How Québec can support the energy transition of northeastern North America

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Energy Modelling Initiative

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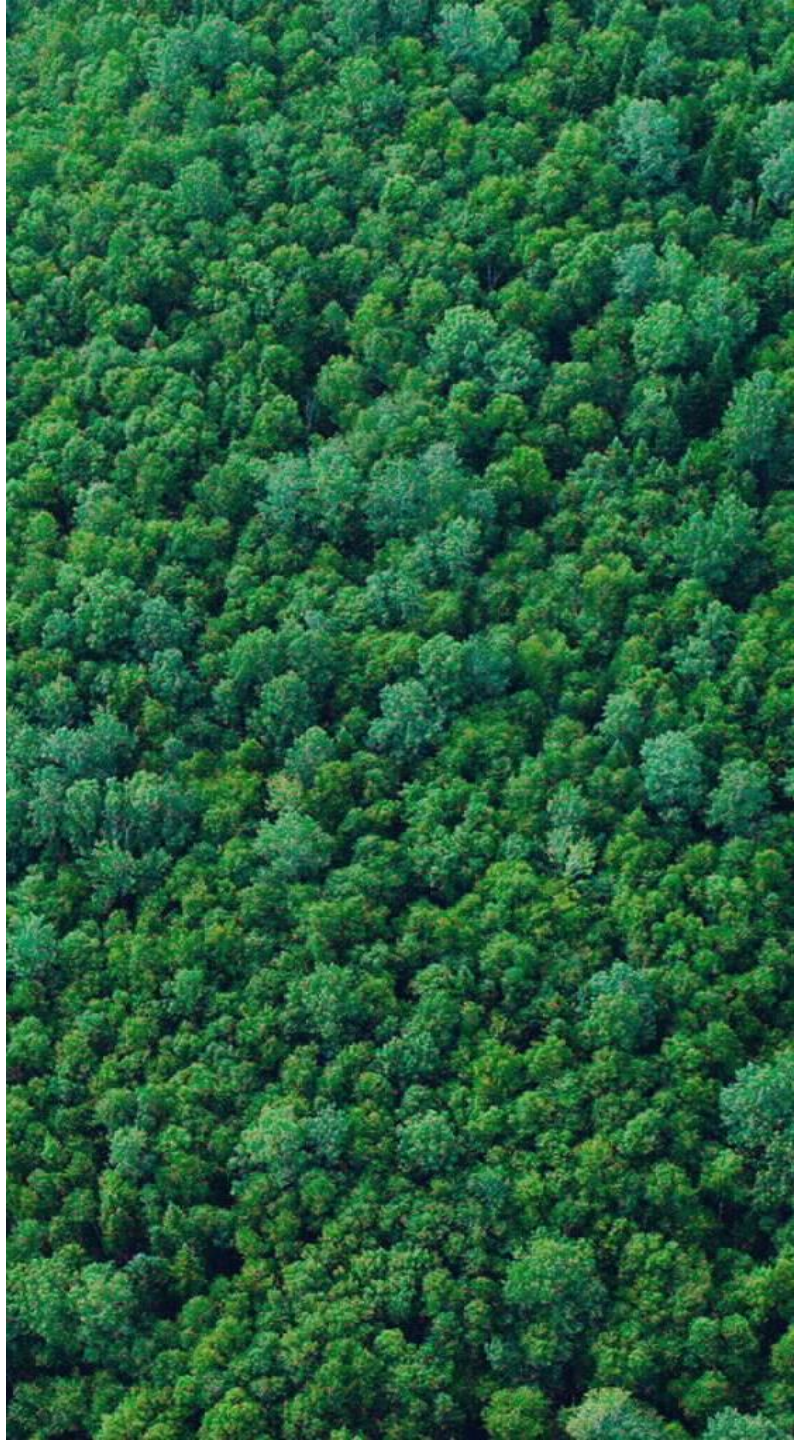
Outline

1. Introduction : the energy transition and Hydro-Québec
2. Description of the models
3. Simulations and numerical results
4. Conclusion : Hydro-Québec, battery of the North American northeast?



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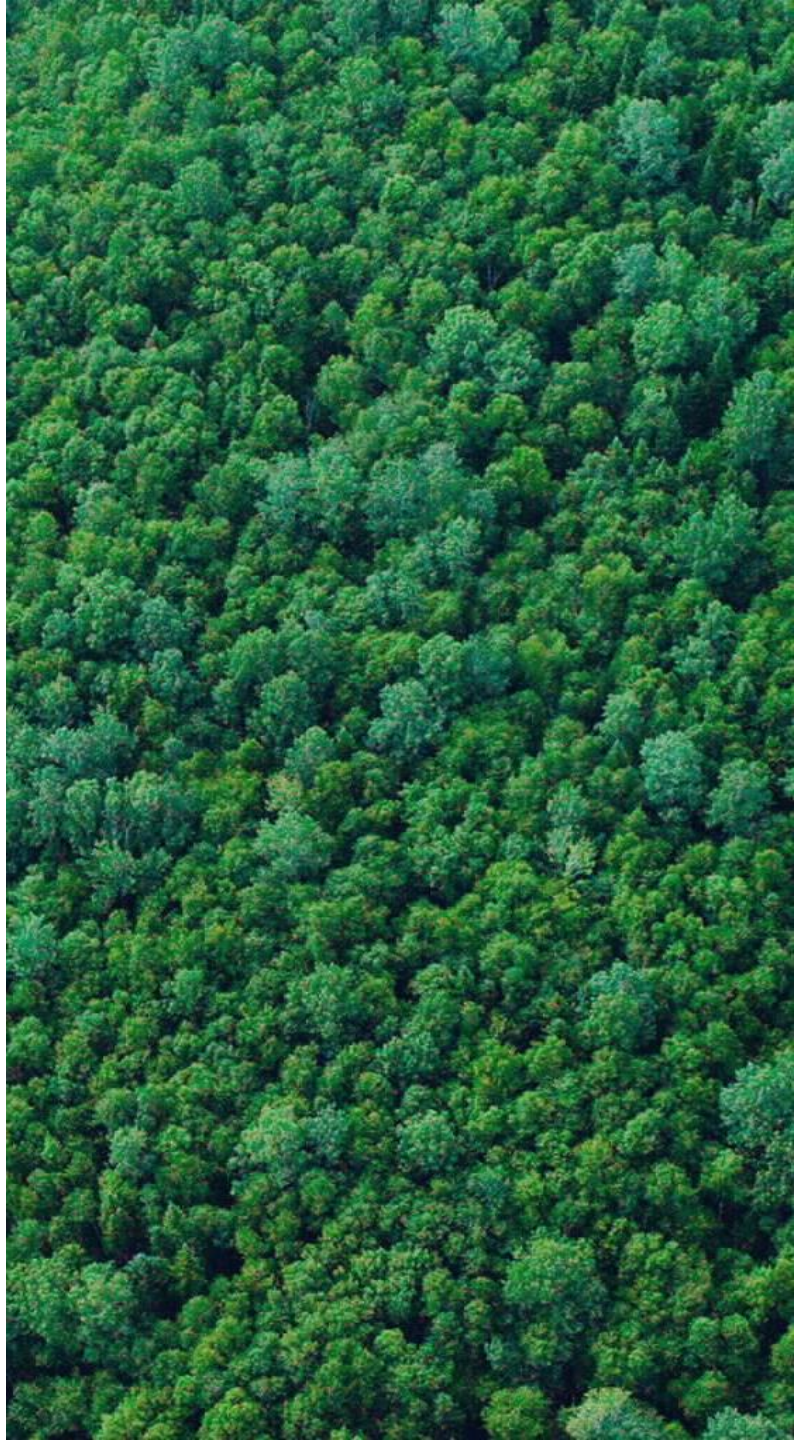


As variable renewable energy sources (VRE) grow, issues within power grids arise.

In 2020, despite a decline in global energy demand, renewable energy demand kept growing. This is mainly due to variable renewable energy sources (VRE), such as wind and solar. (IEA, 2021)

VRE will be essential to decarbonize power grids and, eventually, the economy. However, VRE-related issues must be addressed.

VRE-related issues within power grids

Uncertainty of generation

Intermittency and variability of generation

Mismatch with demand

There is a need for flexibility in terms of power grid management.

Storage hydropower such as Hydro-Québec's has valuable features for VRE integration.

Storage hydropower features

- Energy storage
- Dispatchable generation
- Quick changes of generation levels
- Low GHG emissions
- Low costs

Hydro-Québec and its neighbouring grids

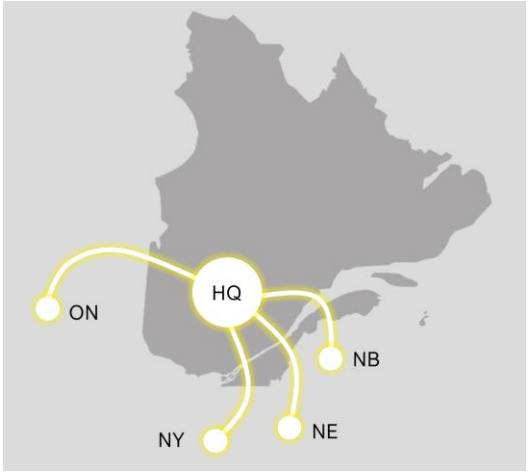
Hydro-Québec (HQ) is the main power utility in Québec. It is one of the largest hydropower producers in the world.

Total installed capacity : 37 GW

Total storage capacity in reservoirs : 176 TWh

As decarbonization targets are set and VRE are on the rise in HQ's export markets, interest is growing towards Québec's hydropower. HQ's max export capacity amounts to 8000 MW, for now.

Recent commercial agreements require steady flows from Quebec. But a more flexible behaviour might be more useful for VRE integration.



This is a first study with detailed models of Hydro-Québec's generation fleet.

There have been several studies on **interregional coordination** between grids.

Silva and al. 2016

Orths and Eriksen 2016

Grabaak and al. 2016

We also saw studies on North American northeast with **simplified models of Hydro-Québec's generation fleet.**

Muzhikyan and al. 2019

Bouffard and al. 2018

Williams and al. 2018

Dimanchev and al. 2020

By using detailed models of Hydro-Québec's generation fleet, we tried to answer these two questions :

What will be the **impacts of the energy transition** on HQ's large-scale hydropower generation fleet?

Can HQ actually take the role of a giant **battery** for its neighbouring grids?

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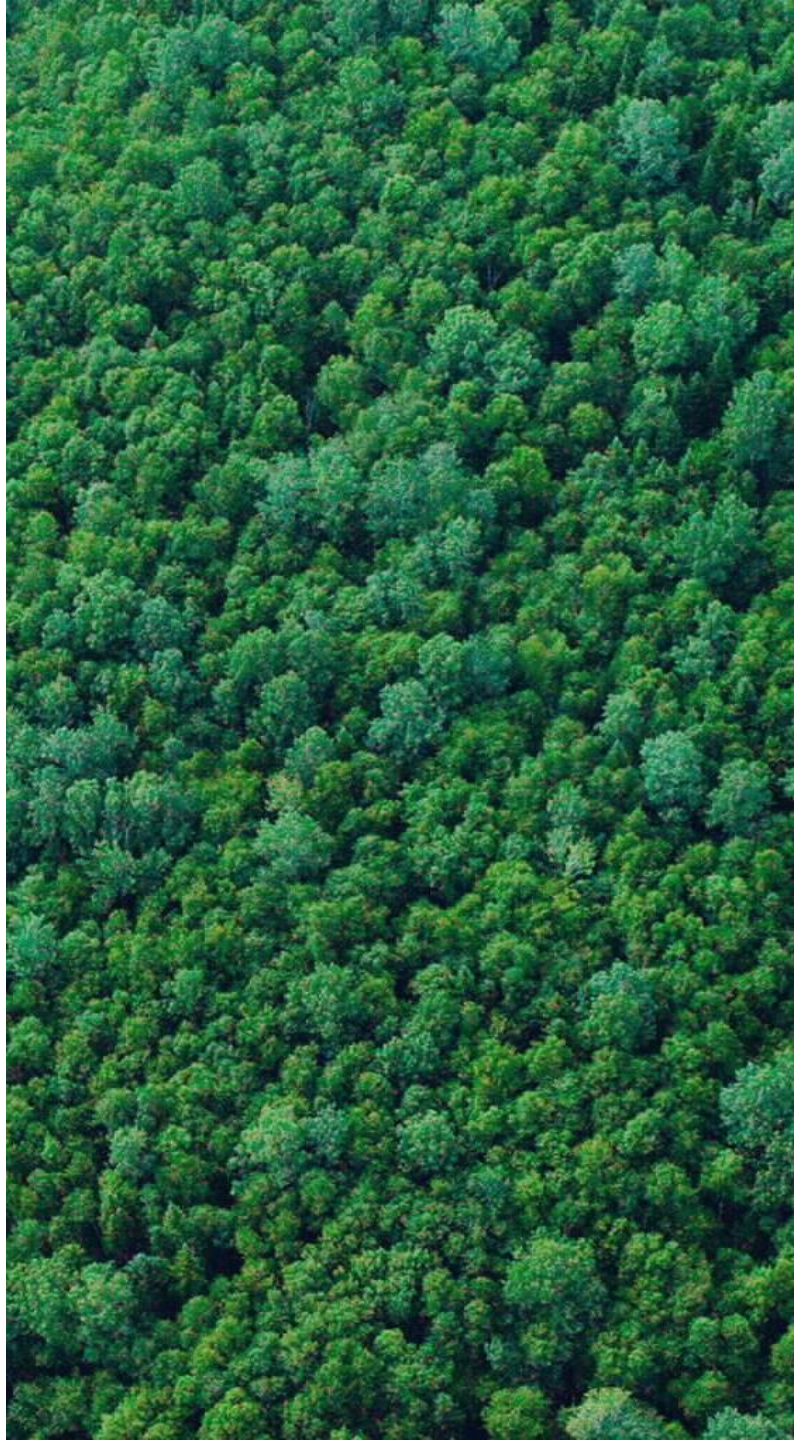
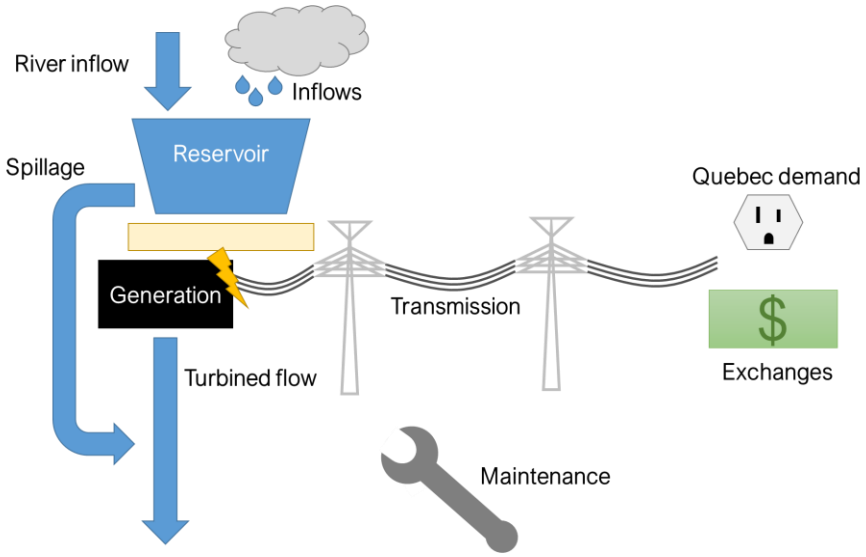


Hydro-Québec's operational production management models were used for the simulations.

The models used for our simulations were developed for HQ's operations. One covers medium-term horizons i.e. a few years and the other considers short-term horizons i.e. from a few days to a few weeks. They are based on a detailed representation of all current generation and transmission assets. Modifications have been made to adapt the models for theoretical scenarios.

A (very) simplified overview of the models



Number of variables : ~ 10^6 *Number of constraints : ~ 10^7*

Main constraints

Operational limits on flows, volumes, generation and transmission

Water conservation at each plant and water system

Maintenance schedule of the generating units

Balance between supply and demand

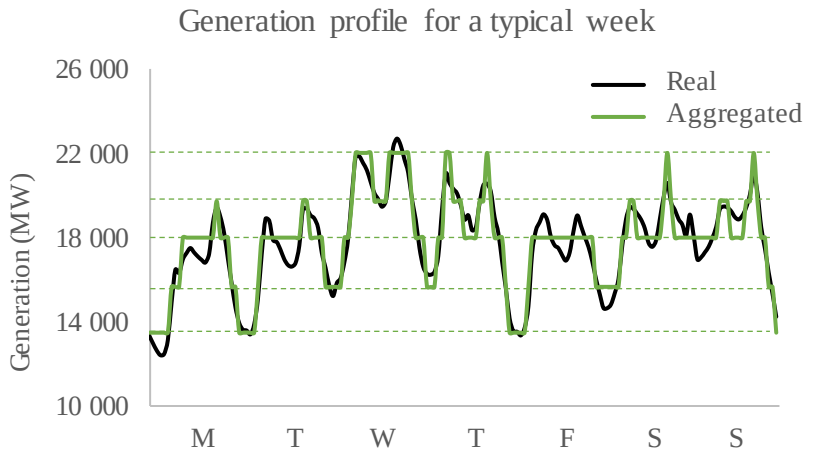
Hydropower generation functions : $P = \eta(q) \cdot \rho \cdot g \cdot q \cdot h$

Using both medium-term and short-term models enables a more comprehensive analysis.

The medium-term model and the short-term model have a similar structure but they provide different information.

	Medium-term	Short-term
Objective	Maximize revenues	
Type of model	Linear, iterative resolution for a near-optimal solution	Mixed-integer linear, iterative resolution for a near-optimal solution
Horizon	Few years	Few days - weeks
Time step	1 week with hours aggregated into 5 groups based on load	1 hour
Output	*Global annual behaviour of the fleet*	*Unit commitment on a specific time period*

An aggregation of hours provides a good estimate of actual data.



The energy transition was simulated through its effects on energy price profiles.

This work aimed at understanding better the impacts of new interactions between markets. We looked at the operation of the generation fleet under various market conditions, represented by selected price patterns. It is assumed that VRE growth will remain higher in HQ's markets than within Québec.

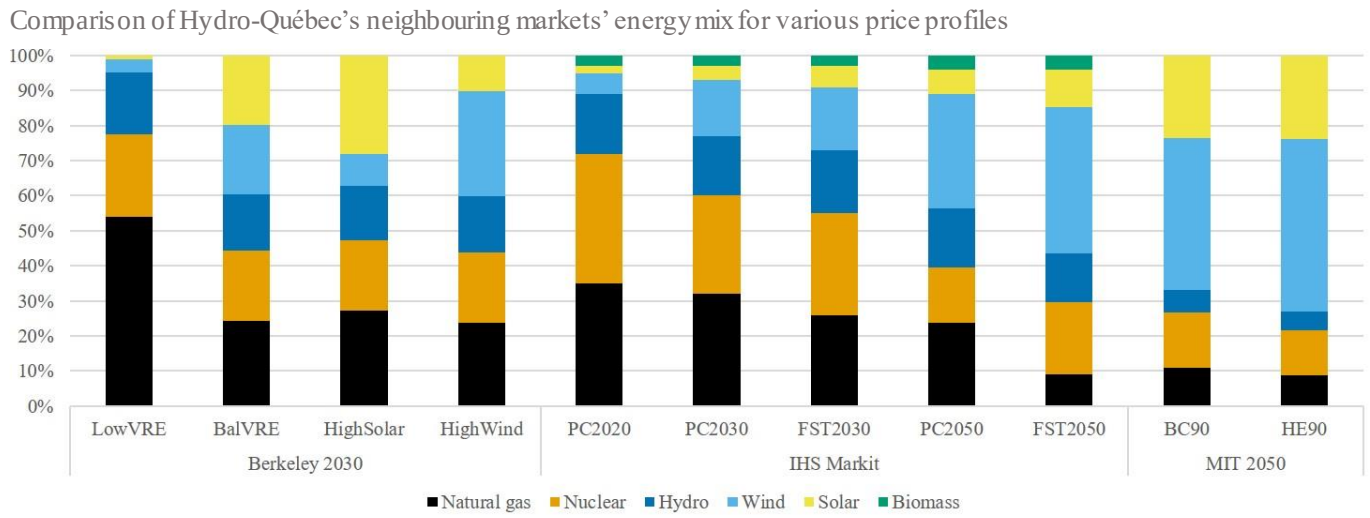
LBNL : Seel and al., 2018

MIT CEEPR : Dimanchev and al., 2020

Source of price profiles in Hydro-Québec's neighbouring markets

Organization	Price profile	Year considered	Power sector description
LBNL	LowVRE	2030	Baseline, 2016 VRE share of generation
	BalancedVRE HighSolar HighWind	2030	VRE generation share of 40%
IHS Markit	PC2020	2020	Baseline
	PC2030 PC2050	2030 2050	Continuity, 77% clean energy in 2050
	FST2030 FST2050	2030 2050	High electrification, 92% clean energy in 2050
MIT CEEPR	BC90 HE90	2050	90% clean energy

LBNL: Lawrence Berkeley National Laboratory
PC: IHS Markit's Planning Case, Nov. 2019, FST: IHS Markit's North American Fast Transition Case
CEEPR: Center for Energy and Environmental Policy Research, BC: base case, HE: high electrification



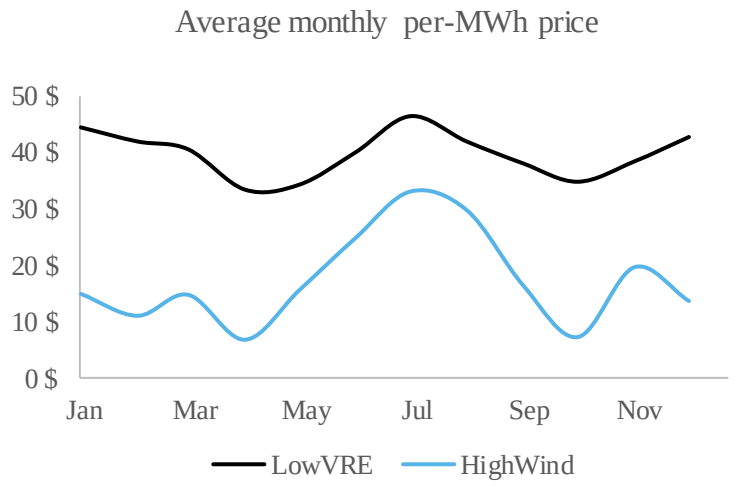
Different price profiles are an incentive for Hydro-Québec to modify its generation profile.

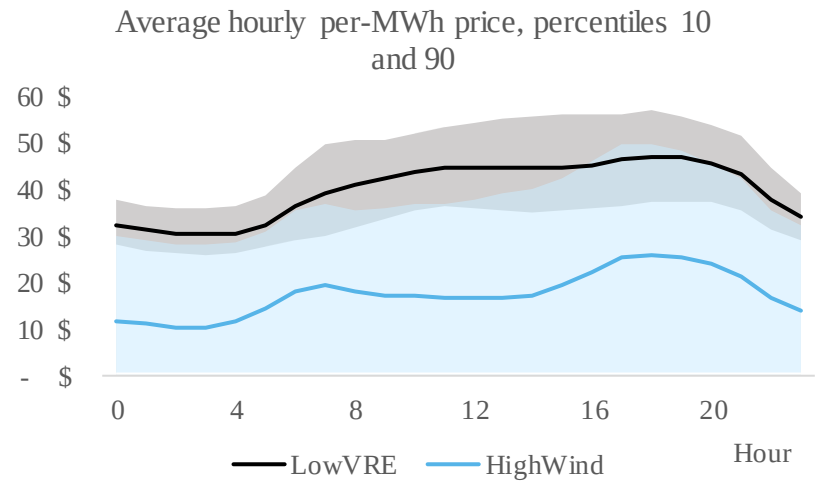
High VRE penetration will impact price patterns in the markets surrounding HQ. Revenue maximization is consistent with harnessing HQ's potential to efficiently balance supply and demand for its neighbouring markets.

When VRE generation is **high**, prices are **low.** HQ has an incentive to **buy** energy on the markets. It produces less and water (energy) is stored.

When VRE generation is **low**, prices are **high.** HQ has an incentive to **sell** energy on the markets.

VRE bring higher variability to energy prices and tend to lower their average value. As an example, values are shown for two price profiles produced by LBNL.





Organization	Price profile	HQ's exports markets power sector description
LBNL	LowVRE	Baseline, 2016 VRE share of generation
	HighWind	10% solar. 30 % wind

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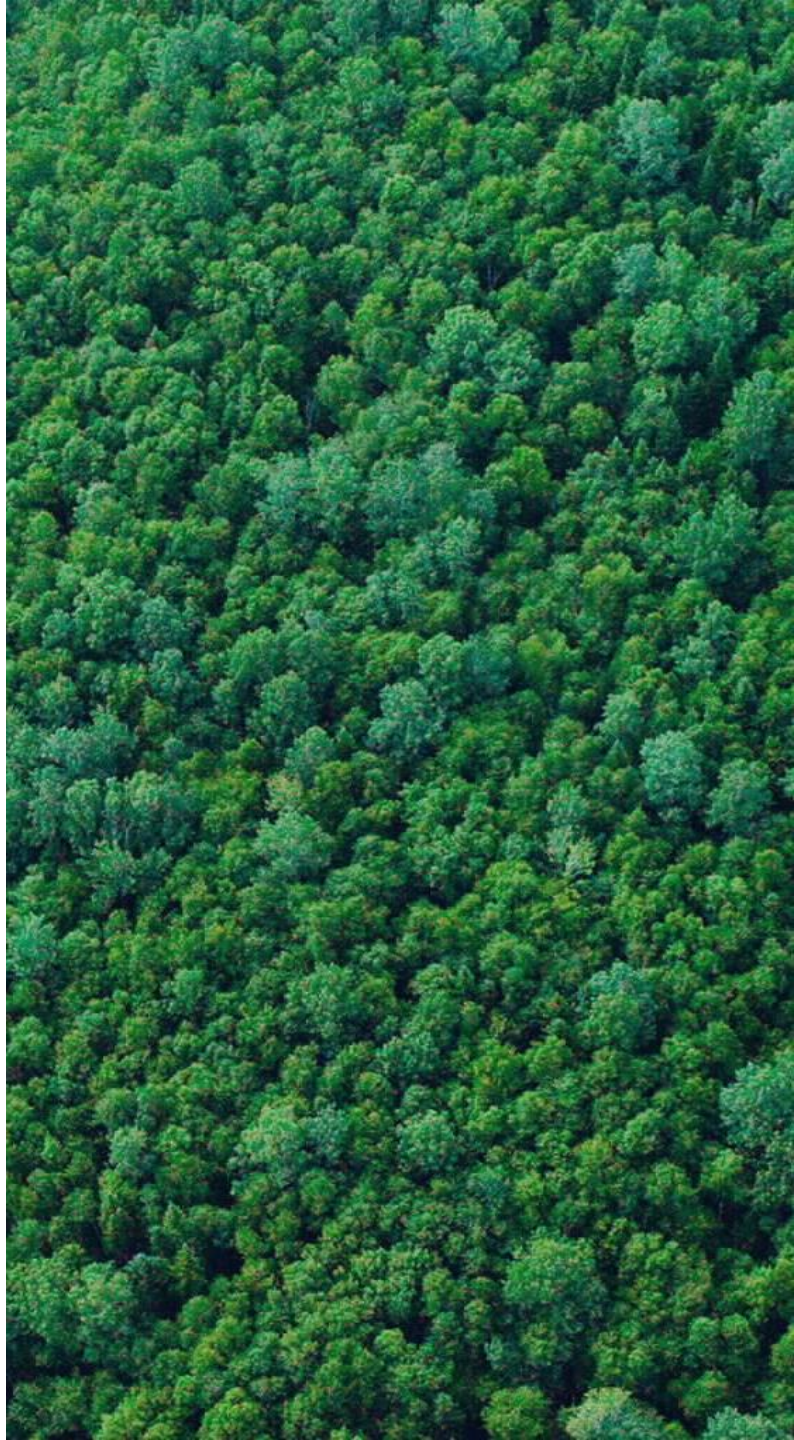
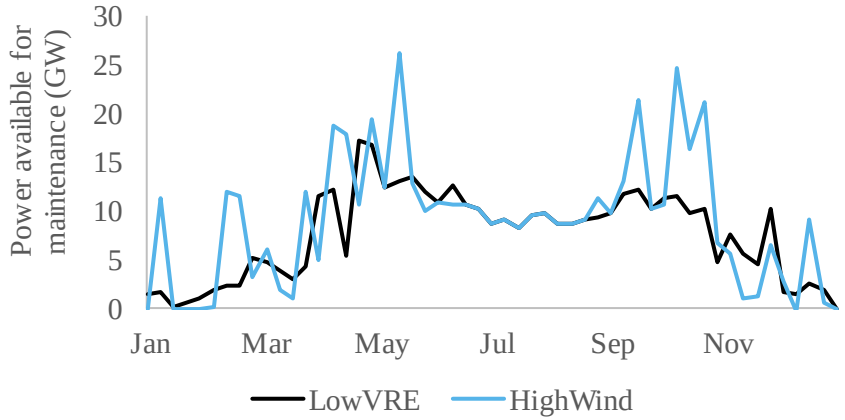


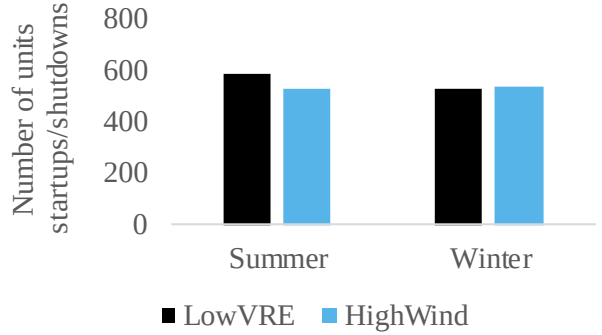
Changes in Hydro-Québec's operations would be mainly sustainable.

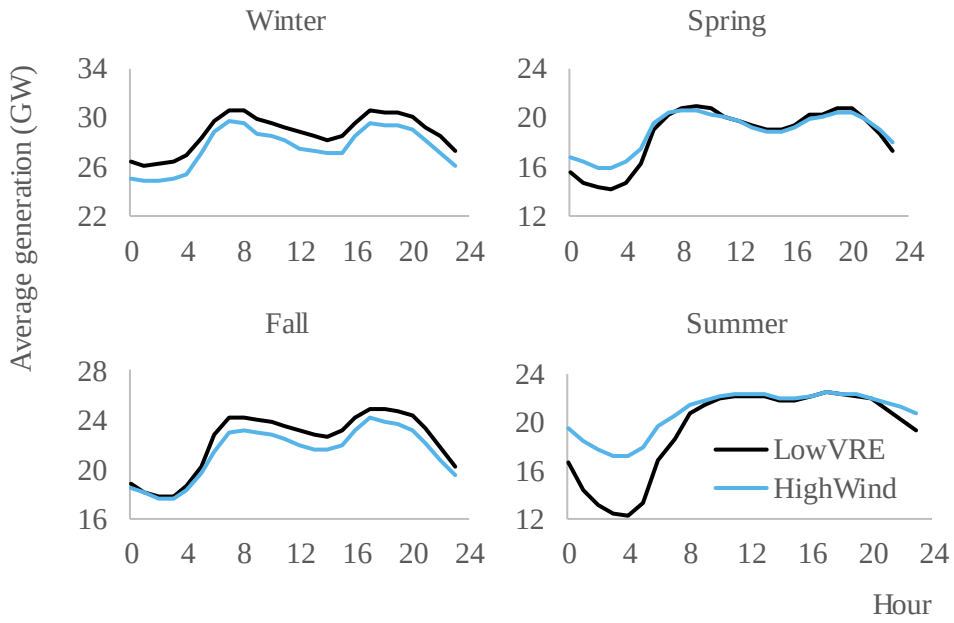
Adapting generation to VRE-induced price patterns seems technically feasible. Even though generation would be more variable as it partially balances VRE intermittency, changes in operations remain minor.

Optimal maintenance planning would however become more of a challenge. As new hydro generation patterns become more profitable in view of VRE growth in the region, the optimal periods for maintenance become more variable over weeks.



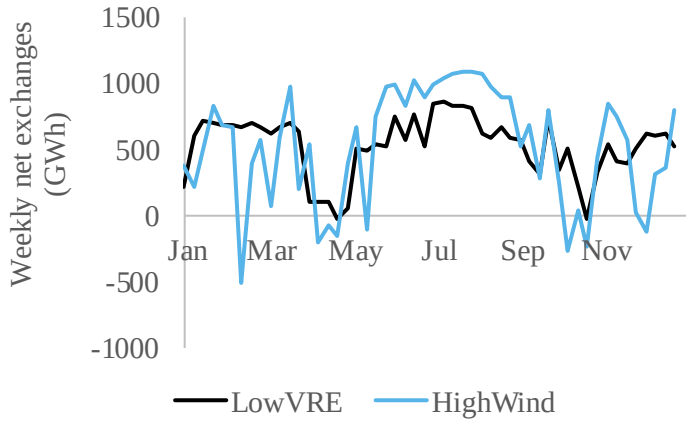
Minor or positive impacts on daily operations

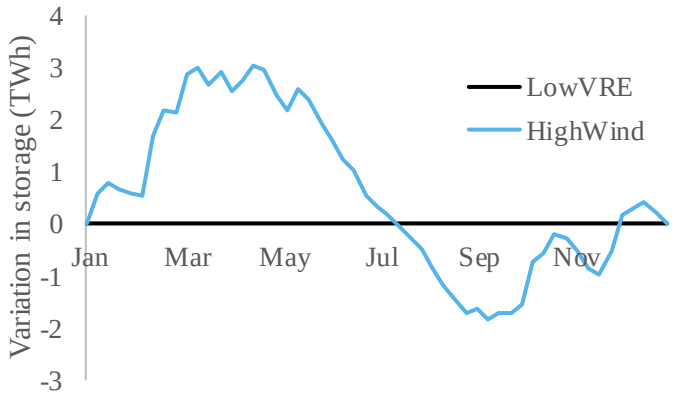




Hydro-Québec has a great potential to provide storage services, but the economic incentive is low.

Greater price variance caused by VRE growth results in more purchase-resale operations. For a same amount of net exports, transmission flows increase significantly with high VRE prices. HQ shifts its generation according to those exchanges and meanwhile stores water in its reservoirs.





HQ can store excess energy generated by VRE in neighbouring markets and return it when needed, through purchase-resale operations based on price arbitrage. Annual or seasonal storage is especially interesting, as it is a service that most commercial storage technologies cannot provide.

$^{1}/_{2}$

With high VRE prices from LBNL, revenues almost drop by half compared to the reference case (from - 47 % to - 43 %).

Even when transactions are optimized for revenues, they do not compensate for the forecasted energy value drop due to the low marginal costs of VRE.

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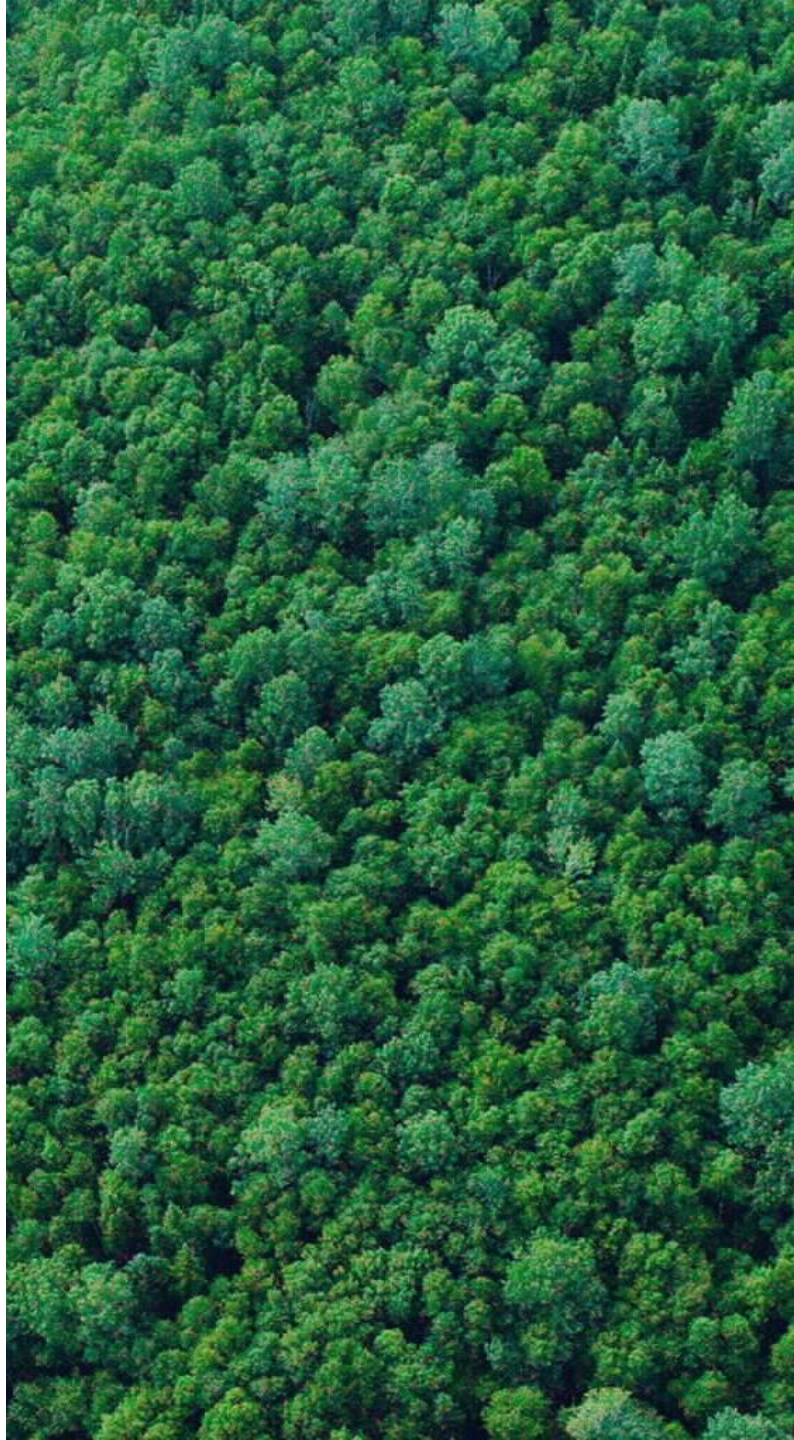


Hydro-Québec has the potential to facilitate the energy transition in northeastern North America.

By using detailed models of Hydro-Québec's generation fleet, we tried to answer these two questions :

What will be the **impacts of the energy transition** on HQ's large-scale hydropower generation fleet?

- Continuity for units startups and shutdowns
- Decrease of summer nights load valleys
- Incentive for flexible maintenance scheduling

Can HQ actually take the role of a giant **battery** for its neighbouring grids?

- High annual storage potential
- More profitable purchase-resale cycles
- Decrease in energy value

The current electricity market structure does not provide incentives for an optimal contribution from HQ to the energy transition.

The income generated by balancing services based on price arbitrage is far from compensating for the forecasted energy value drop due to VRE penetration.

Research on Québec's positioning in the upcoming energy transition is still in progress.

Further work

Sensitivity analyses for maintenance scheduling and available energy budget for exchanges

Stochastic modelling to better capture the **uncertainty** of water inflows and VRE generation

Assessment of **HQ's flexibility value** on the market

Assessment of the **impacts of the energy transition within the province of Quebec** regarding load transformation and the generation mix

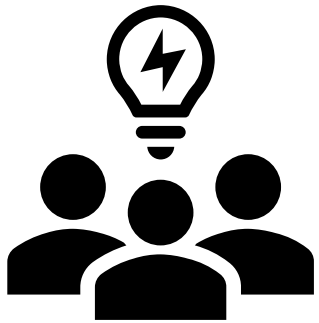
Analysis of HQ's potential for providing **ancillary services on the market** in the context of the energy transition

Integration of **climate change** impacts

On-going collaborations with research groups

We work with research groups to ensure realistic modelling of Quebec's energy system.

- MIT-CEEPR
- NREL
- HEC Montréal



Thanks! Any questions?

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