THE COST OF DECARBONIZING THE NORTHEAST ELECTRICITY SECTOR

Jesús Andrés Rodríguez, HEC Montréal, jesus.rodriguez@gerad.ca
Sébastien Debia, HEC Montréal, sebastien.debia@hec.ca
Pierre-Olivier Pineau, HEC Montréal, pierre-olivier.pineau@hec.ca

Overview

In many countries, massive investments in renewable energies and transmission capacity will be necessary during the next three decades to cope with decarbonization targets, and with ageing power infrastructure. The states of the northeastern United States as well as the Canadian provinces of Québec and Ontario have committed to cut by 75%-80% greenhouse emission (with respect to emission levels of 1990), by the year 2050 (Williams et al., 2018; Bouffard et al., 2018).

Cross-border electricity trade and integration of electricity markets can contribute to deal with these challenges, first, by providing access to renewable energy sources across regions, second, by mitigating the variability of intermittent renewables such as wind and solar energy, and third, by exploiting the complementarities of load profiles and power generation systems of interconnected jurisdictions. For instance, Quebec's large hydropower capacity and reservoirs (176 TWh of storage) can provide power generation flexibility to support the cost-efficient expansion of renewable energies in the province, as well as in its neighbouring territories. Naturally, multi-regional coordination of generation and transmission capacity expansion is necessary to achieve the maximum benefits of an interconnected electricity sector.

Considering the 2050 emission reduction goals, we analyze the impact of decarbonization and integration in the power systems of the Northeast Power Coordinating Council (NPCC), which comprises the sub-regions of Quebec, Ontario, the Maritimes, New York and New England.

We study two types of integration in the electricity sector: physical integration and institutional integration. By physical integration we refer to the coordinated decisions in transmission capacity that maximize the benefits for the Northeast region. We define institutional integration as the cooperation scheme that allows each sub-region to meet part of its peak demand with surplus capacity of neighbouring jurisdictions.

Under different scenarios of demand, emission reduction targets and nuclear power policies, we analyze the investment and operation costs of the Northeast electricity sector, as well as the marginal prices of carbon, and the power generation profiles.

Methods

Through linear programming, we model the optimal generation and transmission capacity investments in the power systems of the NPCC, considering the electricity load in each sub-region, with hourly time-steps during a representative year of operation. In this model we represent the main reservoirs of Hydro-Québec, and we include several generation expansion options (such as wind, solar, nuclear and gas turbines), as well as energy storage. Most of the parameters for this model were obtained from a previous study in the Northeast electricity sector (Bouffard et al., 2018).

In this model, we include transmission expansion decisions (as continuous variables) and we use a linear approximation of the power flows and the transmission losses. For speeding up the solution of the resulting mathematical program (with nearly 2 million variables and 2 million constraints), we applied model reduction techniques, and we used an interior point algorithm.

To analyze different levels of integration in the power systems of the NPCC, we adapt the model to represent the cases of i) no electricity trade between sub-regions, ii) electricity trade limited by current transmission capacity, iii) optimal transmission capacity expansion (physical integration), iv) shared capacity reserves among sub-regions (institutional integration), and vi) optimal capacity expansion together with shared capacity reserves among sub-regions (physical integration and institutional integration).

For each of these cases, we solved a mathematical program under different scenarios:

- Decarbonization levels: ranging from 50 % to 99 %, with respect to power sector emission levels of 1990.
- Nuclear policies: i) no nuclear power, ii) nuclear power expansion limited to current approved nuclear capacity, iii) unlimited nuclear capacity expansion.
- Hourly load in each sub-region with respect to reference year (2016): i) 100 %, ii) 125 %, iii) 150 %.

Results

Our results show that optimal transmission capacity expansion prevents an exponential increase in the total costs of the electricity sector at high decarbonization levels (above 90 % w.r.t. 1990 emission levels, see Fig. 1-a). In all scenarios of load, decarbonization level and nuclear policy, combining physical and institutional integration achieves the maximum benefits for the Northeast region (Fig. 1-a and Fig. 1-b). The results also show that without integration the marginal prices of carbon increase exponentially (Fig. 2-a), and that the availability of nuclear generation capacity substantially cuts the system cost and the carbon marginal price, especially in scenarios with high load (Fig. 1-b and Fig. 2-b). Without nuclear capacity, integration reduces the annual cost by US $ 3 billion.

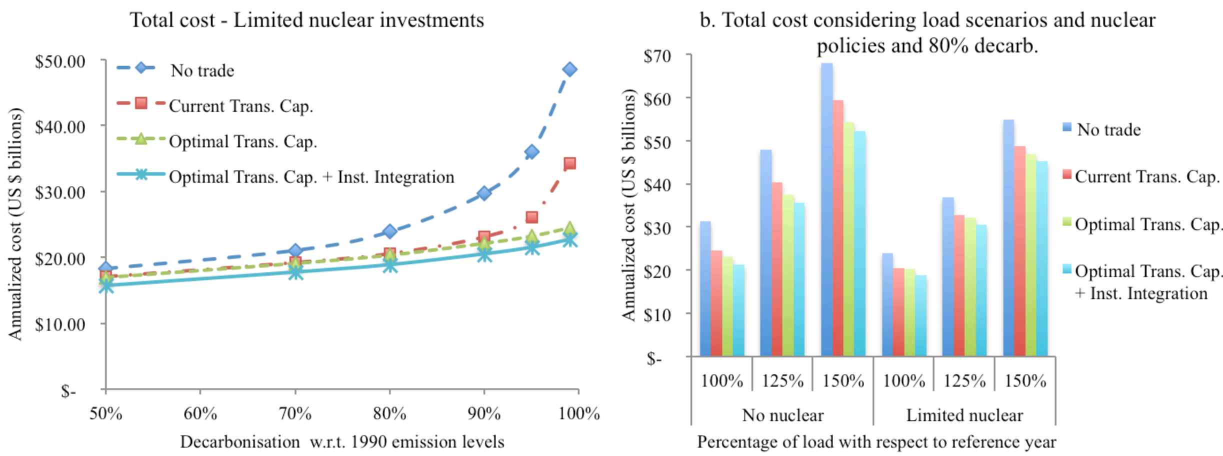

Figure 1. Total annualized cost in the power systems of the NPCC, corresponding to different decarbonisation targets and nuclear policies.

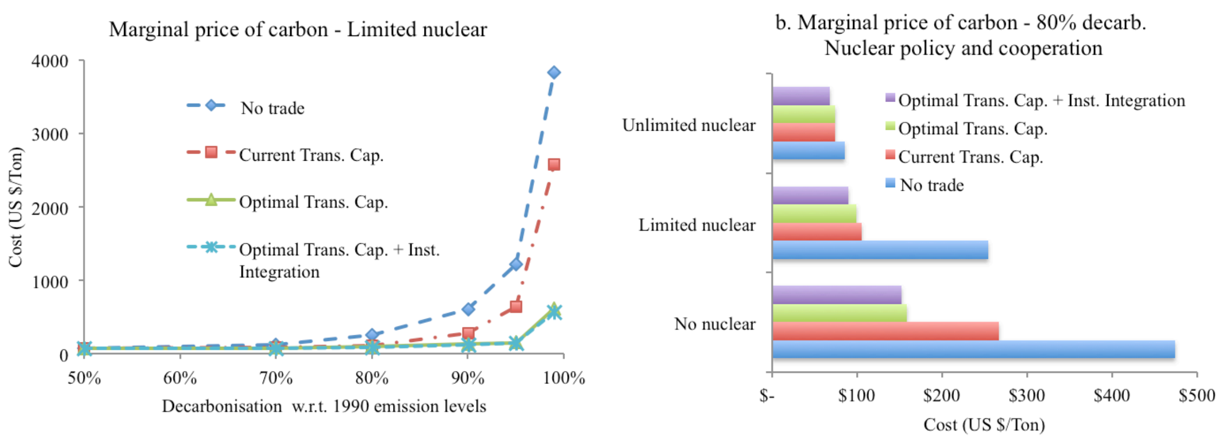

Figure 2. Marginal price of carbon corresponding to different decarbonisation targets and nuclear policies.

Conclusions

Due to decarbonization targets and ageing power infrastructure, the Northeast electricity sector will undertake a significant transformation during the next decades. Although at high decarbonization levels the marginal price of carbon and the total cost tend to quickly increase, they can be significantly reduced through coordinated transmission expansion and cooperation to share capacity among interconnected jurisdictions. In scenarios without nuclear power and 80% decarbonization, regional integration cuts the total cost by US $ 3 billion a year. Our results underscore the need for regional cooperation and integration in the power sector.

References

Williams, J.H., Jones, R., Kwok, G., and Haley, B. (2018). *Deep Decarbonization in the Northeastern United States and Expanded Coordination with Hydro-Québec*. A report of theSustainable Development Solutions Network in cooperation with Evolved Energy Researchand Hydro-Québec.April 8, 2018.

Bouffard, F., Debia, S., Dhaliwal, N., Pineau, P.-O. (2018). *A Decarbonized Northeast Electricity Sector: The Value of Regional Integration*, Chair in Energy Sector Management HEC Montréal, Institut de l'énergie Trottier and Trottier Institute on Sustainability in Engineering and Design, June 2018.