The Clean Power Plan – Impact on the US Nuclear Energy Industry and Analysis of Major Issues

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On 3 August, 2015, the United States Environmental Protection Agency (EPA) released the Clean Power Plan (CPP) Final Rule. This rule has been anticipated for multiple years and follows the Clean Power Plan Proposed Rule, which was initially released on June 18th, 2014. The Clean Power Plan sets limits on carbon dioxide (CO_2) emissions from existing stationary fossil-fuel-fired electricity generating units (EGUs). The CPP is implemented primarily by states, who must each develop and submit to the EPA a State Plan that will bring CO_2 emissions from affected EGUs in their jurisdiction into compliance with the limits the EPA has established.

In this paper, we analyze the situation in four states (Massachusetts, New York, Illinois, and Georgia) to identify the potential impacts and unintended consequences of the rule on electricity supply and carbon emissions. Some key findings:

(1) *The Clean Power Plan presented an opportunity for the EPA to properly value the reliability and low environmental impact of nuclear energy facilities, but that opportunity has been partially missed.*

(2) *The EPA missed a particularly important opportunity to value nuclear energy in its decision not to allow credits for generation from nuclear energy facilities operating under a renewed license.*

(3) *The existing nuclear fleet can only participate in CPP compliance if plant capacity is uprated.*

(4) *These case studies confirm that new nuclear capacity can make substantial contributions toward CPP compliance and will definitely do so in Georgia.*

(5) *Massachusetts may satisfy its final State Goal simply by replacing 2012 coal generation with increased use of current natural gas generators. New York comes very close to compliance by doing the same.*

(6) *Analysis of scenarios in Massachusetts and New York confirms findings from previous investigations showing that, in some states and scenarios, it is possible to comply with the CPP State Goal while increasing the mass of total CO_2 emissions.*

(7) *In both MA and NY, this can be accomplished by replacing both coal and nuclear generation with generation from new natural gas capacity. New NGCCs may also be the cheapest way each state could increase its generation capacity.*

(8) *Large investments in new, low-emission generators are likely to be necessary in coal-intensive states, even in a case like Illinois where substantial low-emission capacity is already present and the statewide emission rate is below the national average.*

I. INTRODUCTION

On 3 August 2015, the United States Environmental Protection Agency (EPA) released the Clean Power Plan (CPP) Final Rule [1, 2]. This rule has been anticipated for multiple years and follows the Clean Power Plan Proposed Rule, which was initially released on June 18th, 2014 [3]. The Clean Power Plan sets limits on carbon dioxide (CO_2) emissions from existing stationary fossil-fuel-fired electricity generating units (EGUs).

The CPP is implemented primarily by states, who must each develop and submit to the EPA a State Plan that will bring CO_2 emissions from affected EGUs in their jurisdiction into compliance with the limits the EPA has established. The EPA has established two categories of CO_2 emission limits (plant-specific limits and state-wide limits). The EPA has further established plant-specific limits for two types of plants ("fossil fuel-fired electric utility steam generating units" and "stationary combustion turbines"), and two types of state-wide limits (mass-based limits expressed in tons of CO_2 emitted per year and rate-based limits expressed in pounds of CO_2 emitted per megawatt-hour of electric power generated).

I.A. Background

The state plan legal framework and the authority of the EPA to issue the Clean Power Plan derive from section 111(d) of the Clean Air Act (CAA, 42 U.S.C. §7411) [4].

The CPP is accompanied by a new rule, first released in final form alongside the CPP on 3 August 2015, called a New Source Performance Standard (NSPS) [5]. This rule sets limits, measured in either pounds of CO_2 emitted per megawatt-hour of electric power generated (lbs / MWh) or pounds of CO_2 emitted per million British thermal units of heat input through fuel combustion (lbs / MMBTU), on any new affected EGU that commenced construction after January 8, 2014 and reconstruction or modification after June 18, 2014. The legal authorization for NSPS rules is derived from CAA section 111(b). This format, in which two rules are released together to set standards of performance for emission of a certain pollutant for each for existing plants and for new plants, has been used previously for many other types of plants and types of pollutants [6].

The text of the CPP Final Rule is found in Code of Federal Regulations Title 40, Part 60 (40 CFR 60), Subpart UUUU, and took effect on 22 December 2015 [6]. The text of Subpart UUUU was officially released on 23 October

2015 in the Federal Register, Volume 80, Number 205, starting on page 64941 [7]. The text of the companion NSPS is found in 40 CFR 60 Subpart TTTT [6].

I.B. EPA and Administration Goals

The Obama Administration's broad goal for the Clean Power Plan is to reduce CO_2 emissions from electric power generation by 32% from 2005 to 2030 [8]. EPA's more specific stated goal in the Clean Power Plan Final Rule is to reduce carbon emissions from any "affected EGUs below current levels" [2]. This is clarified in the discussion of State Plan requirements to mean any EGUs that were operating on or before 8 January, 2014. This date sets their baseline to calculate current emissions, then set goals on how much emissions should be reduced. The basic principle is to incentivize changes that cause reductions in CO_2 emissions.

The bulk electric power system has a very large number of interconnected subsystems across many states. A dense network of thousands of miles of transmission lines connect users of electricity across the country with power generators and with substations that control the voltage and flow of power. Transmission lines cross state borders in hundreds of places, and electric power flows across state lines every second of every day. Therefore, there is a fundamental conflict between the technical structure of the electric power system and the format for emission regulation specified in the Clean Air Act, where states are given emission limits and charged with developing the detailed policies that cause sources within their borders to comply with those limits.

The EPA has attempted to address this conflict in the "building blocks" that make up the "Best System of Emission Reduction" (BSER) underlying the CPP and in the state-specific limits included in the rule. These state-specific limits are calculated based on: (1) the inventory of EGUs present in the state in 2012, (2) a small set of adjustments accounting for particular conditions in certain states in 2012 (e.g. short-term plant outages during that particular year), (3) the EPA's assessment of performance improvements that can be cost-effectively achieved at coal steam generators and combustion turbine generators, and (4) the EPA's assessment of the potential of that state to cost-effectively develop very-low-carbon renewable generation capacity. However, these building blocks do not comprehensively account for all factors in the performance of the current and future bulk electric power system that might influence greenhouse gas emissions.

The EPA acknowledges in the Final Rule that generation from very-low-carbon capacity can reduce carbon emissions from affected EGUs [2] and allows states to provide "Emission Reduction Credits" (ERC) or emission allowances to generation provided by new capacity of a set of very-low-carbon generator types to quantify this reduction. Very-low-carbon capacity built after the baseline date that provides generation between 2022 and 2030 can earn ERCs.

The basic idea here is to incentivize changes away from a business-as-usual scenario that cause a reduction in carbon emissions. Very-low-carbon capacity built after the baseline date clearly makes it possible to generate electricity in the future with lower average carbon emissions. Upgrading very-low-carbon capacity can also make it possible to reduce average emissions; the EPA explicitly acknowledges that capacity uprates at nuclear power plants are an example of this [ref 2, p64735].

I.C. Baseline Date and Existing Generators

The baseline date used in implementation of this rule is 8 January, 2014. Data on generators and electricity generated in calendar year 2012 was used in calculations of State Goals and the various other factors found in the rule; a small number of adjustments were made in cases where 2012 data was known to be exceptional in a way that would substantially change State Goals or other important factors. "Current emissions" should generally be read in the text of the Final Rule to mean emissions during calendar year 2012.

Generation provided by existing very-low-carbon generators, including existing nuclear, renewable, and hydro generators, operating before the baseline date is generally not accounted for in the calculations in the Final Rule. This is deliberate, and the EPA explains their reasoning for this in the text.

Regarding nuclear capacity [ref 2, p64729]:

> *On further consideration, we believe it is inappropriate to base the BSER on elements that will not reduce CO_2 emissions from affected EGUs below current levels. Existing nuclear generation helps make existing CO_2 emissions lower than they would otherwise be, but will not further lower CO_2 emissions below current levels.*

And regarding renewables [ref 2, p64729]:

> *As part of the adjustment in approach, we have also refocused the quantification solely on generation from new RE generating capacity rather than total (new and existing) RE generating capacity as in the proposal.*

II. CPP CARBON ACCOUNTING

The CPP only accounts for CO_2 emitted by a set of specific types of generators:

- Coal-fired steam EGUs
- Natural-gas-fired combined-cycle combustion turbine (NGCC) EGUs
- Oil- and gas-fired steam EGUs.

The CPP explicitly does not account for CO_2 emitted by several other types of generators, including:

- All EGUs with net output capacity lower than 25 MW
- Simple-cycle combustion turbine generators
- Most combined-heat-and-power (CHP) generators
- Municipal solid waste (MSW) combustors
- Industrial solid waste incinerators

The CPP also only accounts for a specific set of CO_2 emission reduction measures in the "Best System of Emission Reduction" (BSER). Each measure listed below is labelled a "Building Block," and along with data on generation and emissions in the state in 2012, these measures are used as the basis of the formula that establishes emission limit State Goals:

1. Improve the efficiency (heat rate) of coal steam generating units.
2. Increase the utilization (capacity factor) of NGCC generating units and reduce the utilization of generators with higher emissions.
3. Increase zero-carbon generation within the state and reduce the utilization of CO_2 emitting generators.

For both mass-based and rate-based emission limits, each state has a final State Goal in 2030, an Initial Goal that must be met in 2022, and a "glide path" of incrementally more stringent limits that must be met during each 2 year period until 2030.

II.A. Regarding "Leakage"

Several investigators analyzing both the CPP Proposed Rule [9] and Final Rule [10, 11] identified situations in which a state might be able to comply with the carbon accounting requirements and emission limits of the CPP while increasing real emissions of CO_2 within the state. The EPA acknowledges in the text of the Final Rule that this is possible and terms this phenomenon "leakage" [ref 2, p64821]:

> *EPA analysis has identified a concern that a mass-based state plan that failed to include appropriate measures to address leakage could result in failure to achieve emission performance levels consistent with the BSER.*

The simplest path by which this can happen is one in which new NGCC generation, which complies with the NSPS, replaces existing very-low-carbon generation. Remy Devoe, Justin Knowles, and a team at the University of Tennessee Knoxville [9] first identified this possibility when considering scenarios in which a nuclear power plant closes and a state must make up the lost generation from other sources. If the generation is made up by newly installed NGCC generators built after the baseline date of the CPP, the result is a reduction in emissions accounted for by CPP but an increase in real emissions.

II.B. New Source Complement

A "new source complement" is the mass of CO_2 emission that is allowed specifically to enable a state to meet incremental electricity demand between 2014 and 2030. Accounting for new CO_2 emitting generators under a new source complement is a direct alternative to accounting for them under the New Source Performance Standard. From the EPA technical support document on new source complements [12]:

> *[N]ew source complements represent the EPA's estimated new source emissions associated with satisfying incremental demand from 2012. States may add these new source complements to the final rule's mass goals in pursuing a mass-based compliance pathway inclusive of both affected EGUs and new fossil fuel-fired sources.*

II.C. Clean Energy Incentive Program

The Clean Energy Incentive Program (CEIP) is a new measure in the CPP Final Rule. According to the Final Rule text, "the CEIP is designed to incentivize investment in certain RE [renewable energy] and demand-side EE [energy efficiency] projects" that come online in 2020 and 2021, the two years before states must begin their "glide path" toward eventual compliance with the rule [ref 2, p64943].

More specifically, the EPA provides early action emission allowances (under a mass-based state plan) or early action Emission Reduction Credits (ERCs, under a rate-based state plan) to match the allowances or ERCs the project earns for each MWh of generation or avoided demand. This can be considered equivalent to an employer's matching contribution to a 401k retirement plan. The state must deduct the allowances or ERCs that are allocated to the early CEIP project from the state's budget of allowances or expected ERCs during the "glide path" period, but since the project gets matching allowances or ERCs from the EPA, the total number of allowances or ERCs available in the state still increases. Depending on how the state implements trading or accounting of ERCs in their State Plan, this could be very valuable for CEIP-eligible projects, who could potentially begin in 2022 with a major advantage in a state emission trading scheme. The EPA has set a nationwide limit of 300 million tons of CO_2 worth of matching credits they will issue to states with eligible CEIP projects.

There are important limitations on the CEIP. First, the timeline above makes it essential that the project be capable of full implementation, from ground-breaking through grid connection, within 38 months or less (there are 38 months between the first state plan deadline and the beginning of the CEIP period). Second, like many clean energy measures, the CEIP has a list of eligible technologies: generators powered by wind and solar resources, and "quantified and verified electricity savings (MWh) through demand-side EE implemented in low income communities." Other potentially significant sources of very-low-carbon generation, including nuclear plants, hydroelectric generators, and geothermal plants are not eligible.

II.D. Pathways to CPP and NSPS Compliance

When the Clean Power Plan and New Source Performance Standard are considered together, there are four major pathways to compliance.

II.D.1. Option 1: Category-specific emission rate limits with NSPS compliance

The CPP provides each state the option to apply simple category-specific emission rate limits directly to each individual affected EGU already operating in the state before the baseline date. In this case, all new generators built after the baseline date would have to comply with the NSPS.

The two technology classes covered by this type of limit are fossil steam generators (any generator which uses fossil fuel combustion to drive a steam turbine) and natural gas combined cycle generators. The Initial and Final Rates for each type are shown in Table 1.

TABLE I.Initial and Final Category-specific Rates (lb / MWh) [2]

Category	Initial	Final
Fossil Steam	1,671	1,305
NGCC	877	771

For reference, the weighted average emission rate of all NGCC plants in the US operating in 2012 was 880 lb / MWh. Particularly high performing NGCC plants had emission rates around 700 lb / MWh. The NSPS requires an emission rate below 1,000 lb / MWh for new NGCC generators, so it is reasonable to expect that all new NGCC generators will easily comply with the NSPS. The weighted average emission rate of coal-fired units affected by the CPP was 2140 lb / MWh. There are no coal-fired power plants with a capacity larger than 25 MW in the dataset with an emission rate below 1,305 lb / MWh.

II.D.2. Option 2: Statewide emission rate limit with NSPS compliance

The CPP includes a limit on the emission rate allowed collectively for all generation and emissions by affected EGUs in the state. In this case, again, all new generators built after the baseline date would have to comply with the NSPS.

II.D.3. Option 3: Mass limit with new source complement

The CPP includes a limit on the mass of yearly emissions from affected EGUs in each state between 2022 and 2030. The CPP also includes new source complements calculated for each state based on EPA projections of new electricity demand, growth of zero-emission generation, and an assumption that all new fossil-fuel-fired generation would otherwise have complied with the NSPS (so, the highest NSPS emission rate limit is used in calculation of the new source complement emission mass).

II.D.4. Option 4: Mass limit with NSPS compliance

States may decide to adopt the limit on the mass of yearly emissions in the Final Rule and simply declare that new generators built within the state must satisfy the NSPS instead of adding the new source complement to their mass limit. This option is intended to result in the same upper limit on emissions that results from Option 3. It is difficult to guarantee that this would be the case in all state, however, since any new generators built after the baseline date might replace generation from CPP affected EGUs. As we discuss in the cases of Massachusetts and New York, below, this provides the most straightforward way for "leakage" to occur.

II.E. Nuclear Energy: License Renewal and Plant Uprates

Section 1 discussed the goals of the EPA and Obama Administration to broadly incentivize changes in the bulk electric power system that reduce CO_2 emissions and specifically to reward changes that reduce emissions by affected EGUs below 2012 levels. The EPA explicitly acknowledges in the text of the Final Rule that nuclear energy has already contributed to reducing CO_2 emissions and that measures that increase the generation of nuclear energy will contribute to reducing emissions in the future [2].

The CPP Final Rule explicitly states that new nuclear power plants and uprated capacity at existing nuclear power plants will be eligible to receive emission allowances or ERCs [ref 2, p64902]. However, the EPA also explicitly states in the Final Rule that generation from nuclear power plants under renewed licenses will not be eligible for allowances or ERCs.

> *[E]xisting nuclear units ... that receive operating license extensions are not eligible for use in adjusting a CO_2 emission rate, except where such units receive a capacity uprate as a result of the relicensing process. Only the incremental capacity from the uprate is eligible for use to adjust a CO_2 emission rate.*

Over time, a license extension at a nuclear power plant increases the number of very-low-carbon MWh of electricity that can be generated, just like a capacity uprate does. If the nuclear plant were denied a license extension and closed down, the result would be a decrease in the number of very-low-carbon MWh of electricity available over time.

It appears that the EPA considers license renewals at nuclear energy facilities from 40 to 60 years of total operation (and 60 to 80 years) to be part of the "business as usual" scenario, and thus do not require any incentives. However, the EPA explicitly acknowledged in the Proposed Rule that some nuclear plants are at risk of premature shutdown and attempted to incentivize continued operation through a 4th Building Block in that proposal [3]. Further, nuclear plant license renewal is generally a time and resource intensive process, always requiring years of effort by contractors and plant employees and usually requiring hundreds of millions of dollars worth of component replacements or improvements in the plant. According to the EPA's own goals and stated reasoning, nuclear plant license renewal should have been incentivized in the Final Rule in the same way capacity uprates are.

III. STATE-SPECIFIC CASE STUDIES

This paper highlights and analyzes several elements of the CPP of particular importance to the nuclear energy industry and discusses the potential impacts and unintended consequences of the rule on electricity supply and carbon emissions. The authors provide their assessment of the most favorable implementation pathways from the perspective of the nuclear industry (maximizing development, use, and profitability of nuclear energy), the environmental movement (minimizing CO_2 emissions), state governors (minimizing cost of compliance, maximizing job growth), and the EPA.

All calculations presented were performed using same set of data on capacity, generation, and CO_2 emissions, for all power plants active in the U.S. in 2012, used by the EPA to develop State Goal emission limits in the Final Rule [13] (found in the Goal Computation Appendix 1 data file).

The State Goals and generation portfolios of the following states vary considerably. As such, their responses to the Final Rule will also vary considerably, and each state is considered here individually with few attempts at cross cutting comparison.

It should be noted that the CPP does not account directly for interstate flows of electricity. EGUs will be subject to the State Plan of the state where they are located.

Finally, for all calculations presented, the reader should assume that all quantities not mentioned in the description of the scenario under consideration have been held constant. Whenever not explicitly stated, electricity demand growth will be assumed to be satisfied by new NGCC generation. Additionally, this paper aims to investigate the CPP and its impacts on nuclear energy; a more detailed study would have to be undertaken to fully understand how the growth of variable renewable energy will be affected by the rule.

For the reader's reference, Table 2 summarizes US power sector emissions. 15% of emissions are not accounted for by the CPP.

TABLE II. US Power Sector Emissions in 2012 [13]

US National Average	Emission Rate (lb / MWh)	Emission Mass (tons)
Power Sector	1,274	2,569,364,153
CPP-accounted	1,696	2,178,716,430

III.A. Massachusetts

Massachusetts is a small northeastern state with high electricity prices, substantial electricity imports, and no in-state production of oil or gas [14]. Energy Information Administration (EIA) data shows that "Massachusetts generated 59% of its electricity from natural gas and 9.5% of its electricity from coal in 2014." [14] The sources of electricity generated in Massachusetts in 2012, according to EPA data, are shown in Table 3. Massachusetts' 2012 CPP-accounted emissions (emissions from affected EGUs), total power sector emissions, and State Goals, both Initial and Final and both rate-based and mass-based, are shown in Table 4.

TABLE III. Electricity generated in Massachusetts in 2012 [13]

Source	2012 Generation (MWh)	Percent
Natural Gas	24,535,722	68%
Nuclear	5,859,540	16%
Coal	2,305,035	6.4%
Municipal Solid Waste	1,794,570	5.0%
Hydro	604,937	1.7%
Wind	89,673	0.25%
Solar	29,614	0.08%
All other	825,687	2.3%

TABLE IV. Massachusetts CPP State Goals [13]

	Emission Rate (lb / MWh)	Emission Mass (tons)
2012 Entire Power Sector	1,091	19,659,846
2012 CPP-accounted	1,003	13,125,248
Initial Goal	982	13,742,197
Final Goal	824	12,104,746

Massachusetts starts with a relatively low emission rate in 2012 and relatively low emission rate goals. Massachusetts does have a distinctively large fraction of total CO_2 emission mass not accounted for in the CPP, 33% of total real mass (larger than any of the following states). This is primarily the result of the presence of a couple of large industrial combined-heat-and-power plants and several municipal solid waste plants.

III.A.1. MA Scenario 1 - Replace Coal with Existing Gas

This scenario is a direct implementation of CPP BSER Building Block #2 - increase the utilization of currently-available NGCC generators to 75% and reduce the use of higher-emitting affected EGUs (i.e. steam cycle generators). Table 5 shows several key figures in this scenario and the resulting emission rate and yearly emission mass, the “Total Available NGCC” is the additional amount of energy which could be generated by existing NGCC units if the capacity factor were increased to 75%.

TABLE V. Key figures and results of MA Scenario 1

MA Scenario 1	Replace Coal with Available NGCC
Total NGCC Generation, 2012 (MWh)	23,554,517
Total Available NGCC, 2012 (MWh)	15,865,812
Coal Generation Replaced (MWh)	2,281,526
EGU Emission Rate (lb / MWh)	907
EGU Emission Mass (tons)	11,870,379
Total Emissions (tons)	18,404,977

This scenario would bring Massachusetts fully into compliance with its mass-based goal for 2030 or with its interim rate-based goal for the first 2 year period, 2022 through 2024. Total emission mass would be reduced by 6.4%. Considering that Massachusetts starts with power sector emissions well below the national average and relatively poor onshore renewable resources, it is reasonable that the state is not expected to make profound emissions reductions.

In our assessment, this scenario represents the CPP working as intended. The EPA’s stated goal is accomplished and no disruptions to the electric power supply in Massachusetts would be expected. The governor might be disappointed by a minor loss of jobs (since power generation is concentrated at a slightly smaller number of plants after coal generation is shut down), but this loss is a quite predictable one that has already been happening gradually since 2012 (coal generation was down to less than 2% of the total in both August and September of 2015 [14]). No power system investments are needed to accomplish this scenario.

III.A.2. MA Scenario 2 - Build a 1GW Nuclear Energy Facility

This scenario is a direct implementation of BSER Building Block #3 - increase zero-carbon generation in the state and displace CO_2 emitting generators. This scenario assumes a 1GW nuclear energy facility is built, is connected to the grid before 2030, and operates at an average annual capacity factor of 90%. This would represent a substantial power sector investment for this relatively small state. The results of this scenario are the same as the result if renewables or other very-low-carbon generators were installed and produced the same amount of electricity as this nuclear energy facility; CPP accounting treats generation from all newly-built very-low-emitting generators the same way. The results are shown in Table 6.

TABLE VI. Key figures and results of MA Scenario 2

MA Scenario 2	New 1GW Nuclear Plant
Nuclear Generation @ 90% CF (MWh)	7,884,000
Avoided emissions (tons)	4,851,679
EGU Emission Rate (lb / MWh)	632
EGU Emission Mass (tons)	8,273,569
Total Emissions (tons)	14,808,167

The result of such an investment is dramatic. The state would be brought into compliance with state goals of either type with a wide margin. Real emissions would be reduced by 25%. If such an investment could be made in an economically sound manner, all of the interests described in the introduction to this section should be highly satisfied with the result. The EPA's stated goals would be satisfied, the governor would have significant job growth to report, environmental activists could celebrate the large reduction in real emissions, and the nuclear industry could celebrate the construction of a new facility.

III.A.3. MA Scenario 3 - Replace Coal and Nuclear with New NGCC

This scenario tests the concern expressed in the section on "leakage" above. First, 1.2 GW of new NGCC capacity is built in the state. Second, coal generation is shut down. Finally, nuclear generation in the state from Pilgrim Nuclear Power Plant is also shut down (as is actually planned by 2019 [15]). This scenario is assumed to follow Compliance Option 4 above - the state pursues a mass-based goal and requires all new NGCC plants to comply with the NSPS. The result is shown in Table 7.

TABLE VII. Key figures and results of MA Scenario 3

MA Scenario 3	Replace Coal + Nuclear with New NGCC
New NGCC Generation at 75% CF (MWh)	8,141,066
EGU Emission Rate (lb / MWh)	901
EGU Emission Mass (tons)	10,763,550
Total Emissions (tons)	20,916,852

We can clearly see that "leakage", which we might also have simply referred to as "cheating", would occur in this scenario. The state would easily comply with its EGU emission mass target while total emissions would increase by 6.4%. It is even more unfortunate that 1.2GW of new NGCC capacity represents a relatively inexpensive power system investment, certainly much cheaper up front than the nuclear plant postulated in Scenario 2.

The interests that might motivate a state to pursue a scenario like this are worthy of further investigation and analysis. It is clearly the intention of the EPA that this type of scenario should not be permitted, but we cannot identify any provision of the CPP that would prevent it.

III.B. New York

New York, like Massachusetts, relies heavily on natural gas, but also has a substantial amount of nuclear and hydroelectric generation. The sources of electricity generated in New York in 2012, according to EPA data, are shown in Table 8. New York's 2012 CPP-accounted emissions (emissions from affected EGUs), real emissions, and State Goals, both Initial and Final and both rate-based and mass-based, are shown in Table 9.

TABLE VIII. Electricity generated in New York in 2012 [13]

Source	2012 Generation (MWh)	Percent
Natural Gas	59,475,119	44%
Nuclear	40,774,560	30%
Hydro	24,150,828	18%
Coal	4,579,082	3.4%
Wind	2,974,615	2.2%
Other	2,180,016	1.6%
Oil	621,242	0.46%
Solar	52,713	0.04%

TABLE IX. New York CPP State Goals [13]

	Emission Rate (lb / MWh)	Emission Mass (tons)
2012 Entire Power Sector	638	42,968,299
2012 CPP-accounted	1,140	34,596,456
Initial Goal	1,129	36,661,943
Final Goal	918	31,257,428

III.B.1. NY Scenario 1 - Replace Coal with Existing Gas

Unlike the Massachusetts scenario, New York can come close to, but not completely meet its State Goals by just replacing existing coal-fired power plants with existing NGCC. This is primarily due to the low percentage of electricity currently derived from coal-fired power plants in New York. Table 10 shows the results for two cases, the first assuming that average emissions NGCC sources are used, and the second assuming the best NGCC sources are used. The capacity factor of those NGCC units in both cases is increased to 75%.

TABLE X. Key figures and results of NY Scenario 1

NY Scenario 1 Replace Coal with …	Average NGCC	Best NGCC Available
Total NGCC Generation, 2012 (MWh)	44,035,434	
Total Available NGCC, 2012 (MWh)	30,098,628	
Coal Generation Replaced (MWh)	4,156,143	
EGU Emission Rate (lb / MWh)	1,054	1,044
EGU Emission Mass (tons)	31,992,714	31,685,159
Total Emissions (tons)	40,364,556	40,057,001

New York could come in compliance by replacing some of the emissions from coal-fired power plants with new NGCC plants that comply with the NSPS. Since these new plants are not considered affected EGUs under the CPP, the emissions from affected EGUs would be lower, and would help NY come into compliance.

III.B.2. NY Scenario 2 - Build a 1 GW Nuclear Energy Facility

If a new 1GW nuclear energy facility were to be built in NY, it could not only replace all existing coal generation, but a substantial amount of existing NGCC as well. Table 11 shows the emissions avoided for two different cases, the first where the new nuclear generation replaces all existing coal generation in NY and the highest emissions NGCC units, and the second where new nuclear generation replaces all existing coal generation and some average emissions NGCC units.

TABLE XI. Key figures and results of NY Scenario 2

NY Scenario 2 New 1GW Nuclear Plant Replaces Coal and…	Highest emissions NGCC	Average emissions NGCC
Nuclear Generation @ 90% CF (MWh)	7,889,400	
Avoided Emissions (tons)	7,614,712	6,441,936
EGU Emission Rate (lbs/MWh)	889	928
EGU Emission Mass (tons)	26,981,744	28,154,520
Total Emissions (tons)	35,353,587	36,526,363

In this scenario, NY comes in full compliance of the Final Rule under the mass-based pathway, and can come in compliance with the rate-based pathway if higher than average emissions NGCC are replaced by the additional nuclear generation. Emissions savings are higher than in MA Scenario 2 because a larger amount of coal emissions are avoided in the NY Scenario. Additionally, total emissions would drop considerably, from 15 - 17.7% statewide, depending on which NGCC units are replaced.

III.B.3. NY Scenario 3 - Replace Coal and/or Nuclear with New NGCC

This scenario, like MA Scenario 3, looks at the possibility of coal-fired units and nuclear energy facilities being closed, and how this would be treated under the CPP. As shown in Table 12, and mentioned before, New York can come in compliance with the mass-based pathway, and make significant progress in the rate-based pathway by closing down coal-fired power plants and replacing them with new NGCC units. Notice, since carbon emissions from new NGCC units are not counted under the CPP, the affected EGU emissions does not change when additional nuclear facilities are closed and replaced with new NGCC.

TABLE XII. Key figures and results of NY Scenario 3

NY Scenario 3 New NGCC replaces…	**Coal only**	**Coal and FitzPatrick**	**Coal and All Nuclear**
EGU Emission Rate (lb / MWh)	1,060		
EGU Emission Mass (tons)	29,970,750		
New NGCC Generation (MWh)	4,156,143	10,226,669	44,930,703
Total Emissions (tons)	40,364,556	43,317,867	60,201,380

Also like Massachusetts, New York can meet the EPA goal by shutting down the existing coal-fired plants and replacing them with new NGCC, or a combination of existing NGCC and new NGCC. And similar to Massachusetts, there is currently a nuclear energy facility (FitzPatrick Nuclear Power Plant) which has announced its closure - replacing this generation by new NGCC would result in total emissions higher than they would have been, and even higher than 2012 emissions, even though this scenario would comply with the CPP. Additionally, closing FitzPatrick Nuclear Power Plant and replacing it with NGCC would more than wipe out the carbon emissions saved from replacing all existing coal in NY with new NGCC. This is another example of leakage.

III.C. Illinois

Illinois presents a very different situation than the northeastern states. Illinois is home to significant heavy industry, oil refining, and coal production. According to the EIA, "Illinois leads the Midwest in crude oil refining capacity ... as of January 2014" and "In 2013, Illinois ranked second in the nation in recoverable coal reserves at producing mines." [16] Nuclear power provided more electricity in Illinois in 2012 than any other source; according to the EIA, "Illinois ranked first in the nation in 2014 in both generating capacity and net electricity generation from nuclear power." [16] Tables 13 and 14 summarize 2012 electricity generation in Illinois and CPP state goals, respectively.

Illinois has a substantial supply of natural gas passing through the state in pipelines and trading hubs but very little natural gas generation. The overwhelming majority of the natural gas used in the state goes to home heating and heavy industry. Illinois is a substantial ethanol producer (3rd largest state in the US by production capacity [16]); ethanol production requires large quantities of natural gas.

TABLE XIII. Electricity generated in Illinois in 2012 [13]

Source	2012 Generation (MWh)	Percent
Nuclear	96,401,309	49%
Coal	81,031,127	41%
Natural Gas	10,972,852	5.6%
Wind	7,683,448	3.9%
All other	541,549	0.28%
Hydro	111,208	0.06%
Solar	15,080	0.01%

TABLE XIV. Illinois CPP State Goals [13]

	Emission Rate (lb / MWh)	Emission Mass (tons)
2012 Entire Power Sector	1,073	105,521,244
2012 CPP-accounted	2,149	102,208,185
Initial Goal	1,647	83,788,272
Final Goal	1,245	66,477,156

Like New York, Illinois has a dramatic difference between its real 2012 emission rate (with all generation, including nuclear, accounted for) and its CPP-accounted emission rate from affected EGUs (which does not include existing nuclear).

Note that adjustments were made to Illinois baseline emissions data for state goal calculation purposes to account for construction of new goal and NGCC plants in 2012. These adjustments added 9.8 million tons of coal emissions and 1.3 million tons of NGCC emissions to the quantities used to calculate state goals. These upward adjustments have been included in the "2012 CPP-accounted emissions" reported above and in all following calculations. These adjustments were not included in the 2012 total emissions reported above but will be included in total emissions reported in the following scenario results. Since investors in these new plants will want to recover their investments, we consider it reasonable to assume that they will seek to make use of those plants during the CPP compliance period.

III.C.1. IL Scenario 1 - Replace Coal with Existing Gas

Since this worked well in Massachusetts, nearly worked in New York, and represents a direct application of BSER Building Block #2, it represents a good place to start with Illinois, too. In this scenario, we replace as much coal generation as possible with available NGCC generation, defined above as the difference between 2012 NGCC generation and possible generation with all plants available in 2012 running at a capacity factor of 75%. Results are shown in Table 15.

TABLE XV. Key figures and results of IL Scenario 1

IL Scenario 1	Replace Coal with Available NGCC
Total NGCC Generation, 2012 (MWh)	10,627,106
Total Available NGCC, 2012 (MWh)	13,050,100
Coal Generation Replaced (MWh)	13,050,100
EGU Emission Rate (lb / MWh)	1,965
EGU Emission Mass (tons)	93,472,886
Total Emissions (tons)	102,887,963

This strategy will not work in Illinois - there is simply too much coal generation and too little NGCC capacity. Further power system investments are almost certain to be required in Illinois to comply with the CPP.

III.C.2. IL Scenario 2 - Add Zero-Carbon Capacity to Achieve Compliance

Since Illinois requires a much more intensive strategy, in this scenario, we calculate the amount of zero-carbon generation that must be added to achieve compliance with CPP. First, existing NGCC capacity is increased to 75% capacity factor, as was done in Scenario 1. Second, zero-carbon generation is added, replacing coal generation, until the mass-based State Goal for 2030 is achieved. The resulting maximum permissible amount of yearly coal generation is shown below. As previously discussed, the new generation this scenario requires can come from any very-low-carbon generation technology listed in the CPP, including both wind and nuclear energy. For each wind and nuclear, the amount of new capacity that would be needed to supply the required generation entirely with generators of that technology has been calculated. Results are shown in Table 16.

TABLE XVI. Key figures and results of IL Scenario 2

IL Scenario 2	Add zero-carbon generation to comply
Permissible 2030 coal use (MWh / yr)	52,403,064
Required 2030 zero-carbon generation (MWh / yr)	29,661,692
EGU Emission Rate (lb / MWh)	1,354
EGU Emission Mass (tons)	66,477,156
Total Emissions (tons)	75,892,232
New Nuclear Capacity @ 90% CF (MW)	3.8 GW
New Wind Capacity @ 30% CF (MW)	11.3 GW

This new generation could also be accomplished by installing 4.5 GW of new NGCC capacity. This would result in final total emissions of 88.8 million tons per year, which is substantially more than the zero-carbon scenario above but still represents a real improvement over 2012 emissions. It is likely that installation of a mix of wind and NGCC would be substantially cheaper than installation of new nuclear capacity unless significant additional incentives are put in place.

III.D. Georgia

Georgia is a large southeastern state with a well diversified generation mix, significant heavy industry, and an electric power system still operating entirely under a traditional cost-of-service regime. Two new Westinghouse AP1000 reactors are under construction at Vogtle Electric Generating Plant and are expected to come online in 2019 and 2020. Tables 17 and 18 summarize 2012 electricity generation in Georgia and CPP state goals, respectively.

TABLE XVII. Electricity generated in Georgia in 2012 [13]

Source	2012 Generation (MWh)	Percent
Coal	41,559,949	34.1%
Natural Gas	41,119,329	33.8%
Nuclear	33,941,634	27.9%
Other	3,780,918	3.1%
Hydro	1,398,416	1.2%
Oil	5,455	0.0%
Solar	1,547	0.0%

TABLE XVIII. Georgia CPP State Goals [13]

	Emission Rate (lb / MWh)	Emission Mass (tons)
2012 Entire Power Sector	1,356	82,574,960
2012 CPP-accounted	1,599	62,851,752
Initial Goal	1,337	56,291,624
Final Goal	1,049	46,346,846

III.D.1. GA Scenario 1 - Use all available NGCC and Vogtle 3 & 4 generation

In the Proposed Rule, the EPA declared that new nuclear plants under construction in 2012 would be counted as part of the baseline generation in a state and would not be available to use for compliance with State Goals. This was reversed in the Final Rule; new nuclear capacity under construction in 2012 will qualify for ERCs.

In this scenario, all available NGCC generation at existing units is used and Vogtle Units 3 and 4 are assumed to come online and operate at an average capacity factor of 90%. All of this generation is used to displace coal generation. The results are shown in Table 19, as well as results for only using all availably NGCC generation, and only using Vogtle to displace coal generation.

TABLE XIX. Key figures and results of GA Scenario1

GA Scenario 1	Use all available NGCC and Vogtle credits	Use all available NGCC (Vogtle not counted)	Coal replaced with Vogtle 3 and 4
Total NGCC Generation, 2012 (MWh)	37,591,123		
Total Available NGCC, 2012 (MWh)	21,722,509		--
Coal Generation Replaced (MWh)	39,067,309	21,722,509	17,344,800
EGU Emission Rate (lb / MWh)	694	1,200	1,091
EGU Emission Mass (tons)	27,311,828	50,399,522	42,948,563
Total Emissions (tons)	47,043,738	66,938,224	62,680,474

We can see that Georgia will easily be able to comply with either a rate-based or mass-based goal. Under a mass-based goal, Georgia would actually have 50 million MWh per year of available generation that could be used to meet new electricity demand.

IV. CONCLUSIONS

The nuclear energy community has been advocating for many years for measures that would properly value the reliability and low environmental impact of nuclear energy facilities. The Clean Power Plan presented an opportunity for the EPA to do exactly that, but some of that opportunity has been missed.

Despite acknowledging in the Proposed Rule that some nuclear plants may be at risk of premature closure, and despite analysis clearly showing that premature closure of nuclear plants will set back progress toward lower power system emissions [11], the EPA signaled quite clearly in both the Proposed Rule and Final Rule that they will not explicitly value generation from existing nuclear energy facilities in this rule. The cases of Illinois, New York, and Georgia above all clearly show that nuclear energy makes a large contribution toward lowering the real emission rates of those states.

The Clean Energy Incentive Program represents an unambiguous case of circumventing the market and picking the winners in generation of very-low-carbon electricity. Study of CEIP illustrates that there are many important elements in technology neutral regulation, all of which are lacking in that particular program. All elements of a regulation or incentive, including its basic structure and format, timeline, and compliance measures, must all be fully neutral in both their intention and impact. Data used to quantify any measures within an incentive or regulation must be complete and comprehensive.

The EPA missed a particularly important opportunity to value nuclear energy in its decision not to allow states to allocate emission allowances or ERCs for generation from nuclear energy facilities operating under a renewed license. License renewal should not be assumed to be an automatic or easy event, but it does represent a proven way to make more low emission generation available over time. Just as substantial effort and investment have gone into improving performance and reducing cost of wind turbines and solar PV installations, substantial effort and investment have gone into the research and operations to make nuclear license renewals possible.

The analysis of Massachusetts and New York compliance scenarios has shown that it is possible to comply with the CPP while increasing real CO_2 emissions, as several investigators predicted when the Proposed Rule was published. As state officials develop their State Plans and compliance strategies, it will be important to identify states and scenarios in which such leakage, or cheating, is possible.

Illinois illustrates the situation of states which make substantial use of coal for electricity generation. In Illinois, and in other coal-intensive states like Kentucky, West Virginia, and several others, it is unlikely that CPP compliance will be possible without major investments in a combination of NGCC and very-low-carbon generators. It should be noted that wind and solar capacities have been growing rapidly in many states, and will clearly be a useful contributor towards compliance for many states. This paper attempted to identify nuclear energy specific issues and opportunities.

The cases of Massachusetts, New York, and Georgia have clearly shown that new nuclear energy facilities could make major contributions toward accomplishing the CPP goals in states that must make investments. The new nuclear capacity under construction in Georgia will contribute substantially toward achieving CPP compliance.

In conclusion, the discussion and analysis above shows that the Clean Power Plan has clear flaws and offers very little direct value for the existing nuclear energy fleet. CPP emission allowances or credits will increase the value of new nuclear energy facilities, but CPP still falls far short of recognizing the full value of nuclear energy.

ACKNOWLEDGMENTS

Thanks to the members of the American Nuclear Society Special Committee on Nuclear in the States for their advice and support in preparing this project.

Thanks to the MIT Department of Nuclear Science and Engineering for their support of this project.

Thanks to Dr. Yaron Danon and the RPI Mechanical, Aerospace, and Nuclear Engineering Department for their support over the years.

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