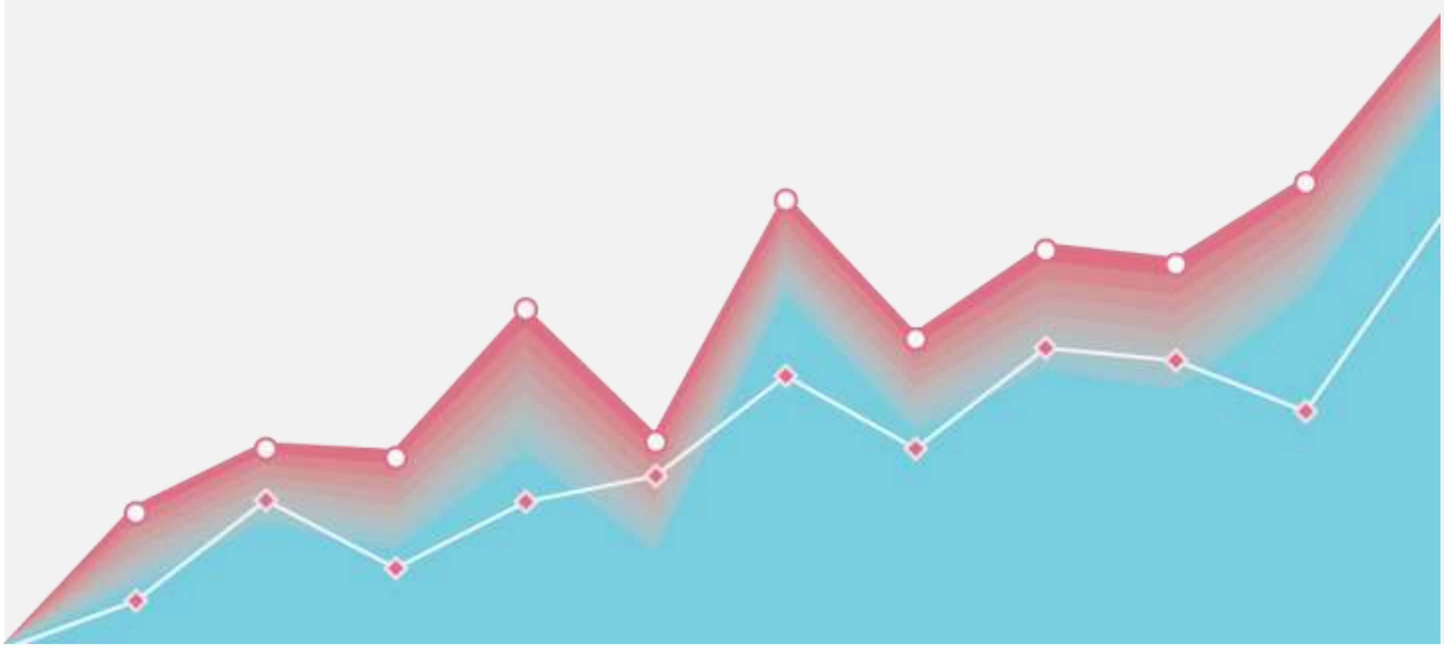
CHAMPLAIN HUDSON POWER EXPRESS ("CHPE")

ANALYSIS OF ECONOMIC, ENVIRONMENTAL, AND RELIABILITY IMPACTS TO THE STATE OF NEW YORK

August 2017



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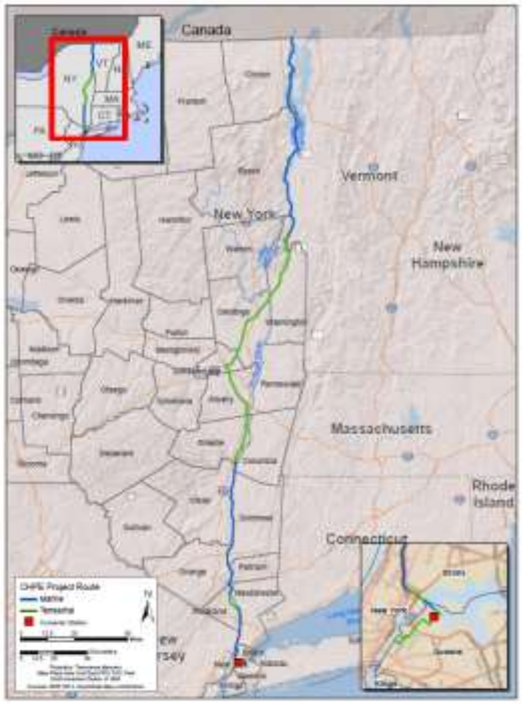
1 EXECUTIVE SUMMARY

This report has been prepared by PA Consulting Group (“PA”) at the request of Transmission Developers, Inc. (“TDI”) to analyze the economic, environmental, and reliability benefits from the Champlain Hudson Power Express project (“CHPE” or the “Project”).

CHPE is a proposed electric transmission line that will run from the Canadian border to Queens, New York, which is within Zone J of the New York Independent System Operator (“NYISO”) electricity system. CHPE will run along underwater and underground routes with a planned commercial online date of December 2022 and an expected operating life of a minimum of 40 years. See Figure 1 below for a map of CHPE’s proposed route. The electricity shipped through CHPE will be generated by hydroelectric and other renewable power plants located in Québec, Canada, and will be delivered directly to the Zone J electricity system. The transmission line will utilize high voltage direct current (“HVDC”) technology, capable of transmitting 1,000 megawatts (“MW”) of clean energy around the clock.

The underwater portions of CHPE, approximately 196 miles in length, will be submerged in Lake Champlain, the Hudson River, the East River and the Harlem River. The overland (terrestrial) portions of the transmission line, approximately 137 miles in length, will be buried underground beneath existing rights-of-way. The Canadian portion of the transmission line will begin at the Hertel converter station in the Province of Québec, Canada, and transmit electricity as described above to the international border at a point in Champlain, New York. From that point, energy will be transmitted over CHPE to Queens, New York, where CHPE will tie into TDI’s proposed CHPE Converter Station. The CHPE Converter Station will convert the electrical power from direct current (“DC”) to alternating current (“AC”) and then connect to the 345 kV Astoria Annex GIS Substation in Bronx County, New York that is owned by NYPA.

Figure 1 - CHPE Overview



CHPE's electricity will be sourced from a pool of hydroelectric and other renewable energy power plants. Québec has a high-performance fleet of 62 hydroelectric power plants with installed capacity totaling over 36,000 MW – which is nearly three times greater than Zone J's highest recorded electricity demand of approximately 11,500 MW.

CHPE is construction-ready, having obtained a Certificate of Environmental Capability and Public Need from the New York State Public Service Commission ("NYPSC"), a Presidential Permit from the U.S. Department of Energy, and permits under Sections 10 and 404 of the Clean Water Act and Rivers and Harbors Act from the U.S. Army Corps of Engineers. CHPE currently holds NYISO Queue Position 458 and is actively undergoing review by the NYISO as part of Class Year ("CY") 2017. As a result of completing the Class Year processes in CY12 and CY15, TDI is confident that it has a robust interconnection point in Queens and that the associated upgrade costs are well understood. Once these upgrades are completed, PA does not project congestion within Zone J to be significantly impacted due to CHPE's operations. On the other hand, PA does expect that congestion across NYISO and into Zone J to be slightly reduced.

In fact, as discussed in this report, CHPE is forecasted to increase the reliability of the New York electricity system by generating fast and flexible clean energy delivered using proven HVDC technology that can safely and reliably meet the needs of the State of New York. More specifically, PA's analysis assumed CHPE begins commercial operations in December 2022[1] with the ability to deliver 1,000 MW of electricity at a capacity factor of 95%, and provide 1,000 MW of firm capacity sales.[2] CHPE would deliver a substantial amount of clean energy (8.3 TWh annually) directly into Zone J. These clean energy deliveries would reduce CO_2 emissions attributed to the State of New York by over 100 million metric tons during the first 30 years

[1] However, the first month of the market simulations performed by PA was January 2023.

[2] Capacity factor for the CHPE HVDC transmission line is a measurement of the actual amount of electricity that is expected to flow over the line versus the potential amount of electricity that could flow over the line.

of operation. Such reductions are critical in helping New York achieve its CO_2 emission reduction and clean energy targets.

The key findings of PA's analysis of CHPE are as follows:

Market Value of Energy Delivered over CHPE

- CHPE's 8.3 TWh per year of clean energy delivered directly into Zone J will have a cumulative market value of $19.9 billion in the first 30 years of operation.[3]

Economic Benefits:

- CHPE is forecasted to decrease wholesale electricity costs for ratepayers across the State of New York by $12.8 billion in the first 30 years of operation. Within Zone J, CHPE is forecasted to decrease wholesale electricity costs for ratepayers by $7.7 billion in the first 30 years of operation, while wholesale electricity costs in the rest of New York State would decrease by $5.1 billion.
- As discussed in Section 3, CHPE will significantly reduce CO_2 emissions attributable to the State of New York and New York City. Over the first 30 years of operations, the total economic benefit of those CO_2 reductions is estimated at $10.6 billion.
- CHPE will support the creation of more than 800 long-term jobs in the State of New York during the first 30 years of operations.
- CHPE will create $1.5 billion in economic output in the State of New York during the project's construction and an additional $2.1 billion during the first 30 years of operations, in addition to the $12.8 billion in wholesale electricity cost savings.
- CHPE is expected to generate approximately $1.7 billion in local taxes and property taxes in the first 30 years of operation, funding towns and school districts across the State of New York.
- Total economic benefits to the State of New York over CHPE's construction and first 30 years of operation will be $28.6 billion.[4]

Environmental Benefits:

- CHPE will decrease CO_2 emissions attributed to the State of New York, specifically New York City, by 3.4 million metric tons per year.[5] This is equivalent to removing 28% of the passenger vehicles from the streets of New York City.
- CHPE's impact on CO_2 emissions will contribute 5% to achieving the State of New York's economy-wide 76 million metric ton target reduction by 2030.[6] CHPE will also contribute 23% to achieving New York City's 15 million metric ton target reduction by 2030.[7]

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[3] Unless otherwise stated, all monetary benefit values are reported in nominal $s and represent the sum (undiscounted) over the first 30 years of CHPE's operations.

[4] Totals may not equal sum of individual values due to rounding.

[5] These emission reduction values are calculated using a consumption-based standard (discussed in Section 3.1).

[6] In Executive Order No. 24, Governor David Patterson established a statewide goal to reduce GHG emissions to 80% below 1990 levels by 2050. The full text of Executive Order No. 24 can be found here: http://www.dec.ny.gov/energy/71394.html. Additionally, the New York State Climate Action Council released an Interim Climate Action Plan in 2010 that established a mid-term benchmark goal to reduce GHG emissions to 40% below 1990 levels by 2030. The full text of the plan can be found here: http://www.dec.ny.gov/docs/administration_pdf/irpart1.pdf

[7] In addition to New York City's established goal to reduce GHG emissions to 80% below 2005 levels by 2050, Mayor Bill de Blasio established an interim goal to reduce GHG emissions to 40% below 2005 levels by 2030. Mayor de Blasio's announcement can be found here: http://www1.nyc.gov/office-of-the-mayor/news/451-14/mayor-de-blasio-commits-80-percent-reduction-greenhouse-gas-emissions-2050-starting-with/#/0

- CHPE has the potential to deliver approximately 1.0 TWh per year of Tier 1-eligible Renewable Energy Credits ("RECs"), which could provide approximately $500 million in additional value during the first 30 years of operations.

Reliability Benefits:

- CHPE, with its 8.3 TWh per year[8] of clean energy sourced from Québec's hydro and other renewable energy plants, will improve the winter reliability of the New York electricity system, particularly Zone J. CHPE will decrease the New York power sector's natural gas usage by 9% across the state and 16% within Zone J, which will increase natural gas supply year-round and on cold winter days.
- CHPE will support summer reliability on the New York grid by replacing older power plants as they retire; especially the 7,250 MW of steam and gas turbine power plants that NYISO has identified as potentially reaching their end of life in the next 10 years.[9]

The sum of the forecasted market value and economic benefits from the 8.3 TWh per year of clean energy provided by CHPE are substantial, totaling nearly $50 billion during its construction and the first 30 years of operation, as illustrated in Table 1. This equates to average annual benefits of approximately $1.3 billion per year. These total forecasted benefits include the sum of the following unique benefits:

1. The market value of the clean energy provided over the CHPE;
2. The wholesale electricity cost savings experienced by New York ratepayers as a result of CHPE's low-cost energy and capacity, which reduce wholesale energy and capacity prices;
3. The net economic output resulting from expenditures on CHPE and wholesale electricity cost savings experienced by New York ratepayers, including economic output attributable to the CHPE's construction;
4. The property taxes that CHPE will pay to towns and school districts along the line's route; and
5. The value of the CO_2 emission reductions caused by CHPE.

[8] Although a capacity factor of 95% (corresponding to 8.3 TWh/year) was used in the market simulations, higher capacity factors are likely achievable, and would result in proportionally greater energy and emission savings.

[9] Source: NYISO Power Trends 2017.

Table 1 - Benefits to the State of New York from CHPE ($millions)

Benefit Type (Market Value and Economic Benefits)	Sum of Benefits (Construction plus 30 years of operation)	Average Annual Benefits
Market Value of CHPE's Energy		
(1) Electricity Market Value of Energy Provided by CHPE	**19,920**	**553**
Economic Benefits		
(2) Total Wholesale Electricity Cost Savings	**12,778**	**355**
Energy Cost Savings	9,274	258
Capacity Cost Savings	3,504	97
Gross Economic Output[10]	**16,341**	**454**
Less Total Wholesale Electricity Cost Savings	12,778	355
(3) Net Economic Output During Construction and Operation	**3,563**	**99**
(4) Property Tax Payments	**1,682**	**47**
(5) Value of CO_2 Emission Reductions[11]	**10,560**	**293**
Total Benefits		
(6) Total Economic Benefits [Sum 2 through 5]	**28,582**	**794**
Total of Market Value and Economic Benefits [Sum 1 and 6]	**48,502**	**1,347**

The remainder of this report is structured into three sections, one for each of the primary benefits, with two appendices, the first summarizing the results of PA's analysis and the second describing the methodology and models upon which PA relied for its analysis.

[10] This figure includes $14.8 billion in gross economic benefits during the first 30 years of operations (2023-2052) plus an additional $1.5 billion in economic benefits during the construction period.

[11] The value of CO_2 emission reductions reported in Table 1 reflect reductions using a consumption-based standard and an associated forecasted CO_2 emission reduction of 3.4 million metric tons per year (on average).

2 CHPE ECONOMIC BENEFITS TO THE STATE OF NEW YORK

This section examines and quantifies the economic benefits (*e.g.,* jobs created, compensation, increased economic output, and increased tax revenue) to the State of New York from CHPE's construction and operation. These economic benefits were calculated using IMPLAN, an Input-Output model, and categorized into (i) direct, and (ii) induced and indirect benefits.[12]

The key findings from this section of the report include the following:

The electricity market value of the clean energy that CHPE will provide is significant.

- CHPE's 8.3 TWh per year of clean energy delivered into Zone J will have an electricity market value of $19.9 billion over the first 30 years of operation.

CHPE will lower wholesale electricity costs for New York ratepayers.

- By decreasing wholesale electricity costs, CHPE is forecasted to save ratepayers across the State of New York $12.8 billion in the first 30 years of operation. Within Zone J, CHPE is forecasted to decrease wholesale electricity costs for ratepayers by $7.7 billion in the first 30 years of operation, while wholesale electricity costs in the rest of New York State would decrease by $5.1 billion.

CHPE will create new long term jobs and compensation.

- During the height of its construction, CHPE will create over 2,600 jobs, and will create approximately $600 million in additional compensation throughout the construction period.
- CHPE will support the creation of more than 800 long-term jobs and create $5.6 billion in additional compensation in the State of New York during the first 30 years of operation.

CHPE will increase economic output.

- Based on the jobs created and compensation paid by those jobs, CHPE will create $1.5 billion in additional economic output in the state of New York during its construction period.
- During the first 30 years of operation, CHPE will create $2.1 billion in additional economic output in the State of New York, in addition to the $12.8 billion in wholesale electricity cost savings.

CHPE will increase local tax revenue.

- CHPE will generate approximately $1.7 billion in local property taxes during the first 30 years of operation, helping to fund towns and school districts along the line's route.

2.1 Overview

CHPE is forecasted to provide economic benefits to New York ratepayers during both its construction and operating periods. These economic benefits are expected to be realized from three primary areas:

- **Construction of the Project** – equipment, materials, and labor employed, as well as taxes, permitting fees, and other activities paid during construction;

[12] As described in more detail in Appendix B, indirect benefits reflect supply chain impacts from CHPE's direct expenditures, whereas induced benefits reflect increased household income due to direct and indirect impacts.

- **Operation of the Project** – fixed and variable costs associated with the materials and labor needed for operations; and
- **Wholesale electricity cost savings from the Project** – CHPE's entry will result in lower wholesale capacity and energy prices, thereby resulting in wholesale electricity cost savings to New York ratepayers.

The model that PA used in its economic impacts analysis is called IMPLAN – Impact Analysis for Planning. IMPLAN has been in use for more than 30 years and was originally commercialized by the Agricultural Department at the University of Minnesota. IMPLAN is used to assess economic impacts related to a wide variety of capital projects by federal and state agencies and private industry, including the U.S. Department of Agriculture, U.S. Department of Interior, U.S. Army Corps of Engineers, and U.S. Coast Guard. In addition to being used to assess the economic impacts of transmission lines and power plants, IMPLAN has also been used to assess impacts from baseball stadiums, forestry, factories (*e.g.*, Tesla's 'Gigafactory'), and other projects.

IMPLAN is an Input-Output model, explained in greater detail in Appendix B, which analyzes relationships among industries and how spending in industry A impacts industries B, C, D, etc. By analyzing and quantifying these inter-relationships and impacts, IMPLAN produces a forecast of economic benefits (both direct and indirect and induced) for regional economies for (i) jobs created; (ii) compensation; (iii) economic output growth, and (iv) local tax revenue.

2.1.1 Methodology

PA calculated the economic impacts to New York ratepayers resulting from (1) CHPE's direct expenditures in New York (*e.g.*, design, engineering, environmental services, and construction projected to be provided by firms in New York), (2) CHPE's expenditures outside New York and their indirect impact on New York and (3) lower wholesale electricity and natural gas costs from CHPE's operations. CHPE's direct and indirect expenditures in New York and outside New York, respectively, were calculated based on inputs provided by TDI related to the development, construction, and operation of the Project.

PA's analysis found that wholesale electricity prices would decrease as a result of CHPE's operations, and that these decreases would lead to lower wholesale electricity costs for New York ratepayers. As a result, ratepayers would have more disposable income to spend in the economy, since they would be spending less on electricity, which would result in higher economic output for New York's economy.

2.2 Findings

Based on PA's analysis, CHPE is forecasted to provide significant economic benefits to New York ratepayers. These benefits will come in the form of (a) job creation, which will result in more compensation, (b) increased disposable income stemming from reductions in electricity costs and compensation increases – creating (c) economic stimulus and more output within the state. In addition, CHPE property tax payments will lead to (d) increased local tax revenue. The jobs and compensation are expected to be stimulated by (1) CHPE's $1.4 billion of expenditures within the State of New York, (2) CHPE's expenditures outside the State of New York, and (3) the wholesale electricity cost savings to New York ratepayers from CHPE's operations.

The cumulative benefits that CHPE is forecasted to provide to New York ratepayers during its construction period (through the end of 2022) are summarized in Table 2.

Table 2 - CHPE Construction Period Benefits in New York

Benefit	Cumulative Benefit (2017-2022)
New Jobs	> 2,600
Higher Compensation	$0.6 billion
More Economic Output	$1.5 billion

The benefits that CHPE is forecasted to provide to New York ratepayers during the first 30 years of commercial operation (through the end of 2052) are summarized in Table 3.

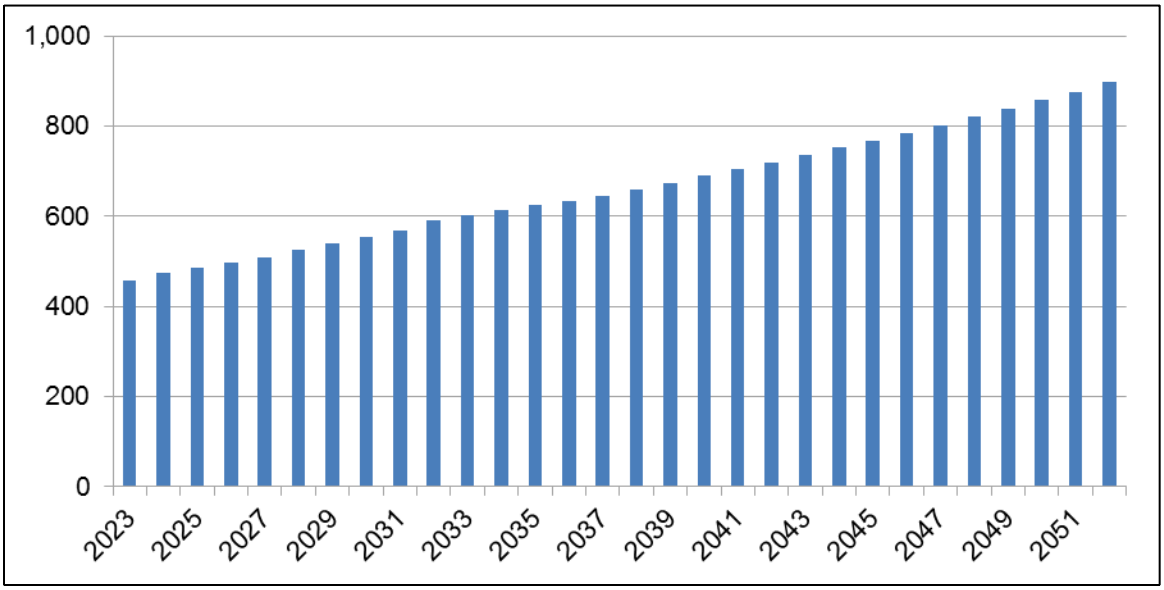
Table 3 - CHPE Operation Period Benefits in New York

Benefit	Cumulative Benefit (2023-2052)
New Jobs	>800
Higher Compensation	$5.6 billion
More Economic Output (including electricity cost savings)	$14.8 billion

2.2.1 The electricity market value of the clean energy that CHPE will provide is significant

Before discussing the electricity cost savings from the 8.3 TWh per year of clean energy that CHPE is forecasted to provide, as outlined in Section 2.2.2, it is important to consider the direct electricity market value of the energy delivered by CHPE to the New York electricity system, specifically Zone J. CHPE is expected to deliver 8.3 TWh per year of clean energy annually via the Astoria Annex GIS Substation in Bronx County, New York. This energy has significant value based on PA's analysis of the forecasted energy price at the Astoria Annex GIS Substation. More specifically, PA forecasts around the clock energy prices at the Astoria Annex GIS Substation to average nearly $80/MWh during the first 30 years of operation. This equates to approximately $665 million per year in the electricity market value of that energy. Over the first 30 years of operation, PA forecasts a total of $19.9 billion in the electricity market value of energy delivered by CHPE, as illustrated in Figure 2.

Figure 2 – Electricity Market Value of Energy Provided by CHPE ($millions)



2.2.2 CHPE will lower wholesale electricity costs for New York ratepayers

An additional benefit of the 8.3 TWh per year that CHPE is forecasted to deliver into the New York electricity system, specifically Zone J, is that CHPE is forecasted to decrease wholesale electricity costs for residential, commercial, and industrial users of electricity. Wholesale electricity costs are primarily comprised of costs for capacity and energy. Capacity costs are the payments made to power plants to ensure they are available to operate when needed, which is effectively a reservation charge paid to power plants. Energy costs are the payments made to power plants for the actual electricity they produce when they are needed, which is effectively a variable production charge. CHPE is forecasted to reduce both categories of costs for New York ratepayers.

CHPE is forecasted to reduce energy costs by providing electricity at a low production cost. Since CHPE will source its electricity from Québec's pool of hydroelectric and other renewable energy power plants, its production costs will be lower than almost all of the existing power plants in the State of New York and Zone J. By providing low cost electricity, CHPE will operate ahead of (*i.e.*, displace) the more expensive power plants (*e.g.,* fuel oil and natural gas) that New York ratepayers would have otherwise relied on for their electricity needs. As a result, CHPE will decrease the electricity market's use of expensive natural gas and fuel oil-fired power plants, thus reducing energy prices and the energy component of wholesale electricity costs.

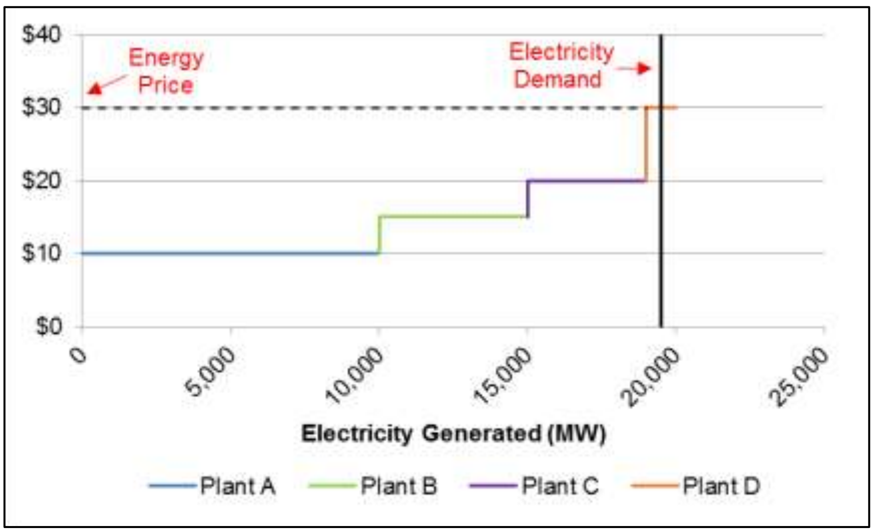
This is illustrated in the following hypothetical example. In this example, we assume that electricity demand is 19,500 MW and that the electricity system has four power plants without CHPE, each with their own unique production cost (as shown in Table 4 below). (In reality, the NYISO system has hundreds of power plants.)

Table 4 - Hypothetical Electricity System Example

Power Plants in the System	Capacity (MW)	Electricity Production Cost ($/MWh)
CHPE	1,000	N/A
Power Plant A (nuclear plant)	10,000	10
Power Plant B (biomass plant)	5,000	15
Power Plant C (natural gas plant)	4,000	20
Power Plant D (natural gas plant)	1,000	30

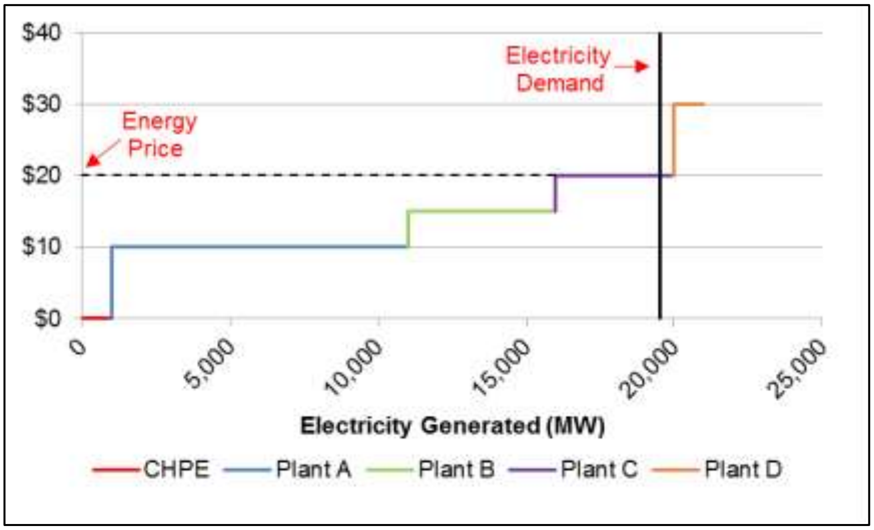
In order to meet electricity demand, all four power plants would be required to generate electricity without CHPE in the market, and the energy price would be set at $30/MWh (*i.e.*, the production cost of the most expensive power plant required to meet electricity demand), as illustrated in Figure 3.

Figure 3 - Hypothetical Energy Price without CHPE ($/MWh)



However, as illustrated in Figure 4, when CHPE enters the system with its extremely low production cost, it will operate ahead of the more expensive power plants (*i.e.*, Plants A-D). As a result, the system no longer requires the expensive electricity generated by Plant D – which results in a decrease in the energy price from $30/MWh to $20/MWh (the new, lower production cost of Power Plant C). This decrease in the energy price is the result of CHPE's 1,000 MW of electricity and results in energy cost savings equal to: ($30/MWh - $20/MWh) x 19,500 MW = $195,000 for one hour.

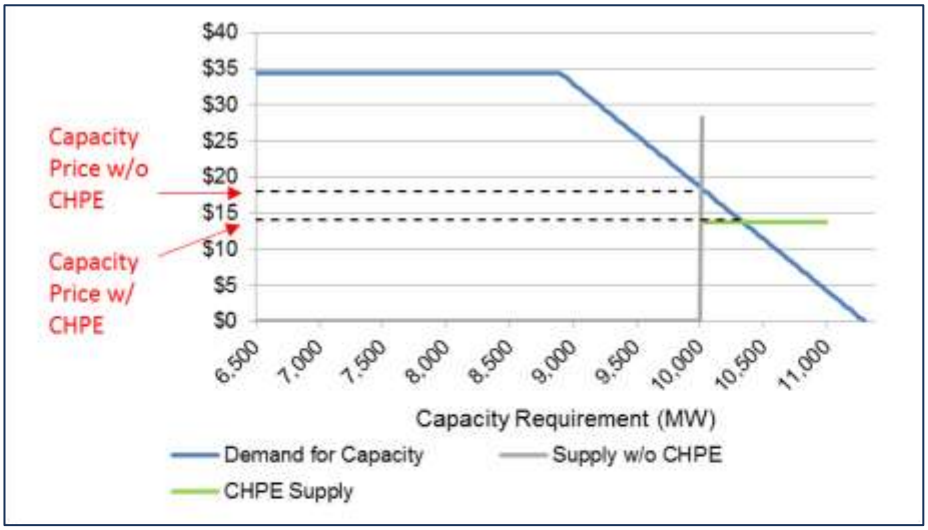
Figure 4 - Hypothetical Energy Price with CHPE ($/MWh)



Similar to energy costs, CHPE is forecasted to lower capacity costs by increasing the amount of low cost capacity available to New York ratepayers. More specifically, capacity costs in New York are calculated based on the ICAP auction, which purchases capacity on behalf of electricity users to meet the New York system's peak electricity demand. All else equal, the more low cost capacity that is available in the auction, the lower the total cost of purchasing capacity. This is because low cost capacity will be purchased before higher cost capacity. As a result, New York ratepayers will pay less for capacity and realize the associated cost savings.

This is illustrated in the following hypothetical example, shown in Figure 5. Without CHPE in the auction, there is less low cost capacity available to be purchased, so the capacity price is $18.40/kW-mo. However, with CHPE in the auction, its low cost capacity is purchased before higher cost capacity – resulting in a lower capacity price of $13.75/kW-mo. In addition, more capacity is purchased with CHPE in the auction, which increases the reliability of the system. This decrease in the capacity price is the result of 1,000 MW of firm capacity sales from CHPE (the minimum amount of firm capacity sales the Project is expected to provide) and results in capacity cost savings equal to: [$18.40/kW-mo x 10,000 MW] - [$13.75/kW-mo x 10,300 MW] = $42,375,000 for one month.

Figure 5 - Hypothetical Capacity Price with and without CHPE ($/kW-mo)



Overall, based on CHPE's forecasted impacts to New York's energy and capacity markets, PA's analysis forecasts CHPE to lower wholesale electricity costs (made up of capacity and energy) by $12.8 billion in the State of New York over the first 30 years of operation, with $7.7 billion of those savings accruing in Zone J. These cost savings are reflected in the economic benefits outlined in Sections 2.2.3 and 2.2.4.

2.2.3 CHPE will create new long-term jobs and compensation

Based on PA's analysis, CHPE is forecasted to create more than 1,500 direct full-time jobs within New York, and approximately 1,100 secondary jobs (indirect and induced), during its construction. Once operational, CHPE is forecasted to create more than 800 long-term jobs in New York.

Through construction-related jobs, CHPE is forecasted to create approximately $630 million in total compensation in New York during the construction period (2017-22), with over $385 million in direct compensation paid and nearly $245 million in secondary compensation created. During its first 30 years of operation (through the end of 2052), CHPE is forecasted to create $5.6 billion in compensation (both direct and indirect and induced) in New York.

2.2.4 CHPE will increase economic output

Based on the jobs created and compensation paid by those jobs, CHPE is forecasted to create approximately $1.5 billion in economic output to New York's economy during its construction (2017-2022). During the first 30 years of operations (2023-2052), CHPE is forecasted to create approximately $14.8 billion in gross economic output to New York's economy. Increased gross economic output during the operations period will be driven primarily by the $12.8 billion in wholesale electricity cost savings, discussed in Section 2.2.2, as these savings increase disposable income that can be spent in the economy. Therefore, the gross economic output created during CHPE's operations incorporates the benefits from these savings, and the net economic output created in addition to the wholesale electricity cost savings is approximately $2.1 billion.

2.2.5 CHPE will increase local tax revenue

CHPE will generate significant local taxes assessed by towns and school districts along its 333-mile route. CHPE, considered to be a real asset for the purposes of property tax assessments, will be assessed based on its cost or value and the applicable mill rate for each town or school district. The $1.7 billion of expected tax payments over the first 30 years of operations will be paid directly to towns and schools, contributing to economic development and public facility improvement.

3 CHPE ENVIRONMENTAL BENEFITS TO THE STATE AND CITY OF NEW YORK

This section examines and quantifies the environmental benefits to the State and City of New York that result from CHPE's operations. These benefits, namely CO_2 emission reductions and progress towards the State of New York's Executive Order No. 24 ("Order No. 24") and New York City's PlaNYC emission reduction goals, were calculated using the AURORA[xmp] electricity market model, which simulates the operation of the NYISO electricity system and adjacent markets (*e.g.,* Hydro-Québec, Ontario, New England, PJM) and the power plants and transmission lines within them.

The key findings from this section of the report include the following:

CHPE will reduce CO_2 emissions in the State of New York and New York City.

- Average annual emission reductions in the State of New York and New York City from CHPE are 3.4 million metric tons of CO_2 under a consumption-based standard.

CHPE will help the State of New York and New York City meet their CO_2 reduction targets.

- These CO_2 reductions would help the State of New York and New York City achieve approximately 5% and 23%, respectively, of the economy-wide emission reductions required to meet their 40% by 2030 emission reduction goals. These reductions are especially critical in New York City, where achieving deep CO_2 emission reductions will be particularly challenging.

CHPE meets New York's preferred GHG reduction plans.

- In addition to the emission reduction benefits CHPE will provide the State of New York and New York City, CHPE's clean energy and low electricity production costs align with New York's stated vision for solutions to reduce its GHG emissions in order to meet specified targets.

The value of the CO_2 reduction benefits CHPE will provide is significant.

- In the State of New York and New York City, total CO_2 emission reductions due to CHPE translate into approximately $10.6 billion of value during the first 30 years of operation.

CHPE can help New York meet its CES Tier 1 targets

- CHPE has the ability to deliver 1.0 TWh per year of Tier 1-eligible RECs, which would provide $500 million in additional value to New York ratepayers and contribute approximately 7% towards New York's potential CES Tier 1 resource target in 2023.

3.1 Overview

Order No. 24, signed in 2009 by Governor David Patterson, established a goal for the State of New York to reduce its greenhouse gas ("GHG") emissions from all sources to at least 80% below 1990 levels by 2050 ("80 x 50").[13] To pursue the 80 x 50 target, Order No. 24 created an interagency working group known as the Climate Action Council to develop a Climate Action Plan. Within the interim Climate Action Plan, published in 2010, the Climate Action Council called for a mid-term benchmark reduction target of at least 40% below 1990 levels by 2030 ("40 x 30"). This 40 x 30 benchmark target was reaffirmed in New York's

[13] The full text of Order No. 24 can be found here: http://www.dec.ny.gov/energy/71394.html

2015 New York State Energy Plan, and again in the NYPSC's *Order Adopting a Clean Energy Standard* ("CES") in August 2016.

When accounting for GHG emissions from the New York power sector (to determine progress toward the 40 x 30 and 80 x 50 targets), the state currently uses a consumption-based accounting method. The first statewide GHG emissions inventory performed after Order No. 24 was included in the interim Climate Action Plan, covering years 1990-2008. This inventory specifically measured GHG emissions from the electric power sector using a consumption-based accounting method, noting that "*emissions estimates reflect the GHG emissions associated with the electricity sources used to meet New York's demands, corresponding to a consumption-based approach to emissions accounting that includes emissions from imported electricity.*"[14] In each subsequent GHG emissions inventory prepared by the New York State Research and Development Authority ("NYSERDA"), the state has used a consumption-based accounting method for emissions from the electric power sector.[15]

A consumption-based method is used because New York imports and exports electricity from and to neighboring states and provinces, and the GHG emissions associated with producing the electricity that is consumed in New York are not necessarily emitted within the state. Furthermore, other states in the Northeast U.S. that have mandated GHG emission reduction targets, including Connecticut and Rhode Island, use a consumption-based method for power sector emissions.

In addition to the State of New York's 40 x 30 and 80 x 50 targets, New York City has adopted its own GHG reduction goal. In the first *PlaNYC* report issued in 2007, Mayor Michael Bloomberg's administration called for a reduction in GHG emissions of at least 30% below 2005 levels by 2030. However, in September 2014, Mayor Bill de Blasio issued a public commitment to reduce the city's GHG emissions to at least 80% below 2005 levels by 2050 with an interim target of 40% below 2005 levels by 2030, a commitment that has been upheld in the City's *Roadmap to 80 x 50* plan.[16] Similar to NYSERDA, New York City uses a consumption-based approach to account for GHG emissions from the electric power sector in order to capture the GHG emissions associated with imported electricity.[17]

Therefore, because both the State of New York and New York City have individual GHG emission reduction targets, and because both use a consumption-based approach to account for GHG emissions from the power sector, CO_2 emission reductions and their associated benefits are presented in this analysis using a consumption-based standard. Additionally, using a consumption-based standard and assuming that all energy delivered by CHPE directly into New York City is consumed within Zone J, all system-wide CO_2 emission reductions associated with CHPE's entry into the market are attributable to New York City.

3.1.1 Methodology

PA determined the annual emission reductions attributable to CHPE by simulating the NYISO electric grid with and without CHPE. The analysis was performed using PA's proprietary electricity market model process, which simulates the operations of power plants and transmission lines within NYISO and adjacent power markets (e.g., PJM) using AURORA[xmp], and calculates the emissions of the individual power plants with and without CHPE. This modeling process is described in greater detail in Appendix B. The emission

[14] Source: New York State Climate Action Council, Climate Action Plan Interim Report, November 2010, page 3-2.

[15] Source: NYSERDA, New York State Greenhouse Gas Inventory and Forecast: Inventory 1990-2011 and Forecast 2012-2030, June 2015;
NYSERDA, New York State Greenhouse Gas Inventory: 1990-2014, February 2017.

[16] Source: The City of New York, New York City's Roadmap to 80 x 50, September 2016.

[17] Source: The City of New York, Inventory of New York City Greenhouse Gas Emissions in 2015, April 2017.

reductions attributable to CHPE were calculated using a consumption-based standard consistent with the accounting standard used by both the State of New York and New York City.

To quantify the value of the environmental benefit to the State of New York and New York City associated with the emissions reductions attributable to CHPE, PA assumed that the value of avoiding one metric ton of CO2 emissions is equal to the most recent federal Interagency Working Group ("IWG") Social Cost of Carbon calculation. The Social Cost of Carbon is a monetized estimate of the societal damages, (e.g., agricultural productivity, human health impacts, property damages caused by flooding, and changes to ecosystem services) attributable to increases in CO2 emissions and associated climate change. The use of the Social Cost of Carbon calculation to monetarily quantify benefits from CO2 emission reductions has been established within New York regulatory processes.[18]

Lastly, while several types of gasses are classified as GHGs, the most common GHG emitted by the electric power sector is CO2, and this analysis focuses specifically on the CO2 emission reductions associated with CHPE. When accounting for emissions of non-CO2 GHGs from various economic sectors, which have different global warming impacts per unit of mass, a common metric is carbon dioxide equivalent ("CO2e"), which standardizes measurement of GHGs based on their estimated global warming impact. Therefore, when assessing the impact that CHPE would have on statewide and New York City GHG emissions and progress towards specified goals, emissions are reported on a CO2e basis.

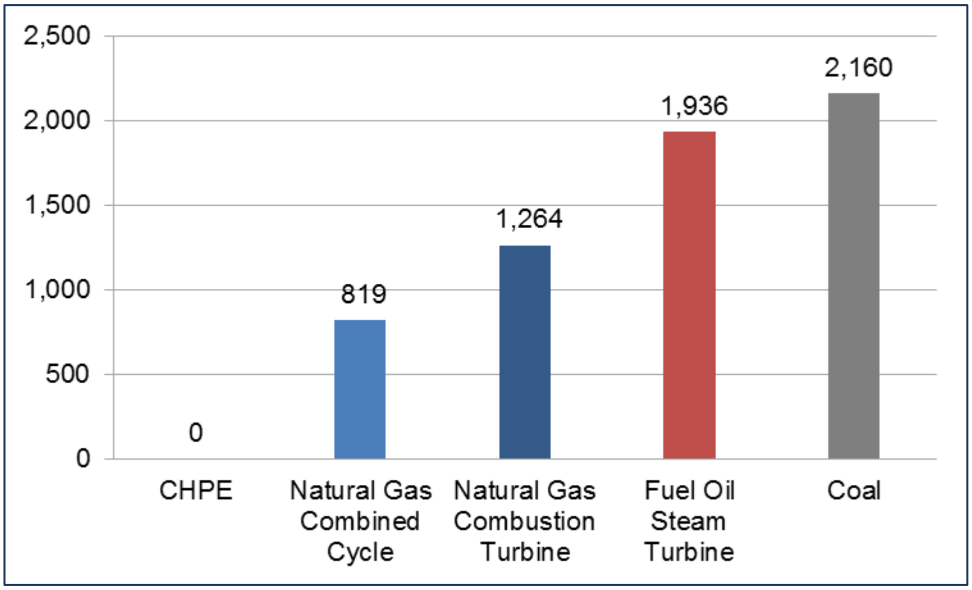
3.2 Findings

This section of the report demonstrates how CHPE will provide material CO_2 emission savings to help achieve specified GHG reduction targets based on a consumption-based accounting standard.

Since CHPE will source electricity from hydroelectric and other renewable energy power plants, which have lower production costs than power plants that emit CO_2 (*e.g.*, coal, fuel oil, and natural gas), CHPE will operate ahead of (*i.e.,* displace) these power plants. See Figure 6 for a comparison of the CO_2 emissions associated with different fuels used to generate electricity. By displacing these CO_2-emitting power plants, both statewide and New York City CO_2 emissions from the power sector will decrease. This includes lower emissions from power plants within New York City, across the State of New York, and in adjacent markets that export power into New York. As a result, CHPE will help the State of New York and New York City meet their respective GHG emission reduction targets.

[18] PA used the Social Cost of Carbon value calculated using a 3% social discount rate. Note that on March 28, 2016, President Donald Trump signed an executive that, among other items, called for the review of estimates of the Social Cost of Carbon, disbanded the IWG, and rescinded IWG technical documents related to the Social Cost of Carbon calculation as no longer representative of federal government policy. However, the Social Cost of Carbon remains the predominant tool for valuing the social, environmental, and human health costs associated with GHG emissions, as well as the benefits associated with reducing those emissions. For example, the NYPSC utilized the Social Cost of Carbon as a baseline for valuing Zero Emission Credits ("ZECs") paid to eligible nuclear generators for carbon-free generation.

Figure 6 - CO2 Emission Rate by Electricity Production Fuel Type (pounds/MWh)[19,20]



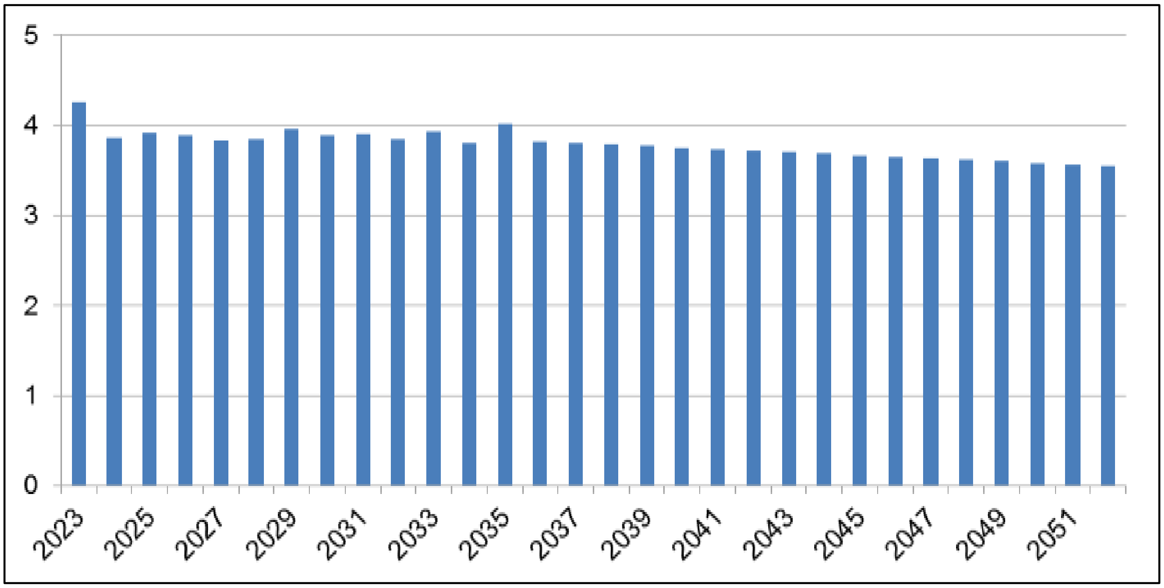
3.2.1 CHPE will reduce CO2 emissions in the State of New York and New York City

The emission reductions attributable to CHPE are substantial. Average annual reductions of CO_2 over the first 30 years of CHPE's operation are 3.4 million metric tons using a consumption-based standard. Because all energy delivered by CHPE directly into Zone J is assumed to be consumed within Zone J, these average annual reductions are attributable to New York City. See Figure 7.

[19] CO_2 emissions data by fuel type was sourced from the U.S. Energy Information Administration. This analysis assumes a heat rate of 7,000 Btu/kilowatt-hour ("kWh") for a natural gas combined cycle power plant, 10,800 Btu/kWh for a natural gas combustion turbine power plant, 12,000 Btu/kWh for an oil power plant, and 10,500 Btu/kWh for a coal power plant.

[20] Because the hydroelectricity delivered through CHPE will be sourced from Québec's existing pool of hydropower resources, CHPE is not expected to create additional GHG emission through new storage impoundments. Additionally, the lifecycle emissions from these existing hydropower resources are negligible, and thus are not included in this analysis.

Figure 7 - CO2 Emission Reductions from CHPE (millions of metric tons)

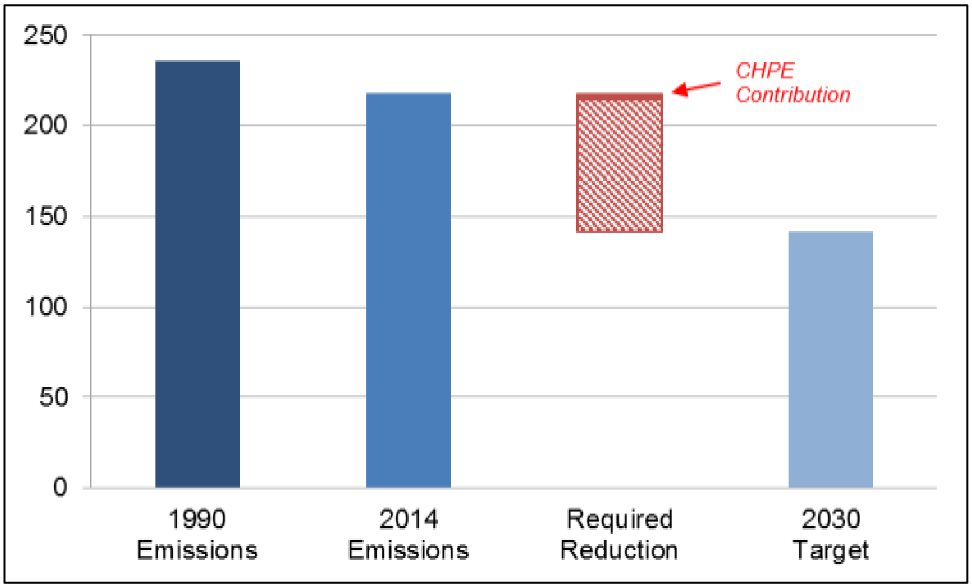


3.2.2 CHPE will help the State of New York and New York City meet their CO2 reduction targets

The emission reductions associated with CHPE will contribute substantially towards GHG reduction targets under Order No. 24. According to the most recent NYSERDA New York State Greenhouse Gas Inventory,[21] 1990 statewide, economy-wide GHG emissions were approximately 236 million metric tons of CO_2e. As of 2014, economy-wide emissions were approximately 218 million metric tons of CO_2e. To meet its 40% by 2030 emission reduction target, the State of New York would need to reduce its economy-wide emissions to approximately 142 million metric tons of CO_2e. This means that New York would need to reduce its emissions by approximately 76 million metric tons in order to achieve emissions 40% below 1990 levels – as illustrated in Figure 8.

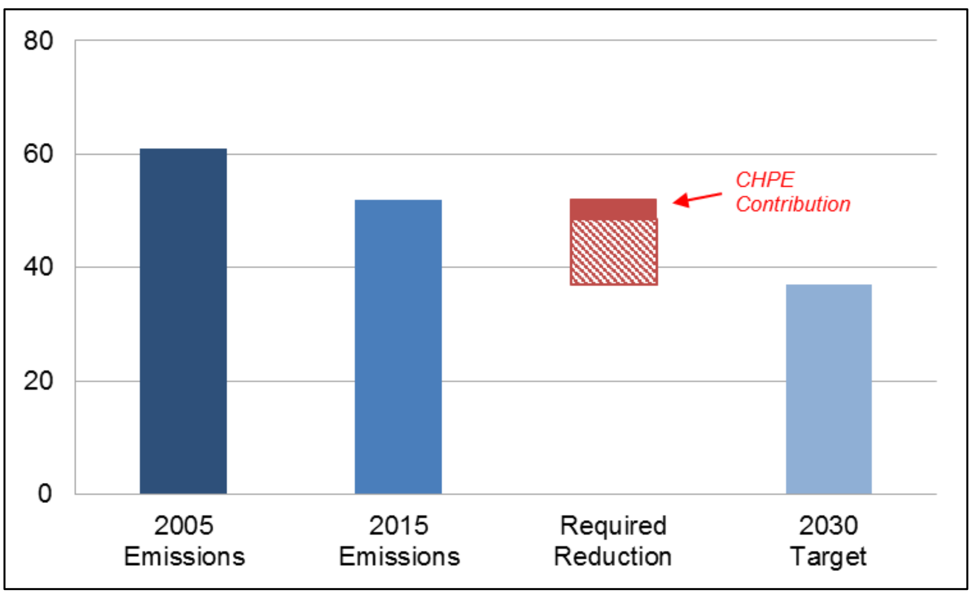
[21] Note that 2014 is the most recent year in which full-year GHG inventory data is available for the State of New York.

Figure 8 - State of New York Economy-Wide CO2 Emission Levels and Targets



Similarly, New York City has its own GHG emissions reduction target, aiming to reduce emissions to at least 40% below 2005 levels by 2030. According to the most recent New York City Greenhouse Gas Emissions inventory,[22] 2005 economy-wide GHG emissions were approximately 61 million metric tons of CO_2e. As of 2015, economy-wide emissions were approximately 52 million metric tons of CO_2e. To meet its 40% by 2030 emission reduction target, the State of New York would need to reduce its economy-wide emissions by approximately 15 million metric tons in order to achieve emissions 40% below 2005 levels – as illustrated in Figure 9.

Figure 9 - New York City Economy-Wide CO2 Emission Levels and Targets

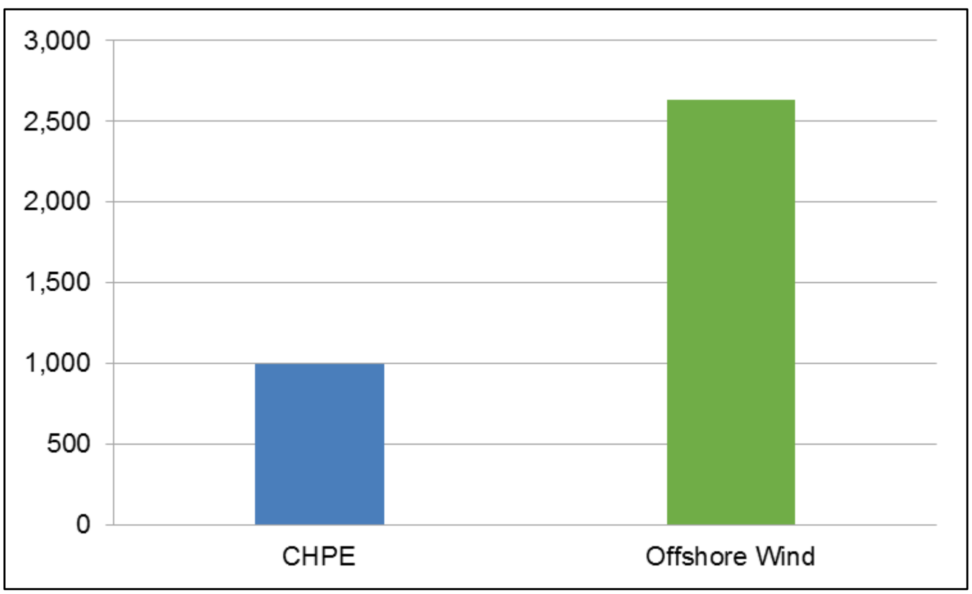


[22] Note that 2015 is the most recent year in which full-year GHG inventory data is available for New York City.

As discussed in the previous section, CHPE would result in an annual average reduction in CO_2 emissions of approximately 3.4 million metric tons under a consumption-based standard. This means that the emission savings associated with CHPE would represent approximately 5% of the remaining 76 million metric ton emission reduction required to meet the State of New York's 2030 target. In New York City, the emission savings associated with CHPE would represent approximately 23% of the remaining 15 million metric ton emission reduction required to achieve the City's 2030 target.

These reductions are critical in meeting stated reduction goals, which will be especially difficult to achieve with the expected retirement of the nearly 2,100 MW Indian Point nuclear plant by 2021 and the associated loss of a non-GHG emitting electricity resource. Reduction goals will be particularly challenging to meet for New York City due to its dense population and urban development, where it is difficult and costly to site renewable energy facilities at scale. While offshore wind is an option for reducing emissions, it remains an intermittent resource. Figure 10 illustrates the difference in the firm capacity of offshore wind power plants to reliably meet peak electricity demand versus CHPE. Since the ability of offshore wind plants to generate electricity is dependent on the weather, their technical ability to generate electricity (referred to as the 'nameplate capacity rating') is 'derated' to reflect uncertainties associated with the weather (*e.g.,* the wind blowing). In order to offshore wind plants to generate the same amount of reliable electricity as CHPE, their nameplate capacity rating needs to be significantly higher than CHPE's, since offshore wind plants' 'derate' is much higher than CHPE's.[23] Said differently, in order to match CHPE's minimum firm capacity of 1,000 MW, an offshore wind plant would need to have nameplate capacity ratings of over 2,600 MW.

Figure 10 - CHPE Capacity Sales versus Equivalent Amount of Offshore Wind Plants (MW)



[23] Since CHPE's ability to generate electricity is largely independent of the weather, it has a much smaller derate to its nameplate capacity rating compared to offshore wind plants that are almost entirely dependent on the weather to generate electricity.

Furthermore, New York City's reduction target is economy-wide, and the City has noted several difficult challenges in achieving deep emission reductions across various sectors. On the use of distributed energy resources ("DERs"), the City stated in its *Roadmap to 80 x 50* that "while the adoption of DERs bears promise for the City's GHG reduction, air quality, and resiliency goals, high levels of DER adoption are hampered by regulatory, technical, and financial challenges." (Page 44). Similarly, the City stated that "it "must both achieve ultra-low energy performance from new buildings and substantial renovations in the next several years while at the same time facilitating deep energy retrofits in nearly all existing buildings over the longer term," (Page 63) and that "*greater GHG emissions reductions will also be challenged by legacy fossil fuel-based systems for heating and hot water production in buildings that are rarely replaced and the billions of vehicle miles powered by petroleum that are expected to continue to travel on city streets.*" (Pages 18-19).

Therefore, CHPE is a critical component in helping New York City meet its CO_2 reduction goals, particularly in the face of such challenges in reducing emissions from other sectors. Note that, for reference, the emission reductions attributable to CHPE are the equivalent to taking approximately 28% of the passenger vehicles off the street in New York City.[24]

3.2.3 CHPE meets New York's preferred GHG reduction plans

In addition to the emission reduction benefits CHPE will provide New York, CHPE is aligned with New York's stated vision for solutions to reduce its GHG emissions. At the state level, Governor Andrew Cuomo has repeatedly praised hydroelectric generation, noting that "*with our nation-leading investments in hydropower, we are building a sustainable resilient, and affordable energy system for all New Yorkers*," and that investments in hydroelectricity represent "*one more major step in our efforts to set a bold, national standard for reducing energy emissions and for creating a cleaner and greener New York for future generations*."[25]

The State of New York has also recognized the clean energy benefits of hydroelectric generation. The 2015 New York State Energy Plan states that "*renewable resources, including solar, wind, hydropower, and biomass, will play a vital role in reducing electricity price volatility and curbing carbon emissions*" (Volume 1, Page 112) and that "*the kinds of health risks associated with the combustion of carbon-based fuels…are not associated with solar energy, wind, and hydroelectric power.*" (Volume 2, Page 76). Furthermore, the state has specifically recognized the potential contribution of transmission projects that would import hydroelectric generation, noting a "*proposed transmission line that would deliver clean, renewable hydropower downstate*" (Page 325) in its 2017 State of the State Report.

New York City has been even more directly supportive of utilizing imported hydroelectric generation to meet its clean energy and GHG reduction goals. The 2011 PlaNYC Report states that "*we will seek to diversify our energy portfolio by importing additional generation resources from outside the five boroughs*," including investigating projects that would "…*allow us to import Canadian hydropower or upstate wind resources*." (Page 116). The 2014 PlaNYC update specifically calls out CHPE, noting that "*with City support, the Champlain Hudson Power Express transmission line was granted a certificate of approval by the PSC*" and that "*it would deliver up to 1000 MW of clean hydropower*…" (Page 48).

New York City also recognized the benefits of imported hydroelectric generation in its Roadmap to 80 x 50 Report. Specifically, the report states that "*New York City will achieve a significant portion of its GHG*

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[24] Source: Source: The City of New York, Inventory of New York City Greenhouse Gas Emissions in 2015, April 2017. Passenger vehicles emitted approximately 12.4 million metric tons of CO_2e in New York City in 2015.

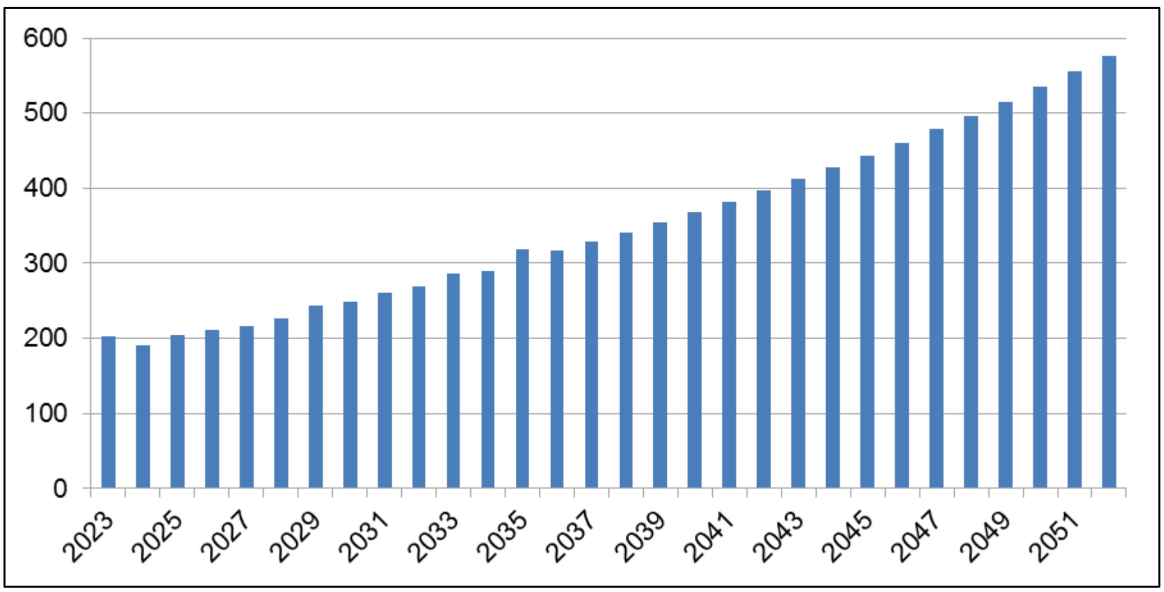
[25] Governor Andrew M. Cuomo, "Governor Cuomo Announces Completion of $26 Million Infrastructure Improvements at Mohawk River Hydropower Plants," April 13, 2017: https://www.governor.ny.gov/news/governor-cuomo-announces-completion-26-million-infrastructure-improvements-mohawk-river

reductions as a result of a dramatic shift towards a renewables-based grid," and that "*large-scale renewable energy sources, including off-shore wind, utility-scale land-side solar and wind, and hydropower – and the transmission of these resources into New York City's electricity grid – play an important role in making this vision a reality*." (Page 19). The report continues by saying that achieving the 80 x 50 GHG reduction target will "*require aggressive action on all fronts…this will include significant volumes of offshore wind, expansive land-side solar and wind installations, hydropower, and new transmission that will allow access to these renewable energy sources from outside the city*." (Page 41). The report even discusses the importance of HVDC transmission lines, noting that "*these types of projects have the ability to tap into numerous renewable energy technologies, including solar, land-based wind, and hydroelectric power, in locations that are more suitable to their development*…" (Page 46).

3.2.4 The value of the CO_2 reduction benefits CHPE will provide is significant

The CO_2 emission reductions attributable to CHPE will substantially benefit the State of New York and New York City, with a value of approximately $10.6 billion during the first 30 years of operation using consumption-based accounting. Because all of the clean energy delivered by CHPE is assumed to be consumed within Zone J, the value of these emission reductions is attributable to both the State of New York and New York City, specifically. See Figure 11.

Figure 11 - Value of CO2 Emission Reductions from CHPE ($millions)



3.2.5 CHPE can help New York meet its CES Tier 1 targets

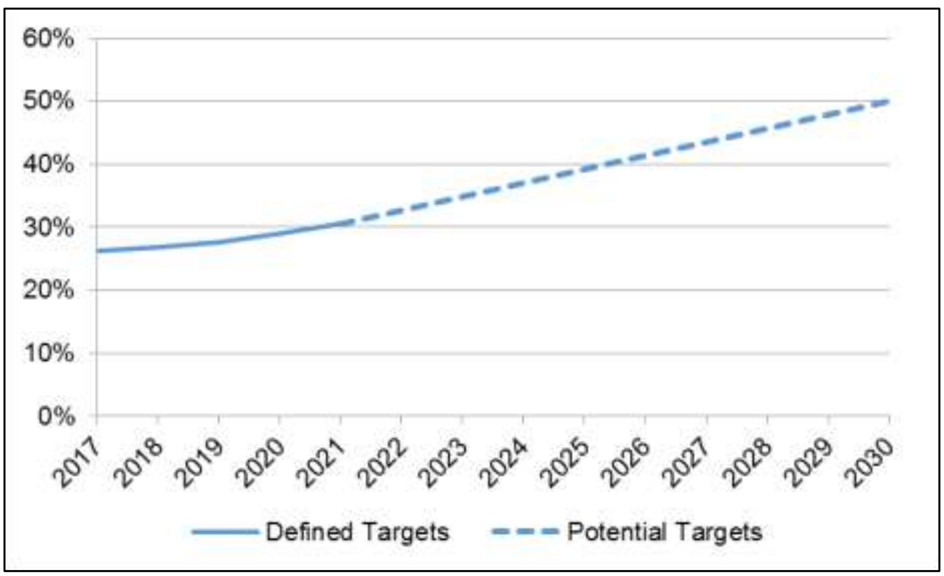
In response to Order No. 24 and a December 2015 directive from Governor Andrew Cuomo for the NYPSC to develop a "50-by-30" goal that requires 50% of electricity sales by 2030 to be sourced from renewable energy, the NYPSC issued an *Order Adopting a Clean Energy Standard* on August 1, 2016. The CES creates three tiers of clean energy resources – new renewable resources (Tier 1), defined as entering service after January 1, 2015; existing renewable resources (Tier 2), defined as entering service before January 1, 2015; and nuclear facilities (Tier 3). Eligible technologies for Tier 1 include but are not limited to wind, solar, run-of-river hydro, and biomass. While there is no capacity limit for individual run-of-river hydro resources to qualify as Tier 1 resources, run-of-river hydro resources that entered service before 2015 must be 5 MW or less in size to qualify as Tier 2 resources.

Each MWh of electricity produced by a Tier 1-eligible resource creates one Tier 1 REC, which can be procured by load serving entities ("LSEs") to meet their Tier 1 requirements under the CES. NYSERDA will act as the central procurement authority for RECs in New York, while LSEs will individually procure RECs from NYSERDA in order to comply with the standard. Under the CES, all New York LSEs must procure Tier 1 renewable resources at 0.6% of total electricity load in 2017, which will increase to 4.8% by 2021. Across Tier 1 and Tier 2 resources, LSEs must procure renewable resources at 26.3% of total electricity load in 2017, which will increase to 30.5% by 2021. Eventually, Tier 1 and Tier 2 renewable resources must serve 50% of total electricity load by 2030, although specific targets beyond 2021 have not yet been defined.

If an LSE does not procure enough Tier 1 RECs (i.e., it has a deficit of RECs), it must pay an Alternative Compliance Payment ("ACP"). In 2017, the ACP price is be equal to the NYSERDA-determined REC price plus 10%, which equals $23.28/MWh. However, the NYPSC must develop a more detailed methodology for determining the ACP amount for subsequent years.

In addition to the clean electricity delivered from Québec's system power, CHPE has the potential to deliver approximately 1.0 TWh of clean renewable electricity annually, generated by wind (approximately 0.7 TWh annually) and solar (approximately 0.3 TWh annually) power plants that would be located in upstate New York. This wind and solar generation would be firmed by Québec's clean system power so that CHPE would continue to provide 1,000 MW of firm capacity that can operate at a 95% capacity factor, delivering a total of 8.3 TWh per year of clean generation annually. The 1.0 TWh per year of generation sourced from the wind and solar plants would be expected to qualify for Tier 1 RECs in New York that can be used to comply with the state's CES.[26] This is especially important because New York's CES target is expected to increase from 30.5% in 2021 to 50% by 2030, as illustrated in Figure 12.

Figure 12 - New York CES Targets (% of load)[27,28]



[26] Since these proposed wind and solar plants would be new power plants and their electricity will be sold in the New York electricity system, they would likely qualify to sell New York Tier 1-eligible RECs (which PA's analysis assumes).

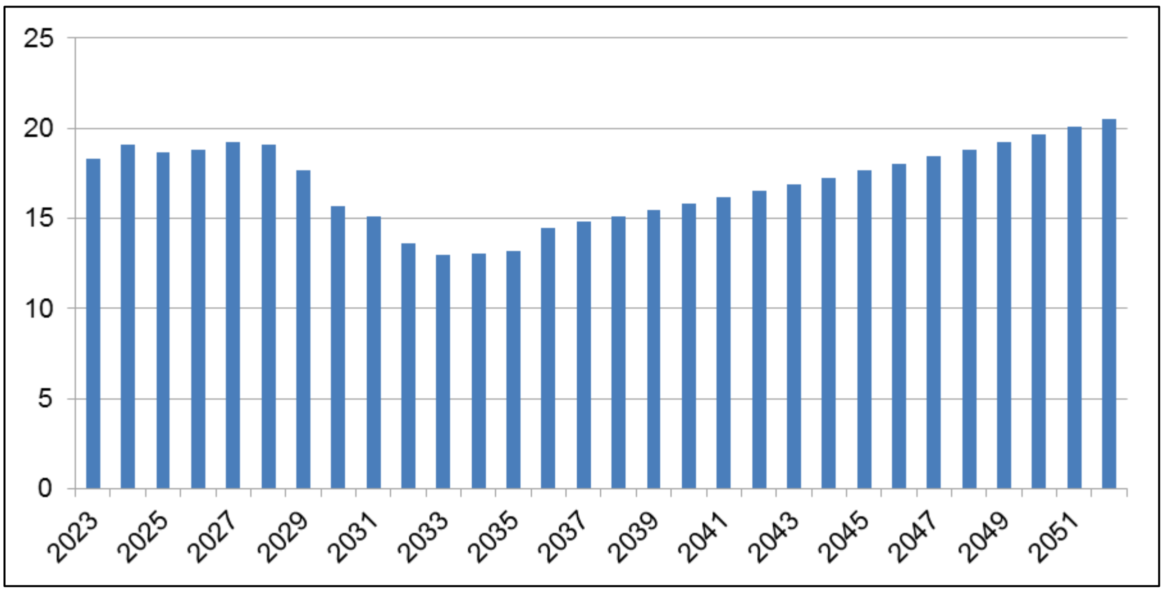
[27] Source: New York Public Service Commission, Order Adopting a Clean Energy Standard, August 1, 2016.

[28] The New York Public Service Commission has established formal CES targets for years 2017 through 2021, but will establish targets for years 2022 through 2030 will be determined through a triennial review process.

However, to date, New York has, at times, struggled to meet its REC target under its former Renewable Portfolio Standard - due to the difficulty in siting and permitting new renewable power plants in the state. CHPE's annual 1.0 TWh of Tier 1 RECs would help New York LSEs meet the state's increasing CES Tier 1 targets and potentially avoid ACP penalties. While New York's CES targets beyond 2021 have not been officially defined, assuming straight-line target growth to the established 50% by 2030, and assuming that the contribution of Tier 2 resources remains the same through 2030, CHPE would contribute 7% to New York's Tier 1 CES requirement in 2023, and 3% in 2030.[29]

More specifically, Figure 13 illustrates the value of the Tier 1 RECs potentially provided by CHPE using the fundamental REC price for New York Tier 1 RECs. PA determined the value of the 1.0 TWh per year of Tier 1 RECs that CHPE could potentially provide by analyzing the capacity and energy prices and the cost to build new wind and solar power plants in the simulation of the NYISO electric grid with CHPE. Fundamentally, the value of one Tier 1 REC should represent the additional monies required by the owner a new Tier 1-qualifying power plant (*i.e.*, a new wind or solar power plant) to realize a return on (and of) capital, after accounting for capacity and energy prices and associated revenues and any federal- or state-level subsidies or incentives.

Figure 13 - Value of Tier 1 RECs Potentially Provided by CHPE ($millions)



It is also possible to evaluate the benefits provided by CHPE as the avoided ACPs for Tier 1 RECs, which would likely provide a higher estimate of value depending on how many Tier 1 RECs New York LSEs are actually able to procure. However, the values reflected in this report, and the benefits outlined in Table 1 and Appendix A, use the fundamental REC price in order to estimate the potential benefit conservatively. Additionally, the NYPSC has not yet determined a methodology for calculating the ACP for future years. Based on this methodology CHPE could provide approximately $500 million of Tier 1 REC value during the first 30 years of operations.

[29] CHPE's potential contribution to meeting New York's Tier 1 RECs requirement decreases over time, as the CES target increases (due to increasing electricity sales and renewable percentage requirements); however, CHPE would consistently provide 1.0 TWh of Tier 1 RECs annually through the study period.

4 CHPE RELIABILITY BENEFITS TO THE STATE OF NEW YORK

This section examines and quantifies the reliability benefits, both in summer and winter, that CHPE will provide to New York ratepayers. These benefits, which include decreased natural gas usage and increased capacity to meet both summer and winter peak electricity demand, were calculated using the AURORA^{xmp} electricity market model.

The key findings from this section of the report include the following:

CHPE will decrease natural gas usage and improve the winter reliability of the electric grid.

- CHPE is forecasted to decrease the power sector's natural gas usage by 9% across the State of New York and by 16% within Zone J, which will result in more natural gas supply to both power plants and residential, commercial, and industrial users.
- This is especially critical to the reliability of the electric grid during the winter months when power plants compete with heating demand for natural gas supply.

CHPE will help support summer reliability by providing an alternative to older power plants that are at risk of retiring.

- Within New York, approximately 2,500 MW of power plants will have retired between 2017 and 2021, of which over 2,000 MW are located just outside of Zone J.[30]
- NYISO has identified 7,250 MW of steam and gas turbine power plants that will reach potential retirement age by 2027, of which 4,700 MW are located in Zone J.[31]

4.1 Overview

As the New York electricity system continues to evolve, the reliability of the electric grid is one of the most critical issues facing New York ratepayers today. More specifically, as the system's coal and oil plant units have been retired or mothballed (*e.g.*, Huntley, Astoria, Dunkirk, Westover, and Poletti) and have primarily been replaced by natural gas-fired power plants, the system's reliance on and usage of natural gas has increased.

With the expected 2017 retirement of the 350 MW Cayuga coal plant and expected retirement of the nearly 2,100 MW Indian Point nuclear plant by 2021, the New York electricity system will be forced to rely even more on natural gas to generate electricity. This creates a fuel diversification issue, especially during the winter months when power plants compete with heating demand for natural gas supplies. This situation is further compounded by the difficulty in siting and constructing new natural gas pipelines into New York – as evidenced by the indefinite postponement of Williams Companies' Constitution pipeline and National Fuel Gas Co.'s Northern Access pipeline. As a result, it is critical that the New York electricity system finds new ways of obtaining electricity that do not rely on natural gas.

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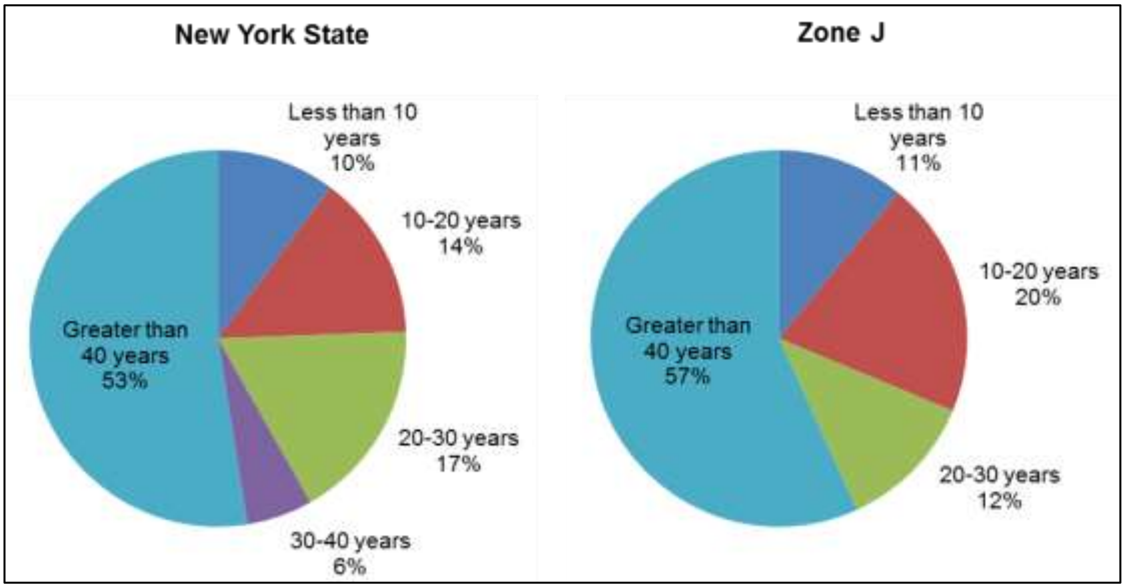
[30] Source: Entergy, "Entergy, NY Officials Agree on Indian Point Closure in 2020-2021," retrieved from: http://www.entergynewsroom.com/latest-news/entergy-ny-officials-agree-indian-point-closure-2020-2021/; NYISO 2017 Load & Capacity Data "Gold Book".

[31] Source: NYISO Power Trends 2017.

Furthermore, most of the power plants in New York, particularly Zone J, are old (built before the 1980s) and are reaching the end of their physical lives, as illustrated in Figure 14. As plants retire in the coming decade, the New York electricity system will require new capacity to take their place and maintain the reliability of the electric grid, especially during the summer months when electricity demand is typically the highest. As discussed further in this section, CHPE – with its 1,000 MW of electrical capacity – can address both of these reliability issues by (i) decreasing the power sector's usage of natural gas and (ii) replacing old power plants as they retire, while simultaneously lowering wholesale electricity prices and providing clean energy for New York ratepayers.

Figure 14 - Age of New York Power Fleet (as of Year-End 2016)[32,33]



4.1.1 Methodology

As part of PA's analysis of the winter and summer reliability benefits provided by CHPE to New York ratepayers, PA analyzed the decrease in New York power sector natural gas usage from CHPE's operations using the AURORA^{xmp} electricity market model. This modeling process is described in greater detail in Appendix B. To do this, PA simulated the electricity market in New York (and specifically Zone J) to determine how reduced operation of natural gas-fired power plants due to CHPE's delivery of 1,000 MW of electricity into New York would impact natural gas usage from the power sector. In other words, PA calculated how a decrease in the demand (*i.e.*, usage) for natural gas by the power sector would result in increased supply for both electric generators and residential, commercial, and industrial users.

4.2 Findings

CHPE will provide the New York electricity system, specifically Zone J, with 1,000 MW of clean energy capable of operating around the clock. This electricity will be sourced from Québec's pool of hydroelectric and renewable energy power plants, providing a diversified source of electricity that can be reliably and safely delivered to Zone J via proven HVDC technology. This reliable supply is something that neither wind

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[32] Source: NYISO 2017 Load & Capacity Data "Gold Book".

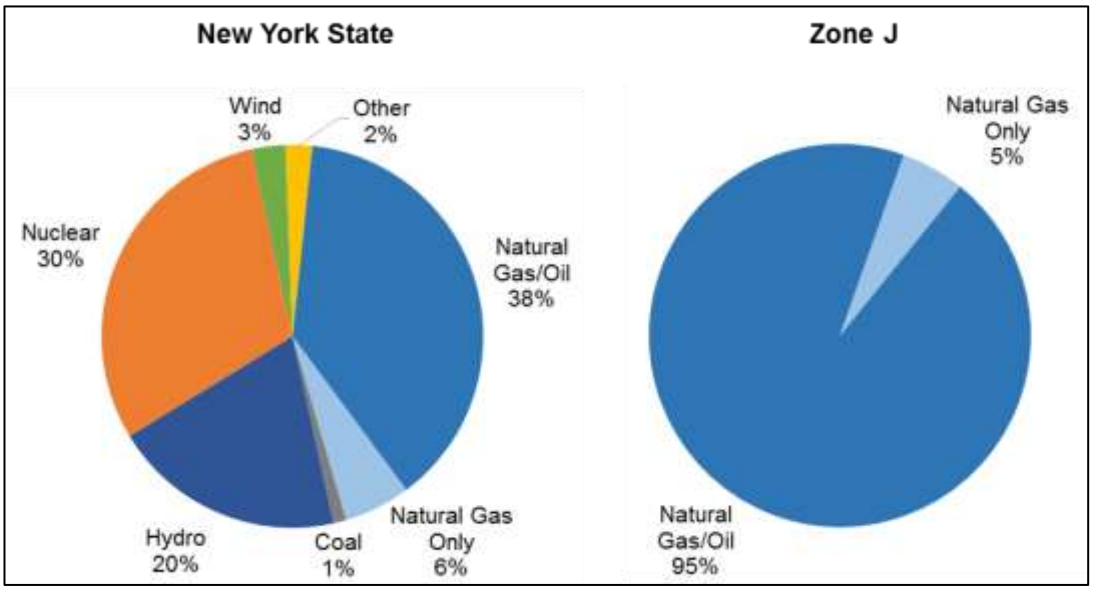
[33] Because hydroelectric power plants typically have much longer operating lives than thermal or other renewable power plants, hydroelectric power plants are excluded from this analysis.

nor solar power plants can provide on their own, since they are (i) intermittent resources whose operations are dictated by weather conditions (*e.g.*, the wind blowing, the sun shining), and (ii) single source (*i.e.*, electricity is generated from a single power plant, rather than a pool of power plants like CHPE). CHPE's operating profile therefore increases the reliability of the New York system and Zone J specifically during both the winter and summer months – as discussed further in this section.

4.2.1 CHPE will decrease natural gas usage and improve the winter reliability of the electric grid

The New York electricity system relies on natural gas to generate over 40% of its electricity today. Zone J is heavily reliant on natural gas, with nearly all of Zone J generation fueled by dual-fuel natural gas and oil power plants. See Figure 15. Additionally, the share of electricity generation across the state that is fueled by natural gas is expected to increase in the near future, with NYISO noting that 56% of proposed generating capacity would use natural gas.[34]

Figure 15 - 2016 New York Electricity Production by Fuel[35]



New York's increasing reliance on natural gas to generate electricity and heat homes and businesses is a significant concern. The North American Electric Reliability Corporation ("NERC"), in its Short-Term Special Assessment on operational risk with high penetration of natural gas-fired generation, stated that "*Despite substantial progress in coordination between the gas and electric industries, the growing reliance on natural gas continues to raise reliability challenges regarding the interdependence of the industries and the adequacy of gas and electric infrastructure.*" (Page 12).

NYISO shares this concern. In its most recent *Power Trends* report, NYISO remarked on Page 34 that "*interdependency between gas pipeline infrastructure and the bulk power system is heightened in New York State*…". Similarly, NYISO noted on Page 8 of its 2016 Comprehensive Reliability Plan that "*New York's reliance on natural gas as the primary fuel for electric generation justifies continued vigilance regarding the status of the natural gas system.*" NYISO went on to say, "*There is increasing concern over the gas system's*

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[34] Source: Ibid.

[35] Source: NYISO 2017 Load & Capacity Data "Gold Book".

ability to keep pace with the needs of gas utilities serving residential, commercial and industrial customers, while simultaneously meeting the expanding needs of gas-fired power plants, especially during peak demand conditions in winter and summer."

These findings are reiterated in the Eastern Interconnection Planning Collaborative's Gas-Electric System Interface Study Target 2 Report (May 2015), which found that "*most generation in NYISO is served under non-firm transportation arrangements*" (Page iv), meaning that natural gas supply to these generators can be interrupted if there is competing demand from higher-priority users, and that "*generators throughout NYISO are exposed to pipeline constraints and/or local delivery constraints during cold snaps when LDCs exercise their superior rights in order to serve RCI load.*" (Page iv).

Furthermore, while the vast majority of downstate natural gas-fired power plants also have dual fuel capability (the capability to burn fuel oil), air quality regulations may limit power plants' ability to generate electricity using fuel oil in the future. For example, New York City passed legislation in 2015 (Local Law No. 38) that bans the combustion of No. 6 grade fuel oil for any purpose, including electricity generation, beginning in 2020. This ban will impact seven existing power plant units totaling approximately 2,800 MW of capacity in Zone J, representing 29% of currently installed Zone J capacity.[36]

CHPE can reduce the power sector's usage of natural gas in the State of New York and Zone J and thereby help mitigate the reliability risk described above. More specifically, CHPE's 1,000 MW of clean energy will be delivered to Zone J. Since CHPE will source its electricity from hydroelectric and other renewable energy power plants, which have lower production costs than power plants that burn natural gas, CHPE will operate ahead of (*i.e.*, displace) these natural gas-fired power plants. By displacing these natural gas-fired power plants, the power sector will consume less natural gas overall, which will in turn decrease both the overall demand for natural gas in the market and the strain on the natural gas delivery system.

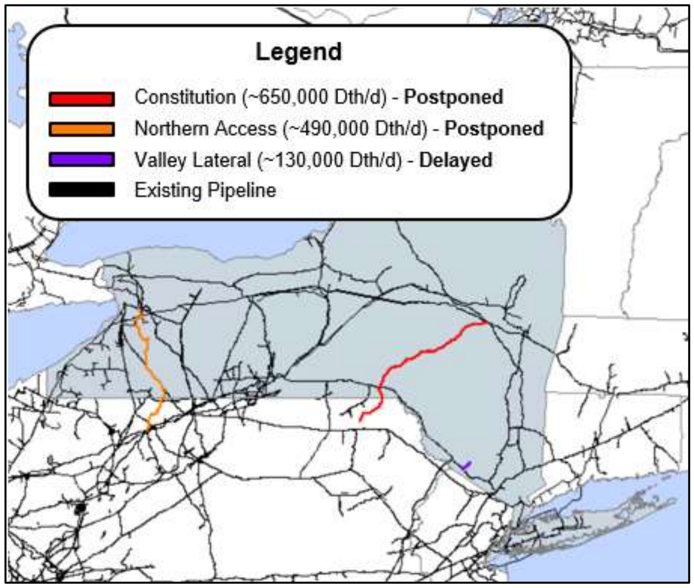
This dynamic is especially important given the current difficulty in siting and constructing new natural gas pipelines (as shown in Figure 16). Proposed pipeline projects in New York have either been (a) delayed (such as Millennium Pipeline Co.'s Valley Lateral pipeline, which is slowed down due to a delay in its Clean Water Act Section 401 permitting application), or (b) postponed indefinitely (such as the Williams Companies' Constitution pipeline and National Fuel Gas Co.'s Northern Access pipeline, which have challenged the State of New York in federal court over its denial of Clean Water Act Section 401 permits, although the state's denial of Constitution's permit was recently upheld by the 2nd Circuit Court). NYISO notes the difficulty of expanding natural gas infrastructure in New York, finding that "*uncertainty in gas pipeline development underscores the challenges the power generation sector faces with regard to natural gas infrastructure needed to support improved fuel assurance*…"[37]

These trends have created a substantial issue where New York is heavily reliant on natural gas to generate electricity, but the supply of natural gas in the market is not increasing due to headwinds against new pipeline projects. This dynamic threatens the reliability the electricity system during the winter months, when natural gas demand is highest.

[36] Source: NYISO Power Trends 2017.

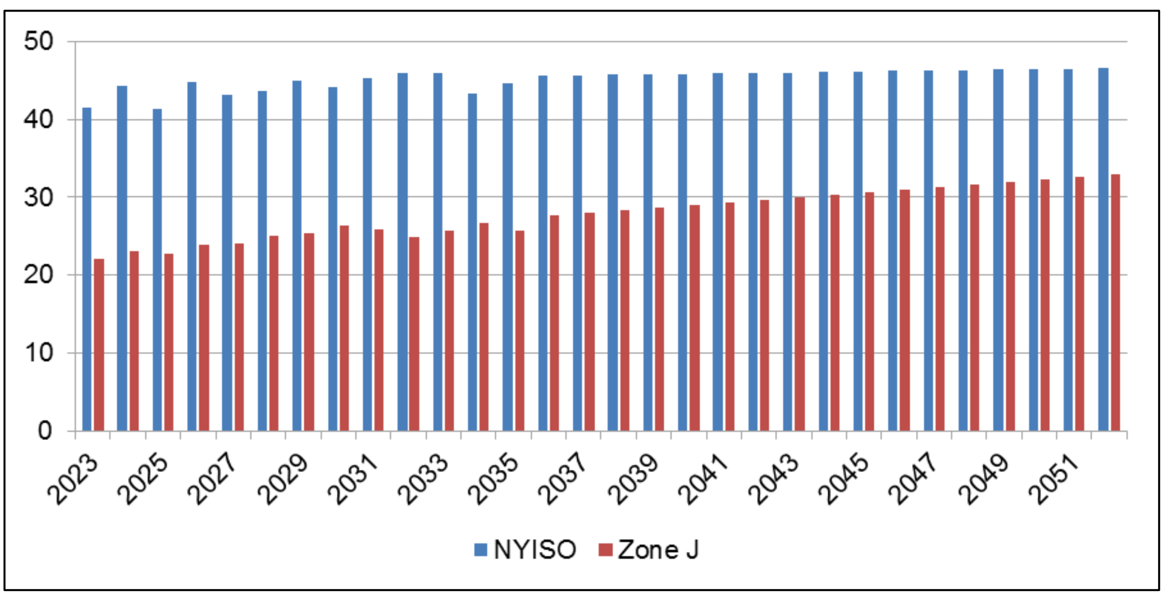
[37] Source: Ibid, Page 37.

Figure 16 - Status of New York Natural Gas Pipeline Projects



PA's analysis estimated that CHPE will decrease the annual demand for natural gas from the power sector by approximately 45 million MMBtu (or 9%) in the State of New York and 28 million MMBtu (or 16%) within Zone J, as illustrated in Figure 17. This reduction is especially valuable to the electric grid's reliability during the winter months, when heavy demand from residential, commercial, and industrial users competes with demand from natural gas-fired power plants. Therefore, CHPE's delivery of 1,000 MW of clean energy will increase the reliability of natural gas supply to both power plants and other users.

Figure 17 - Power Sector Natural Gas Usage Reduction from CHPE (Million MMBtus)



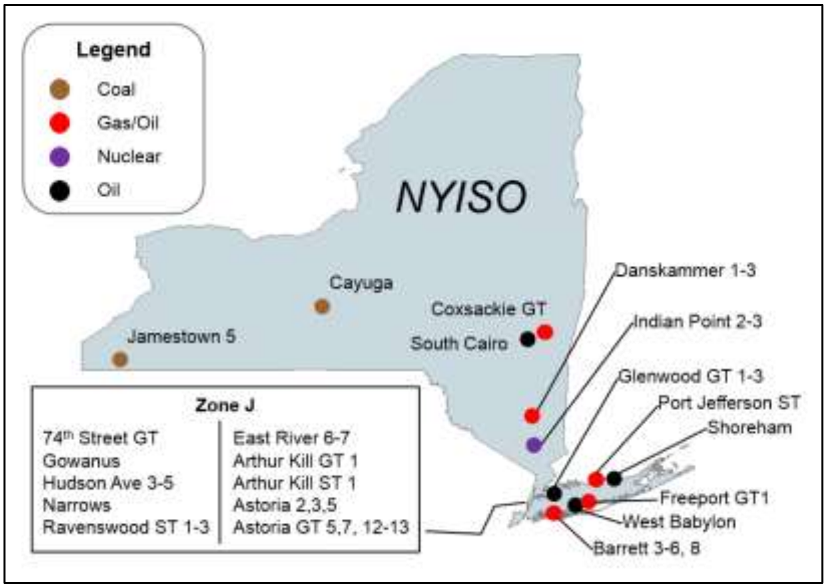
4.2.2 CHPE will help support summer reliability by providing an alternative to older power plants that are at risk of retiring

As previously mentioned, the majority of New York's power plants were built before the 1980s and are reaching the end of their physical lives. In its 2017 Power Trends report, NYISO noted that nearly 2,000

MW of older steam turbine and gas turbine power plant capacity had already reached an age at which 95% of capacity using these technologies retires, based on national averages.[38] This puts these power plants at high risk for retirement. Additionally, by 2027, NYISO projects that more than 7,250 MW of steam turbine and gas turbine capacity, representing roughly 19% of currently installed system-wide capacity, will reach an age at which 95% of capacity using these technologies retires.

Figure 18 and Table 5 below show power plants within New York that have either announced firm retirement plans or are at high risk of retirement by 2027 due to their age.

Figure 18 - New York Power Plants At-Risk for Retirement



[38] NYISO notes that approximately 95% of steam turbine capacity retires at or before 62.5 years of operation, while approximately 95% of gas turbine capacity retires at or before 46 years of operation. Source: NYISO Power Trends 2017.

Table 5 - New York Power Plants At-Risk for Retirement by 2027 (Including Zone J Plants)[39]

Power Plant	Zone	Capacity (MW)	Fuel Type	Status
74th Street GT	J	37	Oil GT	At-Risk
Arthur Kill GT1	J	20	Gas GT	At-Risk
Arthur Kill ST1	J	376	Gas ST	At-Risk
Astoria 2, 3, 5	J	943	Gas/Oil ST	At-Risk
Astoria GT 5, 7, 12-13	J	102	Oil GT	At-Risk
Barrett 3-6, 8	K	90	Gas/Oil GT	At-Risk
Cayuga	C	323	Coal ST	Retiring 2017
Coxsackie GT	G	22	Gas/Oil GT	At-Risk
Danskammer 1-3	G	293	Gas/Oil ST	At-Risk
East River 6-7	J	356	Gas/Oil ST	At-Risk
Freeport GT1	K	48	Gas/Oil GT	Retiring 2018
Glenwood GT 1-3	K	126	Oil GT	At-Risk
Gowanus	J	640	Gas/Oil GT	At-Risk
Hudson Ave 3-5	J	49	Oil GT	At-Risk
Indian Point 2-3	H	2,150	Nuclear	Retiring 2020-2021
Jamestown 5	A	29	Coal ST	At-Risk
Narrows	J	352	Gas/Oil GT	At-Risk
Port Jefferson ST	K	392	Gas/Oil ST	At-Risk
Ravenswood ST 1-3	J	1,827	Gas/Oil ST	At-Risk
Shoreham	K	85	Oil GT	Retiring 2018
South Cairo	G	22	Oil GT	At-Risk
West Babylon	K	52	Oil GT	At-Risk

Note that in addition to the plants identified in Figure 17 and Table 5 above, New York's three upstate nuclear power plants – the approximately 1,940 MW Nine Mile Point, the 880 MW James A. FitzPatrick

[39] Source: NYISO 2017 Load & Capacity Data "Gold Book". Only includes plants greater than or equal to 20 MW.

Nuclear Power Plant, and the 580 MW Ginna Nuclear Generating Station – were recently either slated for or at risk of retirement due to the challenging economics of the plants in a low wholesale price environment. However, the CES established Zero Emission Credits ("ZECs") for generation from these nuclear power plants starting in April 2017. As a result of the implementation of ZECs, PA's analysis assumes that these three upstate nuclear plants will remain in service over the study period. However, the proposed retirements of these facilities before the implementation of ZECs highlight the challenging economic environment for older, capital-intensive generation in New York and the risk of retirement for these plants.

This overall situation presents a significant risk to the reliable operation of the New York electricity system. NYISO has stated that it is important "*to ensure that as older units retire, remaining and newer resources replacing them are integrated into the grid and wholesale markets* ***in a manner that continues to promote reliability***."[40] Specifically, NYISO notes the importance of fast and flexible resources: "*Resources with the ability to follow dispatch signals to ramp up, ramp down or turn off are critical to the reliable operation of the bulk power system. New resources that exhibit these characteristics will strengthen the operation of the bulk power system…*"[41]

CHPE can help meet this reliability need and replace older power plants as they retire. CHPE provides 1,000 MW of clean energy sourced from a diversified pool of hydroelectric and other renewable energy power plants and is capable of fast and flexible electricity production.

CHPE's flexibility will help NYISO integrate increasing amounts of renewable energy

While wind and solar power plants are valuable sources of clean energy, plants that are not firmed by hydro power plants or other dispatchable generation or storage require additional regulation and reserve ancillary services to mitigate the inherent variability and uncertainty in weather conditions and their ability to generate electricity. Regulation balances the minute-to-minute changes in the electricity generated from wind and solar plants, which can be caused by weather conditions, and reserves ensure there are enough quick-start power plants on the system to address large changes in electricity production (e.g., the setting sun). These ancillary services are often overlooked when evaluating the cost-benefit of clean energy sourced exclusively from wind and solar power plants.

As the number of intermittent wind and solar power plants in New York grows to meet state CES, there will be an increased need for these types of ancillary services to safeguard the reliability of the electricity system. This is emphasized in NYISO's most recent Power Trends report, which states that "*the pending influx of new renewable resources necessary to achieve compliance with the state's goals will still pose challenges in terms of system operations, maintaining market efficiency, and planning for future system needs*," (Page 64) and that "*NYISO may need to modify or enhance its operational practices and market products to address new needs that may be triggered by expanded renewable resources, such as needs for fast-acting resources capable of balancing large variations in renewable energy production*." (Page 65).

CHPE, with its 1,000 MW of clean energy generated from a pool of fast and flexible hydroelectric and other renewable energy power plants, can help fill this need. The Bonneville Power Administration (which operates a system with large amounts of electricity generated from hydroelectric and wind power plants) noted that "*hydropower is a sustainable resource that can balance intermittent generation by providing*

[40] Source: NYISO Power Trends 2017: New York's Evolving Electric Grid, page 12.

[41] Source: New York Public Service Commission, Case 15-E-0302, Comments of the New York Independent System Operator, Inc., January 10, 2017, page 2.

relatively large capacity energy storage and reserves," and that "*hydropower is already the preferred technology providing system reserves throughout the world's transmission systems*."[42]

CHPE's Voltage Source Converter ("VSC") will enable it to rapidly control both real and reactive power,[43] which will allow CHPE to vary its output between 0 MW and its maximum 1,000 MW capability at a ramp rate[44] of 99 MW/minute.[45] This will help New York ratepayers safely integrate intermittent wind and solar power plants into the electricity system at the lowest possible production cost. CHPE will also provide other reliability benefits to the transmission system. An HVDC line can automatically adjust its output nearly instantaneously in response to emergency events on the AC grid, such as the tripping of a critical line, which reduces the risk of overloading other lines and causing cascading outages on the grid.

[42] Source: Bonneville Power Administration, Hydroelectric Pumped Storage for Enabling Variable Energy Resources within the Federal Columbia River System, page 2.

[43] Real power can be thought of as the electricity we consume, whereas reactive power helps allow the real power to flow where the electricity is needed.

[44] A ramp rate is a measurement of the speed at which a power plant or transmission line can increase or decrease its output (or delivery) of electricity. The faster the ramp rate, the more quickly electricity can be added to or removed from the system when needed.

[45] Higher ramp rates are possible with the Project if the electricity system conditions permit.

A SUMMARY OF THE MODELING RESULTS

A.1 Annual Benefit Forecast

Tables A-1 through A-4 outline the annual results of PA's analysis for the value of energy (1), electricity savings (2), net economic output benefits (3), property tax payments (4), and CO_2 emission reduction benefits (5) delivered from CHPE. The difference between the gross economic benefits, as discussed in Section 2.2.4, and the net economic benefits shown in the tables below is that the net economic benefits deduct the electricity cost savings (since these savings ultimately drive increased economic output).

Table A-1 – Annual Benefits to the State of New York from CHPE ($millions, 2017-2022)

Benefit Type (Market Value and Economic Benefits)	2017	2018	2019	2020	2021	2022
Market Value of CHPE's Energy						
(1) Market Value of Energy Provided by CHPE	-	-	-	-	-	-
Economic Benefits						
(2) Total Wholesale Electricity Cost Savings	-	-	-	-	-	-
Energy Cost Savings	-	-	-	-	-	-
Capacity Cost Savings	-	-	-	-	-	-
Gross Economic Output	31.8	47.1	259.0	348.7	511.9	306.9
less Total Wholesale Electricity Cost Savings	-	-	-	-	-	-
(3) Net Economic Output[46]	31.8	47.1	259.0	348.7	511.9	306.9
(4) Property Tax Payments	-	-	-	-	-	-
(5) Value of CO2 Emission Reductions	-	-	-	-	-	-
Total Benefits						
(6) Total Economic Benefits (Sum 2 through 5)	31.8	47.1	259.0	348.7	511.9	306.9
Total of Market Value and Economic Benefits [Sum 1 and 6]	31.8	47.1	259.0	348.7	511.9	306.9

[46] Net Economic Output = Gross Economic Output – Total Wholesale Electricity Cost Savings.

Table A-2 – Annual Benefits to the State of New York from CHPE ($millions, 2023-2032)

Benefit Type (Market Value and Economic Benefits)	2023 (Yr 1)	2024 (Yr 2)	2025 (Yr 3)	2026 (Yr 4)	2027 (Yr 5)	2028 (Yr 6)	2029 (Yr 7)	2030 (Yr 8)	2031 (Yr 9)	2032 (Yr 10)
Market Value of CHPE's Energy										
(1) Market Value of Energy Provided by CHPE	**457.5**	**473.7**	**486.5**	**497.5**	**509.1**	**526.1**	**539.9**	**554.6**	**569.8**	**590.6**
Economic Benefits										
(2) Total Wholesale Electricity Cost Savings	**1,581.3**	**1,526.4**	**1,688.2**	**1,242.6**	**1,078.9**	**998.2**	**507.4**	**260.9**	**163.1**	**108.0**
Energy Cost Savings	255.1	259.8	264.8	234.5	254.3	260.3	236.7	233.9	254.2	238.6
Capacity Cost Savings[47]	1,326.2	1,266.6	1,423.4	1,008.1	824.6	738.0	270.7	27.0	(91.1)	(130.5)
Gross Economic Output[48]	**1,677.4**	**1,612.7**	**1,780.9**	**1,321.6**	**1,163.2**	**1,070.9**	**566.9**	**311.4**	**213.6**	**155.9**
less Total Wholesale Electricity Cost Savings	1,581.3	1,526.4	1,688.2	1,242.6	1,078.9	998.2	507.4	260.9	163.1	108.0
(3) Net Economic Output[49]	**96.1**	**86.3**	**92.7**	**79.0**	**84.3**	**72.7**	**59.5**	**50.5**	**50.5**	**47.8**
(4) Property Tax Payments	**44.8**	**45.5**	**46.2**	**46.8**	**47.5**	**48.3**	**49.0**	**49.7**	**50.5**	**51.2**
(5) Value of CO2 Emission Reductions	**202.9**	**191.6**	**203.6**	**210.8**	**216.3**	**226.4**	**243.4**	**249.2**	**261.3**	**268.6**
Total Benefits										
(6) Total Economic Benefits (Sum 2 through 5)	**1,925.1**	**1,849.8**	**2,030.7**	**1,579.2**	**1,427.0**	**1,345.6**	**859.3**	**610.3**	**525.4**	**475.6**
Total of Market Value and Economic Benefits [Sum 1 and 6]	**2,382.6**	**2,323.5**	**$2,517.2**	**$2,076.7**	**$1,936.0**	**$1,871.7**	**$1,399.3**	**$1,164.9**	**$1,095.2**	**$1,066.3**

[47] Capacity cost savings are most pronounced through 2028 as CHPE's capacity increases the reserve margin in import-constrained Zone J. Capacity cost savings decline in the long-term as reserve margins tighten.

[48] Gross Economic Output benefits are strongest in the near term, driven largely by higher electricity cost savings than in future years.

[49] Net Economic Output = Gross Economic Output – Total Wholesale Electricity Cost Savings.

Table A-3 – Annual Benefits to the State of New York from CHPE ($millions, 2033-2042)

Benefit Type (Market Value and Economic Benefits)	2033 (Yr 11)	2034 (Yr 12)	2035 (Yr 13)	2036 (Yr 14)	2037 (Yr 15)	2038 (Yr 16)	2039 (Yr 17)	2040 (Yr 18)	2041 (Yr 19)	2042 (Yr 20)
Market Value of CHPE's Energy										
(1) Market Value of Energy Provided by CHPE	**603.3**	**613.6**	**625.0**	**633.8**	**646.0**	**660.2**	**674.8**	**691.5**	**704.8**	**720.3**
Economic Benefits										
(2) Total Wholesale Electricity Cost Savings	**115.2**	**122.0**	**120.4**	**158.6**	**166.3**	**169.6**	**173.1**	**176.6**	**180.2**	**183.9**
Energy Cost Savings	244.2	251.6	257.6	294.7	301.4	308.2	315.2	322.3	329.6	337.0
Capacity Cost Savings	(129.0)	(129.6)	(137.2)	(136.1)	(135.1)	(138.5)	(142.1)	(145.7)	(149.4)	(153.2)
Gross Economic Output	**166.7**	**172.9**	**174.9**	**213.5**	**225.2**	**227.8**	**232.9**	**238.1**	**243.4**	**248.8**
less Total Wholesale Electricity Cost Savings	115.2	122.0	120.4	158.6	166.3	169.6	173.1	176.6	180.2	183.9
(3) Net Economic Output[50]	**51.5**	**50.9**	**54.5**	**54.9**	**58.9**	**58.1**	**59.8**	**61.5**	**63.2**	**65.0**
(4) Property Tax Payments	**52.0**	**52.8**	**53.6**	**54.4**	**55.2**	**56.0**	**56.9**	**57.7**	**58.6**	**59.4**
(5) Value of CO2 Emission Reductions	**287.1**	**289.8**	**319.0**	**316.6**	**328.8**	**341.4**	**354.5**	**368.1**	**382.2**	**396.8**
Total Benefits										
(6) Total Economic Benefits (Sum 2 through 5)	**505.8**	**515.5**	**547.5**	**584.5**	**609.2**	**625.1**	**644.3**	**663.9**	**684.2**	**705.1**
Total of Market Value and Economic Benefits [Sum 1 and 6]	**1,109.2**	**1,129.1**	**1,172.4**	**1,218.3**	**1,255.1**	**1,285.4**	**1,319.0**	**1,355.4**	**1,388.9**	**1,425.4**

[50] Net Economic Output = Gross Economic Output – Total Wholesale Electricity Cost Savings.

Table A-4 – Annual Benefits to the State of New York from CHPE ($millions, 2043-2052)

Benefit Type (Market Value and Economic Benefits)	2043 (Yr 21)	2044 (Yr 22)	2045 (Yr 23)	2046 (Yr 24)	2047 (Yr 25)	2048 (Yr 26)	2049 (Yr 27)	2050 (Yr 28)	2051 (Yr 29)	2052 (Yr 30)
Market Value of CHPE's Energy										
(1) Market Value of Energy Provided by CHPE	736.1	754.4	768.9	785.8	803.1	823.0	838.8	857.2	876.1	897.8
Economic Benefits										
(2) Total Wholesale Electricity Cost Savings	187.6	191.4	195.3	199.3	203.3	207.4	211.7	216.0	220.3	224.7
Energy Cost Savings	344.7	352.5	360.4	368.6	376.9	385.5	394.2	403.1	412.2	421.6
Capacity Cost Savings	(157.1)	(161.1)	(165.1)	(169.3)	(173.6)	(178.0)	(182.5)	(187.2)	(191.9)	(196.9)
Gross Economic Output	254.4	260.1	265.9	271.9	278.0	284.2	290.6	297.2	303.8	310.5
less Total Wholesale Electricity Cost Savings	187.6	191.4	195.3	199.3	203.3	207.4	211.7	216.0	220.3	224.7
(3) Net Economic Output[51]	66.8	68.7	70.6	72.6	74.7	76.8	79.0	81.2	83.5	85.9
(4) Property Tax Payments	60.3	61.2	62.2	63.1	64.0	65.0	66.0	67.0	68.0	69.0
(5) Value of CO2 Emission Reductions	412.0	427.7	444.0	460.9	478.4	496.6	515.4	535.0	555.2	576.2
Total Benefits										
(6) Total Economic Benefits (Sum 2 through 5)	726.7	749.0	772.1	795.9	820.4	845.8	872.1	899.2	927.0	955.8
Total of Market Value and Economic Benefits [Sum 1 and 6]	1,462.8	1,503.4	1,540.9	1,581.7	1,623.5	1,668.8	1,710.8	1,756.3	1,803.1	1,853.6

[51] Net Economic Output = Gross Economic Output – Total Wholesale Electricity Cost Savings.

A.2 Annual Jobs and Compensation Forecast

Tables A-5 through A-8 outline the results of PA's analysis related to estimated direct and secondary (indirect and induced) job creation and compensation within New York (all values are presented in nominal $s). Jobs and compensation benefits are also discussed in Section 2.2.3.

Table A-5 – Direct Jobs and Compensation Impacts from CHPE in New York (2017-2032)

Year	Period	New Jobs[52]	Higher Compensation ($millions)
2017	Construction	86	10.5
2018		124	15.6
2019		774	63.8
2020		1,097	89.3
2021		1,551	129.2
2022		930	79.0
2023	Operations	92	9.5
2024		71	8.1
2025		72	8.3
2026		72	8.5
2027		93	10.6
2028		72	9.0
2029		77	9.6
2030		73	9.5
2031		78	10.2
2032		74	10.1

[52] Direct job creation fluctuates annually during the operations period largely as a result of TDI's scheduled payments into the Environmental Trust Fund, as well as projected fluctuations in maintenance, administration, and other expenditures from year to year.

Table A-6 – Direct Jobs and Compensation Impacts from CHPE in New York (2033-2052)

Year	Period	New Jobs	Higher Compensation ($millions)
2033	Operations	79	10.8
2034		75	10.6
2035		80	11.4
2036		76	11.3
2037		81	12.0
2038		77	11.9
2039		78	12.3
2040		78	12.6
2041		79	13.0
2042		79	13.4
2043		80	13.8
2044		80	14.2
2045		81	14.6
2046		81	15.0
2047		82	15.4
2048		83	15.9
2049		83	16.3
2050		84	16.8
2051		84	17.3
2052		85	17.8

Table A-7 – Secondary (Indirect and Induced) Jobs and Compensation Impacts from CHPE in New York (2017-2032)

Year	Period	New Jobs[53]	Higher Compensation ($millions)
2017	Construction	81	5.7
2018		118	8.5
2019		593	42.7
2020		772	55.5
2021		1,105	81.3
2022		651	48.9
2023	Operations	8,965	616.7
2024		8,454	594.3
2025		9,143	656.8
2026		6,605	485.1
2027		5,641	423.8
2028		5,096	391.2
2029		2,574	202.4
2030		1,328	107.2
2031		844	70.0
2032		570	48.6

Table A-8 – Secondary (Indirect and Induced) Jobs and Compensation Impacts from CHPE in New York (2033-2052)

Year	Period	New Jobs	Higher Compensation ($millions)
2033	Operations	595	51.9
2034		611	54.4
2035		597	54.4
2036		744	68.9
2037		765	72.5
2038		761	73.6
2039		760	75.2
2040		760	76.8
2041		759	78.4
2042		759	80.1
2043		758	81.8
2044		757	83.6
2045		757	85.3
2046		756	87.2
2047		756	89.0
2048		755	90.9
2049		754	92.9
2050		754	94.8
2051		753	96.9
2052		752	98.9

[53] Indirect job creation fluctuates annually during the operations period largely as a result of variations in the electricity cost savings attributable to CHPE.

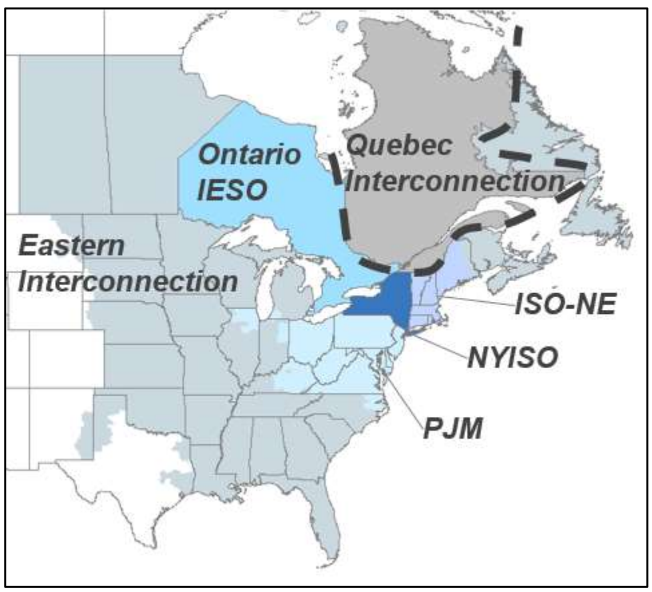
B DESCRIPTION OF THE MODELING METHODOLOGY AND ANALYSIS

B.1 Wholesale Electricity and Natural Gas Modeling

To evaluate the wholesale electricity and environmental benefits from CHPE, PA used its proprietary electricity market modeling process. This process has been vetted in regulatory and litigation proceedings, including some of the largest bankruptcies in the power sector.

At the core of PA's proprietary modeling process, PA uses an industry standard chronological dispatch simulation model, AURORA^{xmp}, to simulate the hourly operations of the power plants and transmission lines within the Eastern and Quebec Interconnections – as illustrated in Figure B-1 – with a focus on the NYISO system. This model enables PA to analyze inter and intra-market hourly energy flows and the operating profile of the power plants and transmission lines within a given system; in this case NYISO and the adjacent systems of PJM, Ontario IESO, Hydro-Quebec, and ISO-NE.

Figure B-1 – North American Electric Interconnections



The AURORA^{xmp} model is widely used by electric utilities, power market regulators, independent system operators and other market consultants. For example, NERC - the non-profit organization that oversees electric reliability in New York - recently used AURORA^{xmp} to assess impacts related to the U.S. EPA's Clean Power Plan. Similarly, ISO-NE used AURORA^{xmp} to forecast the operations of the New England electricity market in its review of the Forward Capacity Auction.

To forecast the long-term wholesale natural gas prices that are used in the AURORA^{xmp} model to forecast wholesale electricity prices, PA used the GPCM® Natural Gas Market Forecasting System™ ("GPCM®"). GPCM models natural gas production, existing pipeline flows and constraint, new pipeline construction, and natural gas demand from the power sector and residential, commercial, and industrial sectors for the entire U.S. PA used GPCM to develop a long-term view of both Henry Hub natural gas prices and the prices of regional hubs such as Transco Zone 6 NY, which is applicable to the New York – Zone J region. GPCM is used across the energy industry, including by government agencies such as FERC and NEB, and independent system operators such as MISO.

To analyze the environmental and economic benefits of the Project, PA modeled the NYISO electricity system under two scenarios - referred to as the Reference Case and the Study Case. The Reference Case modeled the NYISO system without CHPE, while the Study Case assumed CHPE would provide 8.3 TWh per year of clean energy and 1,000 MW of firm capacity sales into the system. In order to evaluate the contribution that the Project would make to New York meeting its CO_2 emission reduction and CES Tier 1 targets, the Reference Case assumed New York is not compliant with its CES Tier 1 targets during the study period.[54] More specifically, the Reference Case assumes the availability of Tier I RECs is insufficient to meet New York's CES Tier 1 targets. This approach enables the reader to evaluate the incremental benefit that clean energy projects, such as CHPE, provide by supplying clean and renewable energy to help the State of New York achieve its environmental policies and goals.

B.1.1 Determining Wholesale Electricity Cost Savings and CO_2 Emission Reductions

As previously discussed, PA's analysis forecasted CHPE's operations to result in wholesale electricity cost savings and CO_2 emission reductions for New York ratepayers. These findings were determined using the aforementioned AURORA^{xmp} model. Two primary assumptions that impact the level of electricity cost savings and CO_2 emission reductions are (1) natural gas prices, and (2) peak electricity demand growth.

1. Natural gas price assumptions

PA developed the natural gas price forecast (both Henry Hub and Transco Zone 6 NY) using the GPCM model. All else equal, the higher the natural gas price forecast the greater the energy portion of electricity cost savings from CHPE will be.[55] This is because the electricity production cost advantage that CHPE enjoys versus the rest of the NYISO system, particularly Zone J, will be greater at higher natural gas prices – since the vast majority of the Zone J electricity system uses natural gas to generate electricity, and higher natural gas prices result in higher costs to generate electricity.

PA's forecast of natural gas prices for Transco Zone 6 NY reflects gradually increasing pricing, as illustrated in Figure B-2. PA's natural gas price forecast reflects (1) higher gas demand from the power sector, increasing from 24.3 Bcf/day today to 30.0 Bcf/day by 2023, (2) more gas demand from liquefied natural gas ("LNG") export terminals, increasing from 2.1 Bcf/day today to 9.4 Bcf/day by 2023 as terminals such as Sabine Pass, Freeport, and Cove Point come online, and (3) more gas exports to Mexico, increasing from 4.0 Bcf/day today to 6.2 Bcf/day by 2023. Combined, these demand-side factors are forecasted to increase the use of U.S. natural gas, causing more expensive gas reserves to be drilled and resulting in higher gas pricing.

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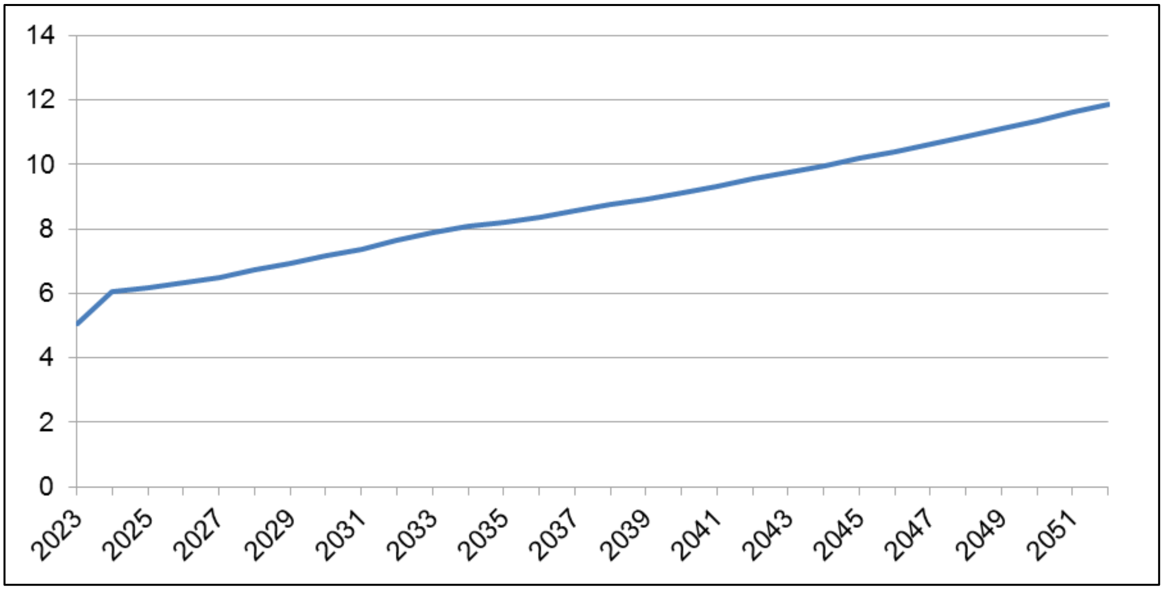
[54] This is based on the assumption that the primary method New York would use to meet it 40% by 2030 GHG emission reduction target would be encouraging the entry of renewable and clean energy power plants in the power sector.

[55] As discussed in Section 2.2.2, electricity cost savings are made up of both energy cost savings and capacity cost savings – where energy costs are the costs to generate electricity and capacity costs are the costs to make sure electricity is available and generated when it is needed.

Figure B-2 – Transco Zone 6 NY Natural Gas Price Forecast ($/MMBtu)



2. Electricity demand assumptions

PA developed its Zone J electricity demand forecast based on the 2017 Load & Capacity Data Report, commonly known as the "Gold Book". Forecasted peak demand growth includes the impacts of statewide energy efficiency programs and behind-the-meter generation, which act to reduce overall energy consumption in both on- and off-peak periods. Energy efficiency and behind-the-meter generation are likely to continue to put downward pressure on both peak load and energy consumption, particularly as initiatives like Reforming the Energy Vision ("REV") spur investment in distributed energy resources.

All else equal, the higher the electricity demand forecast the greater the capacity portion of electricity cost savings from CHPE will be. This is because the higher the peak electricity demand forecast, the sooner Zone J will need new capacity beyond CHPE's 1,000 MW, and this capacity is likely to cost more than CHPE's – resulting in increasing capacity prices and costs as new capacity is needed. Similarly, the higher the electricity demand forecast the greater the CO_2 emission reductions from CHPE will be. This is because a higher electricity demand forecast requires the NYISO system to rely on less efficient (i.e. more expensive) power plants to meet the higher electricity demand. Since the less efficient power plants will generally have higher CO_2 emissions per MWh of electricity generated, adding CHPE to a system with higher electricity demand results in greater CO_2 emission reductions.

PA's load forecast relies on the energy efficiency and distributed generation assumptions from the 2017 Gold Book but relies a gross peak demand growth rate in line with the growth rate from the 2015 Gold Book, which more accurately reflects PA's view of forecasted GDP growth. More specifically, the Gold Book relies on Moody's GDP growth forecasts, which declined by approximately half (from ~2% to ~1% long-term) between 2015 and 2017. PA's view is in line with the 2015 Gold Book. As a result, PA's load growth forecast is slightly higher than the 2017 Gold Book.

3. How electricity cost savings are calculated

The electricity cost savings (made up of energy and capacity cost savings) to New York ratepayers were calculated using the AURORA^{xmp} model (energy cost saving) and PA's ICAP auction simulation model (capacity cost savings). As discussed in Section 1, CHPE was assumed to begin commercial operations in January 2023 with the ability to generate 1,000 MW of electricity at a capacity factor of 95%.

The AURORA^{xmp} model simulated the NYISO system, and the adjacent PJM, Ontario IESO, Hydro-Quebec, and ISO-NE systems, with and without CHPE in the market. CHPE was forecasted to lower wholesale energy prices, and thereby lower energy costs, by reducing the system's reliance on expensive fossil-fueled power plants to generate electricity as a result of its low production cost of electricity – which results in CHPE operating ahead of these fossil-fueled power plants. These dynamics and how wholesale energy prices decrease as a result of CHPE's 1,000 MW of clean energy were described in Section 2.2.2 of this report, specifically Figures 10 and 11.

The ICAP auction simulation model simulated NYISO's capacity auctions with and without CHPE and its 1,000 MW of firm capacity sales in the market. CHPE was forecasted to lower wholesale capacity prices in NYISO and thereby lower capacity costs, by increasing the amount of low cost capacity that is available to be purchased. This dynamic and how wholesale capacity prices decrease as a result of CHPE's 1,000 MW of firm capacity sales was described in Section 2.2.2 of this report, specifically Figure 12.

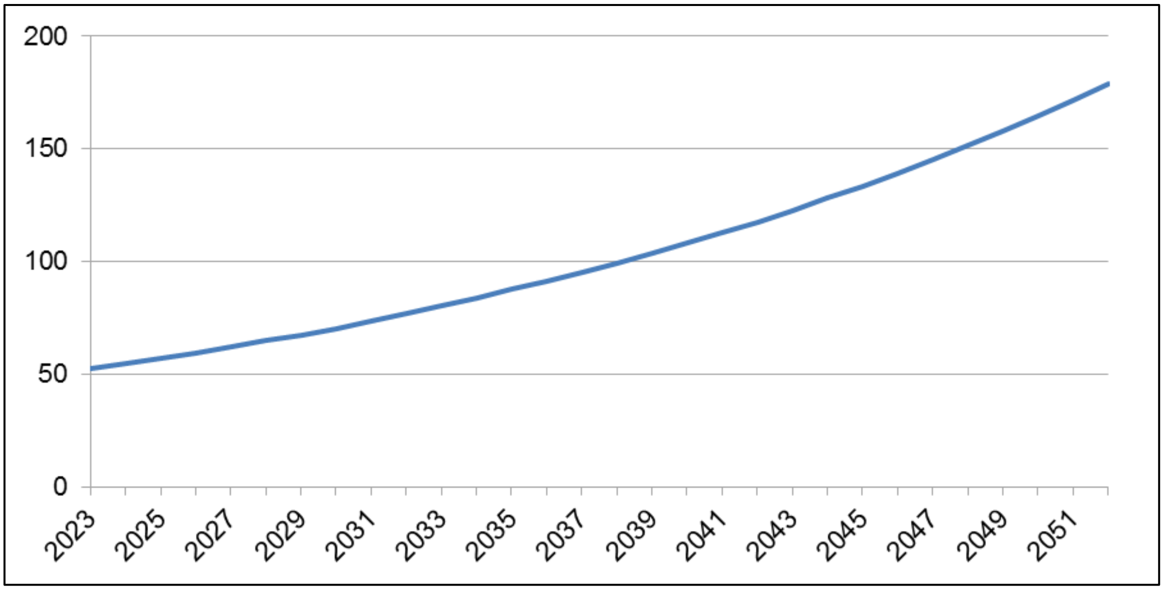
4. How CO_2 emission reductions and environmental benefits are calculated

Similar to how energy cost savings were calculated, PA relied on the AURORA^{xmp} model to simulate the operations of the NYISO system and the adjacent PJM, Ontario IESO, Hydro-Quebec, and ISO-NE systems, with a specific focus on how CHPE would change the operations of CO_2-emitting power plants. Similar to how CHPE creates energy cost savings, CHPE is forecasted to create CO_2 emission reductions by reducing the NYISO system's reliance on CO_2-emitting fuel oil and natural gas-fired power plants to generate electricity as a result of its low production cost of electricity – which results in CHPE operating ahead of these CO_2-emitting power plants.

Once the CO_2 emission reductions from CHPE were quantified, PA calculated the environmental benefit of the reductions (*i.e.*, the value of avoided CO_2 emissions) based on the most recent federal IWG Social Cost of Carbon calculation.[56] The Social Cost of Carbon is a monetized estimate of the societal damages, including agricultural productivity changes, human health risks, and flooding damages, associated with increases in CO_2 emissions. Specifically, the Social Cost of Carbon starts at $59.86/metric ton in 2023, escalating to $173.67 by 2052. However, because New York participates in the Regional Greenhouse Gas Initiative ("RGGI"), the Social Cost of Carbon was reduced by the forecasted price of RGGI CO_2 allowances to calculate the environmental benefit of CO_2 emission reductions, since the RGGI allowance value was already captured in the decrease in wholesale energy costs from CHPE. The net CO_2 cost that was applied to the forecasted CO_2 emission reductions from CHPE is illustrated in Figure B-3 below.

[56] PA used the Social Cost of Carbon value calculated using a 3% social discount rate. Note that on March 28, 2016, President Donald Trump signed an executive that, among other items, called for the review of estimates of the Social Cost of Carbon, disbanded the IWG, and rescinded IWG technical documents related to the Social Cost of Carbon calculation as no longer representative of federal government policy. However, the Social Cost of Carbon remains the predominant tool for valuing the social, environmental, and human health costs associated with GHG emissions, as well as the benefits associated with reducing those emissions. For example, the NYPSC utilized the Social Cost of Carbon as a baseline for valuing ZECs paid to eligible nuclear generators for carbon-free generation.

Figure B-3 – New York Net CO_2 Emission Cost ($/metric ton)



B.2 Economic Impacts Modeling

To estimate the economic benefits, PA's used an Input-Output ("I-O") analysis. I-O analysis accounts for inter-industry relationships within a defined geographic area (e.g. New York) and estimates how the local and regional economies are affected by a given investment, using economic activity multipliers. In this case, that investment is the construction and operation of CHPE.

The specific model PA used to conduct the I-O analysis was IMPLAN – Impact Analysis for Planning. IMPLAN is an economic analysis tool that takes data from multiple government sources and employs an estimation method based on industry accounts, an I-O Matrix, uses multipliers to estimate how changes in income and spending benefit regional economies. IMPLAN estimates are generated by interacting CHPE's direct expenditures (*e.g.*, jobs created and compensation paid) with the Regional Input-Output Modeling System (RIMS II) multipliers for New York, which were provided by the U.S. Bureau of Economic Analysis ("BEA").

Multiplier analysis is based on the notion of feedback through I-O linkages among firms and households who interact in an economy. Firms buy and sell goods and services to other firms and compensate households. In turn, households buy goods from additional firms using the compensation received. This interaction creates economic output in an economy. Similarly, capital projects such as CHPE (1) create jobs, which in turn (2) compensate households and increase household disposable income that (3) is used to purchase goods and services in an economy, which (4) also creates economic output. This is illustrated in Figure B-4 below.

Figure B-4 – How Economic Benefits are Created in an Economy

Economic benefits represent the jobs, income, output, and fiscal benefits created from both the direct jobs created and compensation paid by CHPE, but also from feedback effects where other local firms require more labor and inputs to meet rising demand for their output, which was stimulated by CHPE's construction and operation. Collectively, these total benefits can be categorized into direct, and indirect and induced effects.

Direct effects reflect those impacts resulting from CHPE's direct expenditures, such as CHPE hiring workers. Indirect effects reflect supply chain impacts from CHPE's direct expenditures, such as the incremental jobs and compensation at local contractors or material providers that are supported by investment in CHPE's construction (truckers, concrete providers, etc.). Lastly, induced effects reflect impacts created by household spending of income earned directly from CHPE or indirectly through businesses that are impacted by CHPE or through ratepayer savings resulting from the operation of CHPE.

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