THE Brattle GROUP

Nuclear Impact on NO_X Emissions in Designated EPA Ozone Nonattainment Areas

Dean Murphy and Mark Berkman

May 2018

The EPA's recent release of ozone air quality designations augmented its previous designation of areas that are in nonattainment for EPA's 2015 ozone NAAQS standards.[1] The air quality improvements needed in these nonattainment areas highlight the role that existing nuclear power plants play in air quality. Simply put, nuclear plants avoid air pollutants associated with fossil generation. The loss of nuclear generation increases emissions as fossil generators operate more to fill the gap. We identified and quantified this effect in several previous studies that examined the environmental impacts of nuclear plants in Ohio, Illinois, New Jersey and Pennsylvania. These studies showed that the loss of zero-emission nuclear generation would result in increased fossil generation and thus increased emissions of several pollutants, including NO_X, which is both a pollutant in its own right and a precursor for ozone. Some of the NO_X increases would occur within ozone nonattainment areas, just when states must develop plans to decrease pollutant concentrations in those areas. The loss of nuclear plants would increase the challenge and the cost of bringing nonattainment areas into compliance with air quality standards.

- **EPA's recent ozone NAAQS designations highlight the role of existing nuclear plants in mitigating air pollution.**
- **In previous studies, we found that losing nuclear plants would lead to greater fossil generation and increases in several air pollutants—including NO_X, a precursor for ozone.**
  - **The benefit of avoiding NO_X emissions is over $2,000 per ton on average, totaling about ten million dollars or more in each of the previous studies (for New Jersey, Pennsylvania, Ohio, and Illinois nuclear plants).**
- **Within EPA-designated ozone nonattainment areas in the Mid-Atlantic region, the loss of regional nuclear plants could increase NO_X emissions by 1,000 tons or more each year.**
  - **Additional NO_X increases from upwind plants may exacerbate this.**
- **At a time when states must develop plans to decrease overall emissions and pollutant concentrations in nonattainment areas, these emissions increases make it more difficult and more costly to achieve NAAQS compliance.**

---

[1] Additional Air Quality Designations for the 2015 Ozone National Ambient Air Quality Standards (NAAQS), April 30, 2018. https://www.epa.gov/ozone-designations/additional-designations-2015-ozone-standards

Our previous studies examined the environmental impacts of nuclear plants in several states, including New Jersey, Pennsylvania, Ohio and Illinois.[2] In each of these studies, we characterized the impacts of specific nuclear plants by simulating the power system first with, and then without the nuclear plants of interest. We looked at the entire Eastern Interconnection power system to capture the effects across broad interstate power markets. This allowed us to identify which alternative power plants would operate in the absence of these nuclear plants. We found in general across these studies that if several nuclear plants in a given state were to shut down, their output would be replaced almost entirely by fossil generation, mostly gas-fired with some coal-fired generation. The replacement generation would be spread across a broad geographic region and across different plants at different times, ultimately being provided by a large number of fossil plants in relatively small shares. This additional fossil generation would increase emissions of several types of pollutants (we examined CO_2, NO_X, SO_2, and particulates), in a geographic pattern that is determined by the locations of the fossil generators, how much each one would increase their output, and their emissions rates for the various pollutants. Thus those prior studies offer a "convenience sample" that can offer some general observations about the air quality impacts that could result from losing nuclear generation. Table 1 below summarizes the total state level increases in NO_X emissions found across our previous studies for several selected states, as well as estimated overall average social costs.

[2] Previous studies considered the Salem and Hope Creek plants in New Jersey; the Three Mile Island, Beaver Valley, Susquehanna, Limerick and Peach Bottom plants in Pennsylvania; the Davis-Besse and Perry plants in Ohio; and the Quad Cities and Clinton plants in Illinois. In addition to the environmental impacts, these studies also considered the impact of these nuclear plants on electricity prices and state economies (GDP and jobs); here we refer only to the environmental results. We also performed a study examining the FitzPatrick, Ginna and Nine Mile Point nuclear plants in New York; that study used a different approach that does not fully identify the location of the emissions impacts.

Table 1: Annual NO_X Emissions Impacts of Nuclear Plants (Based on Previous Studies)

State Studied	Nuclear Plants	NO_X Increase by State (Metric Tons) NJ	PA	MD	OH	IL	Other States	Total NO_X Increase	Social Cost (2018 $Millions)
		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
NJ	Salem, Hope Creek	1,637	2,519	233	359	38	1,581	6,367	13.6
PA	All 5 PA Plants (9 units)	1,616	4,136	566	974	16	4,195	11,503	24.6
OH	David-Besse, Perry	64	2,101	141	313	271	1,190	4,080	8.7
IL	Quad Cities, Clinton	20	2,917	-23	322	1,403	4,147	8,786	18.8

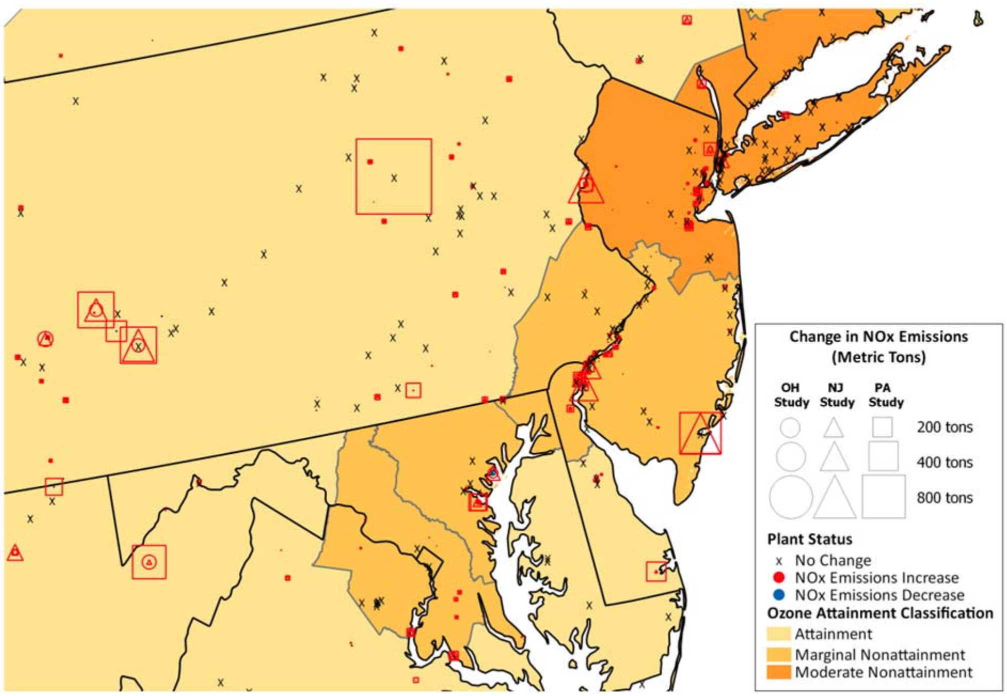
Note: The different studies reported results over different time periods: Illinois 2017-2021; New Jersey and Ohio 2018-2027; Pennsylvania 2017-2026. The values here are the averages over the time period of the original study.
[8]: The Illinois and Pennsylvania reports expressed social costs in 2016 dollars; the New Jersey report used 2017 dollars and the Ohio report used 2023 dollars. All are converted here to 2018 dollars. Average social cost of NO_X is $2,141/ton, from "Hidden Cost of Energy: Unpriced Consequences of Energy Production and Use," National Research Council, 2010.

As we noted in the previous studies, we did not account for the airborne transport of pollutants, and so these results are only indicative of the magnitude and location of the air quality challenges that might be caused by the loss of nuclear generation. Fossil generators located outside a nonattainment area can also contribute to pollutant concentrations within that area, as pollutants are transported by prevailing winds. Also, the social costs of emissions represent environmental and human health damages, with the values presented here representing averages across a wide range of conditions. The actual social cost of pollutants in any particular circumstance depends on numerous factors, including population density and exposures, environmental sensitivity, etc. Still, it is instructive to look back at the NO_X emissions impacts found in those studies and overlay them on the recently designated EPA ozone nonattainment areas, to identify whether potential nuclear shutdowns might complicate states' efforts to bring these areas into attainment. We found that this is the case. The loss of nuclear generation would produce a widespread increase in air emissions, and some of the increase in NO_X, an ozone precursor, would occur within recently designated ozone nonattainment areas.

Across the studies and the different sets of nuclear plants examined in these prior studies, we found that there could be increases of hundreds of tons or more of NO_X emissions within the ozone nonattainment areas just designated. The largest emissions impacts tend to be generally near the nuclear plants in question. Thus the loss of New Jersey nuclear plants would result in a NO_X emissions increase of over 1,600 tons annually within New Jersey, all of which is designated as an ozone nonattainment area. The loss of two northern Illinois nuclear plants would cause a 300 ton annual increase in the Illinois nonattainment areas. There can be substantial impacts across state lines as well. The loss of Pennsylvania's nuclear plants would cause over 1,000 tons of increased NO_X emissions annually within nearby New Jersey. And NO_X emissions would increase by hundreds of tons in Maryland nonattainment areas as a result of nuclear closures in New Jersey or Pennsylvania. Even the loss of two nuclear plants in Ohio would increase NO_X

emissions by over 100 tons in Maryland. As an example of the types of effects observed, Figure 1 illustrates graphically the NOx emissions impacts in the mid-Atlantic region from our studies of the impacts of nuclear plants in New Jersey, Pennsylvania, and Ohio (different marker shapes correspond to the different studies). The red markers show the location of plants whose emissions increase, with marker size corresponding to the size of the increase; ozone nonattainment areas are indicated with shading. The figure shows that the loss of nuclear plants in New Jersey, Pennsylvania or even Ohio would increase power plant NOx emissions within and near the ozone nonattainment areas in the mid-Atlantic region.

Figure 1: Representative Annual NO_X Emissions Increases with Nuclear Loss



To put these increases in context, the NOx emissions increase that would accompany the loss of the Pennsylvania or New Jersey nuclear plants in the Mid-Atlantic ozone nonattainment areas (in New Jersey, Maryland and eastern Pennsylvania) would amount to a 15-25% increase over the baseline power sector NOx emissions in these areas. Since the power sector is responsible for a modest share of total NOx emissions in these areas, this is a smaller share of total NOx emissions, of course, but could still have an impact on the strategies necessary to bring these areas into compliance.

The EPA NAAQS requirements put the responsibility on states to address pollutant concentrations in nonattainment areas, taking account of emissions from all sources. Some of the strategies available to state departments of environmental protection include requiring additional emissions controls on power plants or restricting the operation of generators whose emissions affect nonattainment areas. Similar actions can be taken for other emitting sectors, such as transportation and industrial uses. The loss of large amounts of zero-emission nuclear generation would increase the need to run fossil generators, making it more challenging for states to achieve NO_X emissions reductions to address ozone nonattainment. States would need to take more, and more stringent, actions to achieve reductions beyond those already needed to achieve attainment.

In addition to NO_X emissions, our earlier studies found that the loss of nuclear generation and the attendant increase in fossil generation would also increase other harmful air pollutants, including CO_2, SO_2, and particulates (PM_{10} and $PM_{2.5}$). The most important of these pollutants, in terms of social cost, is CO_2, which would increase by many millions of tons (depending primarily on the total amount of nuclear generation lost, and secondarily on its location and thus the carbon intensity of replacement generation). We found that the increased CO_2 emissions that would accompany the loss of nuclear generation could account for hundreds of millions of dollars – potentially over a billion dollars – in social costs, as summarized in Table 2.

Table 2: Annual CO_2 Emissions Impacts of Nuclear Plants (Based on Previous Studies)

State Studied	Nuclear Plants	Total CO_2 Increase (Metric Tons)	Social Cost (2018 $Millions)
		[1]	[2]
NJ	Salem, Hope Creek	13,779,652	602.2
PA	All 5 PA Plants (9 units)	37,690,407	1,647.2
OH	David-Besse, Perry	9,288,983	406.0
IL	Quad Cities, Clinton	14,936,760	652.8

Note: The different studies reported results over different time periods: Illinois 2017-2021; New Jersey and Ohio 2018-2027; Pennsylvania 2017-2026. The values here are the averages over the time period of the original study.
[2]: As noted at Table 1, the previous reports expressed social costs in different years' dollars; all are converted here to 2018 dollars. Average social cost of CO_2 used here is $44/ton, from the Interagency Working Group on the Social Cost of Carbon, United States Government.