HYDROPOWER STORAGE VALUE IN THE NORTH AMERICAN NORTHEAST

Pierre-Olivier Pineau, professor, HEC Montréal, Phone +1 514 340-6922, E-mail: pierre-olivier.pineau@hec.ca
Sébastien Debia, postdoctoral researcher, HEC Montréal, Phone +1 514 589-5584, E-mail: seb.debia@gmail.com

Overview

As the world attempts to reach the Paris Agreement's central aim of "keeping a global temperature rise this century well below 2 degrees Celsius" (UNFCC, 2017), energy supply will have to be decarbonized and the electricity sector will play a major role. Renewable power sources will be particularly important, as many energy transition studies highlight. See for instance the Trottier Energy Futures Project (2016), Risky Business (2016) or IEA and IRENA (2017).

Most renewable power sources are intermittent: wind and solar, by far the fastest growing renewable energy sources (REN21, 2017), need balancing. The cost of such operation increases with penetration levels and can reach $5/MWh with a 30% wind penetration (EWEA, 2016; NREL, 2011). Balancing approaches include reserve capacity, interconnection with adjacent markets, demand-side management and response and energy storage facilities (IEA, 2013). These solutions will be increasingly valuable as power systems move closer to 100% renewable penetration. Hydropower dams with reservoirs are often simply overlooked as a balancing option. For instance, they are not even mentioned in the dedicated chapter on energy storage and balancing in IEA (2013).

Hydropower with storage can however greatly contribute to balancing: its flexibility and responsiveness in the short run and energy storage in the medium run can provide substantial benefits to power systems, especially with high level of intermittent renewable penetration. Yet, no such study has so far explored the possible game changing contributions of large hydropower with massive storage, such as what exists in Quebec (Canada), to near 100% renewable power systems. It is the objective of this paper to explore the value of hydropower in deep decarbonisation initiatives, in the North American Northeast region (New York and New England states, along with the Canadian provinces of Ontario, Québec and four other small Eastern provices). These states and provinces are already part of the same reliability coordinating organization, the Northeast Power Coordinating Council (NPCC). Quebec benefits from an estimated 228 TWh of energy storage capacity through its existing dams (Séguin, 2017), with Hydro-Québec owning itself 176 TWh of storage capacity through its 27 large reservoirs (Hydro-Québec, 2017a). However, current regulation and planning practices do not consider the region as a single market.

Methods

We use a linear-capacity-expansion model to analyze the value of further regional integration and use the huge storage capacity to reduce investment in generating capacity and other types of storage. The objective of the model is to the minize the annualized investment cost and hourly operation cost, under the constraint of meeting hourly loads in the different sub-regions. An additional key constraint is to have a largely decarbonized electricity system (90% reduction of GHG emissions in the entire region compared to 1990 levels). Investment decisions have to be made in both generation and transmission capacities.

Such a model is close to models developed previously (Tapia-Ahumada et al., 2015; Octaviano, 2015; Dolter and Rivers, 2017) and is in the family of capacity-expansion models such as NREL's Regional Energy Deployment System (ReEDS); see NREL (2014). Compared to these models, however, it innovates by modelling the existing hydropower sytems in much greater details. Yearly water inflows, dams on the same river, storage constraints in various reservoirs and run-of-river plants are indeed modelled.

Different scenarios, based on different level of integration (more or less interconnections, sub-regional capacity constraint or unique regional capacity constraint, global GHG cap or sub-regional caps), results in various investment levels and allow an exploration of the potential regional system value of hydropower with storage.

Hourly wind and solar profile for the different regions are used to calibrate the potential generation resulting from in investment in these technologies, while 2016 real hourly loads for all subregions ensure that non-zero investment and generation. Additional scenarios on load growth and the evolution of load profiles also help explore the potential impact on the power system's costs.

Results

Preliminary results show that fully integrating the different sub-regions generates yearly savings in the order of $10 billions. Investments occurs mostly in wind and transmission capacity, with relatively little solar and battery storage additions. This is due to the relatively high cost of such technologies, and to the scope of the investment needed to replace the existing natural gas power plants and, in some cases, nuclear power plants.

Capacity expansion does not materialize homogeneously across the different sub-regions, raising some political economy questions about the winners and losers of regional integration.

Conclusions

Despite the rising importance of electricity in energy systems and the critical role it will have to play in the decarbonization of the economy, regional aspects of electricity and renewable integration receive too little attention, especially in North America. When, in particular, hydropower reservoirs are available in a specific region, significant gains can be achieved by planning jointly, rather than on the historical state or provincial basis.

Our model integrates real hydropower systems and dyanmics in the investment and operations of an almost fully decarbonized power system. It shows the value of integration, but also the extent to which important changes will have to take place in regulation and in the transmission sector to be able to capture this value.

References

Dolter B. and Rivers N. (2017) "The Cost of Decarbonizing the Canadian Electricity System", *Energy Policy*, forthcoming.

EWEA (2016) *Balancing responsibility and costs of wind power plants*, Brussels: European Wind Energy Association (EWEA).

Hydro-Québec (2017a) *Réservoirs*, Montréal : Hydro-Québec. Webpage accessed on July 26, 2017. http://www.hydroquebec.com/comprendre/hydroelectricite/gestion-eau.html

IEA (2013) "7. Electricity Storage", *Electricity Information*, 2013 Edition, Paris: International Energy Agency (IEA).

IEA and IRENA (2017) *Perspectives for the energy transition – investment needs for a low-carbon energy system*, Paris: International Energy Agency (IEA) and International Renewable Energy Agency (IRENA).

NREL (2011) *Eastern wind integration and transmission study*, Golden: National Renewable Energy Laboratory (NREL).

NREL (2014) *ReEDS: Regional Energy Deployment System*, webpage, Golden: National Renewable Energy Laboratory. http://www.nrel.gov/analysis/reeds/

Octaviano C. (2015) *The Value of Electricity Storage under Large-Scale Penetration of Renewable Energy: a Hybrid Modeling Approach*, Ph.D. thesis, Cambridge: Massachusetts Institute of Technology.

Tapia-Ahumada K., Octaviano C., Rausch C. and Pérez-Arriaga I. (2015) "Modeling intermittent renewable electricity technologies in general equilibrium models", *Economic Modelling*, vol. 51: 242–262.

Trottier Energy Futures Project (2016) *Canada's Challenge & Opportunity : Transformations for major reductions in GHG emissions*, Full Technical Report and Modelling Results, Montréal: Trottier Family Foundation, The Canadian Academy of Engineering, David Suzuki Foundation. http://iet.polymtl.ca/en/tefp/

REN21 (2017) *Renewables 2017 Global Status Report*, Paris: REN21 Secretariat.

Risky Business Project (2016) *From Risk to Return: Investing in a Clean Energy Economy*. http://riskybusiness.org.

UNFCC (2017) *The Paris Agreement*, Bonn: United Nations Framework Convention on Climate Change (UNFCCC). Webpage accessed on July 26, 2017. http://unfccc.int/paris_agreement/items/9485.php