NYSERDA Smart Grid Evaluation Case Study: Central Hudson's Grid Modernization Investments

Final

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Notice

NYSERDA Smart Grid Program Case Study: An evaluation of grid modernization investments at Central Hudson[1]

Key Results

- $6 million awarded to Central Hudson by NYSERDA for grid modernization
- $52.9 million invested by Central Hudson
  - $8.80 committed by Central Hudson for every $1 of NYSERDA funding
- Reliability benefits valued at $7.3 million due to distribution automation investments
- Economic benefits of $41.7 million from reduced electricity generation to meet customer demand and avoided capital upgrades over 20 years
- 741,188 metric tons of CO_2e emissions avoided over 20 years
- $28.0 million environmental benefits of avoided CO_2e
- Total benefit of NYSERDA's and Central Hudson's funding: $77.0 million
  - $12.83 in benefits for every $1 of NYSERDA funding
- Qualitative benefits: NYSERDA's funding influenced Central Hudson's follow-on smart grid investments and supported knowledge sharing among utilities that influenced other New York State utilities to undertake grid modernization upgrades

1. Introduction

NYSERDA's Smart Grid program promotes modernization of New York State's electric grid by funding research and technology development projects that can be implemented at the utility scale. Through these projects, the program aims to:

- Increase grid efficiency by encouraging real-time data collection and management;
- Reduce costs associated with integrating renewable energy sources; and
- Improve the ability of the grid to predict, withstand and recover from power outages.

Examples of smart grid technologies include remote sensing devices for monitoring grid conditions in real-time, tools enabling two-way communication between a utility's operations center and various points on the grid, and automated controls for optimizing grid performance. These technologies and devices are relatively new and are evolving quickly.

Central Hudson Gas & Electric (Central Hudson) is one of New York State's seven electric utilities; its service territory includes the Mid-Hudson River Valley from north of New York City to Albany County (Exhibit 1). Since 2008, NYSERDA's Smart Grid program has funded eight Central Hudson grid modernization projects through a competitive solicitation process. Central Hudson received approximately $6 million from NYSERDA across the eight awards (Exhibit 2). NYSERDA funding supported a range of projects, including development of a microgrid to prevent outages in Denning, NY, and multiple phases of research and development related to

[1] NYSERDA contracted with IEc to evaluate the impacts of NYSERDA's investments in grid modernization at Central Hudson and to present the results in this case study.

grid automation and the integration of renewable resources. Specifically, Central Hudson received support for the development and demonstration of:

- Automated transmission and distribution management systems;
- Superconducting fault current limiters, which prevent problems associated with faults in power lines by detecting and rerouting power flow around the fault; and
- Sensors, smart inverters and other monitoring and power controls to aid the efficient integration of renewable energy resources into the power grid.

Four of the eight projects are completed, while the others, which relate to the integration and optimization of renewable energy, are ongoing.

Exhibit 1. Central Hudson Service Territory

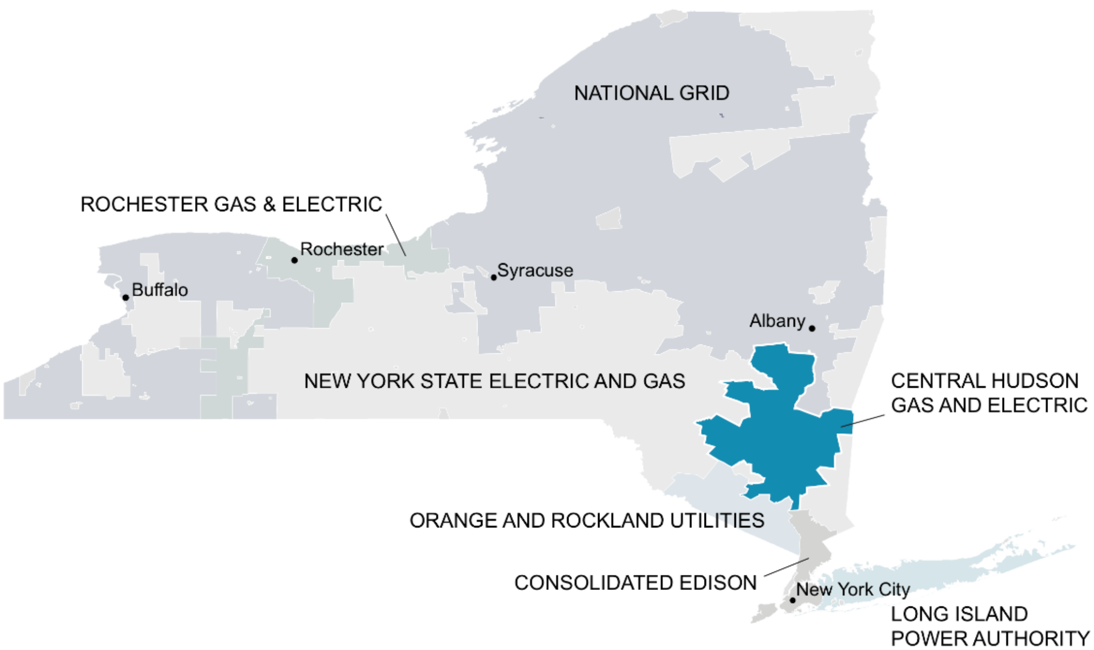
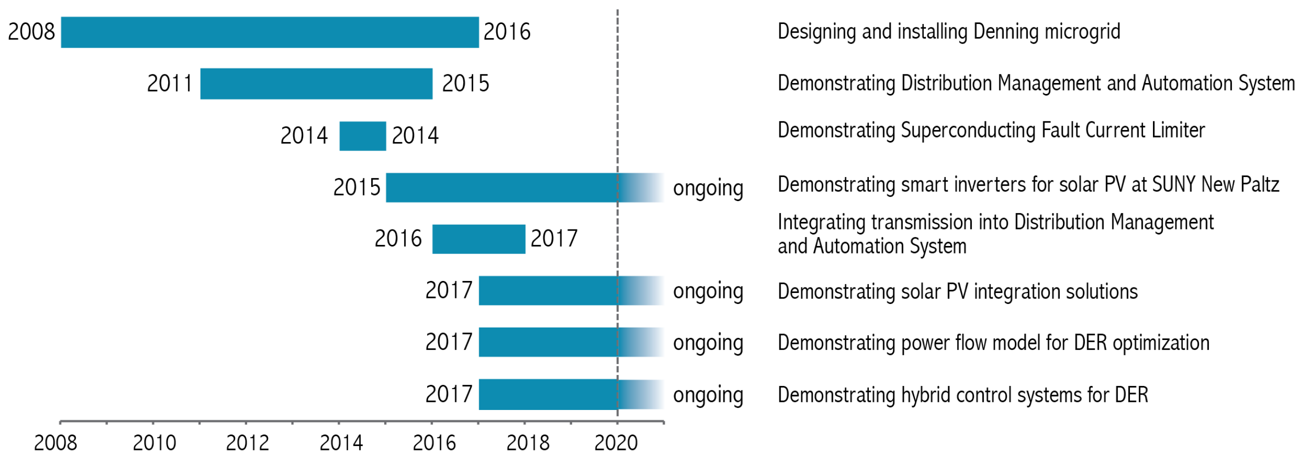


Exhibit 2. NYSERDA Awards to Central Hudson



This case study quantifies the key benefits that resulted from Central Hudson's and NYSERDA's funding for Central Hudson's grid modernization improvements, including improved grid reliability, economic cost savings, and avoided CO_2 emissions. Qualitative benefits related to knowledge sharing across utilities including Central Hudson, National Grid and Con Edison are noted but not quantified. Information for this case study was collected through interviews with Central Hudson, National Grid and Con Edison staff, review of NYSERDA's and Central Hudson's project materials, and supplementary research.

2. Benefits of Smart Grid Development

Potential benefits from investing in smart grid technologies and tools that enable automated power monitoring and control include:

- Improvements in grid reliability (preventing or recovering more quickly from power outages)
- Improvements in grid efficiency and corresponding reductions in energy production by more closely aligning the amount of electricity generated with customer demand, thereby minimizing unnecessary surplus energy lost in transmission and distribution
- Avoided and/or deferred capital upgrades or expansions because of improved grid efficiency
- Reductions in greenhouse gas emissions resulting from improved grid efficiency and increased integration of renewable energy resources
- Operational and system planning efficiencies resulting from access to real-time data and automation

Central Hudson reported that its initial investment in smart grid prior to 2008 were motivated by reliability concerns within its service territory. Reliability in Central Hudson's service territory significantly improved between 2008 and 2016 as a result of NYSERDA's and Central Hudson's smart grid investments and smart grid technologies maturing, and Central Hudson's motivations to modernize its grid expanded to include providing cost savings and other benefits to customers and working towards New York State's renewable energy goals, which calls for greatly increasing the amount of renewable energy generation (see text box below). Achieving these goals requires utilities to integrate smart grid monitoring and control technologies and tools in their operations.

Climate Leadership and Community Protection Act

Introduced in 2019, New York State's Climate Leadership and Community Protection Act (CLCPA) is a comprehensive energy strategy for New York State that lays out a path to carbon neutrality to make the energy system cleaner, more resilient, and more affordable, while committing to environmental justice, benefiting disadvantaged communities, and ensuring a just transition to zero carbon electricity. The programs and initiatives directed by CLCPA are designed to help the state achieve these energy goals:

- 85% reduction in greenhouse gas emissions from 1990 levels by 2050
- 70% of electricity generation from renewable sources by 2030 and 100% zero-carbon electricity by 2040

The projects supported by NYSERDA funding helped Central Hudson to modernize its grid and achieve significantly greater efficiencies in grid operations. Following the NYSERDA-funded demonstration of a distribution management and automation system, Central Hudson invested in full-scale transmission and distribution automation. This technology allows Central Hudson to optimize the operation of its transmission and distribution systems – thus avoiding unnecessary generation, reducing fossil fuel consumption and emissions – and eliminate and/or defer costly capital upgrades. The Denning, NY microgrid has also demonstrably improved the reliability of electric service for customers in that area by reducing the number of outages. The specific benefits resulting from the NYSERDA-funded projects are discussed in the following sections.

3. Reliability Benefits

Many smart grid technologies and tools – particularly those related to grid monitoring and automation – aim to improve grid reliability by preventing or responding to outages in real-time. Smart grid technologies can, for example, monitor grid conditions to identify potential problems and automatically reroute power around those areas to minimize the number of customers affected.

How is Grid Reliability Measured?

Reliability for electric utilities is typically measured using two indices:

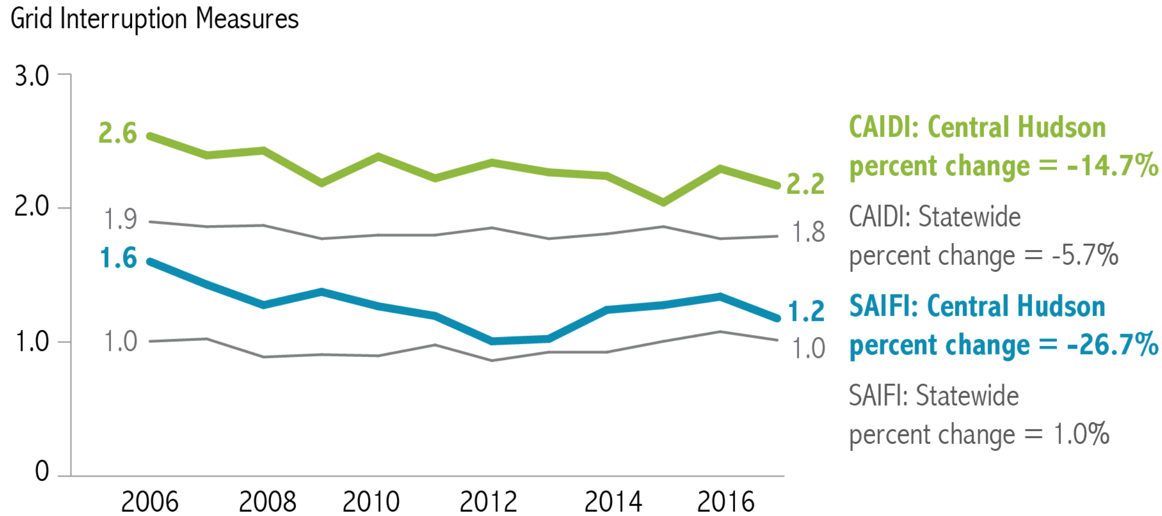
- CAIDI, the Customer Average Interruption Duration Index, which represents the average outage duration that any customer would expect to experience over the course of a year.
- SAIFI, the System Average Interruption Frequency Index, which represents the average number of interruptions a customer would expect to experience in that year.

Electric utilities across the country commonly track and report CAIDI and SAIFI to state public utility commissions. These metrics allow utilities and regulators to monitor reliability performance and take corrective actions when necessary to improve performance.

Because reliability can be affected by weather and other elements beyond the control of the utility, CAIDI and SAIFI are reported in two ways: *including* or *excluding* the impacts of major storms. To better compare across utilities that are located in different parts of the state and therefore experience different weather, this case study considers CAIDI and SAIFI excluding major storms.

Reliability at Central Hudson has improved since its earliest grid modernization investments in the early 2000s, as reflected in improved standard reliability metrics including SAIFI (the System Average Interruption Frequency Index, a measure of outage frequency) and CAIDI (the Customer Average Interruption Duration Index, a measure of outage duration – see text box). Reliability improvements continued with Central Hudson's first NYSERDA award in 2008, and the utility has continued to improve since then (Exhibit 3). Although Central Hudson still lags behind the other New York State utilities in standard reliability metrics, it has shown the most pronounced improvement over the last decade (Exhibit 4).

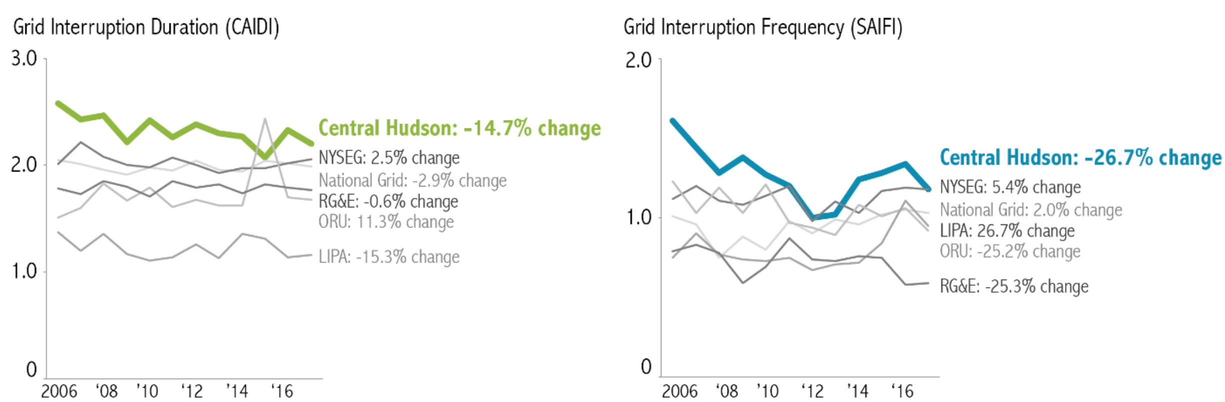
Exhibit 3. Reliability at Central Hudson Compared to Statewide Average[2]



CAIDI, the Customer Average Interruption Duration Index, represents the average outage duration that any customer would expect to experience over the course of a year. SAIFI, the System Average Interruption Frequency Index, represents the average number of interruptions a customer would expect to experience in that year.

Source: New York State Department of Public Service Electric Reliability Performance Reports 2006-2017.

Exhibit 4. Reliability at Central Hudson Compared to Other Utilities



Please see notes to Exhibit 3 for definitions of CAIDI and SAIFI.

Source: New York State Department of Public Service Electric Reliability Performance Reports 2006-2017.

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[2] Statewide averages are presented here excluding data from Con Edison, in order to highlight trends for utilities most similar to Central Hudson. Unlike other New York State utilities, Con Edison uses a *secondary network* for electricity distribution, which means that customers are served by multiple supplies, and interruptions are therefore relatively rare. To avoid distorting statewide data, the Department of Public Service reports statewide averages both with and without Con Edison.

The dollar value of reliability improvements is estimated using the U.S. Department of Energy's (DOE's) Interruption Cost Estimate (ICE) Calculator, an online tool that calculates the cost to different types of customers based on standard reliability metrics for a given electric utility.[3] As shown in Exhibit 5, the ICE Calculator estimates the value of reliability improvements in Central Hudson's service territory to be $19.4 million in benefits to customers between 2006 and 2017 (valued in 2019$). Reliability benefits may continue into the future but future reliability benefits were not quantified for this study.

Exhibit 5. Estimated Value of Avoided Grid Interruptions (Measured in CAIDI and SAIFI)

<table>
<tr><th colspan="4">Measuring Grid Reliability</th></tr>
<tr><th>Grid Reliability Metric</th><th>2006</th><th>2017</th><th>Percent Change</th></tr>
<tr><td>SAIFI: Central Hudson</td><td>1.61</td><td>1.18</td><td>-26.7%</td></tr>
<tr><td>SAIFI: Statewide</td><td>1.00</td><td>1.01</td><td>1.0%</td></tr>
<tr><td>CAIDI: Central Hudson (hours)</td><td>2.58</td><td>2.20</td><td>-14.7%</td></tr>
<tr><td>CAIDI: Statewide (hours)</td><td>1.92</td><td>1.81</td><td>-5.7%</td></tr>
<tr><th colspan="4">Economic Value of Grid Reliability Improvements</th></tr>
<tr><th>Scenario</th><th>2006 Impact (2019$, millions)</th><th>2017 Impact (2019$, millions)</th><th>Change in Annual Impact (2019$, millions)</th></tr>
<tr><td>ICE Calculator Valuation</td><td>$79.1</td><td>$59.7</td><td>$19.4</td></tr>
<tr><td colspan="3">100% Attribution</td><td>$19.4</td></tr>
<tr><td colspan="3">61.2% Attribution
(improvements beyond statewide average)

Derivation:
• Percentage decrease in statewide CAIDI, 2006-2017: 5.7
• Percentage decrease in Central Hudson CAIDI, 2006-2017: 14.7
• Proportion of improvements that are beyond statewide average: 61.2% = 100 - (5.7 / 14.7)</td><td>$11.9</td></tr>
<tr><td colspan="3">37.4% Attribution
(10% reduction due to automation)

Derivation:
• Percentage decrease in Central Hudson SAIFI, 2006-2017: 26.7
• Percentage decrease in Central Hudson SAIFI due to automation: 10
• Proportion of improvements that are due to automation: 37.4% = 10 / 26.7</td><td>$7.3</td></tr>
</table>

CAIDI, the Customer Average Interruption Duration Index, represents the average outage duration that any customer would expect to experience over the course of a year. SAIFI, the System Average Interruption Frequency Index, represents the average number of interruptions a customer would expect to experience in that year.

Source: Analysis based on New York State Department of Public Service Electric Reliability Performance Reports 2006-2017, and the U.S. Department of Energy's Interruption Cost Estimate Calculator

[3] https://icecalculator.com/home

The full value of this improvement is not attributable solely to Central Hudson's and NYSERDA's funding presented in this case study. Central Hudson first received funding from NYSERDA for smart grid investments in 2008, but reliability at Central Hudson began improving before that time. Additionally, reliability also improved between 2006 and 2017 at other New York State utilities and across the state as a whole, suggesting that some of Central Hudson's improvements may have been enabled by factors other than NYSERDA's support and may have occurred even in the absence of NYSERDA funding.

This case study attempts to isolate the impacts of NYSERDA's and Central Hudson's investments apart from what could have been expected to occur based on the statewide average improvements.

- Between 2006 and 2017, the statewide average change in CAIDI was -5.7%; SAIFI remained nearly constant.[4] This suggests that approximately 38.8% of Central Hudson's CAIDI improvement (-5.7% change statewide, divided by -14.7% change at Central Hudson) could have been explained by changes occurring statewide, in parallel with other utilities.
- The remaining 61.2% (100% minus 38.8%) could therefore represent improvements unique to Central Hudson.
- Applying this 61.2% adjustment factor to the total benefits from the ICE Calculator, it is estimated that $11.9 million in avoided interruption costs could be attributable to Central Hudson's and NYSERDA's funding, beyond improvements that would have occurred otherwise.

Grid performance depends on many factors, making it challenging to attribute reliability improvements specific investments. However, Central Hudson estimates that its portfolio of investments in transmission and distribution automation have prevented outages for 10% of its customers each year. Assuming that this reduction maps to a 10% reduction in SAIFI (a measure of outage frequency, rather than CAIDI, which is a measure of outage duration), the evaluation team compared Central Hudson's total reduction in SAIFI to this 10% figure to estimate the portion of reliability benefits that could be attributable to specific investments in transmission and distribution automation.

- Between 2006 and 2017, SAIFI at Central Hudson decreased by 26.7%. Because Central Hudson reports that its smart grid investments have prevented outages for 10% of its customers each year, 37.4% of the reduction can be attributed to investments in automation (-10% change due to automation, divided by -26.7% change overall).
- Applying this 37.4% adjustment factor to the total benefits from the ICE Calculator, it is estimated that $7.3 million in avoided interruption costs could be attributable to Central Hudson's and NYSERDA's investments in automation (Exhibit 5, above).

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[4] Statewide averages presented here exclude data from Con Edison, which operates a distribution network very different from that of other utilities, in order to highlight trends at utilities most similar to Central Hudson. The Department of Public Service commonly reports statewide averages both including and excluding Con Edison to enable these comparisons.

The typical Central Hudson customer will experience an annual reduction in outage duration of about 45 minutes per year on average due to these smart grid investments.[5]

> "NYSERDA grants have given us the freedom to experiment and try tools we are not sure of yet."
>
> -Central Hudson

Central Hudson reported that NYSERDA played an important role in enabling Central Hudson's grid modernization efforts. According to Central Hudson, the greatest benefit of NYSERDA's funding was the support and encouragement to experiment with new tools and technologies that were not yet proven. By providing Central Hudson with the financial support to experiment, NYSERDA was able to minimize the utility's financial risk of innovating. Specifically, Central Hudson noted that NYSERDA's funding to demonstrate a distribution management system allowed the utility to gain confidence in the use of real-time analysis and to identify high-priority features for inclusion in the system that was ultimately selected. Central Hudson was able to develop expertise in real-time modeling and automation during the NYSERDA-funded demonstration project, and later went on to invest in full-scale transmission and distribution automation, which, as noted above, had a direct effect on grid reliability. Prior to receiving NYSERDA's first award in 2008, Central Hudson lagged behind other New York State utilities in reliability and has since narrowed that gap (Exhibits 3 and 4, above). Moreover, the investments that facilitated Central Hudson's "most-improved" status can be traced in large part to the new technologies and approaches that were first demonstrated and validated in the utility's NYSERDA-funded projects.

> The Demonstrating Distribution Management and Automation System project "provided us a comfort level to trust the modeling on a time-series analysis. We compared the model outputs with data collected from devices in the field and saw the model provides feasible outputs. This all allowed us to go down the smart grid road."
>
> - Central Hudson

4. Economic Benefits

Central Hudson reported two examples of cost savings to the utility resulting from investments in smart grid improvements. The first example is a microgrid constructed with diesel generators in the remote town of Denning, NY, that cost Central Hudson $2 million to build (including NYSERDA's cost-share of $371,000); the investment avoided $3-4 million in expenditures that would have been required over a one-year period to provide the same level of reliability with conventional solutions (i.e., the construction of a new three-phase distribution line on an alternate route from the existing feed to the customer), resulting in net economic benefits of at least $1 million.[6] Central Hudson reported this microgrid has been used 41 times since its

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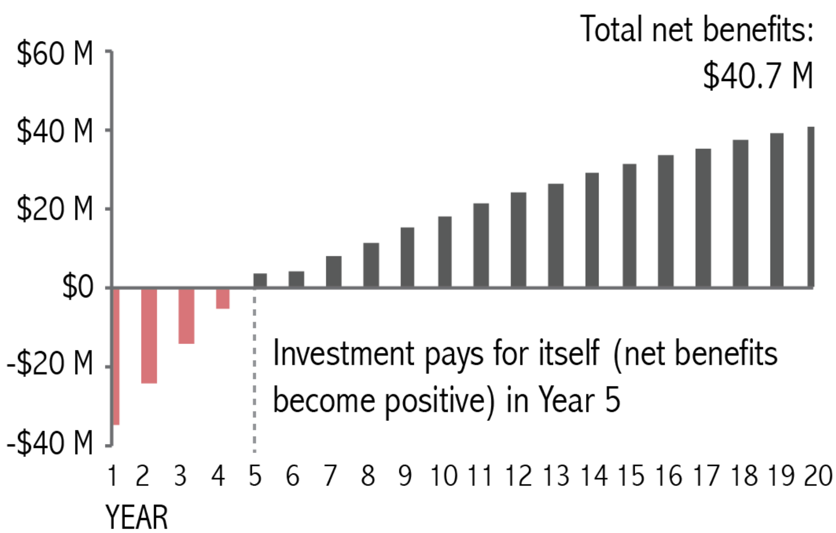
[5] Calculated as the change in the index for SAIFI and CAIDI, adjusted for NYSERDA's attribution factor. For SAIFI, the calculation is 1.61 – [(1.61-1.18)*0.374] = 1.44918. For CAIDI, the calculation is 2.58 – [(2.58-2.20) *0.612] = 2.34744. Multiplying these values gives 3.4018631. (1.61*2.58) – 3.4018631 = 0.75 hour = 45 minutes.

[6] The $1 million in net benefits is calculated as follows: $3-4 million in avoided expenditures minus $2 million to build the microgrid. Central Hudson's estimate of avoided expenditures is based on a preliminary estimate for constructing a redundant distribution feed on an alternate path to serve the customer. The range reflects that the estimate was preliminary without detailed engineering analysis and used rule of thumb costs per mile for distribution line construction. (Personal communication from Central Hudson, January 6, 2020.)

installation in 2010, preventing more than 1,700 customer outages with an estimated total duration of 36,000 minutes (or 600 hours). This benefit is particularly significant because the microgrid serves a facility providing care to children with critical health issues.

A second example is the economic cost savings expected from Central Hudson's planned investments in distribution automation. Central Hudson's 2014 rate case estimated these benefits to be $40.7 million. Included in this figure is $46.3 million in costs incurred over the five-year financial planning period of the rate case and $5.0 million in subsequent costs. Economic cost savings result from reduced energy consumption ($5.9 million annually) and two avoided capital upgrades ($2.7 million annually each over the five-year planning period), with the investment paying for itself within five years. (Please see Exhibit A1 in the appendix for details.) This analysis assumes an equipment lifespan of 20 years and an economic discount rate of 7%.[7] (Discounting is necessary to account for the time value of money – i.e., one dollar today is worth more than one dollar 20 years from now.) Exhibit 6 illustrates the accumulation of net benefits over time for Central Hudson's planned investments in distribution automation.

Exhibit 6. Economic Benefits of Central Hudson's and NYSERDA's Investments in Distribution Automation



Source: The analysis is based on the Central Hudson Rate Case 14-E-0318.

Adding the $40.7 million in net economic benefits from Central Hudson's planned investments in distribution automation to the $1 million in net economic benefits from the Denning microgrid project brings total estimated net economic benefits to $41.7 million.

5. Environmental Benefits

Investments in grid automation lead to emissions reductions through a process called Volt/VAR optimization, which reduces system losses and customer demand by lowering voltage to the

[7] Based on Central Hudson's overall weighted average cost of capital (WACC) as indicated in Central Hudson Rate Case 17-E-0459, Finance Exhibits, July 28, 2017. https://www.cenhud.com/static_files/cenhud/assets/pdf/ebf_finance_exhibits.pdf

minimum level demanded by customers in real-time and avoiding unnecessary generation and emissions. Without grid automation technologies that can monitor and adapt to changing conditions in real time, utilities are required to deliver power at higher voltages to ensure that unexpected changes, related to intermittent renewable power and other factors, do not reduce power quality for their customers. Emissions reductions associated with Volt/VAR optimization and corresponding avoided energy generation associated with investments in Central Hudson's distribution automation presented in Central Hudson's 2014 rate case were estimated using a marginal CO_2 emissions rate of 0.553 tons per MWh.[8] The CO_2 emissions were subsequently converted to CO_2 equivalent (CO_2e).[9]

Central Hudson estimates in its 2014 rate case an annual reduction in energy costs of $5.9 million associated with smart grid improvements. At an average cost of $0.08 per kWh, this translates to 73.8 million kWh of electricity avoided each year, and 1.5 million MWh avoided over 20 years. This reduction translates to 741,188 metric tons of CO_2e emissions avoided over 20 years,[10] which is equivalent to greenhouse gas emissions from approximately 160,000 passenger vehicles driven for one year.[11]

How are emissions reductions valued?

Reductions in CO_2 emissions are valued using the social cost of carbon (SCC). The SCC is a measure of the value (in dollars) of the long-term societal damages resulting from emitting one ton of CO_2 in a given year; these damages include impacts to human health, agricultural productivity, and property damage, among others.

Social cost of carbon estimates are developed by the U.S. Government's Interagency Working Group on the Social Cost of Greenhouse Gases (Interagency Working Group), which released an initial report in 2010 and an update in 2016.

The Interagency Working Group indicates that the social cost of carbon should increase over time (over and above the effects of inflation) due to accelerating climate impacts and anticipated economic growth, which will make future impacts of carbon emissions more costly.

For more information, see https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html.

Reductions in CO_2 emissions were valued using the social cost of carbon (SCC) – a measure of the value of the long-term societal damages resulting from emitting one ton of CO_2 in a given year (see text box). SCC is the standard method for valuing CO_2 emissions when the objective is to value societal benefits or costs associated with changes in CO_2 emissions. The U.S. Government Interagency Working Group on the Social Cost of Greenhouse Gases (Interagency Working Group) for 2019 estimated the SCC to be $50.55 per ton of CO_2 as their central estimate (using a 3% discount rate), and $75.21 per ton for 2019 as a higher estimate

[8] Emission Factors CO_2e New York State GHG Emission Factors, used in DPS' "SCC Netting RGGI Calculation," March 2018.

[9] CO_2e is a common unit of measure for describing the global warming potential of different greenhouse gases. In New York State, average grid CO_2 emissions are 485.12 lbs-CO_2/MWh while average grid CO_2e emissions are slightly higher at 485.92 lbs-CO_2e/MWh. This conversion factor was used to convert CO_2 to CO_2e.

[10] Using the emissions factor cited above of 0.553 tons per MWh and the CO_2e conversion described above.

[11] U.S. Environmental Protection Agency. Greenhouse Gas Equivalencies Calculator. Accessed on July 1, 2020. https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

(using a 2.5% discount rate), both expressed in 2019$.[12] The SCC values escalate over time; the corresponding values in 2038 are $71.51 (central estimate, 3% discount rate) and $101.11 (2.5% discount rate). This case study uses the central SCC estimates for the years 2019-2038 in the calculations, but presents the higher estimate for sensitivity analysis.[13] Using the central estimates, the investment in Central Hudson's grid distribution automation would avoid $28.0 million in societal damages over 20 years, including economic, environmental, health, agriculture, and property damages among others (Exhibit 7).

Exhibit 7. Environmental Benefits of Distribution Automation

Calculating Energy and Emissions Reductions		
Benefit	**Value**	
Annual reduction in energy consumption ($ millions)	$5.9	
Annual reduction in energy consumption (kWh, millions)	73.8	
20-year reduction in energy consumption (MWh, millions)	1.5	
Annual reduction in CO_2e emissions (metric tons)	37,059	
20-year reduction in CO_2e emissions (metric tons)	741,188	
Valuing Emissions Reductions		
Metric	**Value**	
	Central SCC	**Higher SCC**
Annual damages avoided, 2019 ($2019 millions, present value)	$1.9	$2.8
Annual damages avoided, 2019 – Net of RGGI ($2019 millions, present value)	$1.6	$2.5
20-year damages avoided – Net of RGGI ($2019 millions, present value)	$28.0	$45.4

Source: The analysis used social cost of carbon values from the August 2016 Technical Support Document of the U.S. Government Interagency Working Group on Social Cost of Greenhouse Gases.

The New York State Department of Public Service (DPS) advises that if the value of avoided CO_2 emissions is being summed together with the value of avoided electricity costs, it is important not to "double count" the projected Regional Greenhouse Gas Initiative (RGGI) compliance costs that are included in wholesale electricity price forecasts. Exhibit 7 reports

[12] U.S. Government Interagency Working Group on Social Cost of Greenhouse Gases. Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. August 2016. https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html

[13] The difference between the central estimate and higher estimate reflect the choice of social discount rate (3% and 2.5%, respectively). As explained in the Intergovernmental Working Group's (IWG's) report: "Based on the review of the literature, the IWG chose discount rates that reflect reasonable judgements under both prescriptive and descriptive approaches to intergenerational discounting. As discussed in the 2010 TSD [Technical Support Document], in light of disagreement in the literature on the appropriate discount rate to use in this context and uncertainty about how rates may change over time, the IWG selected three certainty-equivalent constant discount rates to span a plausible range: 2.5, 3, and 5 percent per year." (Technical Support Document - Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis, p. 19, https://www.epa.gov/sites/production/files/2016-12/documents/sc_co2_tsd_august_2016.pdf) This case study uses the central (3%) SCC as the primary estimate because it is the central estimate recommended by the IWG and is used by New York State. The higher (2.5%) estimate is shown for illustrative purposes, and reflects the IWG's prediction that the cost of carbon will increase in the future. New York State policy does not use the 5% discount rate for SCC.

avoided environmental damages of $28.0 million over 20 years after RGGI compliance costs are subtracted.[14]

6. Follow-on Investment

Follow-on investment is estimated as the investment made by Central Hudson in grid modernization as a result of NYSERDA's project funding (Exhibit 8).

As discussed in Section 4, Central Hudson committed $46.3 million in distribution automation during the five-year financial planning period of the rate case and expects to commit another $5 million in future years, bringing the utility's total investment in distribution automation to $51.3 million.

For the Denning, NY, microgrid project, NYSERDA provided $371,000 and Central Hudson provided cost share of $429,000, for a total project cost of $800,000. In addition, Central Hudson made a follow-on investment of $1.2 million to build the microgrid, bringing the total cost to build the microgrid to $2 million. Of this amount, $1.6 million was provided by Central Hudson.

Four projects related to the integration and optimization of renewable energy are ongoing, and these projects also may lead to follow-on investment in future years.

Exhibit 8. Follow-on Investment

<table>
<tr><th>Project</th><th>Central Hudson
Follow-on Investment</th></tr>
<tr><td>Project 1 – Designing and installing Denning microgrid</td><td>$1.6 million
($0.4 million cost share plus $1.2 million follow-on investment)</td></tr>
<tr><td>Project 2 – Demonstrating Distribution Management and Automation System</td><td rowspan="3">$51.3 million
($46.3 million during the five-year rate case plus an anticipated additional $5 million after the five-year period)</td></tr>
<tr><td>Project 3 – Demonstrating Superconducting Fault Current Limiter</td></tr>
<tr><td>Project 4 – Integrating transmission into Distribution Management and Automation System</td></tr>
<tr><td>Project 5 – Demonstrating smart inverters for solar PV at SUNY New Paltz</td><td rowspan="4">N/A
(projects are in progress)</td></tr>
<tr><td>Project 6 – Demonstrating solar PV integration solutions (with EPRI)</td></tr>
<tr><td>Project 7 – Demonstrating power flow model for DER optimization (with EPRI)</td></tr>
<tr><td>Project 8 – Demonstrating hybrid control systems for DER (with EPRI)</td></tr>
<tr><td>All Projects</td><td>$52.9 million</td></tr>
</table>

As shown in Exhibit 8, Central Hudson has committed $52.9 million in total follow-on investment ($51.3 million for distribution automation plus $1.6 million for the Denning

[14] Consistent with the Benefit Cost Analysis Framework adopted by the NYS Public Service Commission, this analysis uses the U.S. Environmental Protection Agency's estimate of the social cost of carbon (SCC) at the 3 percent discount rate. For electricity, the net social cost of carbon emissions on a per-MWh basis ($/MWh) is net of the projected Regional Greenhouse Gas Initiative (RGGI) compliance costs. A description of the DPS methodology is provided in Attachment B of the Order Establishing the Benefit Cost Analysis Framework (issued January 21, 2016 in NYS PSC Case 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision).

microgrid) for projects that received $6 million in NYSERDA funding. In other words, for every $1 that NYSERDA committed in project funding, Central Hudson committed over $8.80 in follow-on investment.

7. Total Benefits of NYSERDA Funding for Central Hudson's Smart Grid Improvements

Section 7 sums the benefits from the previous sections to calculate total benefits from NYSERDA's funding for Central Hudson. Economic, reliability, and environmental benefits presented in the previous sections are used to calculate total societal benefits, and these benefits are compared to NYSERDA's $6 million funding.

Total benefits of investments in Central Hudson's smart grid include the following:

- Economic cost savings: $41.7 million[15] (Because Central Hudson reported their follow-on investments in distribution automation were motivated by their work with NYSERDA, we include the benefits from Central Hudson's follow-on funding);
- Reliability benefits: $7.3 million; and
- Environmental benefits: $28.0 million over 20 years (using the central SCC value, net of RGGI).

Together, the economic, reliability, and environmental benefits represent $77.0 million in total benefits. After subtracting NYSERDA's $6 million in awards, the net societal benefit of NYSERDA's funding is $71.0 million (Exhibit 9). That is, for each $1 of NYSERDA funding, Central Hudson is expected to achieve approximately $12.83 in economic, reliability, and environmental benefits.

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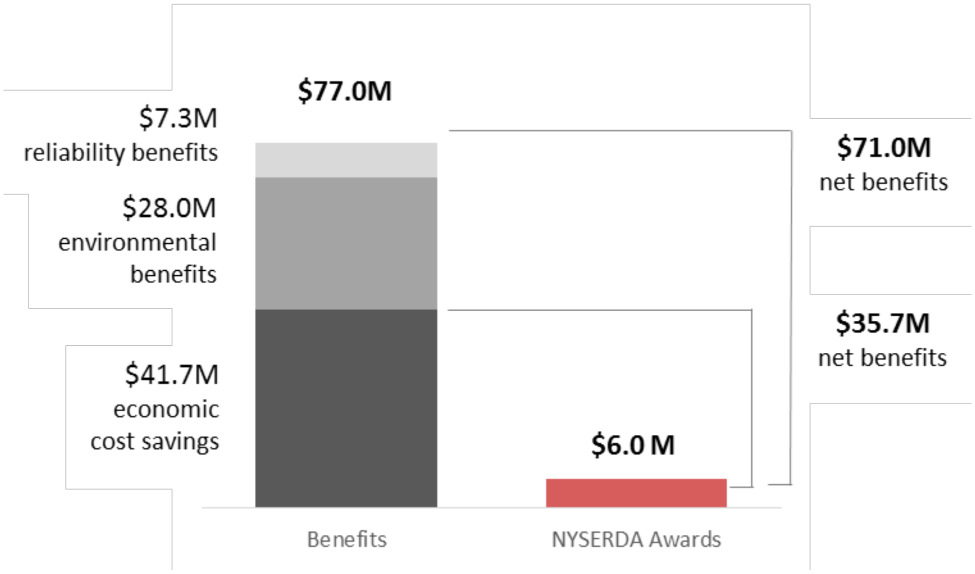
[15] The $41.7 million figure includes $40.7 million in economic benefits of investments in distribution automation plus $1 million in net economic benefits from avoided capital expenditures associated with the Denning microgrid.

Exhibit 9. Summary of Net Benefits



8. Replications of Smart Grid Improvements Following Central Hudson's Example

The technologies demonstrated with NYSERDA awards were reported to have influenced future investments by Central Hudson and replications by other New York State utilities.

The first such replication was Central Hudson's own approach to improving reliability with microgrids. Based on the success of the Denning, NY, microgrid that Central Hudson developed with NYSERDA's support, Central Hudson now views microgrids as a practical method of boosting reliability in remote locations. Central Hudson and community partners identified four additional locations for potential microgrids that they proposed under NYSERDA's NY Prize microgrid design competition.[16] All four proposals were funded for feasibility studies in Stage 1, but did not progress to project design in Stage 2.[17]

Central Hudson reported that it strives to be a leader in grid modernization among New York utilities and regularly shares the results of its experiences with other utilities. Con Edison and National Grid have learned from and adopted some elements of Central Hudson's smart grid strategy. For example:

[16] NYSERDA. NY Prize Stage 1 Winners. https://www.nyserda.ny.gov/-/media/Files/Programs/NYPrize/NY-Prize-Stage-1-Award-Winners.pdf.
[17] "Awarded Projects" PDFs, available at: https://www.nyserda.ny.gov/All-Programs/Programs/NY-Prize/Opportunity-Zones-Map.

- National Grid emulated Central Hudson's approach to grid communications (i.e., data sharing and/or remote control between a utility's operations center and various points on the grid) and load forecasting (i.e., modeling expected patterns in customer electricity demand) in its own efforts to roll out a distribution automation system.

> "We took a lot of stock in [Central Hudson's approach to load forecasting] and copied some of what they were doing."
>
> -National Grid

- Con Edison reported that Central Hudson set the standard for integrating Geographic Information Systems (GIS) into utility operations and enabling a deeper and more accurate understanding of how well the grid is functioning at specific locations. This improves utilities' ability to respond to issues and manage the integration of renewable energy in real-time. For example, GIS-enabled devices such as smart meters allow utilities to diagnose problems remotely without relying on customer reports or field examination by a utility technician. Con Edison is in the process of implementing its own enterprise-wide GIS, which it expects to complete by 2024. Con Edison has also deployed an online data portal for renewable energy developers that is the same as the tool used by Central Hudson.

> "Central Hudson has led in having a much wider-scale deployment of geographic information systems… This grid modernization effort is foundational for us… This is a big effort we are undergoing now."
>
> -Con Edison

Although differences in utility service territories and legacy equipment mean that every utility will ultimately need to develop a customized approach to smart grid development, both National Grid and Con Edison indicated that Central Hudson's efforts have inspired and informed their own grid modernization decisions and investments. All three utilities noted that the ability to share knowledge and learn from each other's approaches is facilitated in part by NYSERDA's support. All three utilities consider NYSERDA's facilitation of knowledge sharing as particularly important in keeping abreast of the quickly evolving technology and policy landscapes of grid modernization.

9. Conclusions

This case study quantified key benefits associated with Central Hudson's grid modernization improvements, including improved grid reliability, economic cost savings, and avoided CO_2 emissions. NYSERDA's support and funding allowed Central Hudson to demonstrate an automated distribution management system and gain confidence with real-time modeling and automation, thereby reducing technology risk and leading to Central Hudson's follow-on investment in full-scale transmission and distribution automation. This has resulted in significant reliability improvements, economic cost savings, and emission reductions in Central Hudson's service territory. The knowledge created through Central Hudson's projects has also influenced grid modernization investments by other New York State utilities.

10. Sources

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Appendix: Detailed Methodology

Reliability Benefits

The value of Central Hudson's improved reliability was estimated using the U.S. Department of Energy's (DOE) Interruption Cost Estimate (ICE) Calculator, an online tool designed to calculate the economic benefits associated with investments to improve grid reliability.[18] The ICE Calculator combines information the user provides on the characteristics of the electric grid being evaluated (e.g., state where the grid is located, number of residential and non-residential customers, and standard reliability metrics) with underlying estimates of the cost of service interruptions for different types of customers to calculate the value of avoiding power interruptions. The ICE Calculator was run with information on Central Hudson's customer base and two standard reliability metrics (SAIFI, the System Average Interruption Frequency Index, which is a measure of outage frequency; and CAIDI, the Customer Average Interruption

[18] ICE Calculator: https://icecalculator.com/home. The Interruption Cost Estimate (ICE) Calculator is an electric reliability planning tool developed by Lawrence Berkeley National Laboratory and Nexant, Inc. This tool is designed for electric reliability planners at utilities, government organizations, and other entities that are interested in estimating interruption costs and/or the benefits associated with reliability improvements in the United States. Development of the ICE Calculator was funded by the Transmission Permitting and Technical Assistance Division of the U.S. Department of Energy's Office of Electricity (OE) Delivery and Energy Reliability under Lawrence Berkeley National Laboratory Contract No. DE-AC02-05CH11231.

Duration Index, which is a measure of outage duration) for 2006 and 2017 to estimate the value of the improvements. According to the ICE Calculator, these improvements reduced annual interruption costs for customers by a total of $19.4 million between 2006 and 2017. The year 2006 was selected as the baseline year in order to estimate the holistic benefits of Central Hudson's investments in grid modernization, which began in the early 2000s. Given the time lag between initial efforts and the realization of benefits, NYSERDA program staff confirmed 2006 as an appropriate baseline. The analysis considered two measures, CAIDI and SAIFI, to estimate the benefits of reliability improvements to Central Hudson's grid, as described in Section 3 of this case study.

Economic Benefits

The economic benefits of Central Hudson's planned investments in distribution automation were calculated using information from the utility's July 2014 rate case. In the rate case, costs are estimated at $46.3 million over the five-year financial planning period, with an additional $5 million to be incurred after that period. Because the rate case does not describe the distribution of these costs over time, two scenarios were considered; one in which costs are conservatively incurred in the first year of each period, and a second in which costs are evenly distributed over each period. Benefits result from reduced electricity generation ($5.9 million annually, or $29.5 million over five years) and two avoided capital projects ($2.7 million each annually, or $13.5 million each over the five-year planning period) summing to $11.3 million annually. Because it is not specified in the rate case, it is assumed that the equipment lifespan is 20 years and the analysis extends the $5.9 million cost savings across a 20-year period. Two discount rates are also considered, 7% and 8%, which are based on the overall weighted average cost of capital (WACC) for Central Hudson as identified in the utility's 2017 rate case. Central Hudson calculated its overall WACC as 6.99% in 2019, rising slightly to 7.07% in 2020 and 7.14% in 2021.[19] These values suggest that a discount rate of 7% is appropriate. However, to test the sensitivity of results to the discount rate used, the analysis also applies a discount rate of 8%, to provide a more conservative estimate of net benefits. Assuming a 7% discount rate, net benefits range from $40.7 million to $47.6 million, depending on the timing of the investments. With an 8% discount rate, net benefits drop to $36.1 million to $43.8 million, depending on the timing of the investments. The calculation of these benefits is shown in Exhibit A1 for each scenario and discount rate.

Exhibit A1. Calculation of Net Benefits of Investments in Distribution Automation

Year [Column A]	Costs: All in First Year ($mil) [Column B]	Cost: Evenly Distributed ($mil) [Column C]	Benefits ($mil) [Column D]	Net Benefits – Low ($mil) [D-B]	Net Benefits – High ($mil) [D-C]
1 (start of rate case planning period)	$46.3	$9.3	$11.3	($35.0)	$2.0
2		$9.3	$11.3	$11.3	$2.0
3		$9.3	$11.3	$11.3	$2.0
4		$9.3	$11.3	$11.3	$2.0

[19] Central Hudson Rate Case 17-E-0459, Finance Exhibits, July 28, 2017.

5		$9.3	$11.3	$11.3	$2.0
6 (start of post-planning period)	$5.0	$0.3	$5.9	$0.9	$5.6
7		$0.3	$5.9	$5.9	$5.6
8		$0.3	$5.9	$5.9	$5.6
9		$0.3	$5.9	$5.9	$5.6
10		$0.3	$5.9	$5.9	$5.6
11		$0.3	$5.9	$5.9	$5.6
12		$0.3	$5.9	$5.9	$5.6
13		$0.3	$5.9	$5.9	$5.6
14		$0.3	$5.9	$5.9	$5.6
15		$0.3	$5.9	$5.9	$5.6
16		$0.3	$5.9	$5.9	$5.6
17		$0.3	$5.9	$5.9	$5.6
18		$0.3	$5.9	$5.9	$5.6
19		$0.3	$5.9	$5.9	$5.6
20		$0.3	$5.9	$5.9	$5.6
Present Value (7% Discount Rate)	$51.0	$42.9	$90.6	$40.7	$47.6
Present Value (8% Discount Rate)	$50.9	$42.0	$85.8	$36.1	$43.8
Source: The Evaluation Team's analysis based on Central Hudson rate case, direct testimony of Paul E. Haering, July 25, 2014.					

Environmental Benefits

To estimate avoided CO_2 emissions associated with reductions in energy consumption, a CO_2 emissions rate 0.553 tons per MWh was used.[20] Reductions in CO_2 emissions for the years 2019-2038 were valued using the social cost of carbon values calculated by the Interagency Working Group on Social Cost of Greenhouse Gases.[21] For each year, the Interagency Working Group estimates the social cost of carbon using three discount rates: 2.5%, 3% (central estimate), and 5% per year. This case study uses the central estimate, which has been adopted by New York State, and also shows the 2.5% estimate for illustrative purposes. The Interagency Working Group presents all values in 2007 dollars. These values were converted to 2019 dollars using the price deflators used with the Federal Reserve Economic Data (FRED) Consumer Price Index.[22] The present value of the 20-year reduction in CO_2 emissions were then calculated. RGGI compliance costs were netted out to avoid double counting, using the DPS methodology

[20] Emission Factors CO_2e New York State GHG Emission Factors, used in DPS' "SCC Netting RGGI Calculation," March 2018.

[21] U.S. Government Interagency Working Group on Social Cost of Greenhouse Gases. Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. August 2016. https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html

[22] Federal Reserve Economic Data (FRED) Consumer Price Index. https://fred.stlouisfed.org/series/CPIAUCSL.

described in the main text. CO_2 figures were converted to CO_2e using a conversion factor of 485.12 lbs-CO_2/MWh to 485.92 lbs-CO_2e/MWh.