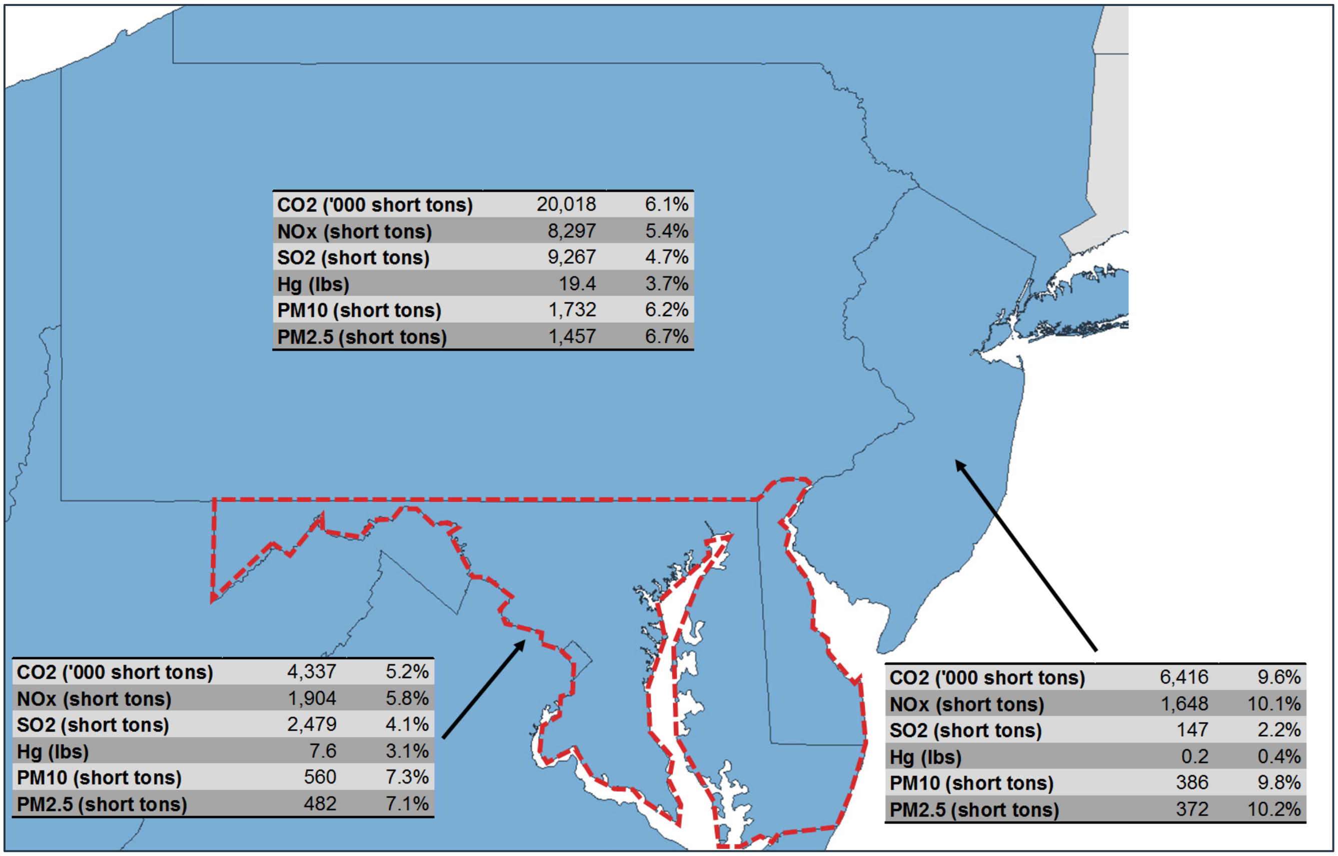


Table 5-3 shows the aggregate CO_2 emission changes under the Full Retirement Case across the RGGI footprint and entire Eastern Interconnect over the Study Period. CO_2 emissions increase by nearly 13 million tons (or 3.1%) across the RGGI footprint, and nearly 38 million tons (or 0.9%) across the Eastern 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	12,877 (3.1%)	37,818 (0.9%)
2019/20 DY	4,667 (3.4%)	13,606 (1.0%)
2020/21 DY	4,293 (3.2%)	12,218 (0.9%)
2021/22 DY	3,917 (2.9%)	11,994 (0.9%)

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?***", 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 significantly with the retirement of only the Hope Creek nuclear generator. As expected, the emission changes under the Hope Creek Retirement Case are less impactful than 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 2.1% to 3.4% in the MAAC Region. NOx and SO_2 emissions increase by over 4,000 tons each, while PM10 and PM2.5 emissions increase by approximately 1,000 tons each. Hg emissions increase by over 14 lbs.
- Similar to the Full Retirement Case, emission impacts are most pronounced in the Mid-Atlantic states, particularly Pennsylvania and New Jersey. In Pennsylvania alone, NOx and SO_2 emissions increase by nearly 3,000 tons, PM10 and PM2.5 emissions increase by over 500 tons, and Hg emissions increase by over 7 lbs.
- CO_2 emissions increase significantly across the RGGI footprint (over 4.5 million tons) and the Eastern Interconnect (nearly 13 million tons).

Across the MAAC, emissions of all Modeled Pollutants increase over all considered time horizons under the Hope Creek Retirement Case. See Table 5-4. Emissions of PM10 and PM2.5 increase by over 3.0% over the Study Period, while emissions of the remaining pollutants increase by over 2.0% over the Study Period. Similar to the Full Retirement Case, improving efficiency and reducing emission intensity of the MAAC generating fleet over the Study Period lead to somewhat less pronounced emission changes later in the Study Period (i.e., 2021/22) than earlier in the Study Period (i.e., 2019/20). However, as in the Full Retirement Case, SO_2 is an exception to this trend as dispatch of coal-fired generators that consume coal with higher sulphur content increases in 2021/22.

Table 5-4: Increase in MAAC Region Aggregate Emissions – Hope Creek 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	10,173.1 (2.5%)	4,274.9 (2.7%)	4,730.9 (2.1%)	14.2 (2.5%)	1,137.8 (3.3%)	960.2 (3.4%)
2019/20 DY	3,864.3 (2.8%)	1,645.9 (3.0%)	1,368.2 (1.7%)	5.7 (2.8%)	448.4 (3.8%)	377.2 (3.9%)
2020/21 DY	3,213.1 (2.4%)	1,361.1 (2.6%)	1,345.9 (1.8%)	4.7 (2.4%)	370.7 (3.3%)	315.0 (3.4%)
2021/22 DY	3,095.6 (2.3%)	1,267.9 (2.4%)	2,016.7 (2.9%)	3.8 (2.1%)	318.6 (2.9%)	267.9 (3.0%)
Typical Summer Day	9.3 (2.2%)	5.1 (3.1%)	7.8 (3.6%)	0.0 (2.1%)	1.1 (3.1%)	0.9 (3.1%)
HEDD	6.7 (1.2%)	5.1 (2.2%)	8.1 (2.8%)	0.0 (1.7%)	0.8 (1.7%)	0.6 (1.6%)
Peak Winter Day	4.1 (1.1%)	0.8 (0.5%)	1.6 (0.6%)	0.0 (0.4%)	0.3 (0.8%)	0.2 (0.8%)

Similar to the Full Retirement Case, the most impactful emission changes if Hope Creek were 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 volumetric and percentage terms. For additional detail on power sector CO_2 emission changes in New Jersey in the year 2020, please see Table A-1 in Appendix A.

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

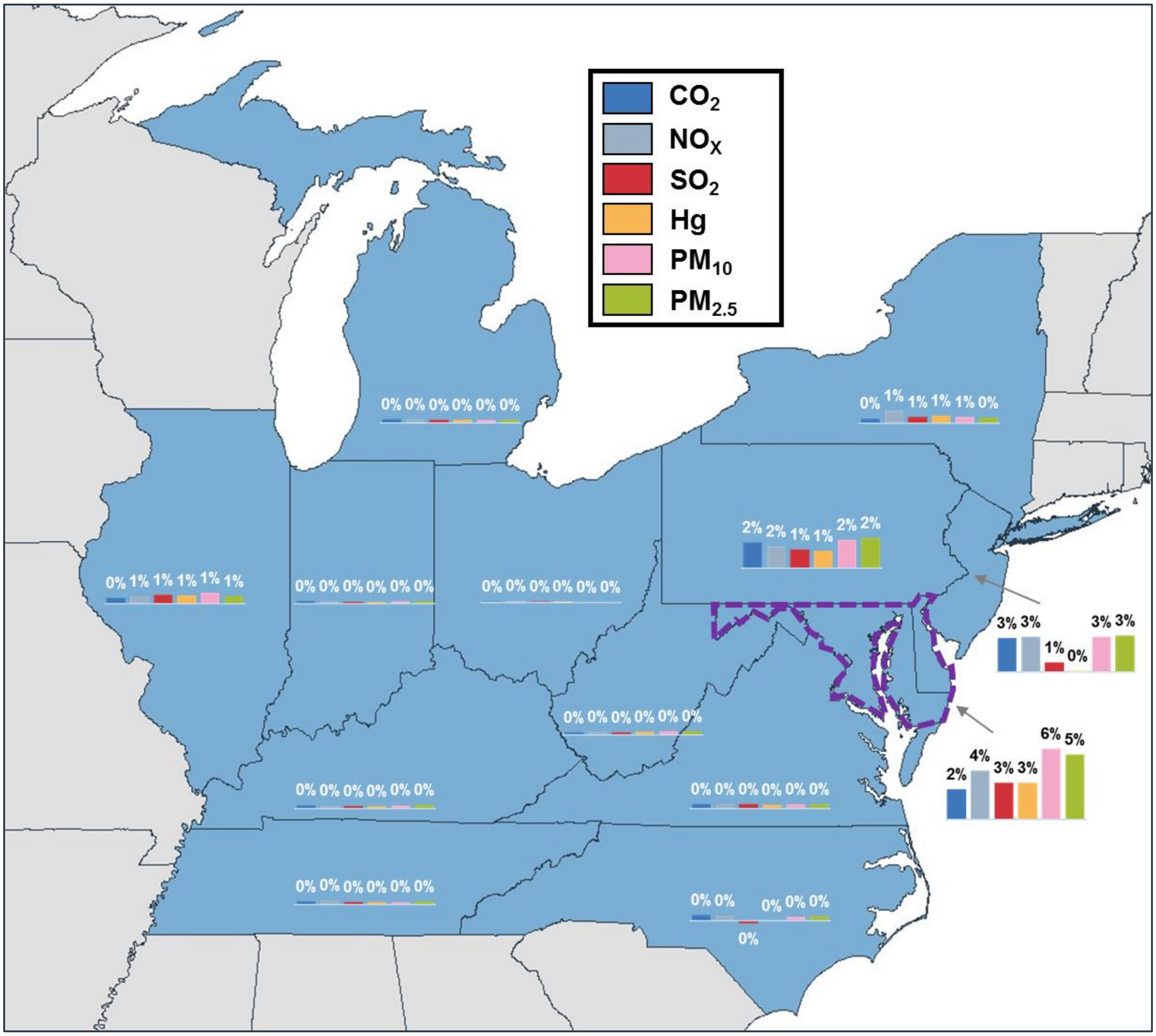


Table 5-5: Increase in State-Level Emissions Across Study Period – Hope Creek Retirement Case

State	CO_2 ('000 short tons)	NOx (short tons)	SO_2 (short tons)	Hg (lbs)	PM10 (short tons)	PM2.5 (short tons)
IL	716.2 (0.5%)	364.3 (0.6%)	846.4 (0.7%)	4.2 (0.7%)	84.5 (0.9%)	45.4 (0.6%)
IN	643.7 (0.2%)	448.7 (0.2%)	529.2 (0.2%)	1.7 (0.1%)	86.7 (0.2%)	73.0 (0.2%)
KY	720.2 (0.3%)	506.7 (0.3%)	466.1 (0.2%)	2.0 (0.2%)	63.5 (0.3%)	53.4 (0.3%)
MD+DE+DC	1,974.7 (2.8%)	1,252.9 (3.8%)	1,760.3 (2.9%)	7.0 (2.9%)	424.4 (5.6%)	348.1 (5.1%)
MI	557.5 (0.3%)	341.9 (0.3%)	194.8 (0.2%)	2.0 (0.3%)	23.5 (0.2%)	17.3 (0.3%)
NC	645.8 (0.4%)	383.1 (0.4%)	283.0 (0.4%)	1.9 (0.3%)	53.3 (0.4%)	49.8 (0.4%)
NJ	1,875.4 (2.8%)	468.4 (2.9%)	53.9 (0.8%)	0.1 (0.1%)	113.4 (2.9%)	109.3 (3.0%)
NY	462.2 (0.4%)	554.8 (1.0%)	303.1 (0.6%)	0.6 (0.6%)	40.3 (0.5%)	33.6 (0.5%)
OH	238.3 (0.1%)	200.1 (0.1%)	205.3 (0.1%)	0.8 (0.1%)	17.5 (0.1%)	14.8 (0.1%)
PA	6,796.9 (2.1%)	2,715.3 (1.8%)	2,947.5 (1.5%)	7.3 (1.4%)	629.0 (2.3%)	529.8 (2.4%)
TN	254.1 (0.3%)	105.2 (0.3%)	65.1 (0.2%)	0.5 (0.2%)	24.4 (0.2%)	22.2 (0.2%)
VA	618.7 (0.5%)	226.0 (0.4%)	-111.4 (-0.2%)	0.0 (0.0%)	38.8 (0.3%)	35.2 (0.4%)
WV	554.5 (0.2%)	504.3 (0.3%)	317.6 (0.2%)	3.0 (0.3%)	67.9 (0.3%)	59.8 (0.3%)

On a volumetric basis, Pennsylvania sees the highest level of emission changes for all Modeled Pollutants. Delaware, the District of Columbia, and Maryland combined also show higher aggregate Modeled Pollutant emission changes than New Jersey. This reflects the greater reliance on cleaner-burning natural gas-fired generating resources in New Jersey than Delaware, the District of Columbia, and Maryland (combined). Figure 5-4 shows the aggregate state-level emission changes (in volumetric 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

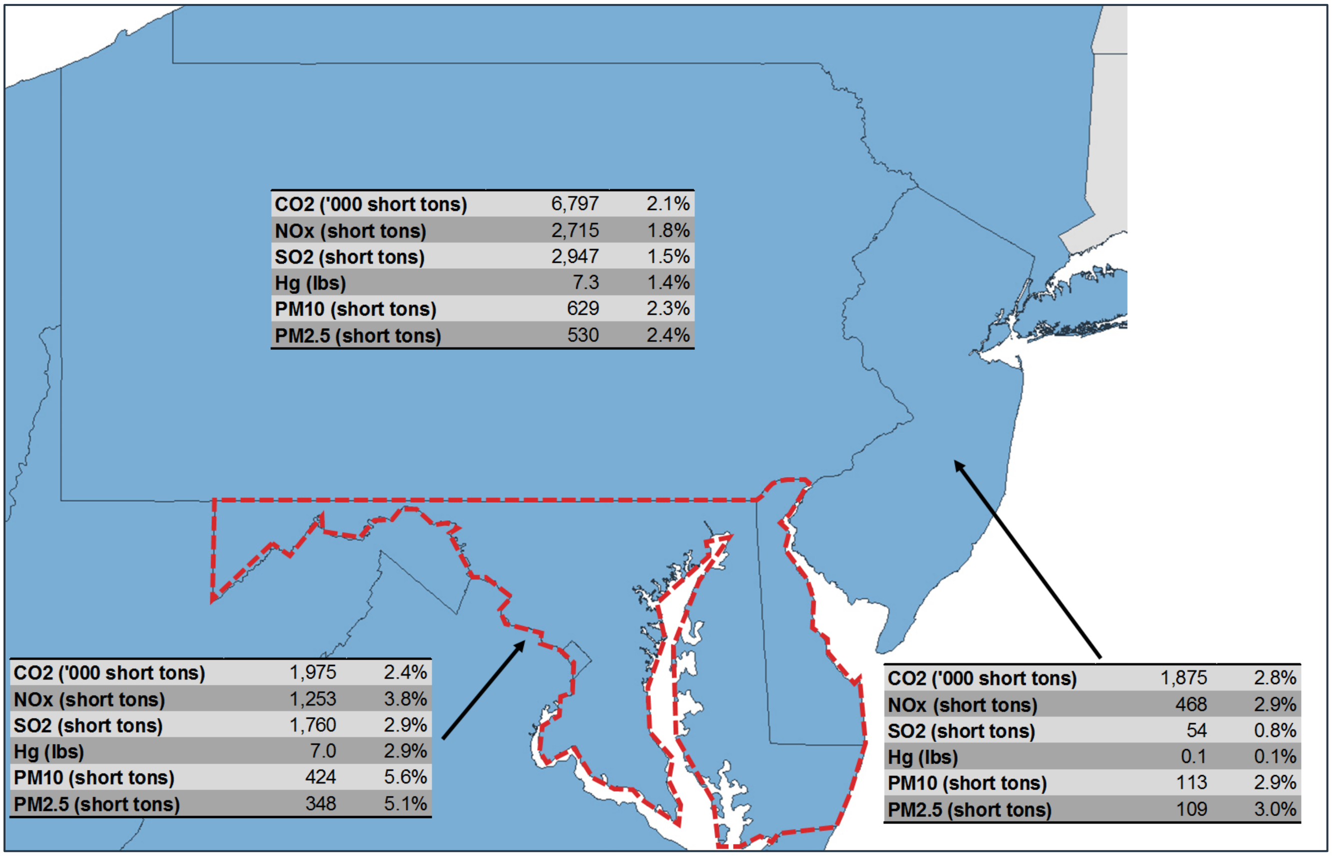


Table 5-6 shows the aggregate CO_2 emission changes under the Hope Creek Retirement Case across the RGGI footprint and the entire Eastern Interconnect over the Study Period. CO_2 emissions increase by over 4.5 million tons (or 1.1%) across the RGGI footprint, and over nearly 13 million tons (or 0.3%) 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	4,593 (1.1%)	12,979 (0.3%)
2019/20 DY	1,727 (1.2%)	5,022 (0.4%)
2020/21 DY	1,515 (1.1%)	4,915 (0.4%)
2021/22 DY	1,351 (1.0%)	3,041 (0.2%)

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 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. 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. 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 significant 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 neighboring electricity regions. This raises concern 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 with higher priority demand for heating, and natural gas-fired generators do not feature material on-site fuel storage capability that could ensure fuel supply during constrained periods. While coal-fired generators typically feature 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 66% of the 82.7 TWh of nuclear generation lost due to full retirement across the Study Period. Coal- and natural gas-fired generation are collectively 8.8% higher in the MAAC region across the Study Period, and 9.6% higher on the Peak Winter Day. The combined coal and natural gas share of MAAC-wide generation climbs from 62.9% to 70.3% of total generation across the Study Period.
- Consumption of natural gas and coal for power generation rises significantly. Total natural gas consumption is 9.8% higher than Base Case, while coal consumption rises by 4.2% across the Study Period. On the Peak Winter Day, natural gas consumption is 11.3% 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 8.8% 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 2020 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

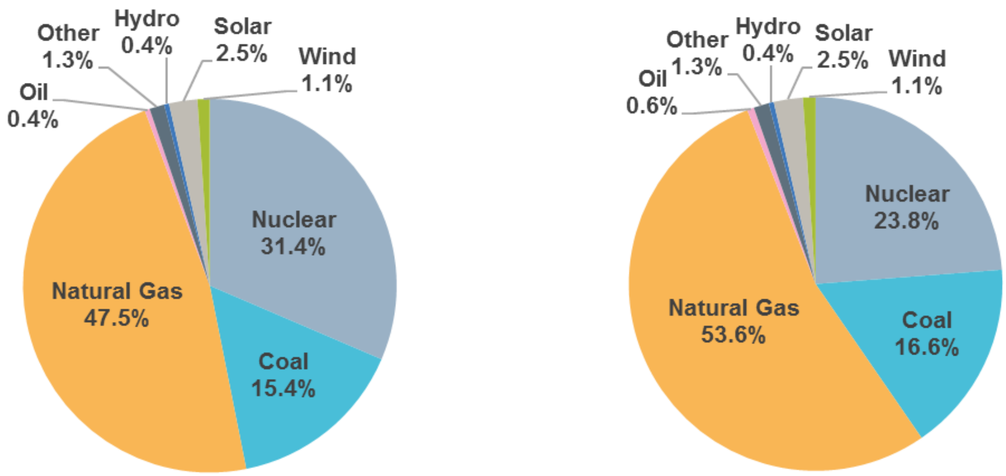
Time Period	Generation (GWh)
Study Period Total	54,925 (8.8%)
2019/20 DY	18,650 (8.9%)
2020/21 DY	18,266 (8.8%)
2021/22 DY	18,009 (8.5%)
Typical Summer Day	48 (7.3%)
HEDD	27 (3.1%)
Peak Winter Day	50 (9.6%)

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 26%. Natural gas- and coal-fired generation within MAAC replace more than 66% 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.[16] Coal- and natural gas-fired generation comprise 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.

[16] 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 Mix (Across Study Period)

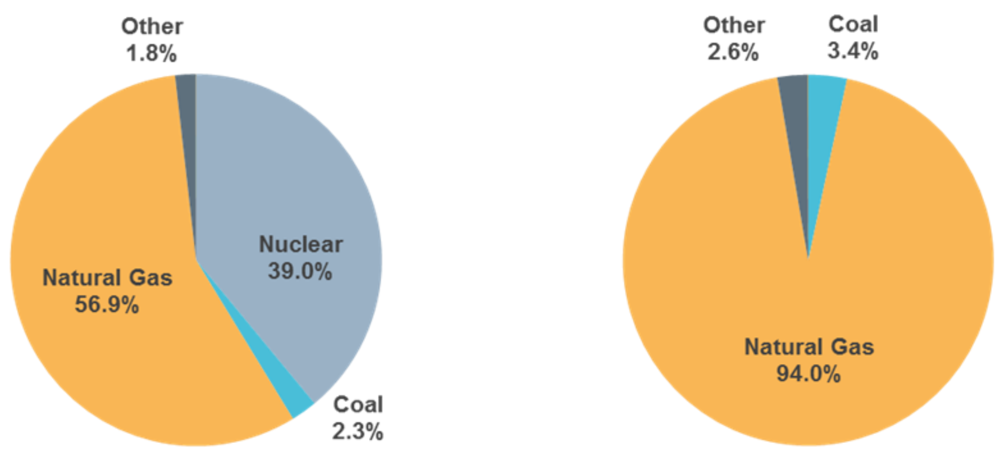
Base Case | **Full Retirement Case**



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 more than 90% of aggregate Study Period generation in New Jersey under the Full Retirement Case.

Figure 6-2: New Jersey Generation Mix (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 Peak Winter Day. Over the Study Period, retirement of Hope Creek, Salem 1, and Salem 2 leads to an additional 355.1 million MMBtu (9.8%) of natural gas consumption for power, along with an additional 68.5 million MMBtu (4.2%) of coal consumption. These increases are roughly balanced across the three delivery years of the Study Period. Projected Peak Winter Day consumption under the Full Retirement Case shows a significant spike in power sector natural gas consumption, with consumption 11.3% higher than under the Base Case.

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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	355,100,016 (9.8%)	68,460,629 (4.2%)
2019/20 DY	122,455,968 (10.2%)	23,279,654 (4.1%)
2020/21 DY	119,893,610 (10.0%)	20,705,803 (3.8%)
2021/22 DY	112,750,437 (9.1%)	24,475,172 (4.7%)
Typical Summer Day	315,293 (7.9%)	86,557 (5.3%)
HEDD	143,858 (2.6%)	102,669 (4.7%)
Peak Winter Day	296,736 (11.3%)	50,272 (2.7%)

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 or 2018 Bombogenesis, as described in Section 2.1 of this report—PA would expect significantly higher pricing than observed on the weather-normalized Peak Winter Day due to the retirement of the nuclear units.

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 less impactful 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 in MAAC replace roughly 63% of the approximately 28 TWh of nuclear generation lost due to the Hope Creek retirement across the Study Period. Coal- and natural gas-fired generation are 2.8% higher in the MAAC region across the Study Period, and 1.7% higher on the Peak Winter Day. The combined coal and natural gas share of the MAAC-wide generation mix climbs from 62.9% to 65.3% across the Study Period.
- Consumption of natural gas and coal for power generation rises. Total natural gas consumption is 3.1% higher than Base Case, while coal consumption rises by 1.4% across the Study Period. On the Peak Winter Day, natural gas consumption is 2.1% 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.

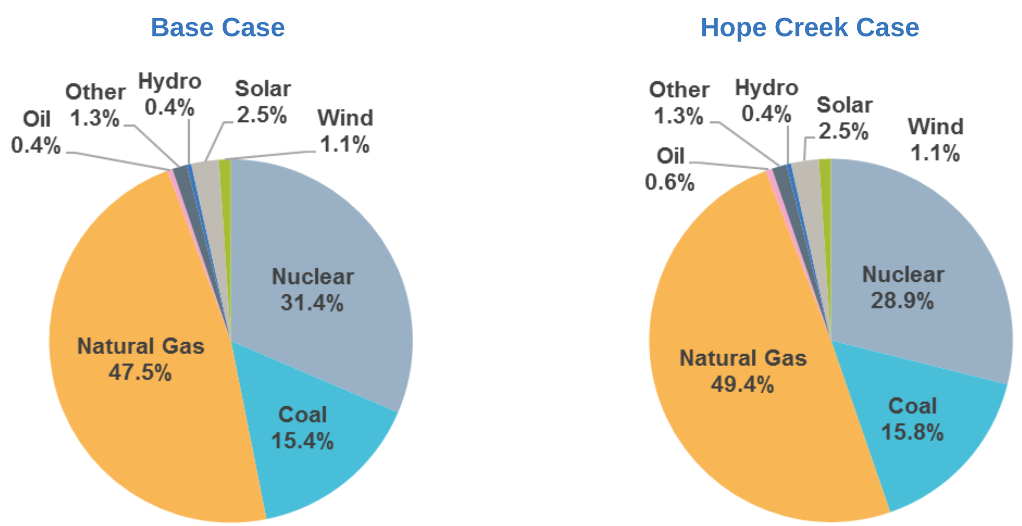
Across MAAC, coal- and natural gas-fired generation are higher under the Hope Creek Retirement Case. Table 6-3 shows projected coal- and natural gas-fired generation compared with the Base Case. Collectively, coal- and natural gas-fired generation are 2.8% higher under the Hope Creek Retirement Case, 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 2020 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	17,649 (2.8%)
2019/20 DY	6,621 (3.2%)
2020/21 DY	5,500 (2.7%)
2021/22 DY	5,529 (2.6%)
Typical Summer Day	14 (2.1%)
HEDD	8 (0.9%)
Peak Winter Day	9 (1.7%)

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 9%. Natural gas and coal replace roughly 63% 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 more than 65% of aggregate Study Period generation in MAAC, with natural gas-fired generation comprising 49.4% of MAAC-wide generation.

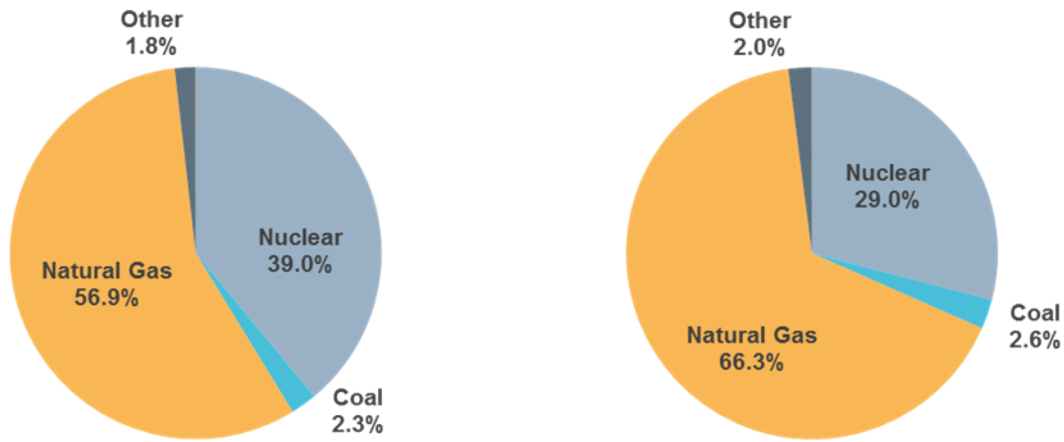
Figure 6-3: MAAC Generation Mix (Across Study Period)



Within New Jersey, the retirement of Hope Creek significantly reduces nuclear generation in 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 approximately two-thirds of aggregate Study Period generation in New Jersey under the Hope Creek Retirement Case.

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

Base Case | **Full Retirement 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 112.8 million MMBtu (3.1%) of natural gas consumption for power, along with an additional 22.1 million MMBtu (1.4%) of coal consumption. These increases are roughly balanced across the three delivery years of the Study Period. Projected Peak Winter Day consumption under the Full Retirement Case shows a spike in power sector natural gas consumption, with consumption 2.1% 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	112,833,586 (3.1%)	22,080,143 (1.4%)
2019/20 DY	43,318,463 (3.6%)	7,617,177 (1.3%)
2020/21 DY	35,920,089 (3.0%)	6,066,253 (1.1%)
2021/22 DY	33,595,035 (2.7%)	8,396,713 (1.6%)
Typical Summer Day	90,181 (2.3%)	24,503 (1.5%)
HEDD	34,208 (0.6%)	40,525 (1.9%)
Peak Winter Day	54,084 (2.1%)	8,399 (0.5%)

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.

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7 SUMMARY OF ANALYSIS

As recent wholesale power market dynamics have narrowed operating margins and created significant ecnomic challenges for baseload nuclear generators operating in deregulated wholesale power markets across the United States, policymakers have grown concerned at the potential environmental, reliability, resilience, and economic implications of retiring zero-emission generating resources. In New Jersey, decades of energy policy measures have highlighted the State's goal to reduce emissions from the electric power sector while ensuring a reliable and resilient electric system. Furthermore, following policy measures to support nuclear generation in New York, Illinois, and Connecticut, the State of New Jersey enacted the ZEC Act to create a ZEC mechanism 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 1.9 million tons from June 2019 through May 2022. For context, this CO2 emission impact is roughly equivalent to having over 120,000 additional passenger vehicles per year driving in New Jersey over the same timeframe. If Hope Creek, Salem 1, and Salem 2 were to retire, CO2 emissions from New Jersey generators would increase by over 6.4 million tons over the same timeframe, roughly equivalent to having over 420,000 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 4.6 million tons from June 2019 through May 2022, roughly equivalent to adding over 300,000 passenger vehicles per year over the same timeframe. Across the entire Eastern Interconnect, CO_2 emissions from generators would increase by nearly 13.0 million tons, 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 nearly 12.9 million tons from June 2019 through May 2022, roughly equivalent to adding nearly 850,000 passenger vehicles per year over the same timeframe. Across the entire Eastern Interconnect, CO_2 emissions from generators would increase by over 24.9 million tons, roughly equivalent to adding over 1.6 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 each increase by over 4 million tons from June 2019 through May 2022. If all three nuclear generators were to retire, emissions of NOx and SO_2 in the MAAC Region would each increase by over 11 million tons over the same timeframe. Similarly, if Hope Creek were to retire, Hg emissions in the MAAC Region would increase by over 14 lbs while PM10 and PM2.5 emissions would increase by approximately 1,100 tons and 1,000 tons, respectively. If all three nuclear generators were to retire, emissions of Hg would increase by over 26 lbs while PM10 and PM2.5 emissions would each increase by over 2,200 tons.

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 2.8% across the MAAC region, and 1.7% on the Peak Winter Day. The combined coal and natural gas share of MAAC-wide generation would climb from 62.9% (the Base Case assumption) to 65.3%. 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 8.8% across the MAAC region, and 9.6% on the Peak Winter Day. The combined coal and natural gas share of MAAC-wide generation would climb to 70.3%. 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 only would significantly reduce nuclear generation within 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 approximately two-thirds of aggregate Study Period generation in New Jersey under the Hope Creek Retirement Case.

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A APPENDIX

This section provides additional New Jersey state-level detail on emission and fuel diversity impacts under the three Cases in the year 2020.

Table A-1: New Jersey Aggregate CO_2 Emissions (Year 2020)

Case	CO_2 Emissions ('000 short tons)	CO_2 Emissions Increase from Base Case ('000 short tons)
Base Case	22,295.8	N/A
Full Retirement Case	24,692.8	2,397.0 (10.8%)
Hope Creek Retirement Case	23,091.6	795.8 (3.6%)

Table A-2: Coal- and Natural Gas-fired Generation in New Jersey (Year 2020)

Case	Coal Generation (GWh)	Natural Gas Generation (GWh)
Full Retirement Case	1,618	45,443
Hope Creek Retirement Case	1,615	41,952

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