Electricity Cost and Environmental Effects of Retiring the Quad Cities and Clinton Nuclear Plants

PREPARED FOR

Chicagoland Chamber of Commerce

Illinois Hispanic Chamber of Commerce

Illinois Retail Merchants Association

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I. Executive Summary

At the request of the Chicagoland Chamber of Commerce, the Illinois Hispanic Chamber of Commerce, and the Illinois Retail Merchants Association, The Brattle Group has estimated the effect that two Illinois nuclear plants, the Quad Cities and Clinton plants, have on electricity costs to Illinois consumers, and on emissions of CO_2 and other pollutants. These two plants are facing particular financial challenges in the current environment of low wholesale power prices, such that their long-term financial viability is under threat. We found that, absent these two nuclear plants, Illinois consumers would pay more for electricity, and there would be substantially higher emissions of CO_2 and other pollutants.

Our analysis has determined the Quad Cities and Clinton nuclear plants:

- **Help keep electricity prices low**. Illinois consumers would pay $364 million more annually (2016$) and over $3.1 billion more over the next ten years (on a present value basis) without these plants. Annually, this is $115 million for residential customers, and $249 million for commercial and industrial customers.
- **Avoid 15 million tons[1] of CO_2 emissions annually** over the next five years, valued at $657 million per year. This is the equivalent of taking 3.2 million cars off the road.
- **Avoid significant amounts of criteria pollutants annually**, valued at $109 million per year over the next five years.

These effects reflect the impact these two nuclear plants have on the regional electricity markets, measured by comparing the performance of regional power systems and markets with and without these nuclear plants. This approach accounts for the alternative generation that would substitute for these two Illinois nuclear plants – both the greater utilization of existing plants and the construction of new plants, as necessary – to determine the incremental nuclear contribution. Absent the energy from these nuclear plants, Illinois and the region would need to rely more heavily on natural gas and coal-fired generating plants, many of which are outside Illinois, leading to greater reliance overall on out-of-state generation, and significantly diminishing the state's status as a net power exporter. The greater reliance on fossil generation would increase carbon and other air emissions, including in some current non-attainment areas of Illinois. It would also raise electricity prices. The absence of these two nuclear plants would increase wholesale prices in Illinois and throughout the broader region; this would flow through to residential, commercial and industrial consumers as higher electricity bills.

[1] Throughout this paper, references to tons indicate metric tons; 1 metric ton = 1.10231 short tons. Here, 15 million metric tons is equivalent to approximately 16.5 million short tons.

Emissions of carbon dioxide (CO_2) and criteria pollutants, such as nitrogen oxides (NO_X) and sulfur dioxide (SO_2), would also be much higher in the absence of the Quad Cities and Clinton nuclear plants, because the replacement generation would be almost entirely fossil-fired (though strict environmental regulations limiting fossil generation or emissions could interact with and might partly override the direct emissions effect of nuclear generation). Compliance with national ambient air quality standards (NAAQS), such as for ozone season nitrogen oxides (NO_X) and small particulate matter ($PM_{2.5}$), could become more costly for remaining generators, both in-state and out of state. It would become more difficult for Illinois to achieve its targeted CO_2 reductions for the Clean Power Plan, and compliance might be jeopardized. Further, the pollutant impacts are not limited to Illinois, first because much of the replacement generation would come from outside Illinois, and second because air pollution impacts can cross state borders – they are often regional in the case of criteria pollutants, and global in the case of carbon dioxide.

We examined the sensitivity of our results to a potential increase in natural gas prices, relative to current expectations, since natural gas is a key driver of electricity markets in the region. We found that in a higher gas price environment, the beneficial impact of these two nuclear plants on electricity prices would be significantly greater. The emissions effect is, ironically, somewhat smaller. In a high gas price environment, higher-emitting coal plants are already generating closer to their full capacity even with the nuclear plants operating, and so have less ability to increase further to replace nuclear generation.

II. Background

The Quad Cities and Clinton plants are among a total of six nuclear plants, comprising eleven nuclear reactors, operating in Illinois. Figure 1 highlights Quad Cities and Clinton among the six plants. These two plants represent almost 2,900 megawatts (MW) of generating capacity and generate 24 million megawatt hours (MWh) annually, as shown in Table 1. Illinois is split between two independent system operators (ISOs), with one of these nuclear plants physically located in each ISO: the PJM portion of Illinois includes Quad Cities, and Clinton is in the MISO region of Illinois.[2,3] The PJM portion of Illinois accounts for about two-thirds of total Illinois

[2] The PJM ISO operates the power system across the PJM interconnection, which includes northern Illinois and extends from Ohio eastward through the Mid-Atlantic states. It establishes and maintains markets for electric capacity and energy. MISO extends throughout much of the western and upper portions of the Midwest, and has recently expanded southward to include the Entergy service territory in Louisiana, Mississippi, and Arkansas. MISO's energy markets are similar in many respects to those in PJM. But unlike PJM, the MISO capacity market has relatively low participation; well-established bilateral markets play a more important role in determining the market value of capacity in MISO.

electricity load, with the MISO portion making up the remainder; both PJM and MISO extend far beyond their respective portions of Illinois (for perspective, the PJM portion of Illinois accounts for about 13% of PJM's total load; the MISO portion of Illinois is about 10% of MISO load). Overall, the six Illinois nuclear plants account for 49% of total generation and 27% of capacity in Illinois. The Quad Cities and Clinton plants together comprise about one fourth of Illinois nuclear generation and capacity, accounting for about 12% of the state's total generation and 7% of its total capacity, as illustrated in Figure 2.

Figure 1: Locations of Illinois Nuclear Plants, and PJM/MISO RTO Boundary

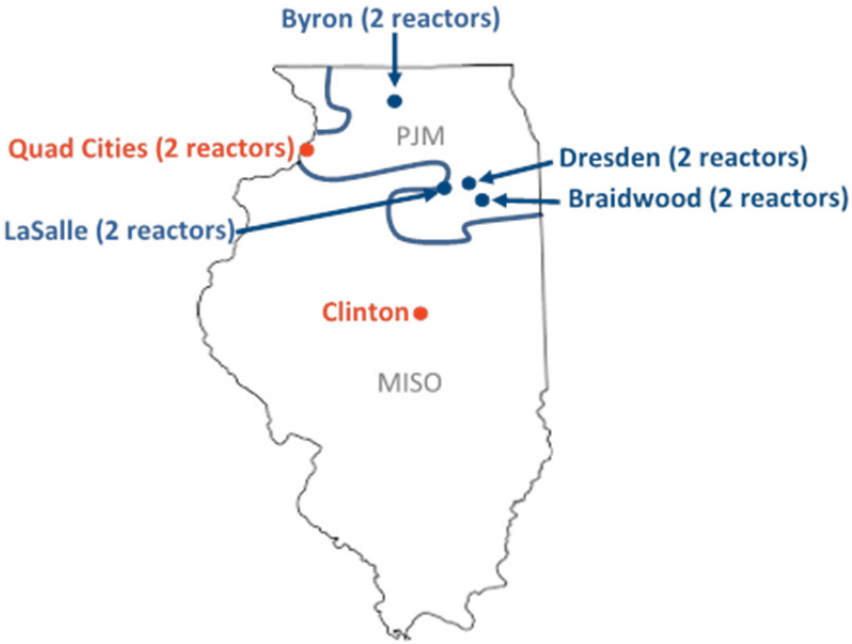

Table 1: Summary of Nuclear Plants in Illinois

Item		Clinton	Quad Cities	**Total Clinton & Quad Cities**	Other Illinois Nuclear Plants	**Total Illinois Nuclear**
[A]		[B]	[C]	**[D]**	[E]	**[F]**
Number of Units	[1]	1	2	**3**	8	**11**
Total Net Summer Capacity (MW)	[2]	1,065	1,819	**2,884**	8,680	**11,564**
Average Annual Generation (GWh)	[3]	8,644	15,501	**24,145**	73,279	**97,424**

Sources & Notes: Data from Ventyx, Energy Velocity Suite. Average annual generation is the average of 2013 - 2015.
The other Illinois nuclear plants are Braidwood, Byron, Dresden, and LaSalle, each of which has two units.

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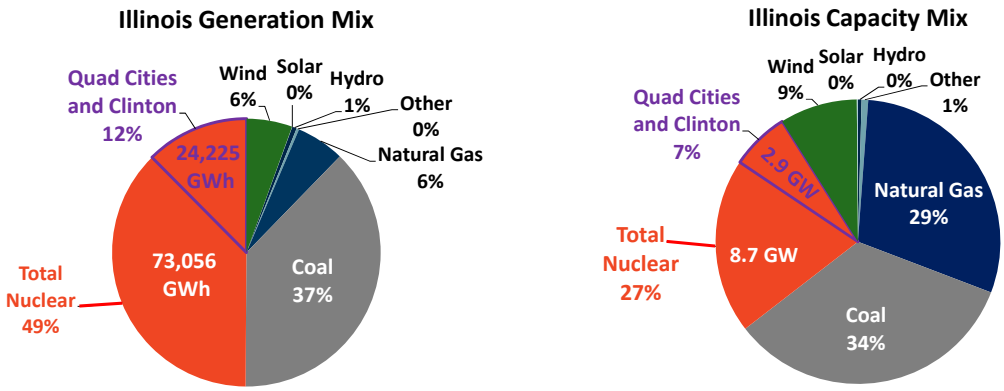
[3] The Quad Cities plant is physically located in the PJM portion of Illinois, but MidAmerican Energy owns 25% of the plant and contractually allocates its share of the capacity and energy into the MISO markets.

Figure 2: Illinois Electricity Generation and Capacity Shares by Fuel



Sources & Notes: Ventyx, Energy Velocity Suite. Generation is 2015 historical values; capacity is as of August 2016.

III. The Quad Cities and Clinton Nuclear Plants Have a Considerable Effect on Illinois Power Prices and Pollutant Emissions

The loss of these two nuclear plants would increase wholesale prices for energy and capacity, since it would reduce the available supply of both. Higher wholesale prices translate to higher retail prices, particularly in a state like Illinois which has restructured and has retail access so that wholesale prices are readily reflected in consumer costs.[4] Although retail costs may diverge temporarily from wholesale prices, due to local energy providers' service offerings and contracting arrangements (and in the case of Illinois, the Illinois Power Agency, which procures power for customers who have not selected an alternative provider), we have not attempted here to characterize such effects; we use the wholesale cost effect directly.

Another major effect of a premature shutdown of the Quad Cities and Clinton nuclear plants would be to increase emissions of CO_2 and criteria pollutants. This would happen since virtually all of the replacement power that would substitute for the output of these two nuclear plants would be fossil-fired generation, at least until and unless strict environmental regulations on CO_2 emissions come into effect.

To characterize the electricity market effects, we utilize Xpand, a capacity planning and dispatch model that captures the dynamics of power system operation, power markets and prices. We simulate the power system for the entire Eastern Interconnection to best capture the interstate electricity market effects. With this power sector model, we are able to characterize wholesale

[4] In non-restructured states that do not have retail access, the link can be less direct. Retail rate regulation in such states can cause divergence between wholesale prices and the rates paid by retail customers; regulated retail rates are typically based on the historical costs of the utility's generation portfolio, rather than the current wholesale market price of power.

power market operations and prices both with and without these two Illinois nuclear plants, to determine the effects attributable to them. Our analysis indicates that the Quad Cities and Clinton nuclear plants make a significant contribution to keeping electricity costs down in Illinois, as well as in the broader PJM and MISO regions. They also have a substantial effect on emissions of CO_2 and other pollutants, since their output would be replaced almost entirely by increased reliance on natural gas and coal-fired generation if they were to retire. Some of this replacement generation would come from in-state, but the large majority would be from other states. Large-scale renewable energy probably would not be significantly different in the near term; existing renewable generators already produce as much power as they can at virtually all times, constrained only by resource availability (wind or sun), and could not increase their output to substitute for lost nuclear generation.

Natural gas prices are a key driver of power sector operations and economics. If future natural gas prices are below current expectations, the cost of replacement power would be lower, thereby reducing the power price impacts of these nuclear plants. If gas prices are above current expectations, it would increase the cost of replacement power, amplifying the effect on power prices and increasing the benefit of retaining these plants. To help understand this, in addition to the Base Case analysis, we also assess the effects of these two nuclear plants in a high gas price environment.[5] In the High Gas Price Case, the pattern is generally similar, though the high gas prices cause considerably greater reliance on coal regardless of whether these two nuclear plants are operating. This leaves coal with less additional flexibility to increase its output to replace nuclear generation if these plants retire. Overall, gas-fired generation accounts for a somewhat larger share of the replacement power than in the Base Case.

1. Impact on Electricity Prices

As noted above, absent the Quad Cities and Clinton nuclear plants, electricity demand would be met by increased utilization of natural gas and coal-fired plants, with the large majority of replacement power coming from outside the state. Without these two plants, while Illinois would still produce more power than it consumes, its net exports would fall by nearly 60%. Illinois is electrically interconnected with adjoining states and is part of the larger regional power markets that include PJM and MISO and beyond. The reduction in supply within Illinois would increase electricity prices not just within Illinois, but also across these broader regional markets, as the nuclear power is replaced by an alternative generation mix that has higher variable costs. As shown in Table 2, average power prices in Illinois would be $2.13/MWh

[5] Our Base Case analysis reflects current expectations for natural gas prices, as represented by the Reference natural gas price forecast from the U.S. Energy Information Administration's 2016 Annual Energy Outlook. The High Gas Price Case assumes delivered natural gas prices that are 35% above the reference gas prices used in the Base Case; this is based on Brattle's experience with the price volatility implied by financial options on natural gas, historical gas price variance and historical forecast errors.

higher without these two nuclear plants.[6] Across all Illinois consumers, this represents an increase of $364 million per year in electricity costs, or $3.1 billion in present value over ten years. Averaged across the state, about two-thirds of these increased costs would fall on commercial and industrial customers, with the remainder on residential customers.

Table 2: Illinois Nuclear Plants Avoid Higher Electricity Prices
(All-in Power Price and Cost Differences due to Quad Cities & Clinton Nuclear Plants)

		10-Year Average			
	% of Utility Load[1]	Power Price Change without Nuclear ($/MWh)[2]	Electricity Consumption (millions of MWh)	Annual Electricity Cost Change (2016 $millions)	Total Electricity Cost Increase Over 10 Years (2016 $millions)[3]
Base Case					
Illinois Average		**$2.13**	**171**	**$364**	**$3,092**
Commonwealth Edison (PJM)[4]		$2.56	116	$297	$2,522
Residential	31%		36	$91	$776
Commercial/Industrial	69%		80	$206	$1,747
Ameren Illinois (MISO)[4]		$1.21	55	$67	$570
Residential	36%		20	$24	$206
Commercial/Industrial	64%		35	$43	$364
High Gas Price Case					
Illinois Average		**$3.28**	**171**	**$562**	**$4,763**
Commonwealth Edison (PJM)[4]		$3.62	116	$419	$3,556
Residential	31%		36	$129	$1,093
Commercial/Industrial	69%		80	$290	$2,462
Ameren Illinois (MISO)[4]		$2.57	55	$142	$1,207
Residential	36%		20	$51	$437
Commercial/Industrial	64%		35	$91	$771

[1]Load share by customer class is based on data from 2014, EIA Form 861.

[2]The reported Power Price Change includes only energy and capacity cost effects; does not include transmission costs, customer costs, etc. Power Price Effects are assumed to be the same, on an average per-MWh basis, for all customer classes; differences in load shape and billing determinants are not distinguished here.

[3]Present value for the 10-year period at a 3% discount rate.

[4]Each of the regions within Illinois is identified according to its dominant utility. So, as used here, "Commonwealth Edison" and "Ameren Illinois" represent the entire PJM and MISO portions of Illinois, respectively, including the smaller utilities within each region.

6 The electricity sector model used here depicts six sub-regions within PJM; one of these is entirely within Illinois. It models MISO as five sub-regions (not counting Entergy), one of which is partly within Illinois. The Illinois average is found as the load-weighted average of the Illinois portion of these two model sub-regions.

The magnitude of the power price effects is sensitive to the price of natural gas, since gas plays a primary role in setting power prices in the region. In a high natural gas price environment, electricity prices would be higher, and thus the savings created by retaining the nuclear plants would be larger. Table 2 shows that a high gas price environment magnifies the electricity price impacts of these two Illinois nuclear plants. Under high gas prices (characterized here as delivered gas prices 35% above the reference gas price), these two nuclear plants would save Illinois consumers about $562 million annually in electricity costs.[7]

By preventing higher electricity prices, these two nuclear plants also create a broader benefit to the Illinois economy. By keeping electricity prices lower, these nuclear plants leave residential, commercial, and industrial consumers with more money to spend on other goods and services, which boosts overall economic activity in Illinois, including jobs, GDP, and tax revenues. These economic effects extend beyond the state's borders as well. This component of economic benefit is further enhanced, in terms of the economic effect within Illinois, by the in-state economic activity associated with power generation. Since these two nuclear plants are in Illinois but the alternative replacement power would come mostly from outside the state, their continued operation helps to maintain the state's status as a significant net exporter of power. We did not quantify these economic benefits in this study, though the Illinois Department of Commerce and Economic Opportunity has addressed the economic impacts of premature nuclear retirements.[8]

2. Quad Cities and Clinton Nuclear Plants Prevent Substantial Carbon Dioxide and Criteria Pollutant Emissions within and outside Illinois

These two nuclear power plants prevent substantial emissions of CO_2, SO_2, NO_X, and particulate matter, compared to the alternative of natural gas and coal-fired generation that would normally

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7 In addition to the effects of gas prices, electricity transmission requirements might also affect the level and the geographic distribution of electricity costs. Although local and possibly regional transmission needs could differ in the absence of these nuclear plants, this report does not consider the effects on the transmission system nor potential changes in transmission investments. Transmission costs could, however, be substantial if a premature transition from nuclear to natural gas were to occur, as noted by a PJM study regarding the closure of nuclear plants in Illinois. See PJM Response to Illinois Commerce Commission (ICC) Request to Analyze the Impact of Various Illinois Nuclear Power Plant Retirements, 10/21/2014, http://www.icc.illinois.gov/electricity/hr1146.aspx. PJM found that premature nuclear retirement would require "substantial time to correct;" "would require substantial construction activity and could significantly inconvenience Illinois citizens;" and "[transmission] costs would be significant – in the hundreds of millions of dollars or more" (see pg. 7).

8 According to a report prepared by the Illinois Department of Commerce and Economic Opportunity, the negative economic impacts resulting from the early retirement of Clinton and Quad Cities nuclear generating stations are considerable: 1,620 direct job losses at the nuclear plants and 2,655 indirect job losses at businesses that do business with the plants, totaling 4,275 total job losses; and $1.239 billion in annual lost economic activity (GDP) for the state of Illinois. Response to the Illinois General Assembly Concerning House Resolution 1146, 1/5/2015; https://www.icc.illinois.gov/electricity/workshops/hr1146.aspx.

replace it. However, the question of measuring the emissions effect of nuclear is complicated by other factors that may affect the future generation mix available to substitute for the missing nuclear generation. For example, the Clean Power Plan (CPP) regulates greenhouse gas emissions from covered sources (most existing fossil generation) and could alter the generation mix going forward in ways that could interact significantly with the emissions effect of nuclear generation. The CPP is scheduled to go into effect in 2022, in the middle of the horizon of this analysis, but has been stayed pending legal challenge, and its actual implementation date and form are uncertain. So to more clearly illustrate the emissions effects of nuclear itself, and to avoid the uncertainties associated with the CPP, this section presents emissions effects only over the five-year period prior to scheduled CPP implementation, 2017-2021.

To understand the emissions effects, it is helpful to characterize the differences in generation with and without these two Illinois nuclear plants. The entire Eastern Interconnection is an integrated power system, and most of the power needed to replace the output of these two nuclear plants would come from outside Illinois. Because gas is often the marginal fuel in the region, most of the replacement energy comes from gas, particularly in the east. The location and type of the replacement generation are summarized in Table 3, which shows that 72% of the replacement generation comes from outside Illinois, and 59% of the total is fired by natural gas. In a high gas price environment, the same general pattern holds, though ironically, the replacement power is even more dominated by gas (71%). This is because coal generation is already running closer to its full capacity even with the nuclear plants operating; since coal has limited ability to increase further, more of the replacement generation must come from gas.

Table 3: Changes in Generation to Replace Nuclear
(Average Annual 2017-2021, GWh, Base Case)

	Illinois	Outside Illinois	Total
Gas	3,882	9,614	13,495
Coal	2,455	6,907	9,362
Wind	70	-72	-2
Solar	0	0	0
Other	27	-24	4
Total	6,434	16,426	22,860

The resulting emissions reductions enabled by these two Illinois nuclear plants under the Base Case are summarized in Table 4. Average annual CO_2 emissions would be about 15 million tons greater absent these two nuclear plants.[9] To put this in perspective, this would be equivalent to

[9] The response by the Illinois Environmental Protection Agency to the Illinois General Assembly Concerning House Resolution 1146 (January 5, 2015) found that Quad Cities and Clinton plants would

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adding about 3.2 million cars to the road, and represents about 18% of the current power sector CO_2 emissions of Illinois.[10] Overall power sector SO_2 emissions would increase by an amount equivalent to 2% of current Illinois emission levels, and NO_X emissions by 26%.[11] Particulate matter emissions of $PM_{2.5}$ and PM_{10} each would increase by about 18% of current Illinois emissions levels.[12] In a high gas price environment, the replacement generation consists of less coal and more gas, as discussed previously. Since emissions rates are generally lower for gas plants, the incremental emissions effects are somewhat smaller with high gas prices.

Table 4: Emissions and Social Cost Prevented by Quad Cities and Clinton Nuclear Power Plants (Average Annual 2017-2021, Base Case)

Pollutant	Avoided Emissions (tons)	Social Cost ($/ton)	Avoided Emissions Value (2016 $millions)
CO_2	14,936,760	$44	$657
SO_2	3,815	$7,371	$28
NO_x	8,786	$2,033	$18
PM_{10}	6,103	$585	$4
$PM_{2.5}$	4,877	$12,073	$59
Total			$766

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avoid about 21 million tons of CO_2, based on assumed nuclear generation of 25 million MWh annually and an average Illinois emissions rate of 0.86 tons CO_2 per MWh (see pp. 119-120). Our somewhat more conservative approach assumes about 23 million MWh of generation annually, and uses a marginal (rather than average) displaced emissions rate of approximately 0.65 tons per MWh, reflecting the carbon intensity of the replacement power that comes from regional power markets.

[10] This is based on EPA's estimate of 4.7 tons CO_2 per year per automobile. EPA, "Greenhouse Gas Emissions from Passenger Vehicles," May 2014, EPA 420-F-14-040a, p.2

[11] The effect of the nuclear plants on SO_2 emissions is limited by the EPA's Cross-State Air Pollution Rule (CSAPR), which caps the allowed emissions of SO_2 from units in some states. This cap is binding in many states even with the nuclear plants operating, and so in the absence of the nuclear plants, additional operational changes are required; these changes partly mitigate the direct effects on SO_2 emissions.

[12] In comparing these emissions increases to current Illinois emission levels, note that although the emissions increase would be triggered by the loss of nuclear generation in Illinois, only a modest share of this total emissions increase actually occurs within Illinois, since most of the replacement generation comes from outside the state.

The overall social cost of these changes in emissions can be estimated using the federal government's social cost of carbon ($44/ton)[13] and the National Academy of Science's externality cost estimates for SO_2, NO_X, PM_{10} and $PM_{2.5}$. Evaluated at these rates, which are shown in Table 4, the average annual avoided social cost of CO_2 is $657 million, and the avoided costs of SO_2 and NO_X are $28 million and $18 million, respectively. The avoided costs of PM_{10} and $PM_{2.5}$ emissions are approximately $4 million and $59 million, respectively. These costs reflect environmental and human health damages and are independent of and in addition to the economic impacts that would result from higher power prices and reduced in-state power production. They reflect costs incurred by society, not directly by the economy.

Because most of the replacement generation comes from outside Illinois, most of the emissions increase also occurs outside the state. Even so, the criteria pollutants that are emitted in or near Illinois may have substantial local impacts. In Appendix A we discuss some of the potential local emissions effects of criteria pollutants, including how they may impact non-attainment areas in Illinois – those areas that are currently in non-attainment for federal air quality standards for one or more of the criteria pollutants.

[13] The social cost of carbon used here, $44 per ton of CO_2, is the federal government's central value (which is based on a 3% discount rate) for 2015, converted from 2007 dollars to 2015 dollars. See the EPA Fact Sheet, Social Cost of Carbon, December 2015.

Appendix A: Local Environmental Impacts

Since criteria pollutants can affect local air quality, it is also important to consider the location of these emissions impacts. We have done so by mapping all of the power plants in Illinois, locating them within Illinois counties, and determining what change, if any, they would experience in generation and emissions in the absence of the Quad Cities and Clinton nuclear plants. The locations of the plants are presented in Figure 3 below, and the plants are identified in Table 5.

Figure 3: Illinois Power Plants by Type

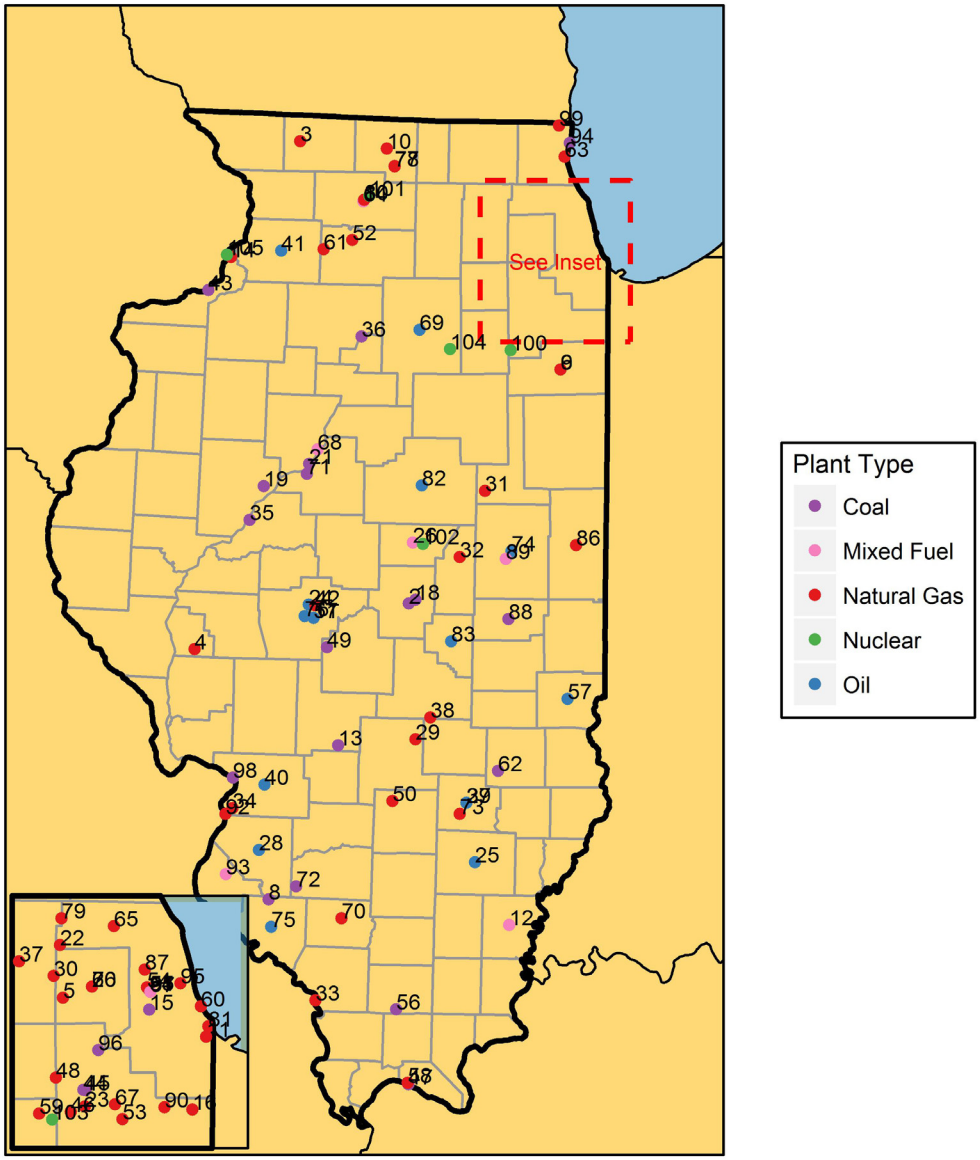


Table 5: Illinois Power Plant Key

Item	Plant Name	Plant Type	Item	Plant Name	Plant Type
1	1515 S Caron Road	Natural Gas	54	Loyola University Health Plant	Natural Gas
2	A E Staley Decatur Plant Cogeneration	Coal	55	M & M Mars Chicago	Natural Gas
3	Adkins Energy	Natural Gas	56	Marion	Coal
4	Alsey	Natural Gas	57	Marshall	Oil
5	Aurora	Natural Gas	58	Mepi GT Facility	Natural Gas
6	Aventis Behring LLC	Natural Gas	59	Morris Power Plant	Natural Gas
7	BP Naperville Cogeneration Facility	Natural Gas	60	Museum of Science & Industry	Natural Gas
8	Baldwin Energy Complex	Coal	61	Nelson Energy Center	Natural Gas
9	Bunge Oil	Natural Gas	62	Newton	Coal
10	Cadbury Adams - Rockford	Natural Gas	63	North Chicago Energy Center	Natural Gas
11	Calumet Energy Team LLC	Natural Gas	64	North Ninth Street	Mixed Fuel
12	Carmi	Mixed Fuel	65	Northwest Community Hospital	Natural Gas
13	Coffeen	Coal	66	Ondeo Nalco	Natural Gas
14	Cordova Energy Center	Natural Gas	67	PPL University Park Power Project	Natural Gas
15	Corn Products International	Coal	68	Peoria	Mixed Fuel
16	Crete Energy Park	Natural Gas	69	Peru	Oil
17	Dallman	Coal	70	Pinckneyville (AMEREN)	Natural Gas
18	Decatur (IL ADM)	Coal	71	Powerton	Coal
19	Duck Creek	Coal	72	Prairie State Energy Campus	Coal
20	Dupage County Region 9 West WA	Natural Gas	73	Raccoon Creek Energy Center	Natural Gas
21	E D Edwards	Coal	74	Rantoul	Oil
22	Elgin Energy Center	Natural Gas	75	Red Bud	Oil
23	Elwood Energy	Natural Gas	76	Reynolds	Oil
24	Factory	Oil	77	Rockford I	Natural Gas
25	Fairfield	Oil	78	Rockford II Energy Center	Natural Gas
26	Farmer City	Mixed Fuel	79	Rocky Road Power LLC	Natural Gas
27	Flora Site B	Oil	80	South Main Street	Natural Gas
28	Freeburg	Oil	81	Southeast Chicago	Natural Gas
29	Freedom Power Project	Natural Gas	82	State Farm	Oil
30	Geneva Township	Natural Gas	83	Sullivan	Oil
31	Gibson City	Natural Gas	84	Thornridge High School	Natural Gas
32	Goose Creek Energy Center	Natural Gas	85	Thornwood High School	Natural Gas
33	Grand Tower	Natural Gas	86	Tilton	Natural Gas
34	Granite City Works	Natural Gas	87	Triton East & West Cogen	Natural Gas
35	Havana	Coal	88	Tuscola	Coal
36	Hennepin Power Station	Coal	89	Univ of Illinois Abbott	Mixed Fuel
37	Hoffer Plastics	Natural Gas	90	University Park Energy	Natural Gas
38	Holland Energy Facility	Natural Gas	91	University of Illinois Cogen Facility	Natural Gas
39	IMEA Flora	Oil	92	Venice	Natural Gas
40	Imea Highland	Oil	93	Waterloo	Mixed Fuel
41	Industrial Park	Oil	94	Waukegan	Coal
42	Interstate	Natural Gas	95	West Side Energy Center	Natural Gas
43	John Deere Harvester Works	Coal	96	Will County	Coal
44	Joliet 29	Coal	97	Winnetka	Mixed Fuel
45	Joliet 9	Coal	98	Wood River	Coal
46	Joliet Refinery	Natural Gas	99	Zion Energy Center	Natural Gas
47	Joppa Steam	Coal	100	Braidwood	Nuclear
48	Kendall County Generation	Natural Gas	101	Byron	Nuclear
49	Kincaid Generation LLC	Coal	102	Clinton	Nuclear
50	Kinmundy	Natural Gas	103	Dresden	Nuclear
51	Lakeside	Oil	104	LaSalle	Nuclear
52	Lee Energy Facility	Natural Gas	105	Quad Cities	Nuclear
53	Lincoln Energy Center	Natural Gas			

We also considered whether the county is in attainment with Clean Air Act standards for criteria pollutants, and checked for instances where a plant that is located within a non-attainment area for a particular pollutant would increase its emissions of that pollutant in the absence of the Quad Cities and Clinton nuclear plants. This analysis is illustrated in a series of maps below.

Each map illustrates, for a given pollutant, the Illinois generating plants, indicating whether their emissions increase (red), stay the same (black) or fall (blue), in the absence of the Quad Cities and Clinton nuclear plants. For the purposes of this analysis, the emissions effect for 2017-2021, prior to the implementation of the CPP, are considered. The size of the dot indicates the magnitude of the change in emissions. We pay particular attention to those counties that are not currently in attainment with U.S. EPA standards under the Clean Air Act for one or more of the criteria pollutants; these counties are shaded on the maps.

This analysis revealed that absent Quad Cities and Clinton, there are a number of instances in which fossil plant emissions of a criteria pollutant would increase in a county that is already in non-attainment for that pollutant. This can be seen where there is a red dot within a shaded county, indicating that a power plant located in a non-attainment area is increasing its emissions. In fact, because those locations are already out of compliance, additional actions may be required to mitigate these emissions increases, including redispatch that would utilize more costly generation sources outside the non-attainment area, or potentially to add costly emissions controls to the affected plants. These additional actions could increase electricity costs beyond our estimates. Emissions increases in locations that are currently in compliance with federal standards could potentially push some of them into non-compliance, creating similar issues in additional locations.

Table 6 presents the aggregate change in emissions within Illinois absent the Quad Cities and Clinton plants. It is important to note that airborne transport of criteria pollutants could spread them to nearby and downwind locations; our analysis does not account for such transport and is thus only indicative of the types of problems that may arise The table also does not present increased emissions at power plants outside of Illinois that might nonetheless affect Illinois air quality due to airborne transport.

Table 6: Emissions and Social Cost Prevented by Quad Cities and Clinton in Illinois (Average Annual 2017-2021, Base Case)

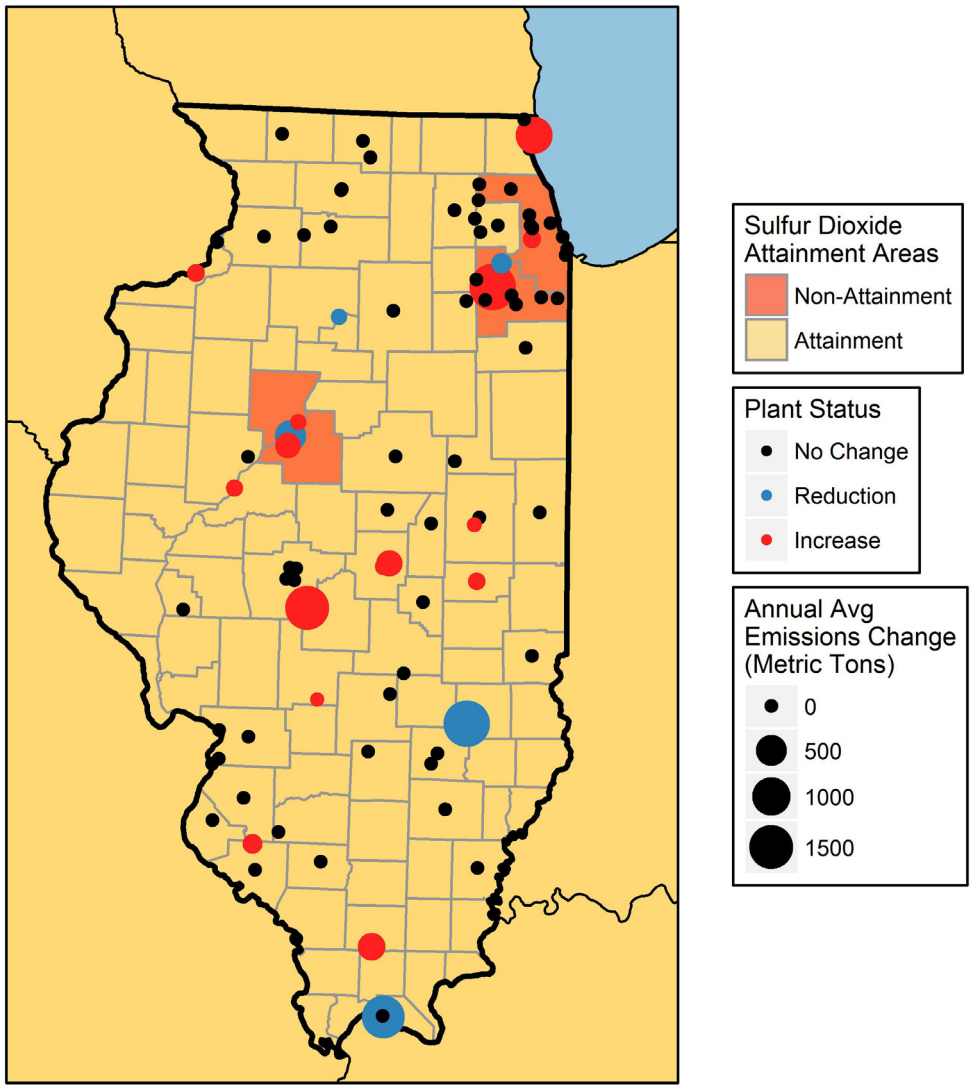
Pollutant	Avoided Emissions (tons)	Social Cost ($/ton)	Avoided Emissions Value (2016 $millions)
CO_2	4,092,281	$44	$180
SO_2	1,831	$7,371	$13
NO_x	1,403	$2,033	$3
PM_{10}	1,662	$585	$1
$PM_{2.5}$	1,330	$12,073	$16
Total			$213

The location and change in emissions by Illinois plant are discussed below.

SO_2

SO_2 presents a significant overall social cost. At present four Illinois counties are in non-attainment for SO_2 (Cook, Peoria, Tazwell, and Will), as shown in Figure 4. Absent the Quad Cities and Clinton nuclear plants, net emissions in two of these counties increase, making attainment more difficult and/or expensive. Several other counties also experience a significant increase in emissions, which could result in non-attainment in some of those counties.

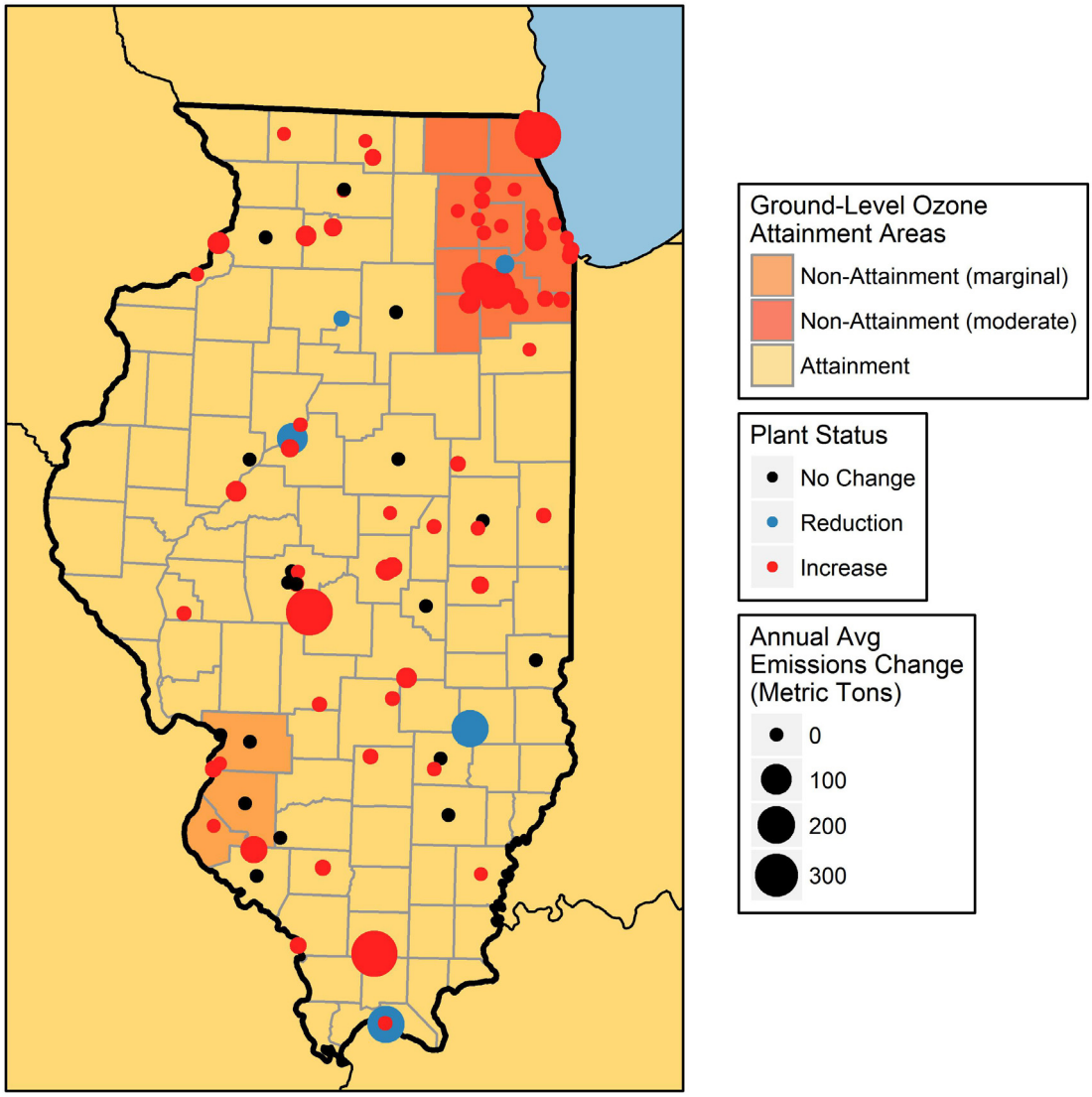
Figure 4: SO_2 Emissions Increase Absent Quad Cities and Clinton – Base Case



NO_x

The overall social cost of the increase in NO_x absent the Quad Cities and Clinton plants is lower than for several other criteria pollutants, but NO_x is also a precursor of ground level Ozone.[14]

Figure 5: NO_x Emissions Increase Absent Quad Cities and Clinton – Base Case



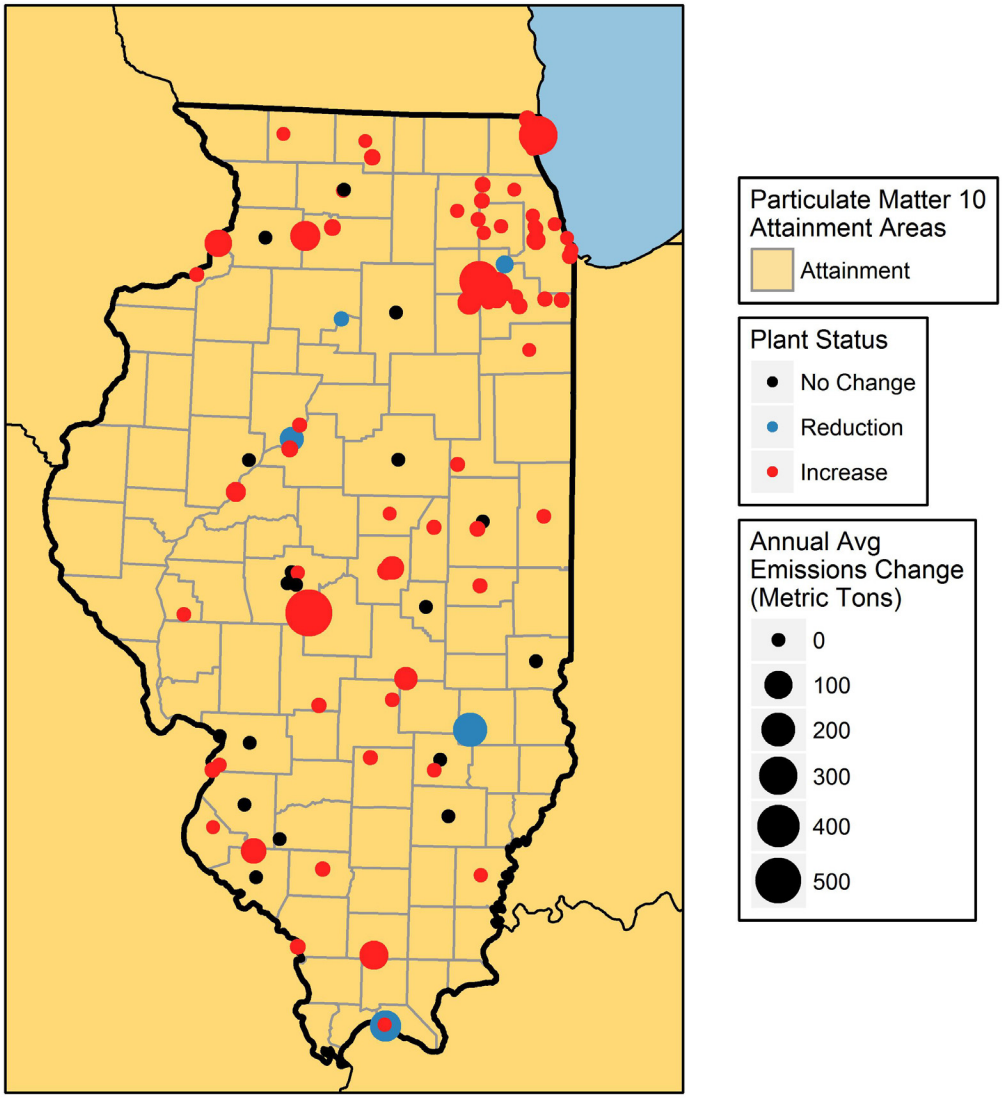
[14] Ground level or tropospheric ozone occurs when nitrogen oxides (NO_x), carbon monoxide (CO) and volatile organic compounds (VOCs), react in the atmosphere in the presence of sunlight. Ozone imposes social costs in the form of adverse health effects, particularly to those with pulmonary system problems including asthma. Low level ozone has also been found to negatively affect agriculture. Reducing NO_x is generally the preferred means to lower ozone levels. Determining the impact of power plant NO_x emissions on ozone levels is beyond the scope of this report, but increased NO_x emissions is likely to compromise efforts to reduce ozone across much of the state.

At present no Illinois county is in non-attainment for NOx, but 11 are in non-attainment for ozone. Three counties, Madison, Monroe, St. Clair, are considered in marginal nonattainment for ozone and 8 are designated in moderate nonattainment of Ozone (Cook, DuPage, Grundy, Caine, Kendall, Lake, McHenry, and Will). NOx emissions in Illinois are projected to increase by more than 1,400 tons per year, absent these nuclear plants. This increase may raise the cost of bringing many of these counties into attainment for Ozone. The locations of NOX increases are shown alongside the non-attainment areas for Ozone in Figure 5.

PM_{10}

The increase in PM_{10} that would occur absent the Quad Cities and Clinton nuclear plants is very modest, imposing social costs of $4 million annually overall, and $1 million within Illinois. No counties were in non-attainment for PM_{10}, as illustrated in Figure 6.

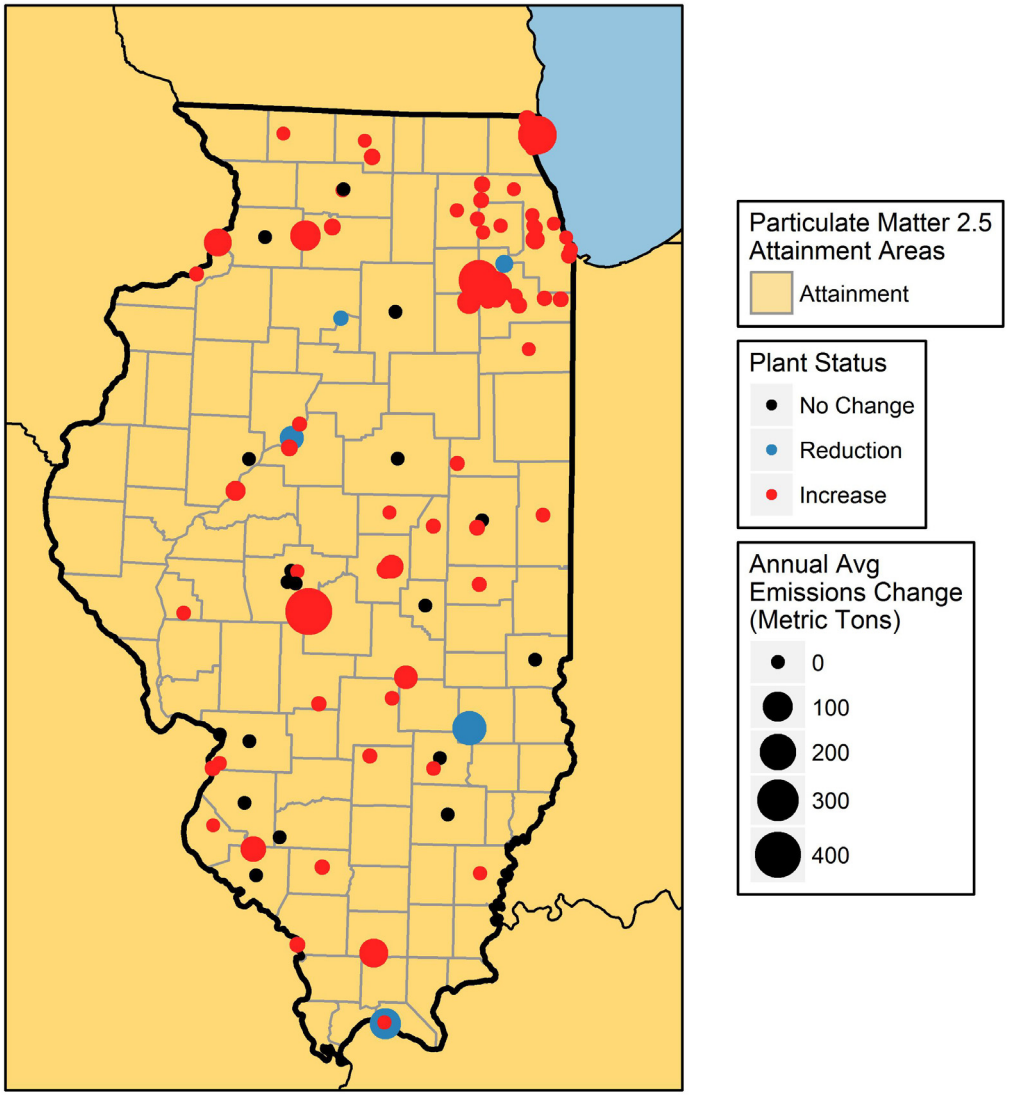
Figure 6: PM_{10} Emissions Increase Absent Quad Cities and Clinton – Base Case



$PM_{2.5}$

As Table 6 indicates, $PM_{2.5}$'s social cost per ton is by far the highest among the criteria pollutants, reflecting its significant impacts on human health. At present, no Illinois counties fail to meet air quality standards for $PM_{2.5}$, as shown in Figure 7 for the Base Case. Several counties, however, would experience substantial $PM_{2.5}$ emissions increases if Quad Cities and Clinton were to shut down prematurely, which could place them into non-attainment with the Clean Air Act. For example, Cook County, home of Chicago, would see increased $PM_{2.5}$ emissions from several plants.

Figure 7: $PM_{2.5}$ Emissions Increase Absent Quad Cities and Clinton – Base Case



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