PSEG

Impact of PSEG Nuclear Unit Shutdowns on Greenhouse Gas Emissions

September 2020

Project No.: 0561673

The business of sustainability

ERM

Document details	
Document title	Impact of PSEG Nuclear Unit Shutdowns on Greenhouse Gas Emissions
Document subtitle	
Project No.	0561673
Date	September 2020
Version	1.0
Author	
Client Name	PSEG Services Corporation

Document history

				ERM approval to issue		
Version	Revision	Author	Reviewed by	Name	Date	Comments
Final	00	Hanna, Shotts, Perry, Van Atten	Hanna	Hanna	Sept. 2020	

Signature Page

September 2020

Impact of PSEG Nuclear Unit Shutdowns on Greenhouse Gas Emissions

Toby Hanna
Partner

David Shotts
Partner

Chris Van Atten
Executive Vice President

Jon Perry
Principal Consultant

ERM, Exchequer Court, 33 St Mary Axe, London EC3A 8AA, UK

CONTENTS

1. EXECUTIVE SUMMARY 4

2. INTRODUCTION 6

3. METHODS AND DATA 8

3.1 NJDEP GWRA Methods and Data 8

3.1.1 Electricity Generation Sector 8

3.2 Ten-Year Lookback 11

3.2.1 In-State Electric Generation and Retail Sales Trends 11

3.2.2 Imported Electric Generation Trends 14

3.2.3 Carbon Intensity Trends 14

3.2.4 PJM System Average and Marginal CO_2 Emission Rates 17

3.2.5 Avoided GHG Emissions Estimates 17

3.3 Five-Year Look Forward 20

3.3.1 Basis of Data and Projections 20

3.3.2 Avoided GHG Emissions Estimates 21

4. CONCLUSIONS 30

5. GLOSSARY 31

List of Tables

Table 3-1. PJM CO_2 Marginal Emission Rates, 2010-2019 (lb/MWh)
Table 3-2. Estimated Range of Avoided GHG Emissions 2010-2019: Full Retirement Case
Table 3-3. Estimated Range of Avoided GHG Emissions, 2010-2019: Hope Creek Retirement Case
Table 3-4. Avoided GHG Emissions, 2020-2025 (MMT)
Table 3-5. Total Electric Sales in New Jersey, 2014-2018 (MWh)
Table 3-5. Hope Creek and Salem Electric Generation, 2014-2019, with 2020-2025 Projections (MWh)
Table 3-6. Hope Creek and Salem Electric Generation, 2014-2019, with 2020-2025 Projections (MWh)
Table 3-7. NJ Electric Generation by Energy Source 2014-2018 (MWh)
Table 3-8. Imported Electric Avoided GHG Emissions – Hope Creek Retirement Case, 2020-2025
Table 3-9. Imported Electric Avoided GHG Emissions – Full Retirement Case, 2020-2025
Table 3-10. Total Avoided GHG Emissions, 2020-2025 (MMT)

List of Figures

Figure 3-1. Estimated New Jersey GHG Emissions, 2018 (MMT)
Figure 3-2. Net Electricity Generation (million MWh): New Jersey (2010-2019)
Figure 3-3. Retail Sales of Electricity (million MWh): New Jersey (2010-2019)
Figure 3-4. Electric Power industry GHG Emissions (MMT): New Jersey (2010-2019)
Figure 3-5. Electricity Imports as Share of Total Supply: New Jersey (2010-2019)
Figure 3-6. PJM System Average CO_2 Emissions Rates, 2010-2019 (lb/MWh)
Figure 3-7. Mid-Atlantic Region: Hourly Electricity Generation by Fuel Source (August 1-10, 2020)
Figure 3-8. Projected Average CO_2 Emissions Rates in PJM East, 2020-2025 (lb/MWh)
Figure 3-9. Projected 2020-2025 GHG Emissions in NJ (MMT)

1. EXECUTIVE SUMMARY

In May 2018, New Jersey Governor Murphy signed legislation directing the New Jersey Board of Public Utilities (BPU) to establish a Zero Emission Certificate (ZEC) program for nuclear power plants that provide electricity to customers in New Jersey. Plants seeking to participate in the ZEC program are required, among other things, to demonstrate that they make a significant contribution to New Jersey air quality and are at risk of closure within three years.

PSEG Nuclear LLC (PSEG Nuclear) owns and operates three of these nuclear units, Hope Creek, Salem 1, and Salem 2[1], that are eligible to receive ZECs, subject to rulemaking and review and approval by the BPU. These units are located at the Hope Creek-Salem facility in Lower Alloways Creek Township, Salem County, New Jersey. Together, the three units have a rated output of 3,631 megawatts (MW), and supply over one-third of New Jersey's electric power, with zero greenhouse gas (GHG)[2] or other air pollutant emissions. The loss of the Hope Creek and/or Salem units would result in a shift of electric generation to other units, including higher GHG-emitting fossil fuel-fired power plants. This generation shift, or re-dispatch of the system, is projected to increase GHG emissions, both from sources within New Jersey as well as out of state sources. Among other impacts, the increase in New Jersey GHG emissions would significantly impede and potentially jeopardize the state's ability to achieve its GHG reduction goals, such as those established in New Jersey's Global Warming Response Act (GWRA).

PSEG Nuclear received ZECs from the first eligibility period of applications and approvals in the 2018-2019 timeframe. The application questions established by BPU Order under which PSEG Nuclear's application for ZECs will be evaluated in this second eligibility period[3] are slightly different than those used in the first eligibility period[4]. For the second eligibility period, the application question that is relevant to this report involves a "ten-year lookback" to evaluate the amounts of GHG emissions that were avoided by the past operation of the Hope Creek, Salem 1, and/or Salem 2 nuclear units, as well as a "five-year look forward" to evaluate the amounts of GHG emissions that would be avoided by the projected operation of these units.

For the ten-year lookback, which covers calendar years 2010 through 2019, inclusive, ERM estimates that the avoided GHG emissions ranged from 3.1 to 5.0 million metric tons (MMT) per year for the Hope Creek Retirement Case[5], and from 9.4 to 13.7 MMT per year for the Full (i.e., all three units) Retirement Case when using PJM system average CO_2 emission factors. The avoided GHG emissions are about 35% to 60% higher when using PJM marginal emission rates, which are the emission rates for the last

[1] PSEG has a 100% ownership stake in Hope Creek, and a 57.41% ownership stake in Salem 1 and Salem 2. PSEG operates all three of these units.

[2] Carbon dioxide (CO_2) is the principal GHG gas emitted from fossil fuel combustion to generate electricity. Other GHG's from fossil fuel combustion include methane (CH_4) and nitrous oxide (N_2O) which, although considerably more potent GHGs than CO_2, contribute less than 1% additional GHG emissions from a CO_2 equivalent (CO_2e) standpoint. Nevertheless, New Jersey must account for these additional GHG emission contributions when assessing achievement of GWRA limits. Throughout this report, the term "GHG" is intended to refer to CO_2e that takes into account CO_2, CH_4 and N_2O emissions from combustion and their respective Global Warming Potentials (GWPs).

[3] BPU Order, August 12, 2020, Agenda Item 9A, Docket No. EO18080899.

[4] BPU Order, November 19, 2018, Agenda Item 9A, Docket No. EO18080899.

[5] Due to the similar capacity and electrical location of Hope Creek, Salem 1, and Salem 2, the retirement of Hope Creek serves as a proxy for retiring any one of these units.

generation resources that are committed to maintain system reliability and match energy supply and demand.[6]

For the five-year look forward, which actually covers the six-year period of calendar years 2020 through 2025, inclusive, independent analyses and reports prepared by PA Consulting Group[7] (PA Consulting) project that Electricity Generation Sector GHG emissions would materially increase each year if any or all of the nuclear units were to retire. The retirement of any one of these units (i.e. Hope Creek Retirement Case)[8] is projected to increase In-State GHG[9] emissions from New Jersey generators ranging from 0.4 to 1.0 MMT per year in the 2020-2025 period. Conversely, the continued operation of any one of these units is projected to avoid In-State GHG emissions ranging from 0.4 to 1.0 MMT per year in 2020-2025.

If all three units were to retire (i.e. Full Retirement Case), In-State Electricity Generation Sector GHG emissions for 2020-2025 range from 1.6 to 3.2 MMT per year. Conversely, the continued operation of all three of the units is projected to avoid In-State GHG emissions ranging from 1.6 to 3.2 MMT per year in 2020-2025.

Additional, more substantial GHG emission increases associated with electricity generated outside New Jersey but imported into New Jersey (Imported Electric, as defined in the GWRA) are expected to occur with the loss of any or all of the nuclear units, and those increases must also be accounted for in assessing the level of avoided GHG emissions as well as the achievement of GWRA limits. Based on the estimated shortfall between In-State electricity generation and total electricity consumption, and applying a calculation methodology consistent with that specified in the GWRA, the GHG increases associated with Imported Electric range from 2.9 to 5.8 MMT per year for the Hope Creek Retirement Case, and 7.6 to 10.3 MMT per year for the Full Retirement Case. Again, these levels can be considered the avoided GHG emissions from Imported Electric if one or all of the units were to remain in service.

Hence, the total avoided GHG emissions for the Electricity Generation Sector (In-State Electric + Imported Electric) are estimated to range from 3.9 to 6.1 MMT per year for the Hope Creek Retirement Case, and 10.9 to 12.2 MMT per year for the Full Retirement Case. These levels represent sizeable portions of New Jersey's historical Electricity Generation Sector GHG emissions, which have averaged about 18 MMT over the last decade (2010-2019) and occurred while PSEG's nuclear units were in service. These GHG emission increases would have significant negative impact and jeopardize the State's ability to achieve its 2050 GHG reduction goals. Also, the Intergovernmental Panel on Climate Change (IPCC) stresses the urgency for transformative policy efforts to reduce GHG emissions in the short term.[10] The retirement of clean, existing nuclear resources runs counter to these efforts. The continued operation of the Hope Creek and/or Salem units is needed to prevent backsliding in the efforts to combat climate change.

---

[6] PJM. 2015 – 2019 CO_2, SO_2 and NO_x Emission Rates: For Public use. April 9, 2020, 1.

[7] PA Consulting, *The Impact of Nuclear Generation Retirements on Emissions and Fuel Diversity in New Jersey*, (September 2020).

[8] Due to the similar capacity and electrical location of Hope Creek, Salem 1, and Salem 2, the retirement of Hope Creek serves as a proxy for retiring any one of these units.

[9] Carbon dioxide (CO_2) is the principal GHG gas emitted from fossil fuel combustion to generate electricity. Other GHG's from fossil fuel combustion include methane (CH_4) and nitrous oxide (N_2O) which, although considerably more potent GHGs than CO_2, contribute less than 1% additional GHG emissions from a CO_2 equivalent (CO_2e) standpoint. Nevertheless, New Jersey must account for these additional GHG emission contributions when assessing achievement of GWRA limits. Throughout this report, the term "GHG" is intended to refer to CO_2e that takes into account CO_2, CH_4 and N_2O emissions from combustion and their respective Global Warming Potentials (GWPs).

[10] IPCC, An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty, 2019, 148.

2. INTRODUCTION

In May 2018, the State of New Jersey enacted the ZEC Act[11], which directs the New Jersey BPU to create a program to determine the eligibility of nuclear generating resources to receive ZECs, as well as eligible resources' ranking for selection to receive ZECs. The ZEC program is designed for nuclear power plants that provide electricity to customers in New Jersey.

Plants seeking to participate in the ZEC program are required, among other things, to demonstrate that they make a significant contribution to improvement of New Jersey air quality and are at risk of closure within three years. PSEG Nuclear owns and operates three nuclear units in New Jersey - Hope Creek, Salem 1, and Salem 2[12] - which are eligible to participate in the ZEC program, subject to rulemaking and review and approval by the BPU. These units are located at the Hope Creek-Salem facility in Lower Alloways Creek Township, Salem County, New Jersey.

Salem 1 and 2 began commercial operation in 1977 and 1981, respectively, and their rated outputs are each 1,170 MW. Hope Creek began commercial operation in 1986 and has a rated output of 1,291 MW. Together, the three units have a rated output of 3,631 MW, and typically supply 35% to 40% of New Jersey's electric power, with essentially zero GHG emissions. The loss of any or all of these units would result in a shift of electric generation to other units on the grid, including higher GHG-emitting fossil fuel fired power plants. This generation shift is projected to increase GHG emissions, both from sources within and outside of New Jersey. Among other impacts, the increase in GHG emissions would significantly impede and potentially jeopardize New Jersey's ability to achieve its 2050 GHG reduction goals, such as those articulated in the GWRA.

The GWRA, at N.J.S.A. 26:2C-37-44, calls for a reduction of statewide GHG emissions to below the 1990 level of 125.6 million metric tons of carbon dioxide equivalent ($MMTCO_2e$) by 2020, and 80% below 2006 levels by 2050. The 2050 limit represents a reduction of about 101.6 MMT, from 127.0 MMT in 2006 to 25.4 MMT in 2050. The GHG emission estimates published by the New Jersey Department of Environmental Protection (NJDEP) in October 2019 indicate that statewide net GHG emissions in 2018 were 97.0 MMT, which would achieve the 2020 limit.

The statutory criterion for ZECs eligibility is:

> *…demonstrate to the satisfaction of the board that it makes a significant and material contribution to the air quality in the State by minimizing emissions that result from electricity consumed in New Jersey, it minimizes harmful emissions that adversely affect the citizens of the State, and if the nuclear power plant were to be retired, that that retirement would significantly and negatively impact New Jersey's ability to comply with State air emissions reduction requirements*[13]

PSEG Nuclear received ZECs from the first eligibility round of applications and approvals in the 2018-2019 timeframe. The application questions established by BPU Order under which PSEG Nuclear's application for ZECs will be evaluated in this second eligibility period [14] are slightly different than those

[11] 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)].

[12] PSEG has a 100% ownership stake in Hope Creek, and a 57.41% ownership stake in Salem 1 and Salem 2. PSEG operates all three of these units.

[13] P.L.2018, c.16 C.48:3-87.5(3)(e)(2).

[14] BPU Order, August 12, 2020, Agenda Item 9A, Docket No. EO18080899.

used in the first eligibility period[15]. This time, the application question in the BPU Order that is relevant to this report is:

> *Provide a detailed description, including any studies and relevant data, of the greenhouse gas ("GHG") emissions avoided by this Unit's operation ten (10) years prior to and projected five (5) years beyond the application date. Identify the emission sources that will be displaced by continued operation of the Unit.*[16]

Hence, this report involves a "ten-year lookback" to evaluate the amounts of GHG emissions that were avoided by the past operation of the Hope Creek, Salem 1, and/or Salem 2 nuclear units, as well as a "five-year look forward" to evaluate the amounts of GHG emissions that would be avoided by the projected operation of these units. The purpose of this report is to estimate the GHG emissions that have been avoided and will be avoided by continuing operation of one or more of PSEG Nuclear's units. Based on the application question established by the BPU, this evaluation focuses on the calculation of avoided GHG emissions over the past ten years, as well as the projected future avoided GHG emissions for the next five years.

[15] BPU Order, November 19, 2018, Agenda Item 9A, Docket No. EO18080899.

[16] Ibid, Appendix A, Section IV. Zero Emission Credit Justification – Environmental, Item 2.

3. METHODS AND DATA

This section describes the methodology used to estimate the GHG emissions that were avoided in the ten-year period of 2010-2019 and that would be avoided in the 2020-2025 period by the continued operation of any or all of the Hope Creek and/or Salem nuclear units.

3.1 NJDEP GWRA Methods and Data

To provide context for the avoided emissions estimates presented in this report, it is appropriate to begin the discussion with an overview of New Jersey's economy-wide GHG inventory and GWRA reduction goals. The GWRA requires the establishment of an inventory of statewide GHG emissions. The most recent statewide GHG Emissions Inventory was published by the NJDEP in October 2019, with 2018 the most recent year covered in this publication. NJDEP indicates that the 2018 GHG Emissions Inventory is mainly based on emissions data from the NJDEP emission statement database, and on fuel usage data from the U.S. Energy Information Administration (EIA). Methods used to derive the emissions estimates from the data are detailed in the report "New Jersey Greenhouse Gas Inventory and Reference Case Projections 1990 – 2020" (Inventory and Projections)", published by NJDEP in November 2008.[17]

3.1.1 Electricity Generation Sector

N.J.S.A 26:2C-41 of the GWRA establishes the rules and regulations for NJDEP to follow regarding the monitoring and reporting of GHG emissions. Specifically, N.J.S.A 26:2C-41(5)(c)(2) pertains to the monitoring and reporting of GHG emissions in the Electricity Generation Sector. It states:

> *c. Pursuant to the rules and regulations adopted pursuant to subsection a. of this section, the department shall require reporting of the greenhouse gas emissions:*
>
> ***
>
> *(2) from any entity generating electricity in the State and from any entity that generates electricity outside the State that is delivered for end use in the State. With respect to electricity generated outside the State and imported into the State, the department shall determine the emissions from that generation by subtracting the kilowatt-hours of electricity generated in the State from the kilowatt-hours of electricity consumed in the State, and multiplying the difference by a default emissions rate determined by the department;*

As described by NJDEP in New Jersey's 2018 Statewide GHG Emissions Inventory, NJDEP breaks the clause "*from any entity generating electricity in the State"* into two inventory components, *"*In-State Electric" and "MSW Incineration" (Municipal Solid Waste incineration)[18]. NJDEP refers to the clause *"and from any entity that generates electricity outside the State that is delivered for end use in the State"* as "Imported Electric". Hence, the GHG contribution for the Electricity Generation Sector inventory as a whole consists of the sum of three components; In-State Electric, Imported Electric, and MSW Incineration. These components are briefly described below.

[17] New Jersey Greenhouse Gas Inventory and Reference Case Projections 1990 – 2020, New Jersey Department of Environmental Protection, November 2008.

[18] New Jersey Department of Environmental Protection, 2018 Statewide Greenhouse Gas Emissions Inventory, (October 2019), App. B, 21.

3.1.1.1 In-State Electric

Per the GWRA, In-State Electric refers to GHG emissions from entities that generate electricity within New Jersey. In-State Electric accounted for 17.4 MMT of GHG emissions in 2018, representing over 96% of Electricity Generation Sector emissions. Within the Electricity Generation Sector, the long-term trend has been a shift from coal to natural gas usage, which is driving GHG emission reductions. Relatively flat overall electricity consumption and decreases in Imported Electric have also contributed to GHG emission reductions.[19] However, as this and PA Consulting's report demonstrate, the loss of any or all of the Hope Creek and/or Salem units would reverse this trend, increasing GHG emissions from In-State Electric and requiring more electricity from other states to meet New Jersey's electricity demand.

3.1.1.2 Imported Electric

Per the GWRA, Imported Electric refers to GHG emissions from entities that generate electricity outside of New Jersey that is delivered for end use in New Jersey. The GWRA specifies that with respect to Imported Electric, NJDEP shall determine the emissions from that generation by subtracting the kilowatt-hours (kWh) of electricity generated in the State from the kWh of electricity consumed in the State, and multiplying the difference by a default emissions rate determined by NJDEP.

Given that the bulk of imported electricity needed to meet the New Jersey shortfall in generation under nuclear unit shutdown scenarios primarily would come from fossil fuel-fired generators in PJM, a reasonable source of default CO_2 emission factors are those published by PJM. NJDEP uses PJM CO_2 emission factors to calculate the Imported Electric values in its GHG inventories, and such factors are therefore appropriate for use in this analysis, and are in fact conservatively low in terms of estimating avoided GHG emissions from any nuclear unit retirement scenarios because they include the zero carbon contribution from nuclear and renewables that are on the grid. Consistent with NJDEP GHG inventories, ERM applied an adjustment factor of 1.006304 to represent the small contribution from the combustion-related GHG emissions of CH_4 and N_2O, and assumed Transmission and Distribution (T&D) losses of 7% in determining the amount of annual generation needed to satisfy New Jersey electricity demand.[20]

With natural gas prices remaining low, and the addition of new natural gas-fired generating capacity in the State, New Jersey's electricity demand is largely being met by In-State natural gas generation, increasing renewable generation, and the PSEG nuclear units. Since 2015, Imported Electric generation and emissions generally have been trending downward.[21] However, starting in 2018 Imported Electric generation and emissions have experienced a moderate increase due to the closure of Oyster Creek and increased electricity demand. As this and PA Consulting's report demonstrate, the loss of any or all of the Hope Creek and/or Salem units would continue this trend, by substantially increasing generation and GHG emissions from Imported Electric.

3.1.1.3 MSW Incineration

NJDEP considers MSW Incineration as its own category of In-State Electric. MSW Incineration accounted for 0.7 MMT of GHG emissions in 2018, representing less than 4% of Electricity Generation

[19] U.S. EIA. EIA-923: Power Plant Operating Data. Accessed: August 10, 2020.

[20] New Jersey Department of Environmental Protection, New Jersey Greenhouse Gas Inventory and Reference Case Projections 1990 – 2020" (Inventory and Projections)", November 2008, 16-17.

[21] U.S. EIA. EIA-861: Annual Electric Power Industry Report. Accessed: August 10, 2020.

Sector emissions. MSW incineration's contribution to overall Electricity Generation Sector GHG emissions has been relatively stable over time, ranging from 0.6 MMT to 1.0 MMT from 2005-2018.[22, 23]

Given its small and relatively static contribution to New Jersey GHG emissions, MSW Incineration is not a focus of this report. The modeling analyses performed by PA Consulting and described in more detail below included MSW incinerators in New Jersey and other states within the modeling domain. Therefore, the GHG emission contributions from MSW Incineration are assumed to be included in the totals for In-State Electric. With MSW Incineration assumed to be included in In-State Electric, Electricity Generation Sector GHG emissions under the GWRA are calculated as follows:

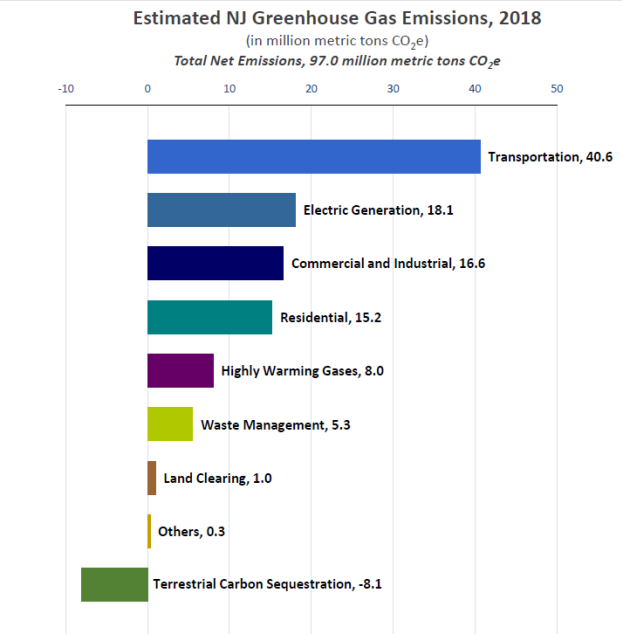
Total Electricity Generation Sector Emissions = In-State Electric Emissions + Imported Electric Emissions

where:

Imported Electric = (kWh of electricity generated in the State – kWh of electricity consumed in the State) x Default Emissions Rate Determined by NJDEP

As noted in Figure 3-1 below, the Electricity Generation Sector accounted for 18.1 MMT of GHG emissions in 2018[24], representing approximately 18.7% of statewide GHG emissions.

Figure 3-1. Estimated New Jersey GHG Emissions, 2018 (MMT)



[22] Ibid.

[23] New Jersey Department of Environmental Protection, 2015 Statewide Greenhouse Gas Emissions Inventory, (December 2017), 4.

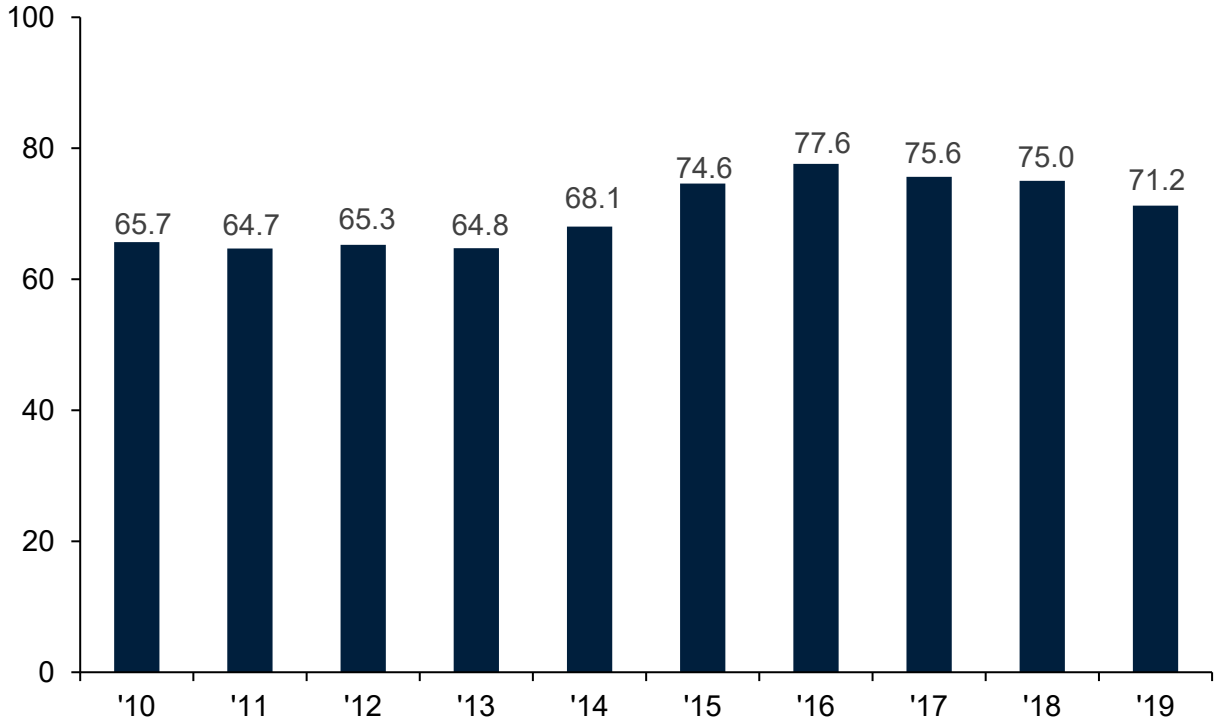
[24] New Jersey Department of Environmental Protection, 2018 Statewide Greenhouse Gas Emissions Inventory, (October 2019), Fig. 1, 4.

3.2 Ten-Year Lookback

3.2.1 In-State Electric Generation and Retail Sales Trends

Figure 3-2 illustrates that electricity generation in New Jersey has modestly increased over the past ten years (2010-2019), with an overall increase of 8.4% between 2010 and 2019. Annual generation averaged 70,257,031 megawatt-hours (MWh) from 2010 to 2019, and 74,825,657 MWh over the past five years (2015-2019).[25]

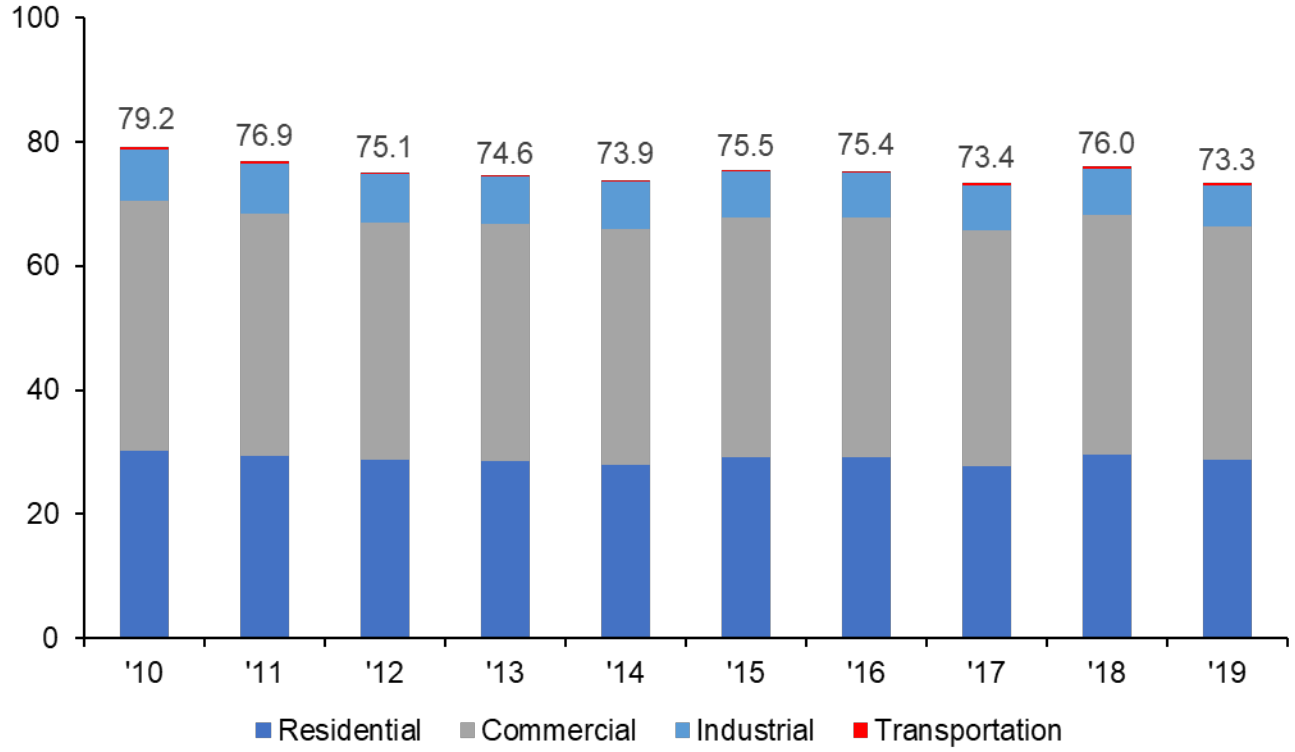
Figure 3-2. Net Electricity Generation (million MWh): New Jersey (2010-2019)



[25] EIA, 1990-2018 annual_generation_by state.

As illustrated in Figure 3-3, retail electricity sales in New Jersey have been on a modest downward trend over the past ten years, with an overall decline of 7.4% between 2010 and 2019. This estimate is based on preliminary 2019 sales data from EIA, which may be revised. From 2010 to 2019, retail sales averaged 75,319,433 MWh. Retail sales averaged 74,718,750 MWh over the past five years (2015-2019).[26]

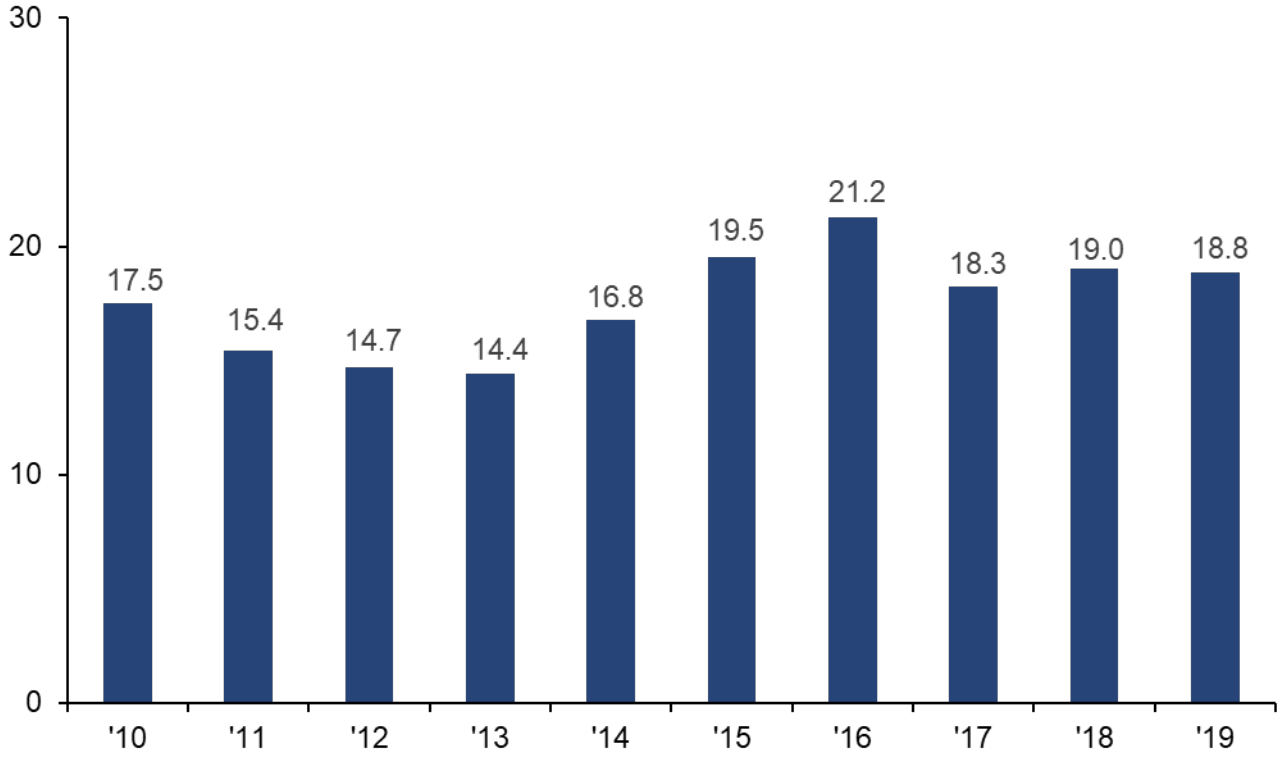
Figure 3-3. Retail Sales of Electricity (million MWh): New Jersey (2010-2019)



[26] EIA, Sales to Ultimate Customers (Megawatthours) by State by Sector by Provider, 1990-2018.

Hope Creek, Salem 1, and Salem 2, on average, produced a combined 27,961,820 MWh of electricity each year from 2010-2019, or nearly 40% of New Jersey's total electricity production. As illustrated in Figure 3-4, GHG emissions from electric generators in New Jersey averaged about 18 MMT per year from 2010 to 2019, according to EIA.

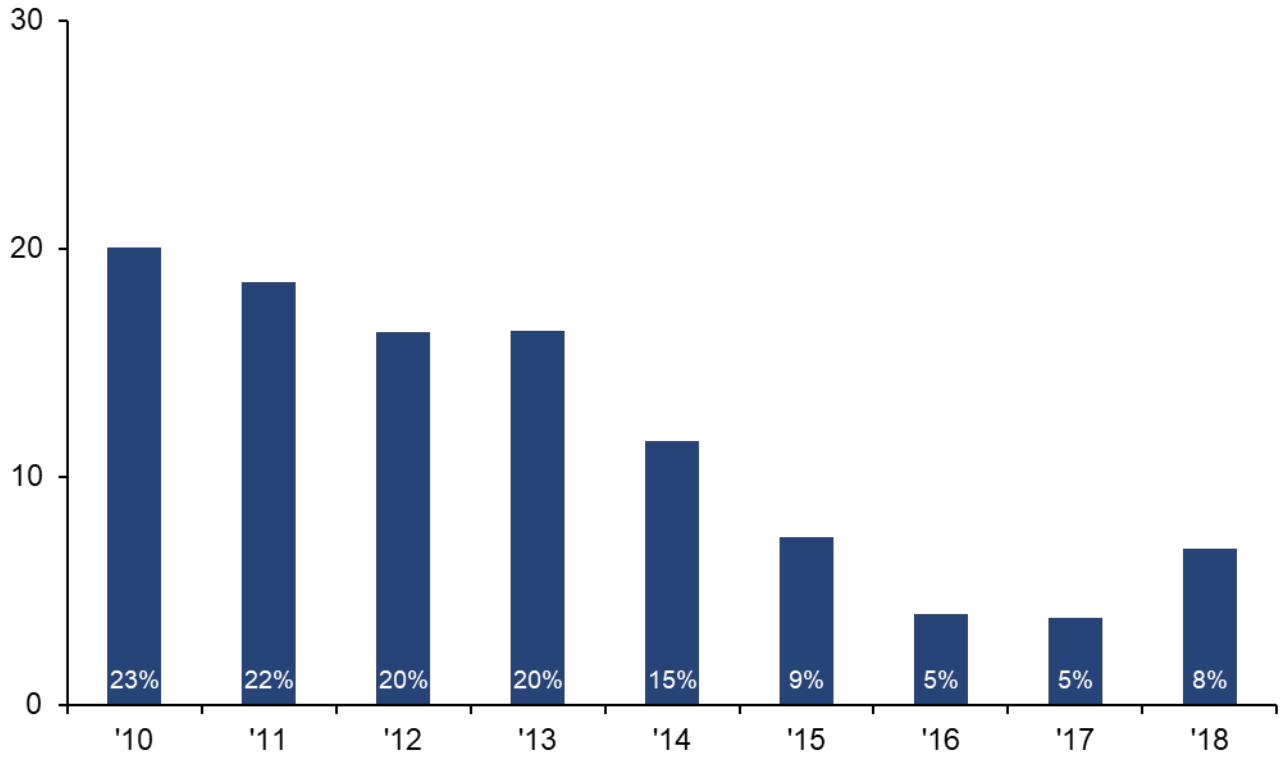
Figure 3-4. Electric Power industry GHG Emissions (MMT): New Jersey (2010-2019)



3.2.2 Imported Electric Generation Trends

Overall, New Jersey is a net importer of electricity, although its reliance on imported electricity has declined significantly over the past several years. In 2016 and 2017, imports accounted for only 5% of the state's total electricity supply (i.e., power sector generation, industrial and commercial sector electricity generation, and imports). Imported electricity then increased in 2018, due in part to higher demand and the closure of the Oyster Creek nuclear plant in New Jersey, but imports were still well below pre-2014 levels. In the period from 2015 to 2018 (2019 data are not yet available), imports ranged from 5% to 9% of the state's total electricity supply. From 2010 to 2014, the average was 20%; hence, imports represented a significantly greater proportion of total supply earlier in the decade. These trends are illustrated in Figure 3-5.

Figure 3-5. Electricity Imports as Share of Total Supply: New Jersey (2010-2019)



3.2.3 Carbon Intensity Trends

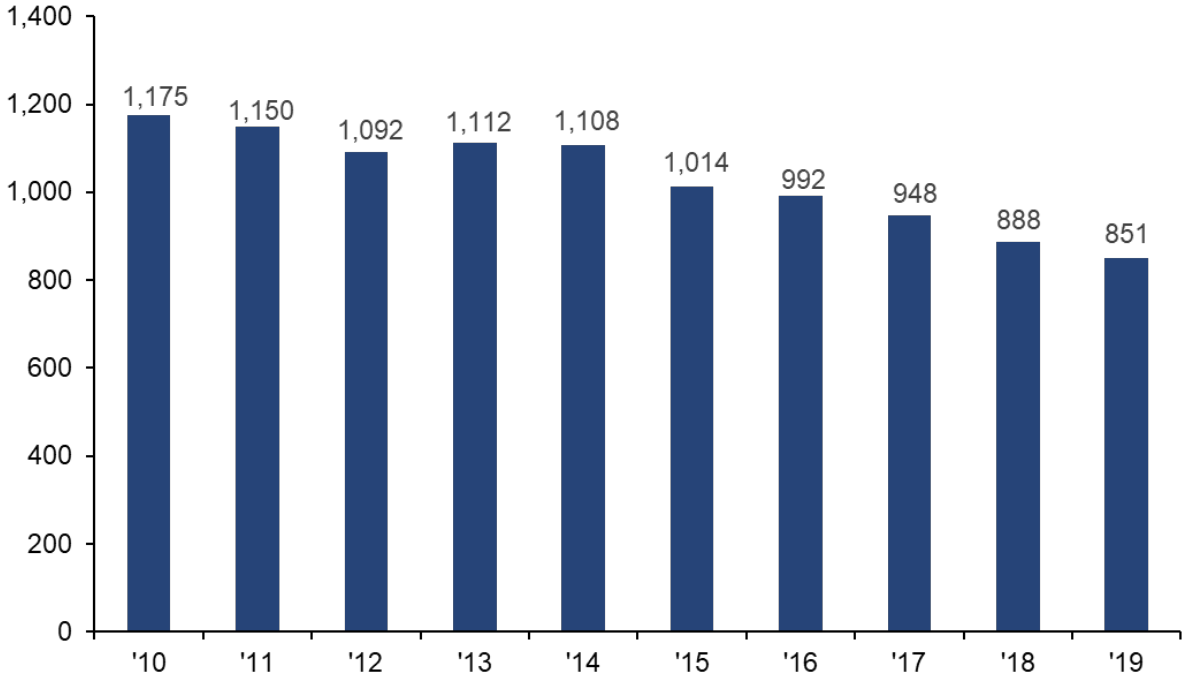
As a Regional Transmission Organization (RTO), PJM operates a wholesale electricity market that spans all or part of Delaware, Illinois, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia. Acting as a neutral, independent party, PJM operates electricity "spot markets" in which generators sell and utilities or electricity providers buy energy for immediate delivery. These energy markets operate every day, and participants in the market establish a price for electricity by matching supply (what generators want to sell) and demand (what utilities and customers want to buy).[27] In this context, PJM emission factors are a

[27] https://learn.pjm.com/electricity-basics/market-for-electricity.aspx

relevant source of emission factors used to estimate the emissions from generating sources that might replace generation from the PSEG nuclear units in the event of their retirement.

Across the PJM market, the carbon intensity of the PJM grid has been declining with increases in gas-fired generation, declines in coal generation, and the addition of renewable resources. In 2010, the PJM system average CO_2 emission rate was about 1,175 lb/MWh.[28] In 2015, the system average CO_2 emission rate was 1,014 lb/MWh.[29] By 2019, the average CO_2 emission rate had declined to 851 lb/MWh.[30] This represents a 28% decrease from 2010 to 2019. This average emission rate includes a mix of fossil, nuclear, and non-emitting generation, including the electricity produced by the Hope Creek and Salem nuclear generating units. These trends are illustrated in Figure 3-6.

Figure 3-6. PJM System Average lb/MWh CO_2 Emissions Rates (2010-2019)



In 2019, coal units supplied 23.8% of the electricity in PJM, nuclear units 33.6%, and natural gas units 36.2%.[31] Wind and solar supplied 3.2% of PJM energy in 2019, increasing in response to state mandates and improvements in technology.[32] Compared to 2018, generation from coal units decreased 17.7% and generation from natural gas units increased 16.9%.[33] In 2019, output from natural gas units was larger than any other fuel source for the first year since the establishment of the PJM energy market in 1999.

Figure 3-7 below illustrates the hourly changes in generation in the Mid-Atlantic Region (MIDA), including New Jersey, for the 10-day period from August 1 to August 10, 2020. This highlights the role of nuclear

[28] Estimated from chart in PJM presentation "PJM Analysis of the EPA Clean Power Plan", October 6, 2016, 8.

[29] PJM. 2015 – 2019 CO_2, SO_2 and NO_x Emission Rates: For Public use. April 9, 2020.

[30] Ibid.

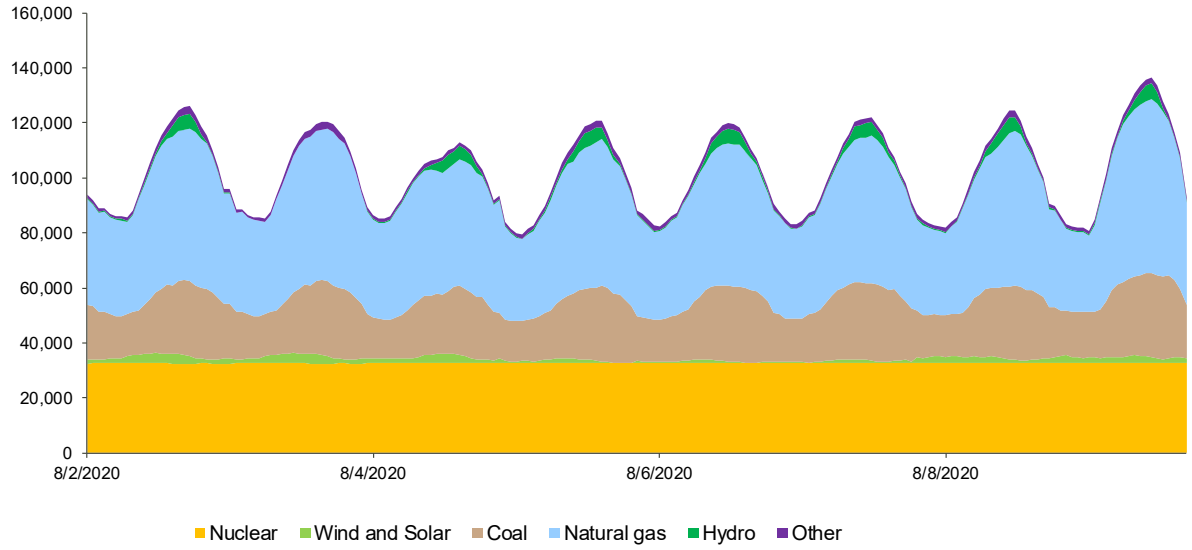
[31] Monitoring Analytics. PJM State of the Market Report: 2019. March 12, 2020.

[32] Ibid.

[33] Ibid.

generators in providing baseload generation, as well as the role of natural gas and coal plants in providing more cycling (i.e., load following) generation. Wind, solar, petroleum, and other miscellaneous sources accounted for 4.5% of generation (on average) across the region, during this time period.

Figure 3-7. Mid-Atlantic Region: Hourly Electricity Generation by Fuel Source (August 1-10, 2020)



Marginal generators in the PJM market have also been changing.[34] In 2019, coal units were 24.4% and natural gas units were 69.4% of marginal resources.[35] In 2018, coal units were 27.3% and natural gas units were 63.3% of marginal resources.[36] By contrast, gas fired units were 37.6% of marginal generation in 2015.[37] Most nuclear units are offered as fixed generation in the PJM market.

Marginal generators provide a proxy for the power plants that would need to be dispatched if New Jersey nuclear units reduced their output or retired. Marginal generators are dispatchable units that can ramp up and down in response to changes in demand.

3.2.4 PJM System Average and Marginal CO_2 Emission Rates

PJM reports both the system average and the marginal CO_2 emission rates of the system. Table 3-1 lists the marginal emission rates reported by PJM (average of on-peak and off-peak).[38]

Table 3-1. PJM CO_2 Marginal Emission Rates, 2010-2019 (lb/MWh)

Year	Marginal Emission Rates[39]
2010	1,569
2011	1,535
2012	1,458
2013	1,678
2014	1,677
2015	1,593
2016	1,599
2017	1,374
2018	1,296
2019	1,220

3.2.5 Avoided GHG Emissions Estimates

The ten-year lookback pertains to generation events that have already occurred, and does not readily lend itself to splitting the avoided GHG emissions into the In-State Electric and Imported Electric components typically used by NJDEP to assess GHG emissions under the GWRA. Hence, avoided GHG emissions were estimated for both the Full Retirement Case and the Hope Creek Retirement Case by applying the net generation (in MWh) of the relevant unit (or units) in each year of the 2010-2019 period by each of the following three lb/MWh CO_2 emission factors (with the appropriate factors mentioned herein applied to convert pounds of CO_2 to short tons to million metric tons of CO_2e):

1) PJM Marginal Emission Rates;
2) PJM System Average Emission Rates; and
3) Average Natural Gas-Combined Cycle (NGCC) Emission Rates.

[34] Marginal generators are the last unit(s) dispatched to meet a given level of demand.

[35] Monitoring Analytics. PJM State of the Market Report: 2019. March 12, 2020.

[36] Ibid.

[37] Ibid.

[38] PJM. 2015 – 2019 CO_2, SO_2 and NOx Emission Rates: For Public use. April 9, 2020 and PJM. 2012 – 2015 CO_2, SO_2 and NOx Emission Rates: For Public use. March 18, 2016. We were unable to identify marginal emission rates for 2011 and 2012.

[39] The Marginal Emission Rates for 2010 and 2011 were estimated by multiplying the PJM System Average Emission Rate for each year by 1.34, which is the lowest ratio of Marginal Emission Rate to PJM System Average Emission Rate in the 2012-2019 period.

This bounding approach captures the range of avoided GHG emissions. The above PJM emission rates are conservatively low because they include the zero carbon contribution from operation of the PSEG nuclear units in the 2010-2019 period.

A sample calculation follows for the Full Retirement Case in 2010, in which the PJM marginal CO_2 emission rate was 1,569 lb/MWh, and nuclear unit generation was 28,169,910 MWh.

28,169,910 MWh x (1,569 lb/MWh) x (1.006304) x (1 kg/2.20462 lb) x (1 metric ton/1,000 kg)

= 18,299,951 metric tons x (1 MMT/1,000,000 metric tons)

= 18.3 MMT

Similar calculations were performed for the other years and CO_2 emission factors. Table 3-2 summarizes the avoided GHG emission estimates for the Full Retirement Case using the three CO_2 emission factors. Avoided GHG emissions, based on PJM marginal emission rates, range from 13.5 to 19.6 MMT per year; avoided emissions based on this approach decline over time as the carbon intensity of the PJM grid has declined. Avoided GHG emissions based on PJM system average emission rates range from 9.4 to 13.7 MMT per year, and also decline over time as the carbon intensity of the PJM grid has declined.

Avoided GHG emissions based on the average emission rate for a NGCC facility range from 9.4 to 10.6 MMT per year. This emission factor represents times in which congestion (or transmission constraints) occur on the grid and produce a different mix of marginal generators within a specific PJM zone, and in this case the "mix" was assumed to be a typical average CO_2 emission rate for a natural gas-combined cycle (NGCC) facility (i.e., 894 lb/MWh). By contrast, PJM's marginal emission rates include a mix of coal and gas-fired generation.

Table 3-2. Estimated Range of Avoided GHG Emissions, 2010-2019: Full Retirement Case

Year	Nuclear Generation (MWh) Hope Creek, Salem 1 and 2	Avoided GHG Emissions Based on PJM Marginal Emission Rate (MMT)	Avoided GHG Emissions Based on PJM System Average Emission Rate (MMT)	Avoided GHG Emissions Based on Average NGCC Rate (MMT)
2010	28,169,910	18.3	13.7	10.4
2011	28,308,000	18.0	13.5	10.5
2012	28,395,547	17.1	12.8	10.5
2013	28,278,134	19.6	13.0	10.5
2014	26,656,214	18.5	12.2	9.9
2015	28,002,931	18.5	11.8	10.4
2016	25,300,096	16.7	10.4	9.4
2017	28,602,507	16.3	11.2	10.6
2018	28,441,791	15.3	10.5	10.5
2019	26,637,324	13.5	9.4	9.9

Table 3-3 applies the same approach to the Hope Creek facility only (as a proxy for the retirement of any one of the three PSEG Nuclear units). Avoided GHG emissions from the Hope Creek facility using PJM marginal emission rates range from 4.4 to 7.2 MMT per year. Avoided GHG emissions based on PJM

system average emission rates, range from 3.1 to 5.0 MMT per year. Avoided GHG emissions based on the average emission rate for a NGCC facility range from 3.2 to 3.9 MMT per year.

Table 3-3. Estimated Range of Avoided GHG Emissions, 2010-2019: Hope Creek Retirement Case

Year	Nuclear Generation (MWh) Hope Creek only	Avoided Emissions Estimate Based on PJM Marginal Emission Rate (MMT)	Avoided Emissions Estimate Based on PJM System Average Emission Rate (MMT)	Avoided Emissions Estimate Based on Average NGCC Rate (MMT)
2010	9,438,542	6.1	4.6	3.5
2011	10,474,891	6.7	5.0	3.9
2012	9,551,241	5.8	4.3	3.5
2013	9,070,386	6.3	4.2	3.4
2014	10,373,816	7.2	4.8	3.8
2015	9,409,357	6.2	4.0	3.5
2016	9,603,443	6.4	3.9	3.6
2017	10,627,333	6.0	4.2	3.9
2018	9,546,684	5.1	3.5	3.5
2019	8,726,946	4.4	3.1	3.2

To put these numbers in context, as indicated above, GHG emissions from all electric generators in New Jersey have averaged about 18 MMT per year from 2010 to 2019. Hence, the avoided GHG emissions from the Hope Creek Retirement Case represent about a 15-40% higher level of New Jersey electric sector GHG emissions. The avoided GHG emissions from the Full Retirement Case reflect what would otherwise have been a 50-100% higher level of New Jersey electric sector GHG emissions.

3.3 Five-Year Look Forward

3.3.1 Basis of Data and Projections

PA Consulting conducted an independent evaluation of projected emissions and fuel diversity impacts of the retirement of the Hope Creek and Salem nuclear units. PA Consulting's evaluation sought to determine how the retirement of the Hope Creek, Salem 1, and/or Salem 2 nuclear units would impact electric power generation air pollution and GHG emissions in New Jersey and the surrounding region, as well as how these retirements would potentially impact fuel diversity and grid resilience. ERM has used PA Consulting's evaluation in its assessment of the avoided GHG emissions from the Hope Creek and Salem nuclear units.

To estimate avoided GHG emissions, PA Consulting conducted a forward-looking analysis over a four-year period (January 2022 through December 2025, inclusive) that assessed the emissions and fuel diversity impacts of retiring one or more of PSEG's nuclear generating resources. In addition, prior analysis conducted by PA Consulting for the first round of ZECs applications covered the period of January 2020 through December 2021, and this data was used to address calendar years 2020 and 2021 in this report. Hence, the five-year look forward in this report actually covers a six-calendar year period (2020 through 2025, inclusive).

PA Consulting modeled the electric system within the U.S. portion of the Eastern Interconnect under the following three cases:

1) "Base Case": this scenario represents PA Consulting's independent view of the Eastern Interconnect, including the continued operation of Hope Creek, Salem 1, and Salem 2;
2) "Hope Creek Retirement Case": this scenario assumes Hope Creek does not operate during the Study Period. 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 one of these nuclear generating units. 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 specifically, Salem 1, or Salem 2;
3) "Full Retirement Case": this scenario assumes Hope Creek, Salem 1, and Salem 2 do not operate during the Study Period. The results of the Full Retirement Case are compared to the Base Case to assess the impacts of retiring all three units.[40]

Emissions rates for CO_2, as well as nitrogen oxides (NO_x), sulfur dioxide (SO_2), mercury (Hg), PM_{10}, and $PM_{2.5}$, were modeled using a proprietary electricity market modeling process which uses AURORA^{xmp}, an industry standard chronological dispatch simulation model.[41] Additional details on PA Consulting's methods, data, and assumptions, can be found in PA Consulting's reports referenced herein.

Total avoided GHG emissions consist of two components, In-State Electric and Imported Electric. For the In-State Electric component, ERM relied heavily on PA Consulting's analysis, focused on the modeled CO_2 emissions, and converted the CO_2 emission data from short tons to metric tons, by multiplying by a factor of 0.90719.[42] ERM also converted metric tons to MMT by dividing by a factor of 1,000,000 to align the units of measure with those in the GWRA. ERM also applied an adjustment factor of 1.006304 to

[40] PA Consulting, *The Impact of Nuclear Generation Retirements on Emissions and Fuel Diversity in New Jersey*, (November 2018), 9.

[41] Ibid., 15.

[42] 1 short ton x (2,000 lb/1 short ton) x (1 kg/2.20462 lb) x (1 metric ton/1,000 kg) = 0.90719 metric tons.

represent the additional GHG emissions contribution of combustion-related CH_4 and N_2O, in order to express GHG emissions in terms of CO_2e.[43]

3.3.2 Avoided GHG Emissions Estimates

3.3.2.1 In-State Electric

Table 3-4 illustrates the avoided In-State Electric GHG emissions for both the Hope Creek Retirement Case and the Full Retirement Case in the 2020-2025 period.

Table 3-4. Avoided In State Electric GHG Emissions, 2020-2025 (MMT)

Retirement Case	2020	2021	2022	2023	2024	2025
Hope Creek	0.7	0.4	0.7	0.8	0.9	1.0
Full	2.2	1.6	2.3	2.8	2.7	3.2

As shown, the avoided In-State GHG emissions range from 0.4 to 1.0 MMT for the Hope Creek Retirement Case, and 1.6 to 3.2 MMT for the Full Retirement Case.

The modeling analyses conducted by PA Consulting identify the emission sources that are projected to be displaced by continued operation of the nuclear unit(s).

3.3.2.2 Imported Electric

The PA Consulting grid model does not directly quantify the MWh of import/export of electricity across state lines, but ERM estimated net import generation amounts (and associated GHG emissions) using data from other sources in conjunction with the PA Consulting model output data. EIA gathers data for electricity generation and sales, and makes the data available by state and by year. As shown in Table 3-5, EIA data reveals that total electric sales in New Jersey have been relatively flat for the last few years, with less than 2% variation in any single year over the 5-year average of 74,822,955 MWh from 2014 to 2018[44]. Therefore, for the purposes of this analysis, the 2014-2018 average value of 74,822,955 MWh was assumed to apply to each year in the 2020-2025 period.

Table 3-5. Total Electric Sales in New Jersey, 2014-2018 (MWh)

Year	2014	2015	2016	2017	2018	Average
Total Electric Sales	73,866,078	75,489,623	75,359,371	73,382,940	76,016,762	74,822,955

NJDEP's original GHG inventory published in 2008 states that T&D losses were assumed to be 7%.[45] Applying this factor projects that generation of 80,454,790 MWh [74,822,955 MWh/(100% - 7%)] is needed to satisfy New Jersey electricity demand each year in the 2020-2025 period.

Table 3-6 summarizes EIA electric generation data from the six-year period of 2014-2019 for Hope Creek, Salem 1, and Salem 2. For the Hope Creek Retirement Case, ERM used the sum of the average

[43] New Jersey Greenhouse Gas Inventory and Reference Case Projections 1990 – 2020, New Jersey Department of Environmental Protection, November 2008, 17.

[44] EIA, Sales to Ultimate Customers (Megawatthours) by State by Sector by Provider, 1990-2018.

[45] New Jersey Greenhouse Gas Inventory and Reference Case Projections 1990 – 2020, New Jersey Department of Environmental Protection, November 2008, 16.

generation from Salem 1 and Salem 2 over this period, 17,558,881 MWh, as an estimate of the annual 2020-2025 electric generation from these units, which would not be retired in this scenario. Nuclear generation is 0 MWh for the Full Retirement Case.

Table 3-6. Hope Creek and Salem Electric Generation, 2014-2019, with 2020-2025 Projections (MWh)

Year	2014	2015	2016	2017	2018	2019	Average	2020-2025 (Projected for Hope Creek Retirement Case)
Hope Creek	10,373,816	9,409,357	9,603,443	10,627,333	9,546,684	8,726,946	9,714,597	0
Salem 1	8,848,906	9,748,411	6,997,238	9,244,745	10,177,507	7,944,369	8,826,863	8,826,863
Salem 2	7,433,492	8,845,163	8,699,415	8,730,429	8,717,600	9,966,009	8,732,018	8,732,018
Salem 1 + 2	16,282,398	16,282,398	15,696,653	17,975,174	18,895,107	17,910,378	17,558,881	17,558,881

As shown in Table 3-7, ERM used historical EIA generation by energy source data to estimate the amounts of generation from other energy sources other than coal, natural gas, and nuclear (i.e. hydroelectric, biomass, petroleum, solar thermal and photovoltaic, and wind).[46] For 2020-2025, ERM assumed that the contribution from these other energy sources is the 5-year historical average (2014-2018) of 6.87% of coal and natural gas generation.

[46] EIA, 1990-2018 annual_generation_by state.

Table 3-7. NJ Electric Generation by Energy Source 2014-2018 (MWh)[(1)]

Year	2014	2015	2016	2017	2018	Average
Coal	2,519,106	1,759,096	1,314,541	1,216,091	1,193,288	1,600,424
Natural Gas	31,410,341	36,974,456	43,807,453	37,707,848	38,863,492	37,752,718
Coal + Natural Gas	33,929,448	38,733,552	45,121,994	38,923,939	40,056,780	39,353,143
Nuclear	31,507,121	33,261,760	29,885,187	34,032,698	31,982,106	32,133,774
Other	2,614,517	2,613,548	2,604,222	2,687,876	2,994,714	2,702,975
Other, as % of Coal + Natural Gas	7.71%	6.75%	5.77%	6.91%	7.48%	6.87%

PA Consulting's analysis projects In-State total coal and natural gas generation for each year of the 2020-2025 period, for both the Hope Creek Retirement Case and the Full Retirement Case. Using 2020 as an example, the 2020 projection for the Hope Creek Retirement Case is 43,566,853 MWh, consisting of 1,614,801 MWh from coal and 41,952,052 MWh from natural gas.

Assuming a total New Jersey generation need of 80,454,790 MWh, a total of 43,566,853 MWh In-State coal and natural gas generation, nuclear generation of 17,558,881 MWh based on Salem 1 and Salem 2 generating their six year historical average, and 2,992,395 MWh of generation from "other" sources based on 6.87% of coal plus natural gas generation, net imports of 16,336,662 MWh [80,454,790 – (43,566,853 + 2,992,395 + 17,558,881) = 16,336,662 MWh] are needed in the Hope Creek Retirement Case in 2020.

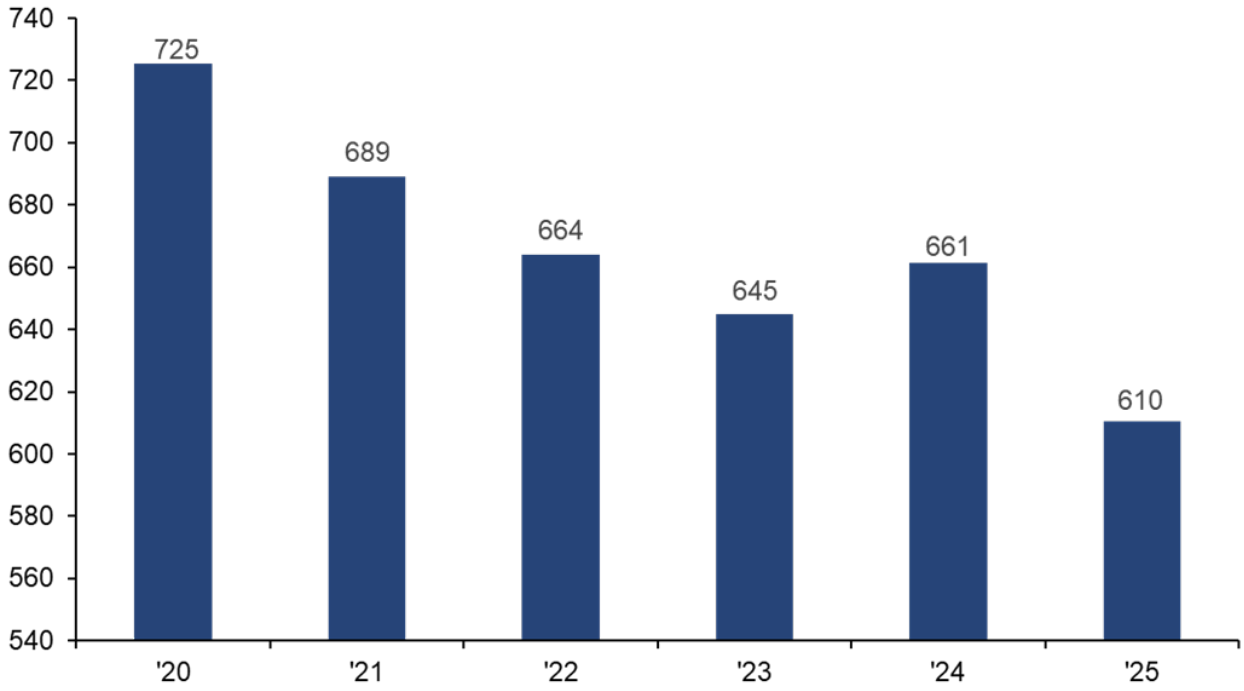
Similarly, for the Full Retirement Case, PA Consulting projects New Jersey In-State total coal and natural gas powered generation of 47,060,489 MWh in 2020, consisting of 1,617,777 MWh from coal and 45,442,711 MWh from natural gas. As shown in Table 3-7, ERM used EIA generation by energy source to estimate that another 3,232,355 MWh from other energy sources other than coal, natural gas, and nuclear is anticipated for the Full Retirement Case[47], assuming that the contribution from these other energy sources is also the 5-year historical average of 6.87% of coal and natural gas generation. In the Full Retirement Case, New Jersey nuclear electric generation is zero in 2020-2025. This indicates that net imports on the order of 30,161,946 MWh [80,454,790 – (47,060,489 + 3,232,355) = 30,161,946 MWh] are needed in the Full Retirement Case.

A CO_2 emission factor must then be applied to the net import amounts (in MWh) to estimate CO_2, and hence, GHG emissions from the imported power. Given that the imported electricity needed to meet the New Jersey shortfall in generation under nuclear plant shutdown scenarios would come in large measure from generators within PJM, a reasonable source of default CO_2 emission factors are those published by PJM. NJDEP uses PJM system average annual CO_2 emission factors in its GHG inventories to calculate Imported Electric emissions in assessing progress towards achieving the GWRA limits. As noted, the PJM system average CO_2 emission factors are conservatively low, given that there will be a lower fraction of New Jersey nuclear zero-CO_2 MWh in the mix in any nuclear unit retirement scenarios evaluated.

[47] Ibid.

Figure 3-6 above illustrates the historical PJM system average CO_2 emission rates from 2010-2019, which show a steady overall decline of 28% over the period, from 1,175 lb/MWh in 2010 to 851 lb/MWh in 2019. EIA's 2020 Annual Energy Outlook projects electricity generation and CO_2 emissions for 2019-2050 in the PJM East region.[48] ERM used this data to calculate an estimated CO_2 emission rate (lb/MWh) for each year in the 2020-2025 period. These calculations were performed by dividing the total Electric Power Sector CO_2 emissions (in short tons) by the total net Electric Power Sector generation (in billion kilowatt-hours), and converting the units to lb/MWh. Figure 3-8 below illustrates the projected average CO_2 emission rates for 2020-2025, which continue the historical trend of steady decline over time.

Figure 3-8. Projected Average CO_2 Emissions Rates in PJM East, 2020-2025 (lb/MWh)



ERM used these projected PJM East CO_2 emission rates to estimate the avoided GHG emissions for both the Hope Creek Retirement Case and the Full Retirement Case by multiplying the lb/MWh CO_2 emission factor for a given year by the estimated amount of imported power determined as described above. For example, for 2020 for the Hope Creek Retirement Case, ERM estimates that 16,336,662 MWh of Imported Electric will be needed in 2020 to satisfy New Jersey electricity demand in the Hope Creek Retirement Case. Multiplying the 2020 PJM East projected average annual CO_2 emission factor of 725 lb/MWh by 16,336,662 MWh of imported power and applying the appropriate adjustment factors to equates to GHG emissions of 5.4 MMT for the Hope Creek Retirement Case, as follows:

[48] https://www.eia.gov/outlooks/aeo/tables_ref.php.

16,336,662 MWh x (725 lb/MWh) x (1.006304) x (1 kg/2.20462 lb) x (1 metric ton/1,000 kg)

= 5,408,828 metric tons x (1 MMT/1,000,000 metric tons)

= 5.4 MMT

Similarly, for the Full Retirement Case, multiplying the 725 lb/MWh CO_2 emission factor by 30,161,946 MWh of imported power equates to GHG emissions of 10.0 MMT.

30,161,946 MWh x (725 lb/MWh) x (1.006304) x (1 kg/2.20462 lb) x (1 metric ton/1,000 kg)

= 9,986,176 metric tons x (1 MMT/1,000,000 metric tons)

= 10.0 MMT

This exercise was repeated for each year in the 2020-2025 period. The results are summarized in Table 3-8 for the Hope Creek Retirement Case, and Table 3-9 for the Full Retirement Case.

Table 3-8. Imported Electric Avoided GHG Emissions, 2020-2025 - Hope Creek Retirement Case

Year	2020	2021	2022	2023	2024	2025
Total NJ Retail Electric Sales (MWh)	74,822,955	74,822,955	74,822,955	74,822,955	74,822,955	74,822,955
T&D Losses	5,237,607	5,237,607	5,237,607	5,237,607	5,237,607	5,237,607
NJ Generation Needed (MWh)	80,454,790	80,454,790	80,454,790	80,454,790	80,454,790	80,454,790
In-State Generation, Coal + Gas (MWh)	43,566,853	41,710,095	45,678,515	48,012,334	47,475,874	49,150,379
In-State Generation, Nuclear (MWh)	17,558,881	17,558,881	17,558,881	17,558,881	17,558,881	17,558,881
In-State Generation, Other (MWh)	2,992,395	2,864,863	3,137,434	3,297,733	3,260,886	3,375,900
Imported Generation (NJ Need - Gen - Losses)	16,336,662	18,320,952	14,079,960	11,585,842	12,159,150	10,369,631
PJM East Projected CO2 Emission Rate (lb/MWh)	725	689	664	645	661	610
CO2 (short tons)	5,924,855	6,313,886	4,675,302	3,735,878	4,021,011	3,164,873
GHG CO2e (metric tons)	5,408,828	5,763,977	4,268,106	3,410,501	3,670,800	2,889,228
GHG CO2e (MMT)	**5.4**	**5.8**	**4.3**	**3.4**	**3.7**	**2.9**

Table 3-9. Imported Electric Avoided GHG Emission Estimates, 2020-2025 – Full Retirement Case

Year	2020	2021	2022	2023	2024	2025
Total NJ Retail Electric Sales (MWh)	74,822,955	74,822,955	74,822,955	74,822,955	74,822,955	74,822,955
T&D Losses	5,237,607	5,237,607	5,237,607	5,237,607	5,237,607	5,237,607
NJ Generation Needed (MWh)	80,454,790	80,454,790	80,454,790	80,454,790	80,454,790	80,454,790
In-State Generation, Coal + Gas (MWh)	47,060,489	44,640,725	45,773,779	48,382,535	47,911,708	49,676,713
In-State Generation, Nuclear (MWh)	0	0	0	0	0	0
In-State Generation, Other (MWh)	3,232,355	3,066,154	3,143,978	3,323,160	3,290,822	3,412,051
Imported Generation (NJ Need - Gen - Losses)	30,161,946	32,747,912	31,537,033	28,749,095	29,252,261	27,366,026
PJM East Projected CO2 Emission Rate (lb/MWh)	725	689	664	645	661	610
CO2 (short tons)	10,938,903	11,285,800	10,471,988	9,270,203	9,673,675	8,352,275
GHG CO2e (metric tons)	9,986,176	10,302,860	9,559,927	8,462,812	8,831,144	7,624,832
GHG CO2e (MMT)	**10.0**	**10.3**	**9.6**	**8.5**	**8.8**	**7.6**

(1) 2014-2018 data obtained from EIA, 2020 Projected MWh for coal and natural gas provided by PA Consulting, and "Other" estimated by ERM.

(2) 2020 Other = 2014-2018 average of "Other as % of Coal + Natural Gas" x 2020 Projected Coal + Natural Gas.

3.3.2.3 Total Avoided GHG Emissions

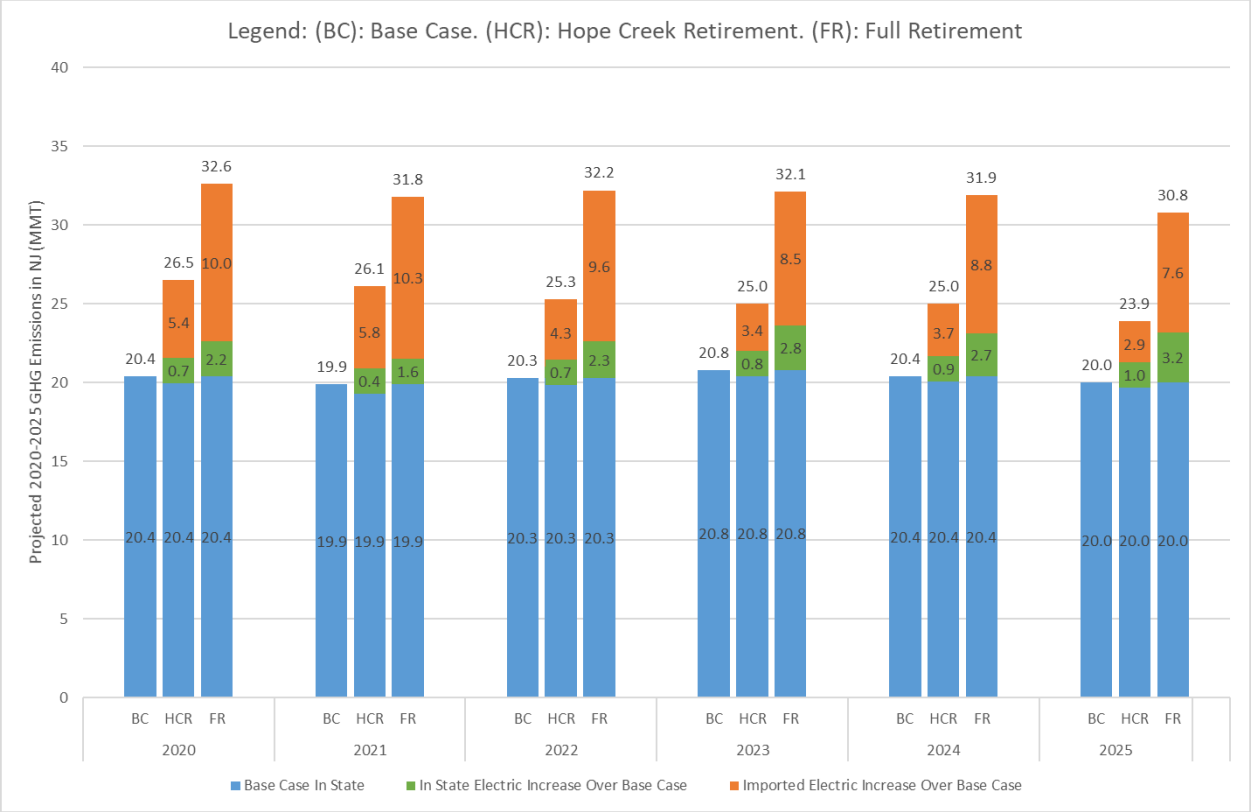
Table 3-10 summarizes the total avoided GHG emissions (In-State Electric + Imported Electric) for both the Hope Creek Retirement Case and the Full Retirement Case.

Table 3-10. Total Avoided GHG Emissions, 2020-2025 (MMT)

Year	Hope Creek Retirement			Full Retirement		
	Avoided In-State GHG	Avoided Imported GHG	Total Avoided GHG	Avoided In-State GHG	Avoided Imported GHG	Total Avoided GHG
2020	0.7	5.4	6.1	2.2	10.0	12.2
2021	0.4	5.8	6.1	1.6	10.3	11.9
2022	0.7	4.3	5.0	2.3	9.6	11.8
2023	0.8	3.4	4.3	2.8	8.5	11.2
2024	0.9	3.7	4.5	2.7	8.8	11.5
2025	1.0	2.9	3.9	3.2	7.6	10.9

The total avoided GHG emissions for the Electricity Generation Sector (In-State Electric + Imported Electric) are estimated to range from 3.9 to 6.1 MMT per year for the Hope Creek Retirement Case, and 10.9 to 12.2 MMT per year for the Full Retirement Case. As illustrated graphically in Figure 3-9 below, these levels represent sizeable increases over the projected 2020-2025 Base Case GHG emissions that are based on the PSEG nuclear units remaining in service.

Figure 3-9. Projected 2020-2025 GHG Emissions in NJ (MMT)



4. CONCLUSIONS

ERM's analyses, in conjunction with analyses conducted by PA Consulting, clearly demonstrate that the operation of PSEG Nuclear's units have resulted, and are projected to continue to result, in significant, material levels of avoided GHG emissions. The presence and operation of the Hope Creek, Salem 1, and/or Salem 2 nuclear units has avoided and would continue to avoid GHG emission increases that would occur both In-State (i.e. within New Jersey) as well as in the greater region. In addition to the increase In-State Electric emissions, the loss of the Hope Creek and/or Salem units would result in even greater increases in emissions from Imported Electric, because New Jersey would need to import substantial amounts of fossil fuel power from outside of the State to make up for the power lost from the nuclear unit retirements. These GHG emission increases would have significant negative impact and jeopardize the State's ability to achieve its 2050 GHG reduction goals. Also, the Intergovernmental Panel on Climate Change (IPCC) stresses the urgency for transformative policy efforts to reduce GHG emissions in the short term.[49] The retirement of clean, existing nuclear resources runs counter to these efforts. The continued operation of the Hope Creek and Salem units is needed to prevent backsliding in the efforts to combat climate change.

[49] IPCC, An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty, 2019, 148.

5. GLOSSARY

- **2020 limit:** means the level of greenhouse gas emissions equal to the 1990 level of Statewide greenhouse gas emissions.
- **2050 limit:** means the level of greenhouse gas emissions equal to 80 percent less than the 2006 level of Statewide greenhouse gas emissions.
- **AURORA^{xmp}:** Computer-based chronological dispatch simulation model used to project electric generator dispatch and wholesale power prices.
- **BPU:** New Jersey Board of Public Utilities.
- **CH_4:** Methane.
- **CO_2:** Carbon dioxide.
- **CO_2e:** Carbon dioxide equivalent, which means the number of metric tons of CO_2 emissions with the same global warming potential as one metric ton of another greenhouse gas.
- **Eastern Interconnect:** A major alternating current electric grid covering much of the eastern US and parts of Canada.
- **EIA:** US Energy Information Administration.
- **EPA:** US Environmental Protection Agency.
- **GHG:** Greenhouse gas, means carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and any other gas or substance determined by the Department of Environmental Protection to be a significant contributor to the problem of global warming.
- **GWP:** Global warming potential, means the ratio of the time-integrated radiative forcing from the instantaneous release of one kilogram of a trace substance relative to that of one kilogram of a reference gas (i.e., CO_2).
- **GWRA:** New Jersey's Global Warming Response Act, codified at N.J.S.A. 26:2C-37-44, which calls for a reduction of statewide GHG emissions to below 1990 levels by 2020, and 80% below 2006 levels by 2050.
- **Hg:** Mercury.
- **kWh:** Kilowatt-hour.
- **lb**: Pound.
- **lb/MWh**: Pounds per Megawatt-hour.
- **Metric ton:** a unit of weight equal to 1,000 kilograms (2,204.62 pounds).
- **MIDA:** Mid-Atlantic Region, as defined by EIA.
- **MMBtu:** Million British Thermal Units, a measure of energy content.
- **MSW:** Municipal Solid Waste.
- **MW:** Megawatt.
- **MWh:** Megawatt-hour.
- **MMT:** Million metric tons.
- **$MMTCO_2e$:** Million metric tons of CO_2 equivalent.
- **N_2O:** Nitrous oxide.
- **NJDEP:** New Jersey Department of Environmental Protection.
- **NO_x:** Nitrogen oxides.

- **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.
- **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 NO_x.
- **$PM_{2.5}$:** 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 NO_x.
- **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.
- **Statewide greenhouse gas emissions:** means the sum of calendar year emissions of greenhouse gases from all sources within the State, and from electricity generated outside the State but consumed in the State, as determined by the Department pursuant to subsection c. of section 5 of the GWRA.
- **SO_2:** Sulfur dioxide.
- **T&D:** Transmission and Distribution.
- **Ton:** Short ton, equivalent to 2,000 lbs.
- **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.
- **ZEC Act:** 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)] enacted by the State of New Jersey on May 23, 2018.

ERM has over 160 offices across the following countries and territories worldwide

Argentina
Australia
Belgium
Brazil
Canada
Chile
China
Colombia
France
Germany
Hong Kong
India
Indonesia
Ireland
Italy
Japan
Kazakhstan
Kenya
Malaysia
Mexico
Mozambique
Myanmar
The Netherlands
New Zealand
Norway
Panama
Peru
Poland
Portugal
Puerto Rico
Romania
Russia
Singapore
South Africa
South Korea
Spain
Sweden
Switzerland
Taiwan
Thailand
UAE
UK
US
Vietnam

ERM's Ewing Office
Princeton South Corporate Center
Suite 160
Ewing, NJ 08628

T: +1 609 895 0050
F: +1 609 359 8664

www.erm.com

The business of sustainability

ERM