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Millstone Power Station:

Providing support for achieving Connecticut's clean energy goals

Executive Summary

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December 2016

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Connecticut has established bold and meaningful goals to reduce greenhouse gas ("GHG") emissions from the state's economy by 80 percent from 1990 levels by 2050, while also aspiring to do so in large part through more affordable, cleaner and more reliable electric supply.[1] These goals are not mutually exclusive: affordable electricity will be critical to facilitating and encouraging the increased electrification of the transportation and building sectors needed to meet the robust GHG-reduction goals.

Connecticut has made progress toward its GHG-reduction goals over the past few years.[2] The state has shifted most of its coal and oil electric generation portfolio to natural gas, and has also enabled consumers to use energy much more efficiently. Additionally, Connecticut has a significant source of clean, in-state electricity supply located at the Millstone Power Station in Waterford. With two operating pressurized water reactors, Millstone is capable of generating 2,111 megawatts of electricity using nuclear power. Millstone is New England's largest generating station and supplies nearly all (98 percent) of the Connecticut's carbon-free electricity supply.[3] The State's dual goals of decarbonization and affordable electricity require a continued and sustained focus on addressing the emerging challenges within the electricity sector.

This is the context in which we have been asked to examine the value that the Millstone Power Station generating units provide to Connecticut consumers.[4] The report seeks to answer this question: What could happen to Connecticut's electric supply – to Connecticut consumers' electricity costs, to statewide carbon dioxide ("CO_2") and other emissions, and to its dependence on natural gas – if Millstone's generating units were to shut down before the end of their current operating licenses?

To address this question, this report analyzes the performance of the New England region's electric system, with and without Millstone operating as part of the generation mix. And it does so making several conservative assumptions about implementation of current energy and climate polices, all of which would tend to reduce the value of Millstone Power Station.

Specifically, we assumed that Connecticut and the other New England states will be able to fully meet their current energy and climate goals, in terms of adding increasing supplies of renewable energy, contracting for hydroelectric imports from Canada (assumed to be available via the Northern Pass electric transmission project by June 2020), making the economy more energy efficient, and thereby mitigating natural gas price increases. Even with these conservative assumptions, an early retirement of Millstone and the loss of its output would lead to significantly higher power prices and electricity bills for consumers. It would increase in-state GHG emissions. It would increase the state's reliance on plants that burn natural gas, putting additional stress on the local natural gas markets that also supply heating and industrial fuels for customers in the state.

The premature retirement of Millstone would move the state in the opposite direction and delay forward progress on its affordable and clean energy goals.

After modeling the electric system and using the conservative assumptions noted above, our analysis found that a hypothetical near-term retirement of Millstone would have the following impacts over the period between 2017 and 2030 (the period for which we modeled the electrical system with and without Millstone in operation):

Electricity Bill Impacts for Customers:[5]

- **Maintaining Millstone in operation through 2030 provides $6.2 billion** (net present value) in benefits to all New England electricity consumers.[6] This equates to average savings for New England consumers of $536 million per year. If natural gas prices end up being higher than the current outlook, operating Millstone would provide even more value than we report here. (Figure ES-1 shows the year-to-year total consumer costs for electric energy in New England, with and without Millstone.)
- Avoiding a premature retirement of **Millstone station saves the average Connecticut residential electricity customer over $500 through 2030. B**ased on 2015 average residential bills, Connecticut residential consumers would benefit by approximately 2.5 percent on average, each year over this period. If paid in a lump sum at the beginning of 2017, this would be like providing **3.5 months of free electricity** to every residential consumer in Connecticut (with savings for other Connecticut and New England energy customers as well).
- The benefits of Millstone increase over time, and by 2030, annual average energy **prices would be 21 percent higher if Millstone were prematurely retired**, compared to keeping Millstone in operation (See ES-2).
- Given our conservative modeling assumptions, **Millstone's economic value to consumers could be – and likely will be – even higher**. For example, keeping Millstone in operation over the next decades could avoid impacts in ISO-New England's wholesale electric capacity markets; while difficult to estimate, these benefits could potentially be as high as **another $1.5 billion**[7] for New England consumers in the year of a Millstone retirement.

Carbon Impacts and Other Air Pollution Impacts:

- **In-state CO_2 emissions from Connecticut's power plants would increase by 2.2 million metric tons ("MMT") a year**, which would substantially increase the difficulty for Connecticut to meet its goal to reduce GHG emissions by 20 MMT by 2050.[8] It will be hard enough for Connecticut – like other regions – to meet this goal – but maintaining Millstone's operations will keep Connecticut from backtracking. Without Millstone, the state will have to do everything it already hopes to do **plus** take additional measures to mitigate the emissions from the

fossil generation dispatched to replace Millstone. These emissions would be substantial and increase the total 2050 GHG reduction goal by 10 percent, with the state needing to reduce GHG emissions by 22.2 MMT instead of the currently planned 20 MMT. (See Figure ES-3.)

- The CO_2 emissions avoided through Millstone's operations are roughly **equivalent to taking nearly 470,000 passenger cars from the road each year**.[9] These would be on top of the 0.5-1.5 million light-duty electric vehicles ("EVs") that Connecticut already anticipates will be required to help meet its interim 2030 GHG reduction targets.[10]
- Under the current nine-state cap on power-sector CO_2 emissions established by the Regional Greenhouse Gas Initiative ("RGGI"), the premature loss of Millstone's carbon-free electricity would **raise regional CO_2 allowance prices by nearly 30 percent** by 2030[11] – contributing to the consumer price increases noted above. (See Figure ES-4.)
- Losing Millstone's output would **increase nitrogen-oxide ("NOx") emissions** from power plants in Connecticut and elsewhere in New England, thus contributing to worsening air quality and health impacts locally. In 2030, Connecticut NO_x emissions could be approximately 2,423 MT, or 38 percent, higher without Millstone.

Natural Gas Market Impacts and Electric-System Reliability Concerns:

- **Without Millstone**, natural gas-fired electric generation would rise **to 58 percent of all regional supply by 2020** and remain above 50 percent through 2030 – even as other imports and renewables come on line as assumed. By contrast, with Millstone's output, natural gas fired electric generation would account for 45 percent of generation by 2020 and only 38 percent by 2030. The premature retirement of Millstone – the region's largest power station and one that runs on a fuel other than natural gas – could increase electric sector reliability challenges, particularly during the winter heating season when New England's gas demand is greatest. This trend towards greater reliance on natural gas is the opposite of what the region's grid operator and the Connecticut officials have said is needed to address both electric-system cost and reliability issues.[12] (See Figure ES-5.)
- Increased demand from incremental gas-fired generation could lead to a **51-percent increase in the winter wholesale prices of natural gas** as measured at the Algonquin City Gate (which serves the majority of New England customers)[13], and **a 17-percent increase in annual average wholesale natural gas prices** for New England consumers by 2030. (See Figure ES-6.)

Thus, even if everything goes perfectly in terms of Connecticut and other states meeting their energy- efficiency and clean-energy goals, our analysis finds that Millstone's operations would provide substantial positive economic and environmental benefits.

But if, for any reason, some or all these objectives and assumptions do not end up as planned or hoped for – that is, if benchmark natural gas prices end up being higher than expected, and/or if new renewables and Canadian hydropower supplies come on line more slowly than anticipated, and/or if electricity demand is above forecasted levels (as could occur with faster-than-expected adoption of electric vehicles) – then the premature loss of the Millstone Power Station would make it much more difficult and costly for Connecticut to meet its fundamental energy and environmental goals.

Losing Millstone during the 2017-2030 period would require, in the near term at least, that its generation be replaced by a mix of new and existing gas-fired resources plus imports from neighboring regions – thus worsening local air pollution and putting pressure on in-state GHG emissions and the region's carbon cap. Alternatively, replacing Millstone's carbon-free generation would require up to an additional 7,000 megawatts ("MW") of onshore wind, over and above the total amount (5,800 MW) already assumed to come on line in New England by 2030 in our base case.

Our analysis led us to conclude that Millstone's continued operation is key to enabling Connecticut to stay on track in its clean energy, climate and affordable-energy goals.[14] At best, maintaining Millstone will bolster Connecticut and the region's electric system as it transitions toward more renewable energy. At worst, maintaining Millstone's operations provides a valuable, effective and efficient insurance policy in helping Connecticut to remain focused on its goals of "lowering energy bills and improving the state's competitiveness."[15] It also helps to avoid the addition of new gas-fired generating units that could exacerbate potential stranded cost problems in the years to come, as the region transitions toward much deeper decarbonization of its electric grid.

Either way, Millstone's electric supply provides substantial value to Connecticut's consumers and to the state's economy.

Figure ES-1: Electric Energy Costs for New England Consumers, With Millstone Versus Without Millstone (2016-2030)

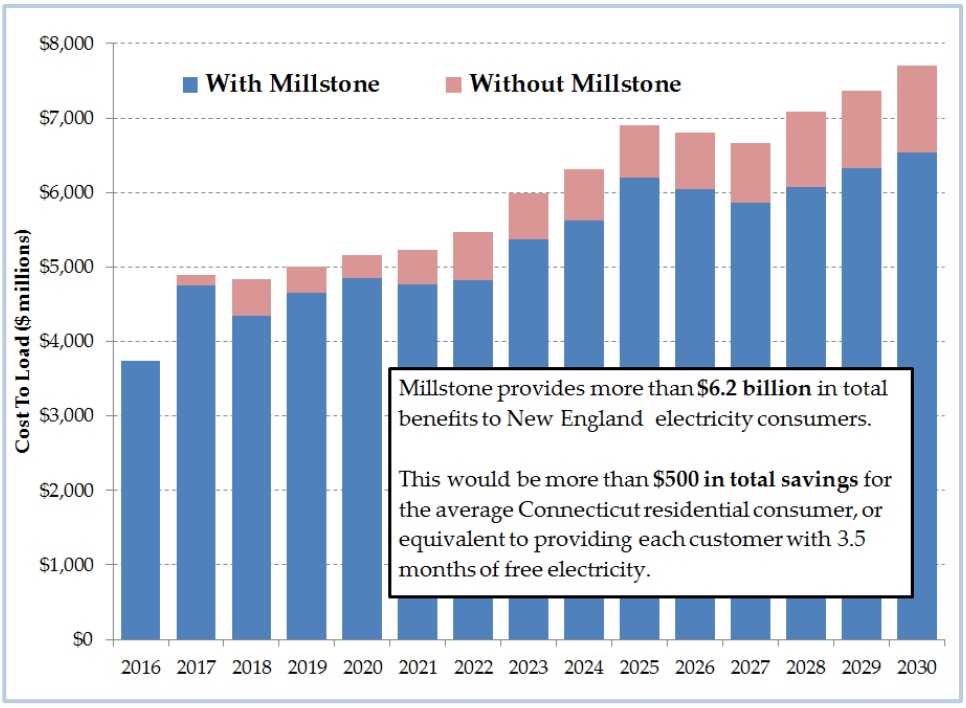


Figure ES-2: Average Wholesale Electric-Energy Price in Connecticut With Millstone Versus Without Millstone ($/MWh) (2016-2030)

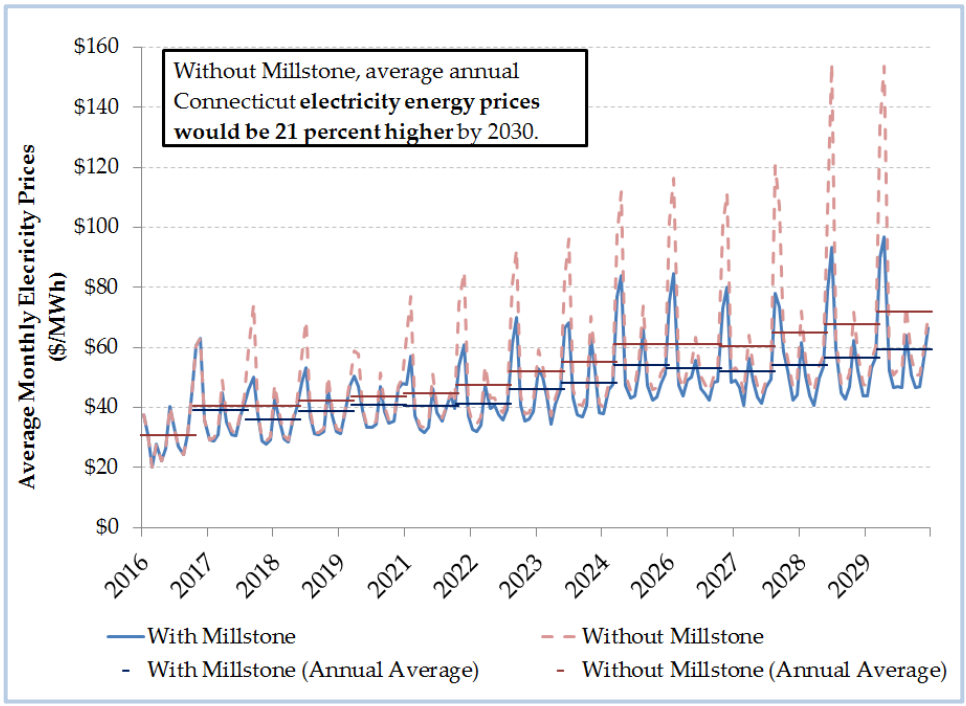


Figure ES-3: Connecticut CO_2 Emissions With Millstone Versus without Millstone (2016-2030)

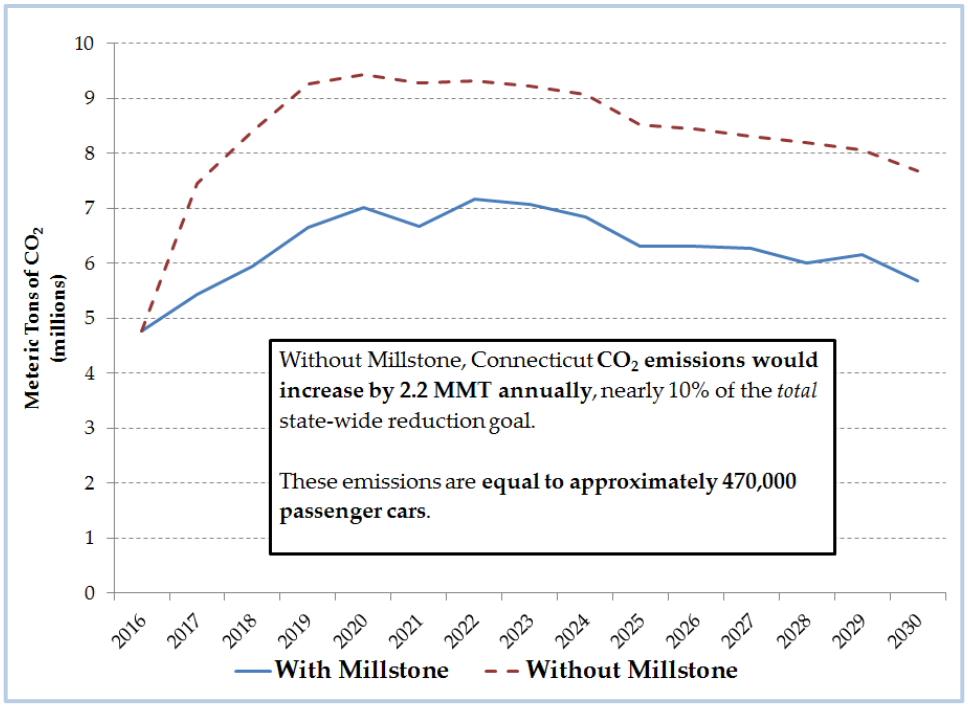


Figure ES-4: Regional CO_2 Emissions, With Millstone Versus Without Millstone (2016-2030)

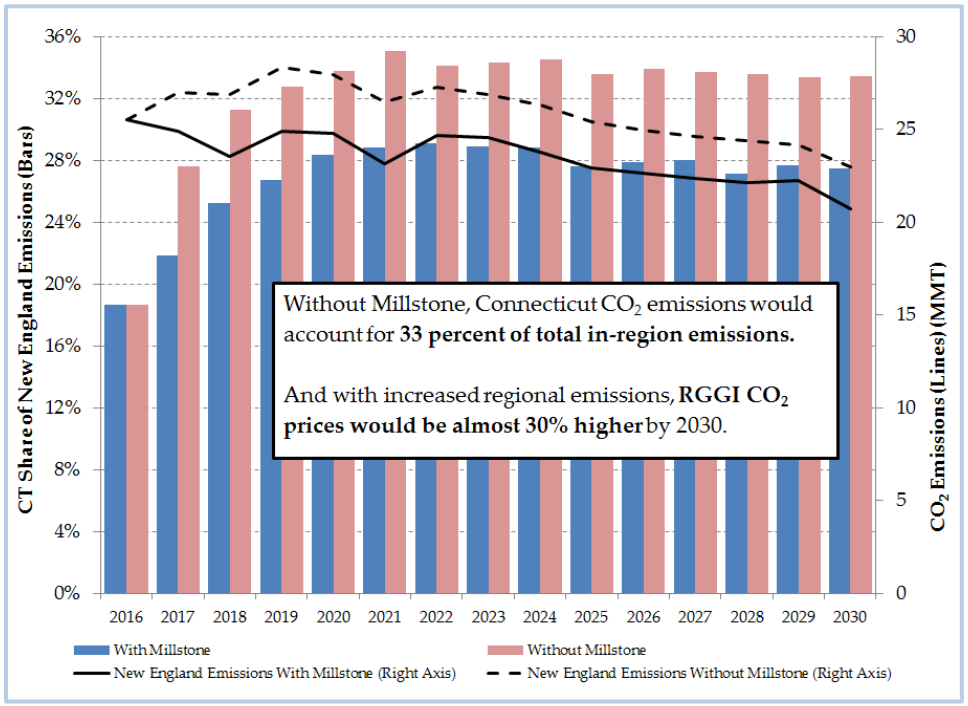


Figure ES-5: Natural-Gas-Fired Generation as Percentage of New England Total Electricity Generation, With Millstone Versus Without Millstone (2016-2030)

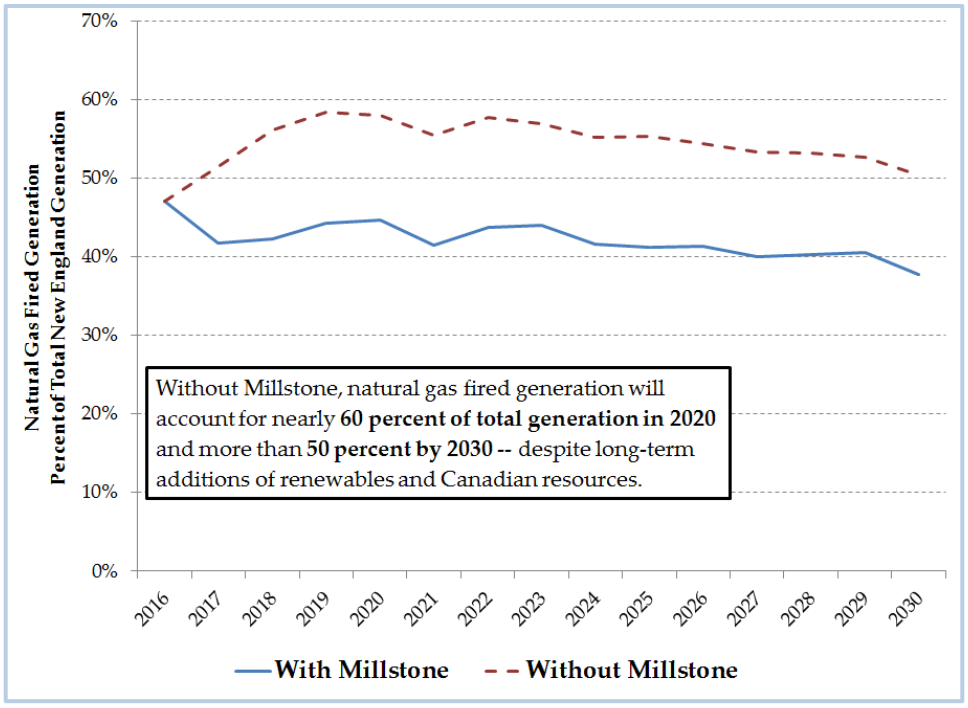
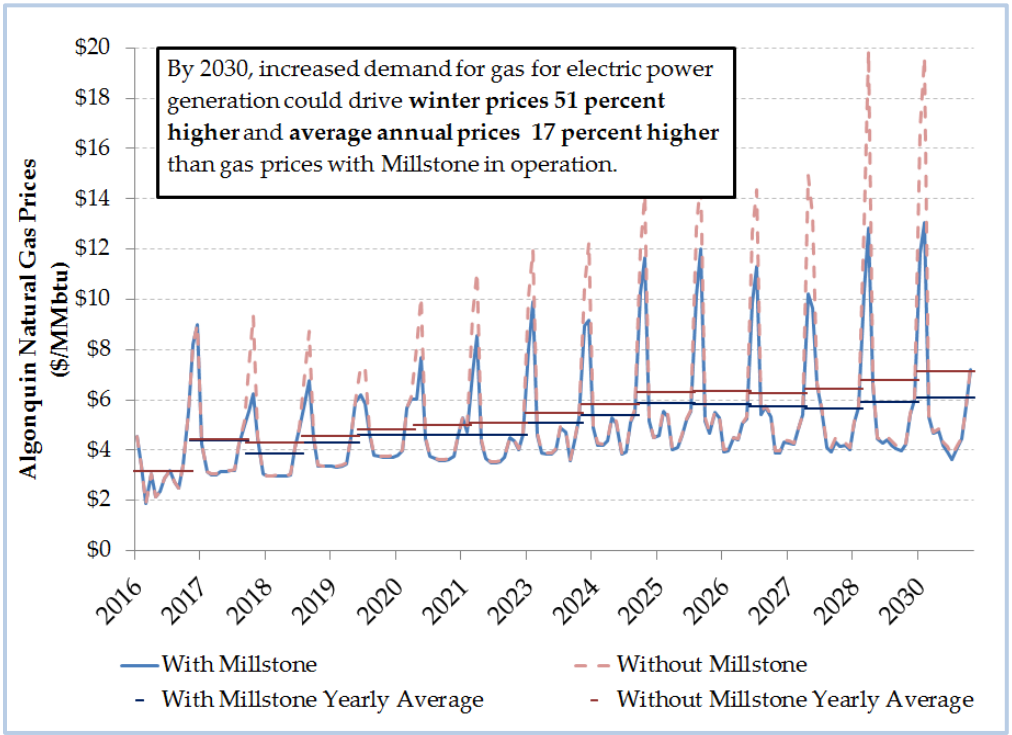


Figure ES-6: Natural Gas Prices (Algonquin Hub), With Millstone Versus Without Millstone (2016-2030)



ENDNOTES

[1] Connecticut Department of Energy and Environmental Protection ("CT DEEP"), "2013 Comprehensive Energy Strategy for Connecticut," February 19, 2013, page iii. http://www.ct.gov/deep/lib/deep/energy/cep/2013_ces_final.pdf.

[2] "From 1990 to 2012 Connecticut reduced its emissions by 10.5%, thereby reaching its 10% reduction by 2020 target under the Global Warming Solutions Act and now aims to continue this progress and achieve greater reductions" CT DEEP, "Clean Energy Strategy Scoping Presentation," May 24, 2016. http://www.ct.gov/deep/lib/deep/energy/ces/CES_Public_Scoping_Presentation_May_24_2016.pdf.

[3] Energy Information Administration ("EIA"), State-level generation and fuel data (EIA-923 survey data), https://www.eia.gov/electricity/data.cfm#generation. EIA, "Electric Power Monthly," February 2016, with Tables 1.9.B (nuclear), 1.10.B (conventional hydro), 1.14.B (wind), and 1.17.B (solar – distributed and utility scale). http://www.eia.gov/electricity/monthly/.

[4] This study was prepared at the request of Dominion Resources, Inc. ("Dominion"), the parent company of Dominion Nuclear Connecticut, Inc., owner and operator of the Millstone Power Station. Dr. Tierney and Mr. Aubuchon determined and are responsible for all modeling assumptions and data sources used in this report. The report reflects the analysis and judgment of the authors only, and does not necessarily reflect the views of Dominion. Dr. Tierney is a Senior Advisor at Analysis Group, and formerly Assistant Secretary for Policy at the U.S. Department of Energy, Massachusetts' Secretary of Environmental Affairs and a commissioner at the Massachusetts Department of Public Utilities. As a consultant, she has previously testified before utility regulatory agencies in many states, the Federal Energy Regulatory Commission, the U.S. Congress, state legislatures, and as an expert witness in proceedings before federal and state courts. She chairs the Electricity Advisory Council of the U.S. Department of Energy, previously served on the Secretary of Energy's Advisory Board, and serves on the boards of various non-governmental organizations. Mr. Aubuchon is a Manager at Analysis Group. He has consulted to individual utilities, system and region planners, and private developers within the electricity, natural gas, and water markets on a wide range of cases, including individualized project finance and asset valuations, planning evaluations and production cost-modeling of system reliability and regional environmental emissions, and consumer-impact analyses for consideration in regulatory proceedings. Prior to joining Analysis Group, Mr. Aubuchon worked at the Federal Reserve Bank of St. Louis, where he specialized in monetary policy and financial markets. For the current study, Dr. Tierney and Mr. Aubuchon relied upon Dominion's modeling team to run the Aurora electric sector production cost model and the GPCM natural gas market model under their supervision. These two models are commonly used by system planners and other market participants, and were used in the current study to model the New England region with and without Millstone. Dr. Tierney and Mr. Aubuchon analyzed and interpreted the modeled results.

[5] We present our economic-impact results using a 3-percent real discount rate, consistent with guidance from the Federal Office of Management and Budget, and assuming a 2-percent inflation rate to convert nominal and real dollars (which is an inflation rate consistent with long-term forecasts from the Survey of Professional Forecasters). In stating a net present value amount of savings into an annual savings for each residential customer, we annualize all values in real terms through 2030.

[6] This is the difference in ***electric-energy market*** costs to serve electricity consumers' demand (load) in the 'with Millstone' versus 'without Millstone' modeling analysis.

[7] All forecasts of capacity costs depend on the shape of the capacity supply curve and the marginal cost for the next available generating resource. FCA #10 recently cleared approximately 35,000 MW of capacity at $7.03/kW-month. Based on the then current, linear sloped demand curve, the net loss of 1,200 MW (Millstone plus 800 MW combined cycle replacement) would have increased capacity prices to $12.41/kW-month, which is greater than the estimated net Cost of New Entry ("CONE") of $10.81/kW-month. Assuming that the market would have cleared at net CONE ($10.81/kW-month), incremental costs would have been approximately $1.5 billion. This is calculated as 35,000 MW times the difference between $10.81/kW-month and $7.03/kW-month. This represents a one-time cost associated with the annual results of that auction. Capacity auction results will also differ in later years following a retirement; the total cost impact will depend on the Installed Capacity Requirement ("ICR") in future auctions, the total quantity of new entry in that year, and the shape of the capacity supply curve in that year, including the marginal cost of the next available generating resource. For example, if the market cleared at $9.55/kW-month (the price from FCA #9), incremental costs would have been approximately $1.0 billion.

[8] See Figure 7 relating to the 'Connecticut GHG Emissions Reference Case,' developed as part of the Governor's Council on Climate Change ("GC3") Exploratory Report, July 2016. Connecticut's "reference case" includes future reductions due to Connecticut's Renewable Portfolio Standard; the Regional Greenhouse Gas Initiative 2013 carbon cap; and federal

regulations for energy efficiency. Available: http://www.ct.gov/deep/cwp/view.asp?a=4423&Q=568878&deepNav_GID=2121

[9] Greenhouse Gas Equivalencies Calculator. (n.d.). Retrieved November 02, 2016, from https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator . We calculated the number to be 419,771 passenger cars.

[10] CT DEEP Presentation, "Meeting of the Governor's Council on Climate Change (GC3)," September 8, 2016.

[11] This is based on our modeling assumption that the RGGI states will seek to lower their CO_2 targets by 2.5 percent a year going forward.

[12] For example, in a presentation made by the CT DEEP as part of the Comprehensive Energy Strategy ("CES") scoping session on May 24, 2016, the following points were made about electric and gas interdependencies and concerns in New England: "Guiding Principles for 2016 CES" [include addressing] increased reliance on natural gas generation, gas pipeline constraints. Winter Operations Highlight Natural Gas Pipelines Constraints as a Continuing Reliability Challenge:

- Close to half—13,650 MW, or 44%—of the total generating capacity in New England uses natural gas as its primary fuel
- 2015/16 winter outlook identifies up to 4,220 MW of natural gas-fired generation at risk of not being able to get fuel when needed
- To address continuing concerns about natural gas pipeline constraints, the ISO will administer Winter Reliability Programs until 2018 to help improve fuel security and protect power system reliability."

(See CT DEEP: http://www.ct.gov/deep/lib/deep/energy/ces/CES_Public_Scoping_Presentation_May_24_2016.pdf.)

Also, the head of ISO-New England, Gordon van Welie, recently warned "that natural gas pipeline constraints, power plant retirements, and states' renewable and environmental policies threaten to make the region's power system unsustainable during extreme winter conditions after 2019, SNL reported yesterday. 'We currently have a precarious operating situation in the winter time and we're worried about it becoming unsustainable beyond 2019,' van Welie told SNL in an interview. 'The reality is that we're really operating with a very slim operating margin during the winter time that may not cover these large contingencies that worry us. To date, the combination of coal, nuclear, oil and liquefied natural gas-fired generation have kept New England's lights on during the coldest winter snaps, such as the 2014 polar vortex, when demand for gas to heat buildings limited fuel supplies for natural gas-fired generators. Van Welie fears what could happen if the increasingly gas-dependent Northeast were to lose any more of its baseload generation that's not fired by gas. A Sept. 28 presentation by van Welie outlined those concerns and warned the region's problem of meeting electricity demand as a result of inadequate natural gas infrastructure all year round, but especially during winter. Beyond the uncertain future of some 997 MW of capacity from four coal and oil-fired plants in New Hampshire, once they are divested by Eversource Energy subsidiary Public Service Co. of New Hampshire, van Welie is troubled by the planned retirements in Massachusetts of Dynegy's roughly 1,500-MW Brayton Point coal and oil-fueled plant by June 2017 and Entergy Corp.'s nearly 684-MW Pilgrim nuclear plant by June 2019. Van Welie is also concerned that permits to run plants that burn gas and another fuel are now increasingly difficult to obtain and that the run times of those are being restricted as states tighten their air emissions regulations.." "ISO New England's van Welie has serious concerns about winter reliability post -'19," ElectricityPolicy.com, October 11, 2016. https://www.electricitypolicy.com/News/iso-new-england-worries-about-reliability-post-2019.

[13] New England generators are served by natural gas at three primary locations: Algonquin, Iroqouis Zone 2, and Tennessee Zone 6. The Algonquin City Gate index is typically assumed to be the most representative of gas costs in New England. See, for example, Potomac Economics, 2015 Assessment of the ISO New England Electricity Markets, June 2016, at 17 and 43.

[14] The most recent Connecticut Comprehensive Energy Strategy ("CES") (2013) includes the following findings and goals: "Providing Connecticut's citizens with cheaper, cleaner, and more reliable electricity is a core focus of the Strategy." http://www.ct.gov/deep/lib/deep/energy/cep/2013_ces_final.pdf. The CES is currently under review by the CT DEEP, and is being guided by the following principles: "" Cheaper, Cleaner, More Reliable and Sustainable… for Communities and Customers. Cheaper: Lower bills; Reduced volatility; Equitable rates; Equal opportunity for energy savings; Lower fuel costs, relative to other types of fuels; Scaling clean energy resources at lowest cost to ratepayers through optimal use of grants and financing; Connecticut's 2015 Economic Development Strategy." The Connecticut Global Warming Solutions Act of 2008 requires that the state: "Reduce greenhouse gas emissions by 10% below 1990 levels by 2020 → Reduce greenhouse gas emissions by 80% from 2001 levels by 2050." CT Clean Energy Strategy Scoping Presentation, http://www.ct.gov/deep/lib/deep/energy/ces/CES_Public_Scoping_Presentation_May_24_2016.pdf.

[15] In his cover letter for the current CES in 2013, Governor Malloy highlighted the "need to deploy a portfolio of energy options for consumers and expand energy efficiency as the surest way to lower energy bills, reduce the budget stress from electricity costs, and improve our state's competitiveness." http://www.ct.gov/deep/lib/deep/energy/cep/2013_ces_final.pdf.

Acknowledgments

This Report presents the results of an independent analysis of the value provided to Connecticut and New England consumers from the continued operation of the Millstone Power Station in Waterford, Connecticut.

This study was prepared at the request of Dominion Resources, Inc. ("Dominion"), the parent company of Dominion Nuclear Connecticut, Inc., owner and operator of the Millstone Power Station. Dr. Tierney and Mr. Aubuchon determined and are responsible for all modeling assumptions and data sources used in this report. The report reflects the analysis and judgment of the authors only, and does not necessarily reflect the views of Dominion.

The authors would like to recognize and thank Analysis Group colleagues – Alex Iselin and Jacob Silver – for their significant analytic and research support throughout the project.

About Analysis Group, Inc.

Analysis Group, Inc. provides economic, financial, and business strategy consulting to leading law firms, corporations, and government agencies. The firm has more than 600 professionals, with offices in Boston, Chicago, Dallas, Denver, Los Angeles, Menlo Park, New York, San Francisco, Washington, D.C., Montreal, and Beijing.

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