



RESEARCH BRIEF

Two-Way Trade in Green Electrons: Deep Decarbonization of the Northeastern U.S. and the Role of Canadian Hydropower

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Meeting climate policy targets in the U.S. Northeast will likely require the nearly complete decarbonization of electricity generation. To that end, consideration is being given to expanding imports of hydropower from neighboring Quebec, Canada. We use a capacity expansion and dispatch optimization model to analyze the role Canadian hydro might play, and the economic trade-offs involved. We find that, in a low-carbon future, it is optimal to shift the utilization of the existing hydro and transmission assets away from facilitating one-way export of electricity from Canada to the U.S. and toward a two-way trading of electricity to balance intermittent U.S. wind and solar generation. Doing so reduces power system cost by 5-6% depending on the level of decarbonization. Expanding transmission capacity enables greater utilization of existing hydro reservoirs as a balancing resource. New transmission also reduces the costs of deep decarbonization. Adding 4 GW of transmission between New England and Quebec is estimated to lower the costs of a zero-emission power system across New England and Quebec by 17-28%.

Recent policy changes in the Northeast region of the U.S. commit several states to deep decarbonization of the electricity sector. New laws in New York and Maine mandate 100% clean electricity by 2040 and 2050 respectively. An executive order in Connecticut calls for 100% clean electricity by 2040. A recent bill in Massachusetts contained a goal of economy-wide net

zero emissions by 2050. Meeting such climate policy objectives will require decisions about how to design a portfolio of low- or zero-carbon technologies that can meet future electricity demand.

Pathways toward zero-carbon electricity systems tend rely more or less heavily on wind and solar PV generation. An emerging question is what additional

technologies are best suited to compensate for the high variability of wind and solar. Planners have to consider renewable intermittency at multiple scales: daily, synoptic (lasting multiple days), and seasonal. Solutions may include dispatchable low-carbon technologies, power-to-gas production of synthetic fuels such as hydrogen, thermal energy storage, or new technologies for long-term energy storage. For Northeastern U.S. states, a solution based on existing technology may be the use of hydropower reservoirs in neighboring Quebec.

This paper addresses three main questions: 1) how the optimal technology mix and operation of the power systems of New England, New York, and Quebec, including the optimal trade between regions, change with deep decarbonization; 2) how transmission expansion impacts low-carbon power systems; and 3) how transmission expansion impacts power system costs. We explore each of these questions separately for New England and New York.

To address these questions, we use capacity expansion and dispatch modeling to simulate the planning and operation of a power system encompassing New England, New York, and Quebec. We model this power system in 2050 using projections for future demand, as well as costs and operational characteristics for electricity technologies. The power system is required to meet a range of decarbonization targets, reflecting CO₂ emission reductions between 80% and 100% relative to 1990 levels. Our model computes the cost-optimal mix of electricity technologies in 2050 by selecting among existing power plants that are expected to be operational in 2050 as well as possible new plants. Our model also estimates the least-cost operation of the power system needed to satisfy electricity demand for each of the 8,760 hours of the year. This includes choosing which type of power plant to turn on when, how to charge and discharge energy storage technologies, how to operate reservoir hydropower, and how electricity is to be traded between New England, New York, and Quebec. This work results in three main findings.

First, the optimal use of U.S.-Canadian transmission lines will change drastically as Northeastern states decarbonize their power systems.

Today transmission capacity is used to deliver energy south, from Quebec to the Northeast (see the blue line in the figure below based on 2018 data). The role of Quebec hydro in Northeastern power systems is therefore as a generation resource. However, our results suggest that, in a future low-carbon grid, it is economically optimal to use the transmission to send energy in both directions (illustrated by the brown line in the figure below). In periods of renewable scarcity in the Northeast, Quebec exports energy (drawing down reservoir levels). In periods of relatively high renewable output in the Northeast, Quebec imports energy (leaving its reservoirs to recharge). This allows power system costs across New England and Quebec to be 5-6% lower than if we limited transmission flows to be north-to-south only. Two-way trading helps balance renewable intermittency at multiple time scales ranging from daily to seasonal. These results suggest that the optimal utilization of Quebec's hydro capacity in a low-carbon future is as a virtual energy storage resource for the Northeast, rather than as a generation resource.

Second, expanding transmission enables Quebec hydro to play a greater balancing role in future low-carbon power systems in the Northeast. We find that new transmission between Northeastern states and Quebec increases both imports from and exports to Quebec (shown by the purple line in the figure below for transmission expansion of 4 GW), allowing trading to further complement intermittent renewables. If we employ the analogy of Quebec's reservoirs as a battery for Northeastern power systems, more transmission to Quebec effectively increases the rate at which this battery can be charged and discharged. The additional balancing provided by new transmission would allow New England to reduce its reliance on gas-powered plants, reducing CO₂ emissions.

The role of Quebec hydro as a storage resource suggests that building additional transmission is a complement to deploying clean energy in the Northeast, rather than a substitute. This is in contrast to current plans by Massachusetts to use new transmission to import energy that substitutes for output from retiring nuclear plants. In the near term, new transmission will likely result in more imports. However, we show that, in the longer term, cost

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effective decarbonization entails that states build wind and solar PV plants and utilize transmission with Quebec to manage their intermittency.

Third, state goals for zero-emission electricity will be achieved at a lower cost if transmission with Quebec is expanded according to our results. We find that new transmission delivers net electricity cost savings (after accounting for the cost of new power lines) for decarbonization levels beyond 90%. For New England, we estimate that 4 GW of additional transmission reduces power system costs across New England and Quebec by \$3/MWh (13%) in a 99% decarbonized power system and by \$7/MWh (24%) in

a 100% decarbonized power system in our central Base Case. For New York, we estimated savings across New York and Quebec of \$3/MWh (12%) and \$8/MWh (23%) respectively.

The magnitude of cost savings depend on additional assumptions such as whether states pursue a renewable-only approach to decarbonization, or whether states electrify other energy sectors such as transportation and heating. The full range of estimated cost savings from building 4 GW of additional New England-Quebec transmission is 11-26% for 99% decarbonization and 17-28% for 100% decarbonization.

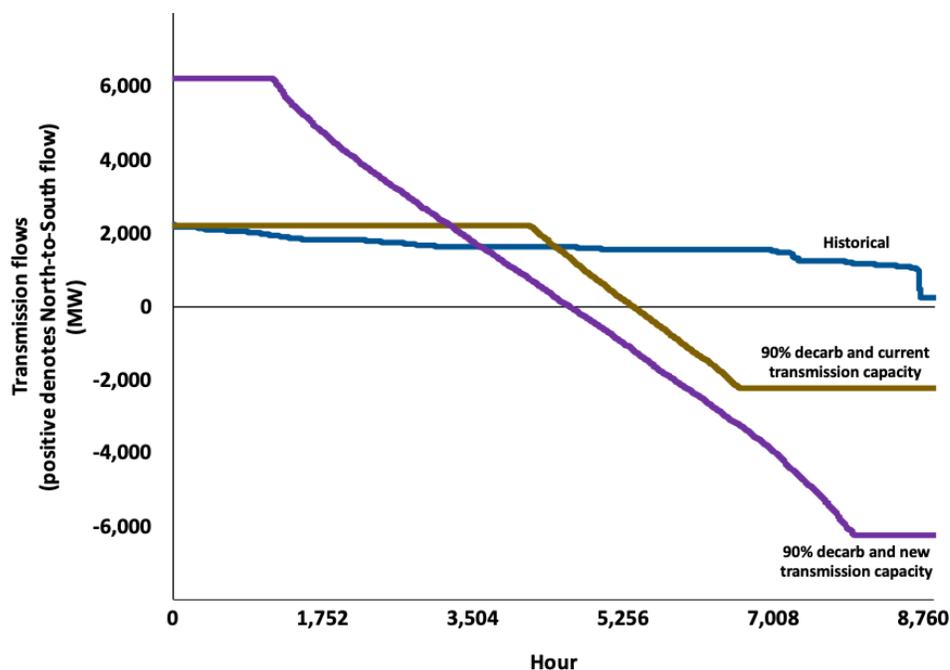


Figure 1. Changes in the optimal use of transmission infrastructure between New England and Quebec

(i) The historic flows in 2018 are described by the blue line: flows are always from Quebec into New England and capped by the current transmission capacity limit of 2,225 MW.

(ii) The brown line shows our model result when New England decarbonizes 90% and the transmission capacity limit remains at 2,225 MW. Looking to the right side of the figure, there are nearly 3,500 hours when the transmission flows are from New England to Quebec, more than 2,200 of them when the flow is at its maximum in that direction.

(iii) The purple line shows our model result when New England decarbonizes 90% and the transmission capacity has been expanded to 6,225 MW. This enables greater flows in both directions: looking to the left side of the figure, there are more than 1,000 hours when the flow from Quebec to New England is at the new maximum, and looking to the right side, there are nearly 1,000 hours when the flow is at the maximum in the opposite direction.

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References

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About the Authors



Emil Dimanchev is a Senior Research Associate at MIT CEEPR. His research focuses on climate and energy policy design and leverages diverse techno-economic modeling methods matched to the problem at hand. Emil has testified in front of legislators on climate policy, served as a consultant to government officials on carbon pricing, and briefed senior staff at Fortune Global 500 companies.



Prior to his appointment as Executive Director at CEEPR, Joshua Hodge served for three years as Deputy Executive Director at both CEEPR and the MIT Joint Program on the Science and Policy of Global Change. Previous to joining MIT, Mr. Hodge ran the Commodities Research and Forecasts business, Americas, at Thomson Reuters where he managed the launch of the firm's North American power and gas forecast modeling services. Prior to Thomson Reuters, Joshua was Managing Director, North America, at Point Carbon where he was the firm's first hire in the region and oversaw the launch of Point Carbon's North American products. Mr. Hodge holds an MBA from the Darden Graduate School of Business at the University of Virginia.



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