Impact on Emission of Pollutants Resulting from the Elimination of Emergency Generators from Capacity Markets

Prepared for:
Advanced Energy Management Alliance

Submitted by:
Navigant Consulting, Inc.
1200 19th Street NW
Suite 700
Washington, DC 20036
navigant.com

Reference No.: 185725
March 3, 2016

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

Figures:

Tables:

NAVIGANT

DISCLAIMER

This report was prepared by Navigant Consulting, Inc. (Navigant) for Advanced Energy Management Alliance. The work presented in this report represents Navigant's professional judgment based on the information available at the time this report was prepared. Navigant is not responsible for the reader's use of, or reliance upon, the report, nor any decisions based on the report. NAVIGANT MAKES NO REPRESENTATIONS OR WARRANTIES, EXPRESSED OR IMPLIED. Readers of the report are advised that they assume all liabilities incurred by them, or third parties, as a result of their reliance on the report, or the data, information, findings and opinions contained in the report.

EXECUTIVE SUMMARY

Navigant was engaged by the Advanced Energy Management Alliance to estimate the impact of removing emergency generators as capacity resources from the bulk power system on the emission of carbon dioxide (CO_2), and criteria and hazardous air pollutants.[1] This study uses the following definition for emergency generators: demand response resources provided by Reciprocating Internal Combustion Engines (RICE). PJM is the focus of this analysis due to its size as the largest wholesale market and largest demand response market in the United States, and the availability of data for that region. The applicability of the results to other regions of the United States is also discussed.

The analyses have two components:

1. Comparison of the emissions during system emergency periods when emergency generators are included in the resource mix and when they are removed and replaced by other resources;
2. Comparison of annual emissions from the base case in which emergency generators provide capacity versus the alternative case in which other resources have replaced emergency generators in the capacity market and must also offer into PJM's day-to-day energy market.

The detailed description of the analysis methodology can be found in Section 2.

Changing the economics of any resource has ripple effects across other resources and overall emissions. In this study, Navigant applies several market models to assess the impact of removing emergency generators from PJM's capacity market.

Emergency generators represent a subset of demand response resources that participate in the PJM capacity market. There are currently 1,750 megawatts (MW) of emergency generators participating in the PJM Emergency Load Reduction Program (ELRP).[2] The removal of these resources will have impacts on multiple wholesale power markets operated by PJM in two primary ways:

1) Substitute energy generation will be needed during emergencies. This substitute generation will also emit pollutants, though levels will depend on the type of generation;

2) Replacement capacity will be needed to provide for system adequacy. Replacement capacity will change the regional generation mix, impacting the dispatch of that mix in the daily energy market, which changes the emissions in the region.

The total emission changes from removing emergency generators from PJM are driven by the impacts of using substitute generation during emergencies and the potential for changes in regional generation mix in non-emergency periods resulting from the replacement capacity. The study shows that the emissions impact from the change in regional generation mix (see 2. above) far outweighs the emissions impact

---

[1] These emergency resources were never intended to participate in energy markets, but were viewed as being able to contribute capacity needed in the event of system emergencies.

[2] According to PJM ELRP report

from substitute generation during emergency periods (see 1. above). **The overall conclusion is that emissions in the PJM region will increase without emergency generators in the market.**[3]

EMISSIONS DURING EMERGENCY EVENTS

Emergency generators in PJM are dispatched only in times during which the system is severely constrained. These events correlate with periods of very high demand, or a large number of forced outages by base load and marginal units. Unlike other generating resources which are dispatched based on economic merit in order of low to high variable cost of operation, emergency generators do not participate in the energy market and do not have a must offer requirement. These units are strictly a resource of last resort, dispatched for system emergencies.

When emergency generators are removed from the market, PJM's capacity procurement mechanisms will ensure that sufficient capacity is available for emergencies. The result is a different mix of capacity that will now be the last resort generation during system emergency periods. Due to the extremely high pricing that occurs during these events, it is reasonable to assume that all combined cycle, renewable, and relatively efficient steam-coal units available to meet the system demand will have already been dispatched, leaving older gas and oil-fired combustion turbines and steam units to fulfill the need.

The results of this analysis are given in Table 1 and Table 2 comparing emissions from emergency generators (EG) and the substitute generation (SG). All emissions in this analysis are presented in short tons and expressed as tons (T). Excluding emergency generators from the market and calling on marginal oil and gas units results in an increase in carbon and formaldehyde emissions but a decrease in emissions of the remaining eight pollutants examined in this analysis. This is the intuitive result based solely on differences in emission signatures of emergency generator engines versus marginal oil and gas units.

Table 1. CO_2 and Criteria Emissions Impacts due to Substitute Generation (*in Tons*)

	CO2		SO2		NOx		CO		Filterable PM		Filterable PM10	
	EG	SG	EG	SG	EG	SG	EG	SG	EG	SG	EG	SG
2010	5,510	6,554	2.30	0.11	111	86	28	23	1.95	1.57	3.79	1.56
2011	10,640	12,655	4.44	0.22	214	167	54	44	3.77	3.04	7.31	3.02
2012	2,677	3,184	1.12	0.06	54	42	13	11	0.95	0.76	1.84	0.76
2013	8,200	9,753	3.42	0.17	165	128	41	34	2.91	2.34	5.63	2.33
2014	25,869	30,770	10.80	0.54	521	405	130	107	9.18	7.39	17.77	7.34
Average	10,579	12,583	4	0	213	166	53	44	3.75	3.02	7.27	3.00
% Change	19%		-95%		-22%		-18%		-19%		-59%	

Source: Navigant

[3] There have been several other studies to consider the same issue. This report expands upon the methodology of those studies to consider an integrated view of the economic and operational impacts of removing emergency generators from the market. A short discussion of how this paper fits into the context of the prior work is given in Appendix A.2.

Table 2. Hazardous Air Emissions Impacts due to Substitute Generation (*in Tons*)

	Benzene		Formaldehyde		Toluene		Mercury	
	EG	SG	EG	SG	EG	SG	EG	SG
2010	0.03	0.02	0.01	0.02	0.01	0.01	0	0
2011	0.05	0.04	0.03	0.03	0.02	0.02	0	0
2012	0.01	0.01	0.01	0.01	0.00	0.00	0	0
2013	0.04	0.03	0.02	0.03	0.02	0.01	0	0
2014	0.12	0.09	0.06	0.08	0.05	0.05	0	0
Average	0.05	0.04	0.03	0.03	0.02	0.02	0	0
% Change	-24%		36%		-3%			

Source: Navigant

EMISSIONS FROM DAY-TO-DAY SYSTEM OPERATION

Decisions to retire existing capacity and to build new capacity units in PJM are driven by the capacity market. This analysis modeled the impact that retiring 1,750 MW of emergency generators has on capacity prices. When emergency generator capacity is removed from the market, (i) prices rise, (ii) marginal existing resources may stay in the market, (iii) new capacity may be incentivized, or (iv) total capacity procured by the ISO might be reduced as defined by the slope in the ISO demand curve.

Navigant used the Capacity Market Model to forecast PJM capacity prices in the Base case (discussed below) and then alternatively in the case with 1,750 MW of emergency generator capacity removed from the market without any replacement. The increase in prices is about $35/MW-day starting in 2019/2020. That increase would drive additional annual revenue of over $6 million for a 500 MW power plant. This increase in prices provides incentive for existing units that are being considered for retirement (i.e., on the margin with respect to economics) to remain in the market.[4]

Navigant forecasts coal units to retire or retrofit to gas burning based on utility announcements and economics. Some units will retire regardless of the level of capacity prices. Announced retirements are not necessarily final for marginal units.

The coal retirement decision is complex and this analysis focuses on marginal units that have economics close to the decision of whether or not to retire or retrofit. To address the uncertainty in the forecasted coal retirement decisions, this analysis compares the Base case assuming the status quo that emergency generators are in the market, with a Low case of un-retired coal, and a High case of un-retired coal and coal units un-retiring to convert to gas burning. The Low and High cases bracket the range of forecasted retirements from the modeling, and show the impacts of different levels of capacity changes in PJM.

The analysis simulates the operation of PJM from 2016 through 2026 under these three sets of assumptions. T The emission impacts outputted in these simulations are shown in Table 3. For CO_2, sulfur dioxide (SO_2), oxides of nitrogen (NO_x), carbon monoxide (CO), particulate matter (PM), benzene, and mercury, the removal of the emergency engines from the market and increase in coal units causes

[4] PJM operations calls for an upward sloping demand curve to be used for pricing above the target reserve margin to recognize the fact that there is additional value for capacity above the target reserve margin, i.e., the value of capacity does not fall to zero right at the target reserve margin. As a result, not all of the 1,750 MW of capacity would be expected to be replaced or else prices would fall back to the Base case level and there would be no incentive for marginal units to stay in the market.

emissions to increase. The only pollutants whose emissions decrease are formaldehyde and toluene. **The primary result is that the emissions impact of replacement capacity remaining in the market is orders of magnitude larger than the impact of substitute generation operating during system emergencies.**

Table 3. Total Emissions by Case (*in Tons*)

	Total Emissions			Emissions Change	
Pollutant	Baseline	Low Unretirements	High Unretirements	Low Unretirements	High Unretirements
CO2	4,545,103,227	4,554,808,558	4,588,519,292	9,705,331	43,416,064
SO2	4,350,077	4,377,419	5,022,986	27,342	672,909
NOx	3,275,223	3,277,111	3,358,017	1,888	82,794
CO	3,985,286	3,994,272	4,031,156	8,985	45,869
Filterable PM	43,449,693	43,580,970	44,281,528	131,277	831,835
Filterable PM10	8,742,646	8,768,829	8,907,710	26,182	165,064
Benzene	957	960	971	2	14
Formaldehyde	6,174	6,167	6,029	-8	-146
Toluene	1,260	1,259	1,235	-1	-24
Mercury	55	55	56	0	1

Source: Navigant

Parameter Sensitivities

In addition to the two coal retirement scenarios, the analysis examines 5 key parameter sensitivities to test the robustness of the result– 1) even fewer coal retirements than the Low case, 2) emergency generator operating hours, 3) reduced PJM load, 4) reduced emergency generator efficiency, and 5) coal plants retiring prior to 2026 regardless of the capacity prices. **The conclusion of each of these sensitivities is that the directionality of increased emissions due to the removal of emergency generators from PJM is not impacted; i.e., elimination of emergency generators leads to increased emissions due to the impact of even small amounts of unretired generation.**

CONCLUSIONS

The total emission changes from removing emergency generators from PJM are the sum of the impacts of using substitute generation during system emergencies and keeping un-retired coal capacity operating in the energy market.

The emission impacts of the substitute generation (Component 1 of this Study) range from increases in thousands of tons of CO_2 emissions to negligible changes to other pollutants. These only occur if there is a system emergency and the grid operator calls on these emergency resources.

The un-retirement of coal (Component 2 of this Study) results in increases of millions of tons of CO_2; thousands of tons of SO_2, NO_x, CO, and PM; and few tons or less of benzene and mercury per year even in the low un-retirement case. A slight decrease of formaldehyde and toluene is observed with the removal of emergency generators due to the high relative emissions of these by the engines.

The combined impacts of Component 1 and Component 2 of this study over the 2016 – 2026 study period are shown in Table 4.

Table 4. Net Emissions from Removal of Emergency Generators (*in Tons*)

Pollutant	Baseline Emissions from Emergency Generators	Emissions Change from Substitute Generation	Emissions Change in Low Unretirement Case	Net Emissions from Removal of Emergency Generators
CO2	116,369	22,045	9,705,331	**9,727,376**
SO2	49	-46	27,342	**27,296**
NOx	2,344	-522	1,888	**1,366**
CO	586	-103	8,985	**8,882**
Filterable PM	41	-8	131,277	**131,269**
Filterable PM10	80	-47	26,182	**26,136**
Benzene	0.54	-0.13	2.4	**2.3**
Formaldehyde	0.28	0.10	-7.8	**-7.7**
Toluene	0.22	-0.01	-1.0	**-1.1**
Mercury	0.00	0.00	0.2	**0.2**

Source: Navigant

This analysis used the outputs of Navigant's market models to forecast several estimates of the generation mix impacts due to removing emergency generators from the system. The results in both the low coal un-retirement case and the high coal un-retirement case show increases in emissions. Further tests were completed as sensitivities on key analysis parameters and these also show increases in emissions if emergency generators are excluded from the market. **The overall conclusion is that increased emissions will occur in the market without emergency generators.**

Potential Applicability to Other Regions

The PJM region was used for this study due to its size and the availability and quality of data. The study results can be applied to other regions and would be adjusted according to the regional resource mix.

The emissions impact of substitute generation is broadly applicable across the country because a mix of oil and gas peakers would provide the substitute generation in any region. The emissions impact of un-retiring coal can be applied to regions with significant coal generation and expected retirements. These regions include MISO, SPP, ERCOT, SERC, and parts of WECC. In all of these regions, it can be expected that removing emergency generators from the markets is likely to increase most emissions due to coal staying online.

Regions without significant coal generation would be expected to replace the emergency generator capacity with gas units, so the emissions impact would be different. These regions include ISO-NE, NYISO, California, and NWPP.

The results from substitute generation during emergency events show that the overall changes in emissions from removing emergency generators is small and slightly positive for CO_2 and slightly negative for the other pollutants. In ISO-NE and NYISO, the proportion of replacement generation that is oil fired compared to gas fired is likely to be higher than 50/50 so the estimate of the emissions impact during emergencies is conservative (on the low side) for those two regions.

1. BACKGROUND

1.1 STUDY OVERVIEW

Navigant was engaged by the Advanced Energy Management Alliance to study the impact of removing emergency generators from the bulk power system on the emissions of CO_2 and Reciprocating Internal Combustion Engine (RICE) criteria and hazardous air pollutants.[5] This study uses the following definition for emergency generators: demand response resources provided by RICE. PJM is the focus of this analysis due to its size as the largest U.S. wholesale market and largest demand response market, and the availability of data for that region. The applicability of the results to other regions of the United States is also discussed. [6]

The analyses have two components:

1. Comparison of the emissions during system emergency periods when emergency generators are included in the resource mix and when they are removed and replaced by other resources;
2. Comparison of emissions from the day-to-day operation of the system in the base case in which emergency generators provide capacity versus the alternative case in which other resources have replaced emergency generators in the capacity market.

1.2 POLICY CONTEXT

RICE regulates criteria pollutants – nitrogen oxides (NO_X), carbon monoxide (CO), sulfur dioxide (SO_2), volatile organic compounds (VOC), and particulate matter (PM) along with hazardous air pollutants (HAPs)[7] – such as, formaldehyde, acetaldehyde, acrolein, and polycyclic aromatic hydrocarbons (PAHs). The United States Environmental Protection Agency (EPA) regulates the air emissions of RICE in three ways:

- National Emission Standard for Hazardous Air Pollutants (NESHAP) for RICE[8];
- New Source Performance Standards (NSPS) - Standards of Performance for Stationary Spark Ignition (SI) Internal Combustion Engines[9];
- NSPS - Standards of Performance for Stationary Compression Ignition (CI) Internal Combustion Engines.[10]

A change in the regulations that would require additional investment in RICE units would make it uneconomic for these units to participate in emergency demand response programs.

---

[5] These emergency resources were never intended to participate in energy markets, but were viewed as being able to contribute capacity needed in the event of system emergencies.

[6] There have been several other studies to consider the same issue. This report expands upon the methodology of those studies to consider an integrated view of the economic and operational impacts of removing emergency generators from the market. A short discussion of how this paper fits into the context of the prior work is given in Appendix A.2.

[7] The EPA uses CO as an appropriate surrogate for HAPs

[8] 40 Code of Federal Regulations (CFR) Part 63 Subpart ZZZZ

[9] 40 CFR Part 60 Subpart JJJJ

[10] 40 CFR Part 60 Subpart IIII

1.3 ASSESSING THE RESOURCE MIX

Changing the economics of any resource has ripple effects across other resources and overall emissions. The goal of this study is to assess how removal of emergency generators would impact wholesale energy markets and hence impact resource investment and retirement. Retirements of older fossil fuel plants (coal, oil and gas) impact emissions. Of these, coal plants have the largest impact on emissions. Coal power plants emit both criteria pollutants (NO_X, SO_2, PM, and lead) and HAPs (most notably mercury, but also cadmium, other heavy metals, and arsenic), as well as significant amounts of CO_2. Control technologies help lower some of these emissions. The degree to which emissions are lowered depends on the type of control instituted, and generally newer controls tend to be more effective than older controls as they can take advantage of technology improvements. Across the nation, 4% of coal capacity is completely uncontrolled. These tend to be smaller units (representing 14% of units). For comparison, 11% of coal units in PJM are uncontrolled, but these represent less than 1% of coal capacity. Emissions are also driven by the type of coal that is burned. Table 5 shows air pollutant controls on PJM coal units. Most units in PJM have controls for NO_x and PM, with some larger units controlling for SO_2. Few units control for mercury and none for CO_2. This is typical across the industry.

Table 5. Coal Capacity and Units in PJM with Emission Controls

	Percent of Capacity with Controls	Percent of Units with Controls	Average Age of Controls (years)
SO_2 Controls	84%	55%	13
NO_X Controls	98%	73%	22
PM Controls	99%	87%	6
Mercury Controls	19%	12%	6
CO_2 Controls	0%	0%	N/A

Source: Navigant (data from Energy Velocity, downloaded February 2016)

Coal plants in PJM, as well as other regions of the country, are experiencing coal retirements as the less clean and typically older generation cannot compete with cheaper natural gas and renewables. These coal plants are marginal in the capacity market. One economic outcome is that higher capacity prices driven by the removal of emergency generators from the capacity market could result in some amount of marginal coal capacity that would otherwise have retired to stay online. Because generation that is marginal in the capacity market is not necessarily marginal in the energy market, that generation that essentially “un-retired” would operate “in the money” in the energy market at a capacity factor of 50% or higher (meaning the unit’s annual energy output is 50% or more of its potential annual energy output). To the extent that these may be coal units, there will be an impact on emissions of criteria pollutants, HAPs, and CO_2.

1.4 MARKET IMPACTS OF REMOVING EMERGENCY GENERATORS

There are currently 1,750 MW of emergency generators participating as ELRP in PJM.[11] The removal of these resources would have impacts on multiple wholesale power markets operated by PJM. PJM’s energy market calculates hourly locational marginal prices (LMPs) based on generation offers, demand bids, and scheduled bilateral transactions. It also includes a spot market in which LMPs are calculated at five-minute intervals based on actual grid operating conditions. PJM’s capacity market is based on making capacity commitments three years ahead and is designed to create long-term price signals to attract needed investments in reliable capacity resources in PJM. It includes incentives that are designed

[11] According to PJM ELRP participation summary

to stimulate investment both in maintaining existing generation and in encouraging the development of new sources of capacity.

1.4.1 Energy Market Impact and System Dispatch

Emergency generators are used in PJM (and across the entirety of the country including regulated, deregulated and municipal and cooperative utility regions) to meet capacity requirements. In PJM and the other ISO markets, capacity resources comprised of emergency generators are specially classified resources, do not have a must-offer requirement into the day-ahead or real-time energy markets and are thereby not dispatched on an economic basis. They are only dispatched under specific system emergency conditions and only have emissions during these times. The number of hours that emergency generators are dispatched varies year to year, but historically has been very low.

If the emergency generators are removed from PJM, alternative, substitute generation will be needed during emergencies. This substitute generation will also emit pollutants, though levels will depend on the type of generation.

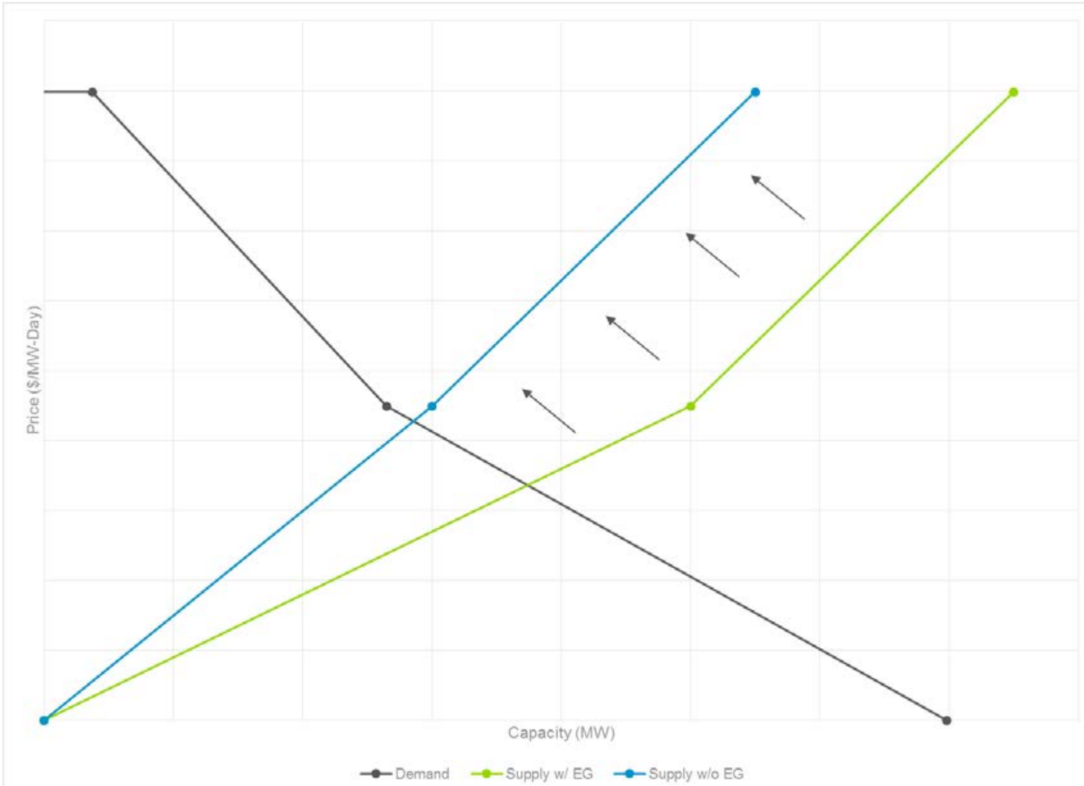
1.4.2 Capacity Market Impacts

Demand response is a major part of the PJM capacity market which is referred to as the Reliability Pricing Model (RPM). PJM holds a Base Residual Auctions (BRA) for each delivery year (June 1 – May 31). The purpose of the BRA is for PJM to procure capacity to meet demand plus a reserve margin in a least cost manner[12]. The amount of capacity that PJM procures and the capacity prices are determined at the intersection of an administratively determined downward-sloping demand curve and a supply curve built up by bids from market participants.

Emergency generators represent a subset of demand response resources that participate in the PJM capacity market. An illustrative example of the impact of removing emergency generators from the capacity market is shown in Figure 1. The capacity price in a case with emergency generators is at the intersection of the demand curve and the green supply curve. The capacity price in a case without emergency generators is at the intersection point of demand curve and the blue supply curve. Removing emergency generators raises capacity prices and either reduces the total quantity of capacity procured or requires the procurement of replacement capacity.

[12] NYISO and ISO-NE also have annual capacity auctions that procure capacity resources including demand response and EG resources to provide demand response. ERCOT does not utilize a capacity market, but does hold capacity-like auctions three times per year to specifically procure demand response resources including EG resources to ensure reliability. The ISOs with capacity markets all have similar rules about must-offer obligations in their energy markets. The obligation is placed on traditional energy resources. EG participating as demand response resources in these markets are not obligated to offer into the energy market.

Figure 1. Illustrative PJM Capacity Market Demand Curve



Source: Navigant

The latest BRA took place in August 2015 for delivery year 2018/2019. Demand response provided 6.6% of the capacity cleared and approximately 15% of that demand response total is backed by emergency generators. Removing these emergency generator resources from the market would decrease supply and result in a higher capacity price that would cause some capacity that did not clear the market to clear.

2. STUDY METHODOLOGY

The analyses conducted look at the impacts of removing the 1,750 MW of emergency generators in PJM. The analysis uses Navigant's Base Case forecast for PJM system generation and emissions. The Base case is developed using assumptions on system generation mix, environmental regulations, fuel prices, load, and other system operation characteristics. A description of these assumptions and their sources are discussed in Section 2.2. The Base case includes the assumption that the 1,750 MW of emergency generator resources stay in the system. PJM operation is simulated with Navigant's suite of energy market models.

2.1 MODELING METHODS

Forecasting the impacts of removing the emergency generators involves modeling system operation without these resources and comparing the results to the Base case. The analyses are divided into two segments to evaluate the impacts of removing the emergency generators from the system:

Part 1: Substitute Generation during Emergency Events
Emergency generation must be provided by a substitute operating unit other than emergency generators during emergency events (referred to here as "substitute generation"). The emissions from substitute generation partially or fully offset the emissions from the emergency generators.

Part 2: Replacement Capacity and the Resulting System Operation
Removing the emergency generators from PJM will raise capacity prices and there will be some capacity procured in the capacity market that would not have otherwise cleared the market. To the extent that the replacement capacity is comprised of traditional generating units, it will have a daily must-offer requirement in the energy market and will thus operate at its generation cost within the PJM system. Putting these replacement resources into the daily energy market impacts the day-to-day generation mix and operation of the PJM system and PJM emissions.

2.1.1 Modeling Substitute Generation during Emergency Events

Emergency generators are dispatched in PJM (i.e., during system emergencies), to provide emergency generation to the system. In the absence of these emergency generators, that capacity is still required to be provided to the system, and it will be sourced from substitute dispatchable generating resources in PJM. This analysis takes into consideration the expected emissions that would have been emitted by the existing emergency generators and compares it to the emissions output from the substitute resources that will be used instead.

This analysis examines historical day-ahead and real-time energy prices during instances in which emergency generators were called in order to determine the substitute unit fuel type and unit efficiency that would be available to provide the emergency generation to the system. The analysis is based on data from emergency events in the PJM market between 2010 and 2014. Historical operations from emergency generators are calculated by allocating the 1,750 MW of emergency capacity across PJM in proportion to each zone's 2014 peak demand. Annual emergency generator usage is calculated by taking into consideration the event location and duration.

Day-ahead and real-time prices from each historic event are examined to identify the marginal units that would be called to provide generation to replace the emergency generators excluded from the market.

Annual fuel consumption for the assumed mix of substitute generation is calculated from unit heat rates and emissions are calculated from EPA emissions factors by fuel type[13]. Emissions from the substitute generation are then compared to emissions from the emergency generators to determine the total emissions output with and without the emergency generators.

2.1.2 Modeling Replacement Capacity and the Resulting System Operation

Much of PJM's coal fleet is planning on or considering retirement and a key driver in this decision is capacity prices. Modeling the impact of removing emergency generators in PJM requires forecasting the impact on capacity prices and the replacement capacity that could clear in the auctions. This will influence coal retirements, and result in changes in system operations. This modeling combines industry and Navigant proprietary energy market models. Together, these models forecast the impact on the capacity market and coal retirements and simulate system operation given the forecasted changes. The descriptions of the steps of this analyses and the role of primary models used in the study are listed below:

Step 1: *Capacity Price Impacts*
The change in PJM capacity price by removing the emergency generators is forecasted by running the Capacity Market Model with and without the emergency generator resources. The model is tailored to the specific market rules in PJM including resource eligibility, locational prices, and auction structure. It can be used to both forecast expected revenue from entering the capacity markets as well as for scenario analysis of uncertainties that may impact the revenue forecasts.

Step 2: *Coal Retirement Impact*
The higher capacity prices from Step 1 are input into Navigant's Coal Retirement and Retrofit Model (CRRM) to forecast whether any retirement decisions are changed by removing emergency generators. The CRRM estimates the total coal fired capacity in danger of retirement due to economics and identifies the specific units and plants most at risk of retirement. The tool reviews the forecast balance sheet of all existing coal units, the existing emissions equipment, and retrofit costs in order to determine which units are economic to retrofit with pollution control technology and which should be retired. The retirement or retrofit decision is based on the economics of each individual coal plant and the costs of retrofit equipment. The CRRM summarizes the coal retirements and retrofits by state, ISO, and NERC region, and reports the retirements and retrofits as announced or economically driven. The tool identifies the coal that can "un-retire" due to higher capacity prices.

Step 3: *System Operation Impact*
The change in PJM system operations including both the change in generation and the change in emissions is simulated using Navigant's Portfolio Optimization Model (POM). The outputs of this model provide the final estimates of the emissions impact from the PJM replacement capacity. POM is a capacity expansion model that is designed to analyze the impacts of environmental policies and renewable generation, while being suitable for risk analysis. It simultaneously performs least-cost optimization of the electric power system expansion and dispatch in multi-decade time horizons.

2.2 ASSUMPTIONS

The basis for this analysis is the set of assumptions that define Navigant's Base case forecast of PJM markets. This forecast considers regulations, load growth, current capacity mix, expected retirements, and new capacity to model PJM wholesale markets and system operation. The following provides the key assumptions and sources.

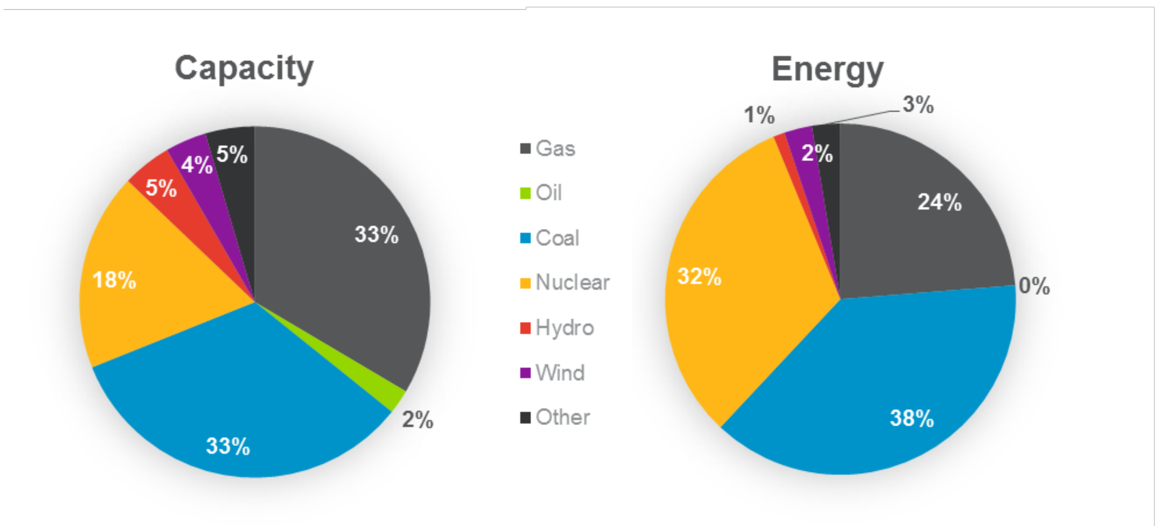
[13] EPA AP-42, Fifth Edition, Compilation of Air Pollutant Emission Factors

2.2.1 Load and Generation Mix

2.2.1.1 Current Mix

PJM's generation portfolio is diverse but relies heavily on coal and nuclear resources for baseload energy and natural gas resources for peaking capacity, as can be seen in Figure 2. Natural-gas-fired power plants, which are generally located in eastern PJM and near metropolitan areas, account for about 33% of PJM installed capacity but only about 24% of energy. Nuclear generation, on the other hand, accounts for only 18% of capacity, but produces 32% of the energy. Coal generation, which is mainly located in western PJM, is equivalent to nuclear for capacity (33%) and leads in energy production (38%).[14]

Figure 2. PJM 2016 Summer Capacity and Energy by Fuel Type



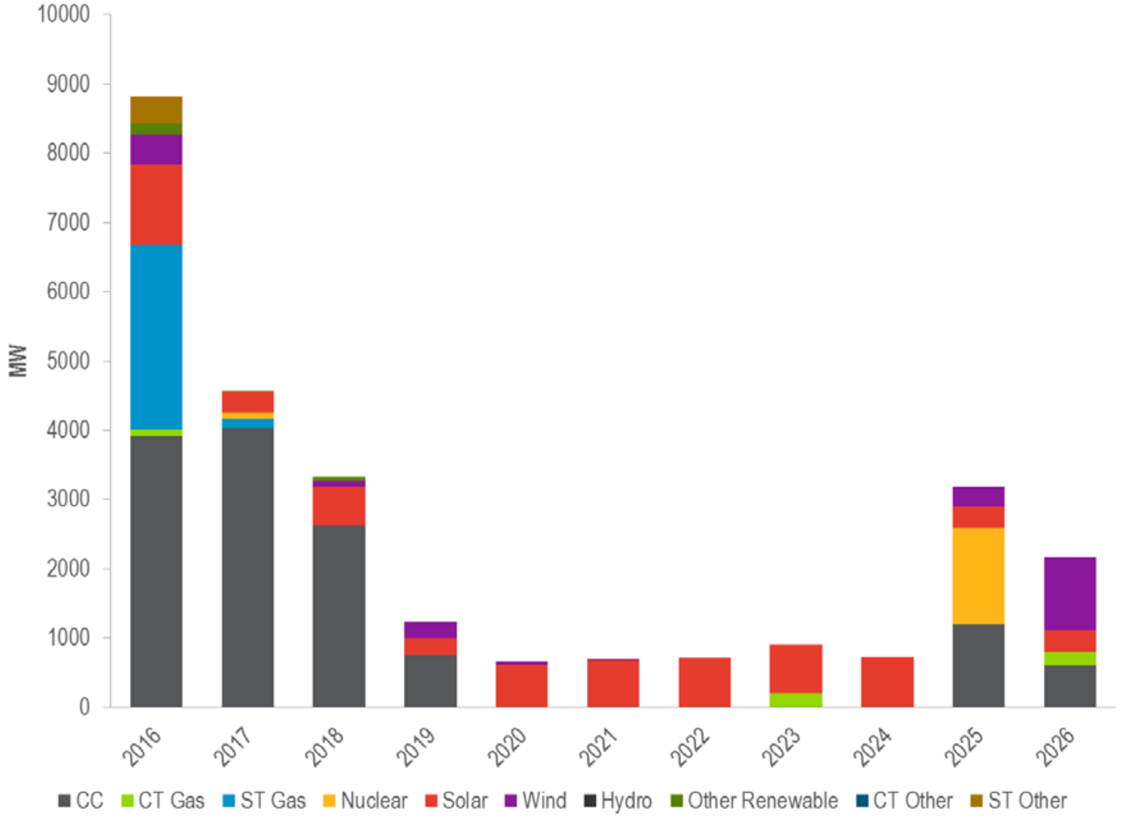
Source: Navigant Base Case, October 2015

2.2.1.2 New Capacity

Navigant's forecast includes existing and forecasted generation that is grid-connected. Figure 3 shows the capacity additions in PJM throughout the study period. The combined cycle (CCs) included in the early years of the expansion plan are named new projects that have cleared in the capacity market. However, the market is currently overbuilt and there is little need for new capacity other than renewables in the mid-term. The renewable additions are needed to meet state Renewable Portfolio Standards (RPS). This capacity includes existing generation, new named projects, demand-side resources, imports, and generic capacity construction assumed by Navigant.

[14] The source of the unit information in the Navigant Base case is the Ventyx database for PROMOD with scrubbing of the dataset by Navigant to fix errors.

Figure 3. Capacity Additions by Type by Year in PJM



Source: Navigant Base Case, October 2015

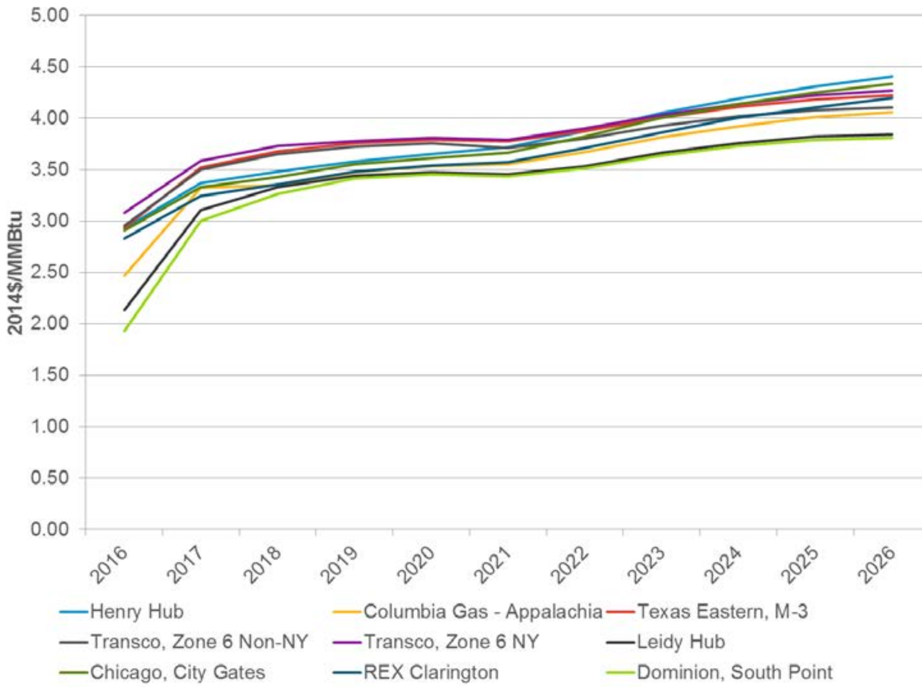
2.2.1.3 Demand

The peak demand and energy forecasts for PJM are taken from the 2015 PJM Load and Capacity Report.

2.2.2 Fuel Price Forecasts

Navigant's Fall 2015 Base Case natural gas forecast, which was adjusted for forward prices through 2016, was used in this analysis and is shown in Figure 4. Annual prices are expected to increase in the short term as demand increases, though current supplies and shale gas keeps prices relatively flat in the 2017 to 2021 timeframe. In 2022 and beyond annual prices in PJM are expected to follow national trends by increasing steadily.

Figure 4. Annual Natural Gas Prices (2014$)



Source: Navigant Base Case, October 2015

Figure 5 shows forecast capacity-weighted coal prices in PJM. Overall, PJM coal prices have slight real escalation driven by global demand, despite decreases in North American coal consumption due to retirements in coal generation.

Figure 5. PJM Annual Capacity-Weighted Coal Prices (2014$)

Source: Navigant Base Case, October 2015

2.2.3 Clean Power Plan Assumptions

The EPA finalized the Clean Power Plan (CPP) in 2015. This CPP regulates CO_2 emissions from existing fossil-fuel power plants under the Clean Air Act.[15] The plan sets state-level emissions reduction goals that result in a 32% reduction in CO_2 emissions nation-wide over 2005 levels by 2030. States must demonstrate compliance with interim reduction goals from 2022-2029. States will determine how to best meet emissions reductions goals through implementation of state plans. Compliance mechanisms could include improving heat rates at older fossil-fired plants, replacing older coal-fired plants with natural gas, increasing renewable penetration, and demand side management measures including energy efficiency and demand response. States can implement plans to meet either a rate-based goal (in lbs/MWh) or a mass-based goal (in tons/year), and can include language from the EPA's proposed model rule to opt-in to trading regimes with other states that are implementing plans under the same regime (i.e. rate states can trade with rate states, mass states can trade with mass states).

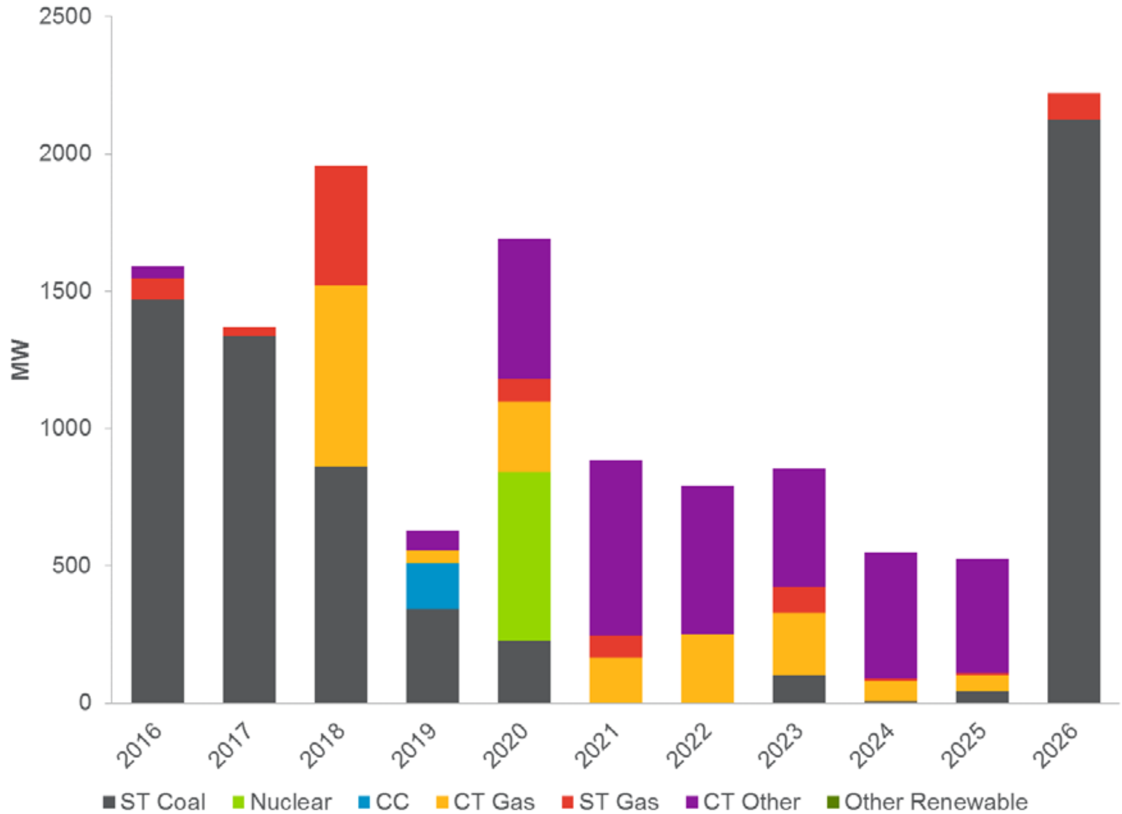
Navigant's Base case assumption on CPP implementation is a regional mass-based cap-and-trade system. The Base case also includes RGGI carbon prices prior to 2022 for Delaware, Maryland, and Washington, DC.

2.2.4 Coal Retirements

A key input for this analysis is which coal units are retiring in PJM and why. The issue with removing emergency generators from the system is that coal plants which are marginal and considering retirement will be directly impacted by increased capacity prices due to the removal of the emergency generators, which may alter the retirement decision of those coal plants. Figure 6 shows Navigant's forecast of coal retirements in the Base case (without removing emergency generators). The majority of assumed retirements in PJM are near-term announced retirements of coal-fired power plants. In addition to announced retirements, economic retirements projected by Navigant's detailed analysis are included in these forecasts. These economic retirements are driven by a combination of competition from low natural gas prices and added costs from environmental regulations (primarily the Mercury and Air Toxics Standards and the CPP).

[15] The Supreme Court issued a stay of the CPP in February 2015 until all appeals to the Supreme Court are exhausted. This has the potential to delay planning and implementation of the CPP, though exact timeframes are yet unknown. A decision by the DC Circuit Court is expected by the end of 2017.

Figure 6. PJM Retirements by Type by Year



Source: Navigant Base Case, October 2015

2.2.5 Emissions Factors

This study considers ten different pollutant emissions due to combustion of coal, gas, oil, and diesel. The emission rates provided by the EPA are reported in Table 6. For the purposes of this analysis, emission factors for oil represent internal combustion engines greater than 600 horsepower. Diesel is representative of PJM's emergency generator use – assumed to be diesel internal combustion engines with a mix of 25% less than 600 horsepower and 75% greater than 600 horsepower.

CO_2, NO_x, and SO_2 emissions rates per MMBtu of fuel combustion are unit specific in Navigant's Base case. For calculation of emissions from emergency and substitute generation the EPA's emission rates based on unit fuel type and engine size are used for these pollutants as the analysis does not identify the specific units that will be called upon during emergency events.

Table 6. Emissions Factors (lb/MMBtu)

Pollutant (lb/MMBtu)	Coal	Natural Gas	Oil	Diesel
CO2	-	110.0	165.0	164.8
SOx	-	0.0034	0.0015	0.0736
NOx	-	0.3200	3.2000	3.5025
CO	0.1923	0.0820	0.8500	0.8750
Filterable PM	2.5385	0.0019	0.0620	0.0620
Filterable PM10	0.5077	0.0066	0.0573	0.1205
Benzene	5.00E-05	1.20E-05	7.76E-04	8.15E-04
Formaldehyde	9.23E-06	7.10E-04	7.89E-05	3.54E-04
Toluene	9.23E-06	1.30E-04	2.81E-04	3.13E-04
Mercury	3.19E-06	0.00E+00	0.00E+00	0.00E+00

Source: Environmental Protection Agency AP 42, Fifth Edition

2.2.6 Emergency Generator Usage during Emergency Events

There are currently 1,750 MW of emergency generators in the PJM market that is at risk of being excluded. Table 7 shows that over 90% of this is fueled by petroleum products with the remainder largely fueled by natural gas. These analyses forecast market impacts under the assumption that this generation is excluded from the market. The emissions from emergency generators are calculated using the fuel mix in Table 7.

Table 7. Existing Emergency Generators

Fuel	Emergency Generation (MW)
Coal	0
Diesel	1,610
Gasoline	9
Natural Gas	117
Oil	12
Propane	0
Waste Products	2
Total	**1,751**

Source: PJM

Emergency generator capacity is combined with duration data from 2010 through 2014 to calculate the annual generation from these units which is reported in Table 8. Annual fuel consumption and emissions from both emergency generator and substitute generation are calculated using these annual operating assumptions. Each emergency generator has been dispatched an average of 7.4 hours per year.

Table 8. Annual Emergency Generator Usage (MWh)

	Emergency Generation (MWh)
2010	6,723
2011	12,981
2012	3,266
2013	10,004
2014	31,563

Source PJM

Annual fuel combustion for emergency generator and substitute generation is derived using the generator heat rates provided by Energy Velocity in Table 9 below. The values are based on the top 50% of all unit heat rates for each category (in PJM). Emissions for emergency generator and substitute generation are calculated from annual fuel combustion[16].

Table 9. Substitute Generator Heat Rates (MMBtu/MWh)

	Heat Rate (MMBtu/MWh)
Diesel	10.0
Gas	13.4
Oil	14.7

Source: Energy Velocity and Diesel Service and Supply

[16] www.dieselserviceandsupply.com

3. RESULTS

3.1 EMISSIONS DURING EMERGENCY EVENTS

3.1.1 Substitute Generation

Emergency generators in PJM are called upon in times during which the system is severely constrained. These events correlate with periods of very high demand, or a large number of forced outages by base load and marginal units. Unlike other generating resources which are dispatched based on economic merit in order of low to high variable cost of operation, emergency generators do not participate in the energy market and do not have a must offer requirement. These units are strictly a resource of last resort, dispatched for system emergencies.

When emergency generators are removed from the market, PJM's capacity procurement mechanisms will ensure that sufficient capacity is available for emergencies. The result is that a different set of units will now be the last resort generation during system emergency periods. Due to the extremely high pricing that occurs during these events it is reasonable to assume that all combined cycle, renewable, and relatively efficient steam-coal units available to meet the system demand will already have been dispatched. A number of combustion turbines are also likely to have been dispatched, leaving older gas and oil-fired combustion turbines and steam units to fulfill the need.

Corresponding day-ahead and real-time prices indicate that during each emergency event in the PJM market between 2010 and 2014 the marginal units that will be called upon to replace emergency generators are gas and oil-fired peaker plants. A conservative mix of 50% gas and 50% oil combustion turbines was assumed for emissions calculations. In assessing the robustness of results, sensitivity analysis is conducted around the number of hours that emergency generators are called.

The intuitive emission impacts from the removal of emergency generators stems from the emission differences between emergency generators and the substitute oil and gas-fired combustion turbines. Minimum runtime considerations for substitute generation were also taken into account but did not impact the analysis as the duration of emergency events exceeded min-run time constraints on combustion turbines, however operating constraints remain a valid consideration for future events that may be called for shorter durations.

3.1.2 Emission Changes

Excluding emergency generators from the market and calling on marginal oil and gas units results in an increase in carbon and formaldehyde emissions but a decrease in emissions of the remaining eight pollutants examined in this analysis. This is the intuitive result based solely on differences in emissions signatures of emergency engines versus marginal oil and gas units. We found that there were no material differences in run-time limits, general efficiencies or emissions levels.

The emissions changes are impacted by the emissions rates of the emergency generators compared to those of the substitute oil and gas combustion turbines.

The 1,750 MW of emergency generator capacity was distributed across PJM in proportion to each zone's 2014 peak demand for this analysis, providing zonal emergency generating capacity. Annual usage of emergency generators, reported in Table 8, was calculated from the zonal capacity assumptions and 2010 to 2014 event location and duration data.

Fuel consumption from emergency generators is calculated based on the mix of emergency generators in Table 7 and the generator heat rates in Table 9. Emissions of the ten pollutants considered in this analysis are calculated using the EPA emissions factors in Table 6.

Substitute generation emissions are calculated as a conservative mix of 50% gas-fired and 50% oil-fired combustion turbines with heat rates found in Table 9 and emission factors in Table 6. These heat rates coincide with the top half of heat rates by technology type, again, a conservative approach. Historical emissions from emergency generators (EG) and the assumed substitute generation (SG) mix are reported in Table 10 and Table 11. The five year averages and percent change in emissions from emergency to replacement generation are also reported. Note that emissions are reported as short tons.

Table 10. CO_2 and Criteria Emissions Impacts due to Substitute Generation (*in Tons*)

	CO2		SO2		NOx		CO		Filterable PM		Filterable PM10	
	EG	SG	EG	SG	EG	SG	EG	SG	EG	SG	EG	SG
2010	5,510	6,554	2.30	0.11	111	86	28	23	1.95	1.57	3.79	1.56
2011	10,640	12,655	4.44	0.22	214	167	54	44	3.77	3.04	7.31	3.02
2012	2,677	3,184	1.12	0.06	54	42	13	11	0.95	0.76	1.84	0.76
2013	8,200	9,753	3.42	0.17	165	128	41	34	2.91	2.34	5.63	2.33
2014	25,869	30,770	10.80	0.54	521	405	130	107	9.18	7.39	17.77	7.34
Average	10,579	12,583	4	0	213	166	53	44	3.75	3.02	7.27	3.00
% Change	19%		-95%		-22%		-18%		-19%		-59%	

Source: Navigant

Table 11. Hazardous Air Emissions Impacts due to Substitute Generation (*in Tons*)

	Benzene		Formaldehyde		Toluene		Mercury	
	EG	SG	EG	SG	EG	SG	EG	SG
2010	0.03	0.02	0.01	0.02	0.01	0.01	0	0
2011	0.05	0.04	0.03	0.03	0.02	0.02	0	0
2012	0.01	0.01	0.01	0.01	0.00	0.00	0	0
2013	0.04	0.03	0.02	0.03	0.02	0.01	0	0
2014	0.12	0.09	0.06	0.08	0.05	0.05	0	0
Average	0.05	0.04	0.03	0.03	0.02	0.02	0	0
% Change	-24%		36%		-3%			

Source: Navigant

3.2 EMISSIONS FROM DAY-TO-DAY SYSTEM OPERATION

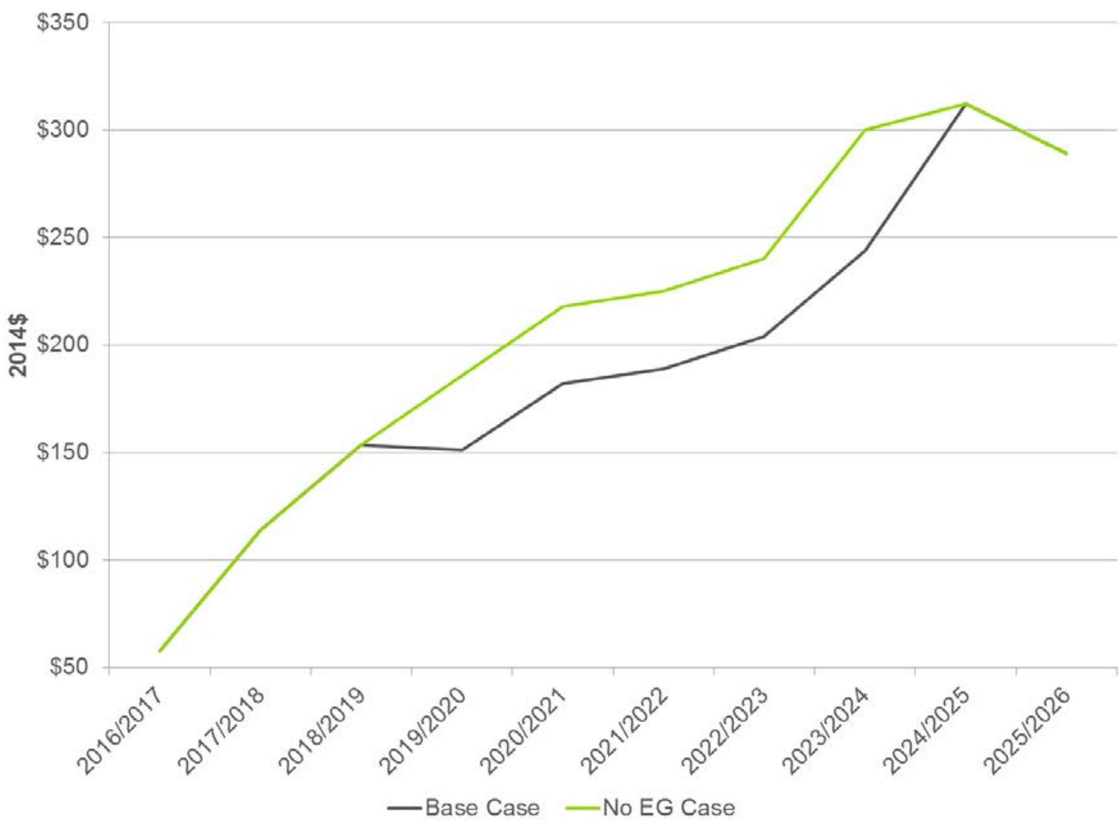
3.2.1 Capacity Price Changes and Resulting Replacement Capacity

Decisions to retire existing capacity and to build new capacity in PJM are largely driven by the capacity market prices. This analysis modeled the impact that retiring 1,750 MW of emergency generators has on capacity prices. Capacity market prices are set at the intersection of the demand curve for capacity that is administratively determined by the ISO and the supply curve for capacity which is defined by the offers to sell capacity of market participants. When emergency generators are removed from the market, prices rise, marginal existing resources may stay in the market, new capacity may be incentivized, or total capacity procured by the ISO might be reduced as defined by the slope in the ISO demand curve.

One of the parameters in the capacity market is the net Cost of New Entry (CONE). CONE is reported by PJM as their estimate of the capacity market price that a new merchant generation facility would require in order to be constructed. This value for the 2018/2019 PJM auction was $300.57/MW-day[17]. As new units would be expected to be built if the prices reached this level, it can be considered as a rough ceiling on prices.

Navigant used the Capacity Market Model to forecast PJM capacity prices in the Base case and then alternatively in the case with 1,750 MW of emergency generator capacity removed from the market without any replacement. The increase in prices is about $35/MW-day starting in 2019/2020 (the next auction to be held) through 2024/2025 (when the prices reach net CONE in the Base case and new gas units are expected to be required). That increase would drive additional annual revenue of over $6 million for a 500 MW power plant. This increase in prices provides incentive for existing units that are being considered for retirement (i.e., on the margin with respect to economics) to remain in the market.[18]

Figure 7. PJM Capacity Prices (2014$/MW-day)



[17] 2018/2019 RPM Base Residual Auction Planning Period Parameters, http://www.pjm.com/~/media/markets-ops/rpm/rpm-auction-info/2018-2019-planning-parameters-report.ashx.

[18] PJM operations calls for an upward sloping demand curve be used for pricing above the target reserve margin to recognize the fact that there is additional value for capacity above the target reserve margin, i.e., the value of capacity does not fall to zero right at the target reserve margin. As a result, not all of the 1,750 MW of capacity would be expected to be replaced or else prices would fall back to the Base case level and there would be no incentive for marginal units to stay in the market.

Source: Navigant

Navigant forecasts coal units to retire or retrofit to gas burning based on utility announcements and economics using the CRRM. Some units will retire regardless of the level of capacity prices. Announced retirements are not necessarily final for marginal units. For example, NRG has stated with respect to its decision to retire Will County:

> *"After analyzing forecast market conditions, NRG has determined that we can't justify continued operation of Will County Unit 4 and meet those goals beyond May 2018." "However, it's important to note that we can withdraw the notice and bid into the auction if conditions change in the market," emphasized Gaier. Currently, NRG plans to deactivate the unit by mid-2018, he said.*[19]

3.2.2 Plant Retirement Scenarios

The coal retirement decision is complex and this analysis focuses on marginal units that have economics close to the decision of whether or not to retire or retrofit. There is uncertainty in the results but due to the amount of PJM coal capacity that is retiring, there are multiple units that could ultimately not be retired due to a material increase in capacity prices. To address this and to show the impacts of different levels of capacity changes in PJM, this analysis considers a Low case forecast of coal retirement changes and a High case forecast of coal retirements together with retrofitting coal units to burn gas, and compares these two cases against the Base case which assumes the status quo with emergency generators in the market and no changes to coal retirements., The results of the analysis of marginal coal units and potential changes to their retirement decisions are shown in Table 12.

Table 12. Coal Retirement Change Results

Category	Base Case	Low Case	High Case
Coal Unretired (MW)	0	520	625
Coal to Gas Conversion (MW)	0	0	385

Source: Navigant

3.2.3 System Operation Changes

The analysis uses the POM model to simulate the operation of PJM from 2016 through 2026 under these three sets of assumptions. POM simulates the operation of the system over the entire study period including the impacts that the generation from the unretired capacity has to reduce the generation of other units. The coal units whose retirement decisions are changed are marginal units economically (including all fixed operating costs) but given that they are operating, the model shows them still having a 30% to 50% capacity factor as energy dispatch decisions are made on a marginal cost basis.

3.2.4 Emission Changes

Total emissions from day to day system operations from the three cases over the time period for all pollutants are shown in Table 13. The values are given in short tons to be easily comparable to the emission impact of the first component of the analyses in Section 3.1 above. For CO_2, SO_2, NO_x, CO, PM, benzene, and mercury, the removal of the emergency generators from the market and increase in coal units causes emissions to increase. The only pollutants whose emissions decrease are formaldehyde and toluene.

[19] "NRG set to close Illinois coal plant unless markets change", SNL, December 09, 2015.

The primary result is that the emissions impact of replacement capacity remaining in the market is orders of magnitude larger than the impact of substitute generation operating during emergencies.

Table 13. Total Emissions by Case (*in Tons*)

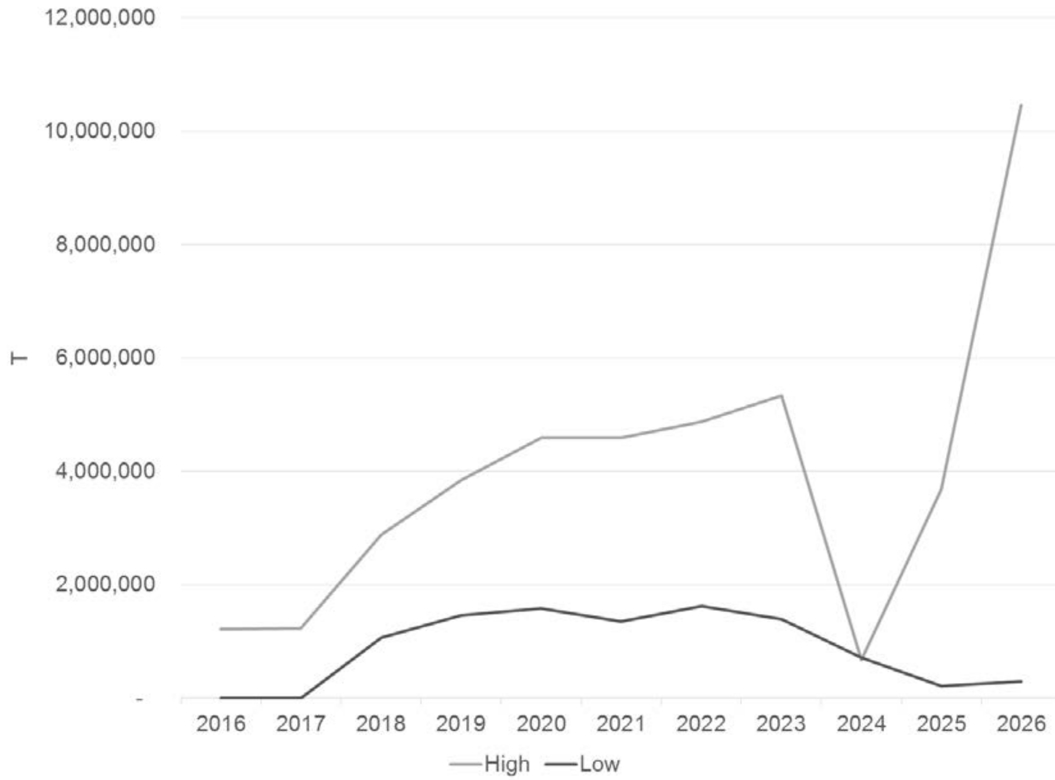
Pollutant	Total Emissions			Emissions Change	
	Baseline	Low Unretirements	High Unretirements	Low Unretirements	High Unretirements
CO2	4,545,103,227	4,554,808,558	4,588,519,292	9,705,331	43,416,064
SO2	4,350,077	4,377,419	5,022,986	27,342	672,909
NOx	3,275,223	3,277,111	3,358,017	1,888	82,794
CO	3,985,286	3,994,272	4,031,156	8,985	45,869
Filterable PM	43,449,693	43,580,970	44,281,528	131,277	831,835
Filterable PM10	8,742,646	8,768,829	8,907,710	26,182	165,064
Benzene	957	960	971	2	14
Formaldehyde	6,174	6,167	6,029	-8	-146
Toluene	1,260	1,259	1,235	-1	-24
Mercury	55	55	56	0	1

Source: Navigant

Annual CO_2 emissions increases by coal retirement scenario and year are shown in Figure 8. The key result shows that emissions are increased in both the Low Un-retirement Case and High Un-retirement Case when emergency generators are removed from the system.[20]

[20] The drop in 2024 emissions changes in the High case is due to the values being the difference between total emissions in this case and the Base case. In both cases, overall CO_2 emissions are dropping and in the Base case there is a faster drop in 2024 and slower in 2025 while in the High case the emissions drop at a more constant rate.

Figure 8. PJM CO_2 Emissions Changes (*in Tons*)



Source: Navigant

The average change in emissions per year is given in Table 14**.** For comparison, the emission changes from replacement generation are given in the table and illustrate the order of magnitude difference in the impacts. The annual averages show the impact of coal retirements that are deferred for a few years instead of having the units operate throughout the forecast period.

Table 14. Average Change in Emissions/Year (*in Tons*)

Pollutant	Average Emissions Change/Year Low Unretirements	High Unretirements	Replacement Generation
CO2	882,303	3,946,915	2,004
SO2	2,486	61,174	-4
NOx	172	7,527	-47
CO	817	4,170	-9
Filterable PM	11,934	75,621	-1
Filterable PM10	2,380	15,006	-4
Benzene	0.2	1.3	0.0
Formaldehyde	-0.7	-13.2	0.0
Toluene	-0.1	-2.2	0.0
Mercury	0.0	0.1	0.0

Source: Navigant

3.3 SENSITIVITY TO ASSUMPTIONS

This section examines the sensitivity of the results. Five sensitivities are examined: 1) even fewer coal retirements than the Low case, 2) emergency generators operating hours, 3) reduced PJM load, 4) reduced emergency generators efficiency, and 5) coal plants retiring prior to 2026 regardless of the capacity prices. **The conclusion of each of these sensitivities is that the directionality of increased emissions due to the removal of emergency generators from PJM is not impacted.**

3.3.1 Sensitivity 1: Only 100 MW Coal Unretired

One key sensitivity is how the results would change if the coal units that change their retirement decision are small. To test this, POM was run assuming that 3 small coal plants, with a capacity of approximately 100 MW total, change their retirement decision. This is a conservative case as these small units tend to have low capacity factors due to inefficiency. The three units in this case were operating as peakers with an average capacity factor of ~5% over the study period.

The results of this sensitivity are shown in Table 15. The emissions impact under these assumptions is still significant and larger than the emissions during emergency events shown above in Section 3.1. **The implication is that the directionality of the results is clearly to increase emissions even if a small amount of coal capacity un-retires when emergency generators are removed from the market.**

Table 15. Emissions Impact if 100 MW Coal Un-retires (*in Tons*)

Pollutant	Baseline	100MW Coal	Emissions Change
CO2	4,545,103,227	4,545,438,619	335,391
SO2	4,350,077	4,351,112	1,035
NOx	3,275,223	3,275,434	211
CO	3,985,286	3,985,619	333
Filterable PM	43,449,693	43,454,921	5,228
Filterable PM10	8,742,646	8,743,687	1,041
Benzene	957.20	957.29	0.09
Formaldehyde	6,174.43	6,173.90	-0.53
Toluene	1,259.55	1,259.47	-0.08
Mercury	54.62	54.63	0.01

Source: Navigant

3.3.2 Sensitivity 2: Emergency Generators Operate 100 Hours per Year

Historically, emergency generators have only operated an average of 7.4 hours per year but these resources are able to legally operate 100 hours per year (conservatively assuming that there is zero runtime for testing and maintenance). Table 16 shows the annual change in emissions if emergency generators are removed from PJM but there are 100 hours of system emergency when they would be called. Even in this extreme scenario, the reductions in NO_x, SO_2, CO, PM, and benzene are all smaller than the annual increases shown in Table 14 from considerations of day-to-day operations of the regional capacity mix due to unretired coal.

Table 16. Annual Emissions Change Assuming 100 hours Emergency Operation (*in Tons*)

Pollutant	Emissions Change
CO2	27,082
SO2	-57
NOx	-641
CO	-127
Filterable PM	-10
Filterable PM10	-58
Benzene	0
Formaldehyde	0
Toluene	0.0
Mercury	0.0

Source: Navigant

3.3.3 Sensitivity 3: PJM Reduced Load Forecast

PJM has been working to update their load forecasting model and the updated forecasts tend to result in lower load than was previously used to procure capacity in the capacity market. The impact of this, all things equal, would be to lower capacity prices from the Navigant Base case.

The estimated increase in capacity prices due to the removal of the emergency generators remains broadly applicable with lower capacity prices. There are a large number of coal units in PJM planning or considering retirement and capacity prices factor heavily into their decision. There are coal units in PJM that may not have considered retirement at Navigant Base case capacity prices that would be marginal under the lower prices. Removing the emergency generators and raising capacity prices would impact their decision. A large amount of coal is slated to retire, and some of these units will always be on the margin when making a retirement decision. The test of 100 MW of coal un-retiring shows that any coal that changes their retirement decision will have an impact on emissions.

3.3.4 Sensitivity 4: Less Efficient Emergency Generators

The heat rate of emergency generators, given in Table 9, is derived from heat rates reported by sellers of the generators. The impacts of coal un-retiring are orders of magnitude higher for all the pollutants than the change from emissions during emergencies even if the emergency generators are 20% less efficient than reported.

3.3.5 Sensitivity 5: CPP or Fuel Prices Cause Coal to Retire Before 2026 Anyways

The current wave of coal retirements is caused by low natural gas prices, environmental regulations, and anticipation of the impacts of the CPP. The economics of coal units could be impacted prior to 2026 if natural gas prices continue to stay as low as they are currently or state implementation of the CPP penalizes coal units more than expected. One possibility is that higher capacity prices would keep marginal coal units online for a few years, pushing back retirement. The directionality of the emission impact would be the same. The increase in annual emissions that would result from removing emergency generators, shown in Table 14, are significantly higher than the total emissions changes during emergency event periods. Keeping coal units online for an additional 1 or 2 years would result in an increase in lifetime emissions.

4. CONCLUSIONS

4.1 TOTAL EMISSION CHANGES

The total emission changes from removing emergency generators from PJM are the sum of the impacts of using substitute generation during emergencies and keeping un-retired coal capacity operating in the energy market.

The emission impacts from the substitute generation (Component 1 of this Study) range from increases in thousands of tons of CO_2 emissions to negligible changes to other pollutants. These only occur if there is a system emergency and the grid operator calls on these emergency resources.

The un-retirement of coal (Component 2 of this Study) results in increases of millions of tons of CO_2; thousands of tons of SO_2, NO_x, CO, and PM; and few tons or less of benzene and mercury per year even in the low un-retirement case. A slight decrease of formaldehyde and toluene is observed with the removal of emergency generators due to the high relative emissions of these by the engines.

The net emissions from both impacts over the 2016 – 2026 study period are shown in Table 17.

Table 17. Net Emissions from Removal of Emergency Generators (*in Tons*)

Pollutant	Baseline Emissions from Emergency Generators	Emissions Change from Substitute Generation	Emissions Change in Low Unretirement Case	Net Emissions from Removal of Emergency Generators
CO2	116,369	22,045	9,705,331	**9,727,376**
SO2	49	-46	27,342	**27,296**
NOx	2,344	-522	1,888	**1,366**
CO	586	-103	8,985	**8,882**
Filterable PM	41	-8	131,277	**131,269**
Filterable PM10	80	-47	26,182	**26,136**
Benzene	0.54	-0.13	2.4	**2.3**
Formaldehyde	0.28	0.10	-7.8	**-7.7**
Toluene	0.22	-0.01	-1.0	**-1.1**
Mercury	0.00	0.00	0.2	**0.2**

Source: Navigant

These analyses used the outputs of Navigant's market models to forecast several estimates of the generation mix impacts due to removing emergency generators from the system. The results in both the low coal un-retirement case and the high coal un-retirement case show increases in emissions. Further tests were completed as sensitivities on key analysis parameters and these also show increases in emissions if emergency generators are excluded from the market. **The overall conclusion is that increased emissions will occur in the market without emergency generators.**

4.2 POTENTIAL APPLICABILITY TO OTHER REGIONS

The PJM region was used for this study due to its size, and the availability and quality of data. The study results can be applied to other regions and would be adjusted according to the regional resource mix.

The emission impact of substitute generation is broadly applicable across the country since a mix of oil and gas peakers would provide the substitute generation in any region. The emission impact of un-retiring coal can be applied to regions with significant coal generation and expected retirements. These regions include MISO, SPP, ERCOT, SERC, and parts of WECC. In all of these regions, it can be expected the removing emergency generators is likely to increase most emissions due to coal staying online.

Regions without significant coal generation would be expected to replace the emergency engine capacity with gas units, so the emissions impacts would be different. These regions include ISO-NE, NYISO, California, and NWPP.

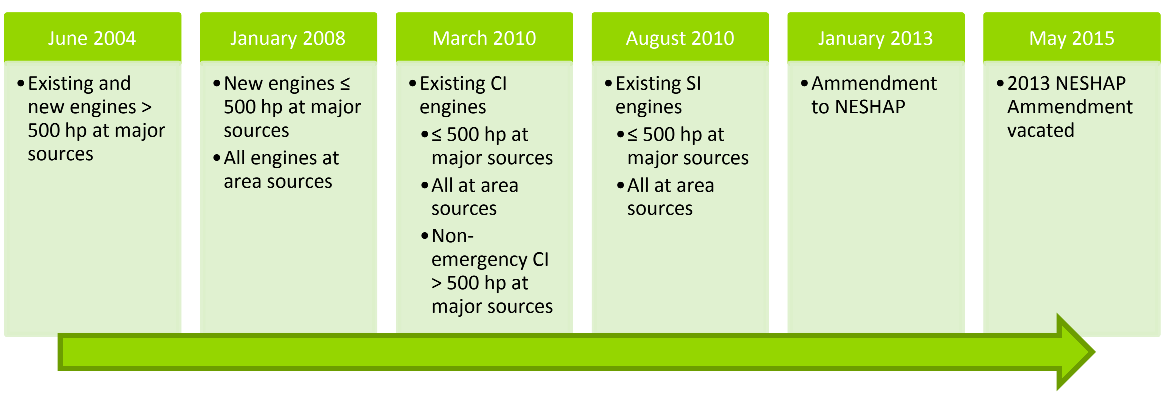
The results from substitute generation during emergency events show that the overall changes in emissions from removing emergency generators is small and slightly positive for CO_2 and slightly negative for the other pollutants. In ISO-NE and NYISO, the proportion of replacement generation that is oil fired compared to gas fired is likely to be higher than 50/50 so the estimate of the emission impact during emergencies is conservative for those two regions.

APPENDIX 1: POLICY BACKGROUND

A snapshot of the relevant regulatory actions related to the RICE and NESHAP rules is shown in Figure 9.

The EPA first finalized the RICE NESHAP in 2004 and amended it in 2008. Under both of these iterations the regulation did not apply to existing emergency generators at area HAP sources or engines that are less than 500 hp and located at major HAP sources[21]. The EPA first included existing emergency generators in the NESHAP in 2010 and proposed limiting testing and maintenance to 100 hours per calendar year, of which 15 hours could be used for emergency demand response. Industry stakeholders petitioned EPA with concerns that this would prevent RICE from participating in emergency demand response programs because most required availability of more than 15 hours per year. The EPA reconsidered this aspect of the rule, opening up a comment period in 2012 following the release of their proposed revision. The final rule released in January 2013 amended the initial rule by expanding the 100 hour per year limit for testing and maintenance to also allow emergency generation use, which is defined as North American Electric Reliability Corporation (NERC) Energy Emergency Alert (EEA) Level 2 situations and situations when there is at least a 5% or greater change in frequency or voltage. The January 2013 amendments also allow for up to 50 hours per year when dispatched by the local transmission and distribution system operator to mitigate local transmission and/or distribution limitations in order to prevent the interruption of power supply in a local area or region. At the same time, the EPA modified the NSPS to include the same emergency and transmission emergency generation limits for RICE. In May 2015 the DC Court of Appeals vacated the EPA's provision to limit emergency engines that participate in emergency demand response programs to operating for 100 hours without meeting more stringent requirements.

Figure 9. Timeline of RICE NESHAP Applicability



Source: EPA

The RICE rule applies to engines that are:

- Located at major or area sources of HAPs
- Used for local reliability and/or obligated to run at least 15 hours per year.

[21] Major sources are sources that emit 10 short tons or more annually of a single HAP or 25 short tons or more annually of a mixture of HAPs. Area sources are other sources that do not fall into the major sources category.

NAVIGANT

The emission standards under the RICE NESHAP vary by engine type and size (by horsepower), age, and source type (major or area), and are shown in Figure 10, Figure 11, and Figure 12. The EPA uses CO as an appropriate surrogate for HAPs, so most of the standards are for CO emissions. The divide between existing and new is December 19, 2002 for engines >500 hp at major sources and June 12, 2006 for engines ≤500 hp at major sources and all engines at area sources. The NSPS regulates CI engines by tier classifications (e.g., the higher the tier, the cleaner the engine) and SI engines by emission limits.

Figure 10. Standards for Existing Engines at Major Sources

HP	Engine Subcategory					
	Non-emergency					Emergency
	CI	SI 2SLB	SI 4SLB	SI 4SRB	SI LFG/DG	
<100	Change oil and filter and inspect air cleaner (CI) or spark plugs (SI) every 1,000 hours of operation or annually; inspect hoses and belts every 500 hours of operation or annually					Change oil/filter & inspect hoses/belts every 500 hours or annually; inspect air cleaner (CI) or spark plugs (SI) every 1,000 hours or annually
100-300	230 ppm CO	225 ppm CO	47 ppm CO	10.3 ppm CH_2O	177 ppm CO	
300-500	49 ppm CO or 70% CO reduction					
>500	23 ppm CO or 70% CO reduction	No standards	No standards	350 ppb CH_2O or 76% CH_2O reduction	No standards	No standards

Source: EPA

Figure 11. Standards for Existing Engines at Area Sources

HP	Engine Subcategory					
	Non-emergency					Emergency or Black start
	CI	SI 2SLB	SI 4S in remote areas	SI 4S not in remote areas	SI LFG/DG	
≤300	Change oil/filter & inspect air cleaner every 1,000 hours or annually; inspect hoses/belts every 500 hours or annually	Change oil/filter, inspect spark plugs, & inspect hoses/ belts every 4,320 hours or annually	Change oil/ filter, inspect spark plugs, & inspect hoses/belts every 1,440 hours of operation or annually	Change oil/ filter, inspect spark plugs, & inspect hoses/belts every 1,440 hours of operation or annually	Change oil/ filter, inspect spark plugs, & inspect hoses/ belts every 1,440 hours of operation or annually	Change oil/filter & inspect hoses/ belts every 500 hours or annually; inspect air cleaner (CI) or spark plugs (SI) every 1,000 hours or annually
300-500	49 ppm CO or 70% CO reduction					
>500	23 ppm CO or 70% CO reduction		Change oil/ filter, inspect spark plugs, & inspect hoses/belts every 2,160 hours of operation or annually	If engine used >24 hrs/yr: 4SLB: Install oxidation catalyst 4SRB: Install NSCR		33

Source: EPA

Figure 12. Standards for New Engines at Major Sources

HP	Engine Subcategory					
	Non-emergency					Emergency
	CI	SI 2SLB	SI 4SLB	SI 4SRB	SI LFG/DG	
<250	Comply with CI NSPS	Comply with SI NSPS	Comply with SI NSPS	Comply with SI NSPS	Comply with SI NSPS	Comply with CI/SI NSPS
250-500			14 ppm CH_2O or 93% CO reduction			
>500	580 ppb CH_2O or 70% CO reduction	12 ppm CH_2O or 58% CO reduction		350 ppb CH_2O or 76% CH_2O reduction	No standards	No standards

Source: EPA

APPENDIX 2: OTHER ANALYSES OF EMERGENCY GENERATORS

In August 2012, the Analysis Group published an estimate of the emission impacts of removing emergency generators from PJM. [22] The report focuses on the day-to-day operating impacts from replacing the capacity that was previously provided by the emergency generators. In the analysis, a varying proportion of emergency generators are assumed to be replaced with mix of 2/3 natural gas combined cycle units and 1/3 wind units. The resulting capacity mix is then used in an hourly simulation of the PJM market for a 10 year study period. The results show an overall decline in emissions due to the removal of the emergency generators for the specific mix of replacement capacity that is assumed.

In October 2012, NERA published a review of the Analysis Group report. [23] The review critiques the Analysis Group report for assuming the capacity that replaces the emergency generators rather than demonstrating it. The review suggests that other candidates for replacement capacity could "decrease, increase, or have little to no effect on system-wide emissions."

Navigant's analysis expands on these two analyses by considering the issue of the impact of removing emergency generators using an integrated set of models to forecast what capacity replaces the emergency generators, how that impacts day-to-day system operation, and how it impacts operation during emergency periods. In particular, Navigant's analysis is consistent with the Analysis Group paper in terms of methodology but the use of the Capacity Market Model, Coal Retirement and Retrofit Model, and the Portfolio Optimization Model expand on the understanding of what capacity is likely to replace emergency generator generation if it is removed.

[22] "Reliability and Emission Impacts of Stationary Engine-Backed Demand Response in Regional Power Markets", Analysis Group, August 2012.
[23] "Evaluation of the Calpine Report on the Reliability and Emission Impacts of RICE-Based Demand Response in PJM", NERA, October 2012.