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Ontario's High-Cost Wind Millstone

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Declaration of Interest

The views expressed in this CCRE publication are based on the comprehensive analyses undertaken for *Renewables and Ontario/Quebec Transmission System Interties: An Implications Assessment*, June 2016, commissioned by the Power Workers' Union.

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Ontario's High-Cost Wind Millstone

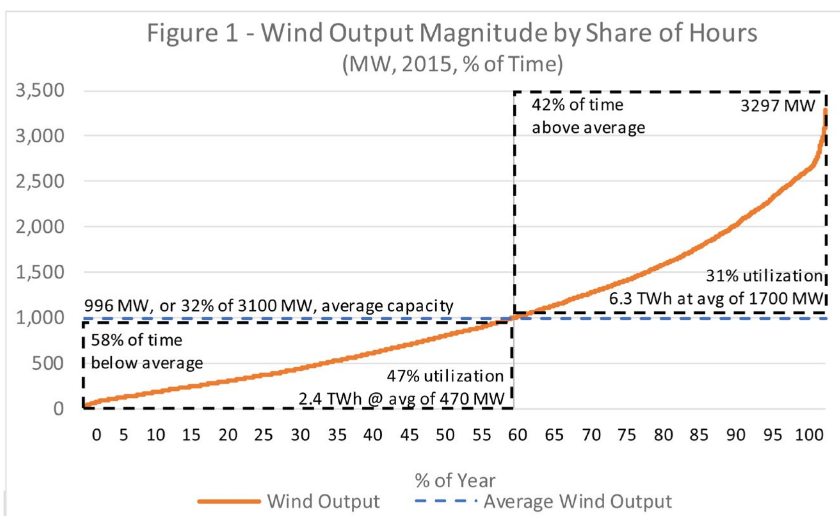
Marc Brouillette

The update of Ontario's Long-Term Energy Plan (LTEP), expected this summer, provides an opportunity to address the impact that the deployment of wind generation has had on the province's electricity system. Analysis shows that wind intermittency makes it an unproductive and expensive choice that doesn't meet customers' needs and also undermines the price of electricity exports. The 2013 LTEP suggested that energy storage in Quebec's massive hydroelectric reservoirs could intermediate Ontario's electricity consumption and wind production. However, the seasonal and daily patterns of electricity use in both provinces, along with the current surplus of wind generation in the Great Lakes region, mean that Ontario's wind generation and Quebec's hydroelectric power are not good dance partners.

WIND'S INTERMITTENT NATURE IS MISALIGNED WITH DEMAND

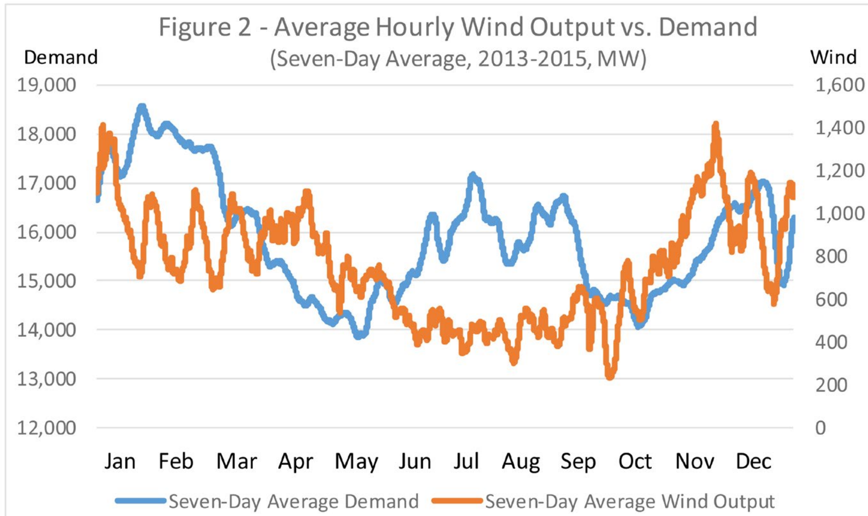
"Wind variations don't match consumption patterns."

Wind generation output is inherently intermittent as it depends on Mother Nature. For example, in 2015 Ontario's wind farms operated at less than one-third capacity more than half (58 per cent) the time (Figure 1). That means 70 per cent of wind energy was produced in the remaining 42 per cent of the time, indicating that wind's intermittency also experiences severe spikes. Indeed, wind output over any three-day period can vary between almost zero and 90 per cent of capacity.



Source: IESO 2015 hourly wind generation; Brouillette, 2016.

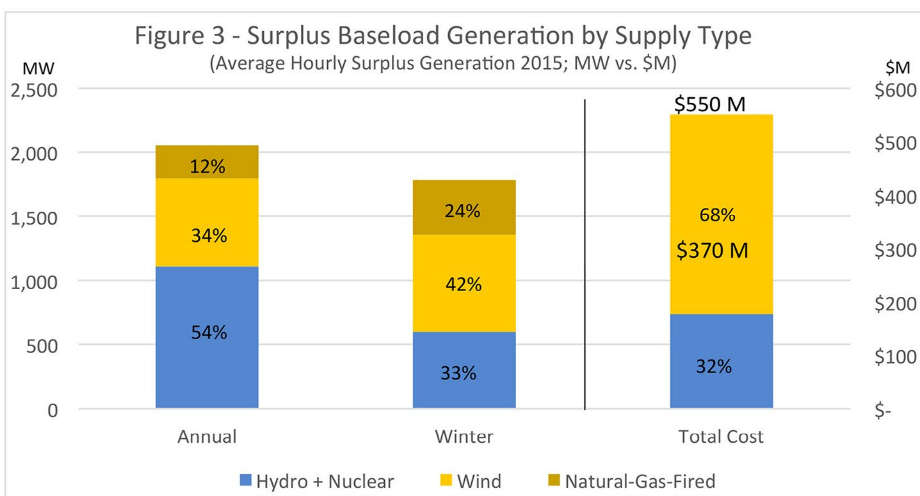
Seasonally, Ontarians' energy use is highest in winter and summer and lowest in spring and late fall (Figure 2). This is almost a mirror image of wind production patterns: wind is highest in the spring and fall, when electricity needs are lowest, and lowest in summer when electricity demand peaks. While Ontario's peak energy needs occur in the summer, average demand is actually higher in winter. Unfortunately, wind output is lower then than it is in the fall, leaving a demand gap that must be filled by other resources.



Source: IESO 2013-2015 hourly wind generation and demand.

"Wind accounts for 68% of the cost of current electricity surpluses."

Ontario's electricity system relies on nuclear, hydro and gas-fired generators to ensure supply continuity. Much of this generation capacity cannot modulate its output to accommodate wind intermittency. Since wind generation can occur on any day of the week and at any time of day, wind generation often contributes to Ontario's surplus baseload generation (SBG) during off-peak periods (Figure 3).[1] In 2015, wind represented one-third of off-peak SBG (reaching a high of 42 per cent in winter).[2] In 2015, consumers paid about $550 million for SBG, of which wind contributed some two-thirds, or $370 million.[3]



Source: IESO 2015 hourly demand and generation by source; Brouillette, 2016.

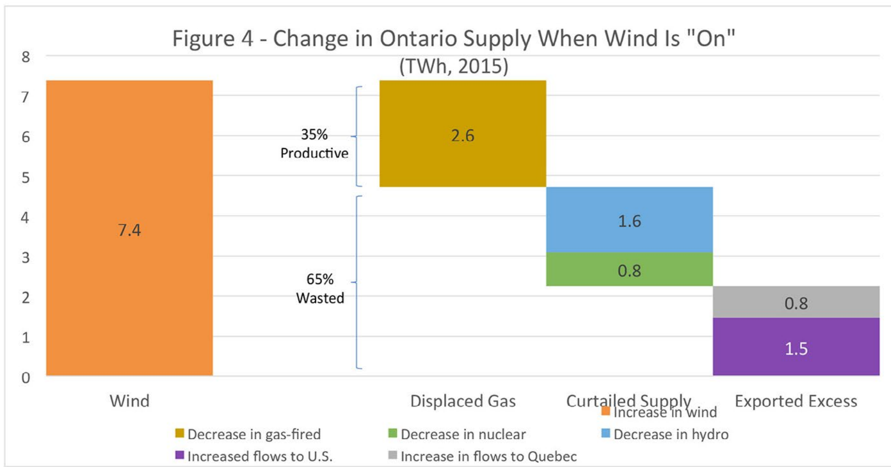
[1] Baseload generation is designed to produce a steady output with a generally fixed cost. Nuclear and hydro plants fall in this category. Although wind is intermittent, the province has guaranteed the purchase of its output at fixed prices whether the energy is needed or not.

[2] Off-peak is defined as overnight from 11 p.m. to 7 a.m., which is also when Ontario exported power to Quebec in 2015. Note that must-run, natural-gas-fired capacity that is required on standby, partially due to the presence of intermittent wind assets, contributes another 12 per cent of SBG.

[3] Net of export revenues based on Hourly Ontario Electricity Price.

PRODUCTIVE BENEFIT OF WIND IN ONTARIO IS LOW

Wind output, however, is surplus not only in times of provincial SBG. In 2015, Ontarians used only 35 per cent of wind-generated output (Figure 4).[4] The intermittent nature of Ontario's wind generation and its misalignment with demand impacts on the use of electricity generated from other sources.[5] Two-thirds (65 per cent) of wind generation is surplus to demand and must be wasted or dissipated either through forced curtailment of hydro and nuclear generation or by increased exports to Quebec and the United States, generally at low prices.[6]



Source: IESO 2015 hourly demand, zonal flows, intertie flows and generation by source; Brouillette, 2016.

"Wind wastes other clean supply and devalues exports."

SURPLUS WIND GENERATION DEPRESSES EXPORT PRICING

Ontario's wind surplus depresses the Hourly Ontario Electricity Price (HOEP)[7] affecting all exports. As such, surplus wind output reduces the revenue received from Ontario's other energy exports. When Ontario demand is high in winter or summer, wind output causes an 18-per-cent HOEP reduction. During spring and fall, when demand is lowest, surplus wind causes the price to drop by about 39 per cent (Figure 5).

With the forecast for generally flat-to-declining electricity demand in the Great Lakes region, these price signals underscore the low value the market places on wind generation and the very clear implication of already excessive wind output in the area. If Ontario sustains the 2013 LTEP plan to almost double[8] wind capacity to ~6,500 megawatts (MW) by 2025, the severity of export price depression can be expected to magnify.[9, 10]

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[4] Productively used by Ontarians is defined as displacing natural-gas-fired generation. The 35 per cent was calculated from the 2.6 terawatt hours (TWh) of measured gas-fired generation displaced by the 7.4 TWh of "on" wind generation that exceeds 10 per cent of installed wind capacity.

[5] The analysis examined the change in supply mix when wind production was "on" or "off." "Off" is defined as when output is less than 10 per cent of capacity. As a result, wind is "off" approximately 22 per cent of the time, corresponding to about 18 per cent of wind output. Total wind output in the analysis was 9.1 gigawatt hours (GWh): 1.7 TWh when "off" and 7.4 TWh when "on." This methodology was applied separately to seasons, weekday/weekends and to on-peak/off-peak circumstances. As wind output is not correlated with demand or these periods of output, this methodology effectively filters out impacts from unrelated changes to other capacities (e.g., newly commissioned hydro facilities, etc.)

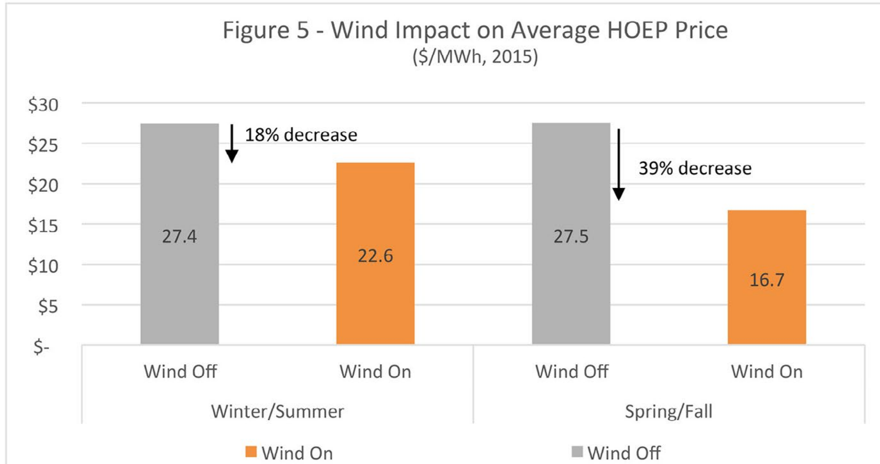
[6] Exported wind energy may reduce gas-fired generation in other jurisdictions, but does not benefit Ontarians who pay the cost.

[7] HOEP is set by the real time market as the price offered by the last most expensive generator dispatched to meet hourly demand.

[8] This is respect to the 2015 measured peak wind generation output of 3300 MW as shown in Figure 1.

[9] In 2016, the Independent Electricity System Operator (IESO), responsible for operating Ontario's electricity market, began curtailing wind output to reduce low-price exports while still paying for its generation. However, for consistency, 2015 data is used throughout this analysis.

[10] When the PNGS retires, some reduction in surplus wind will occur in 2025 as its output will be mostly replaced by natural-gas-fired generation that can interplay with wind. Analysis shows that surplus wind capacity will be reduced only by half and will be accompanied by significant emissions increases and carbon-price costs.



Source: IESO 2015 hourly wind generation and HOEP; Brouillette, 2016.

"Wind costs four-times higher than average electricity."

LOW WIND UTILIZATION MEANS HIGH COSTS

Ontario's annual net cost of wind generation in 2015 was more than $1.2 billion. Both incurred and avoided cost factors contribute to this overall amount. The cost of wind production itself was the largest factor at more than $1.1 billion in 2015,[11] but an additional $300 million was incurred for the costs of curtailed nuclear and hydro generation and lost export revenues due to wind-depressed pricing. Offsetting these costs were $200 million in combined benefits from avoided natural-gas-fired generation and export revenues received from the surplus energy.

Dividing the net cost by the wind output used by Ontarians means usable wind energy in 2015 cost Ontarians over $410/MWh,[12] after considering additional peak reserve capacity and transmission costs.[13] Therefore, the cost of usable wind is well above the $101/MWh 2015 provincial average.[14] Clearly, this provides a strong incentive to find a better way of modulating wind output to match Ontarians' demand.

QUEBEC'S HYDROELECTRIC STORAGE IS NO SOLUTION FOR ONTARIO'S WIND

The potential for energy storage in Quebec's hydroelectric reservoirs to help modulate Ontario's wind intermittency involves three factors: the potential for energy flows both into and out of storage; the current intertie's ability to accommodate the intermittent nature of wind output; and the propagation of wind generation through Ontario's electricity system for presentation to Quebec.

Using Quebec's hydro reservoirs to store wind energy and play it back is posited because there are no other plausible storage solutions. To balance wind intermittency requires at least a seven-day storage capability that can meter out the energy in sync with daily and weekly demand variations, a capability the reservoirs could provide. But to make use of Quebec's reservoirs for all of Ontario's surplus wind, the interties[15] would have to accommodate up to 90 per cent of the installed wind capacity. The intertie capacity would need to be much greater than the currently available 1,250 MW – up to 6,000 MW by 2025. However, since the flows would only intermittently use the interties (Figure 1), the intertie investments would be cost prohibitive.

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[11] Based on LTEP 2013 calculations.

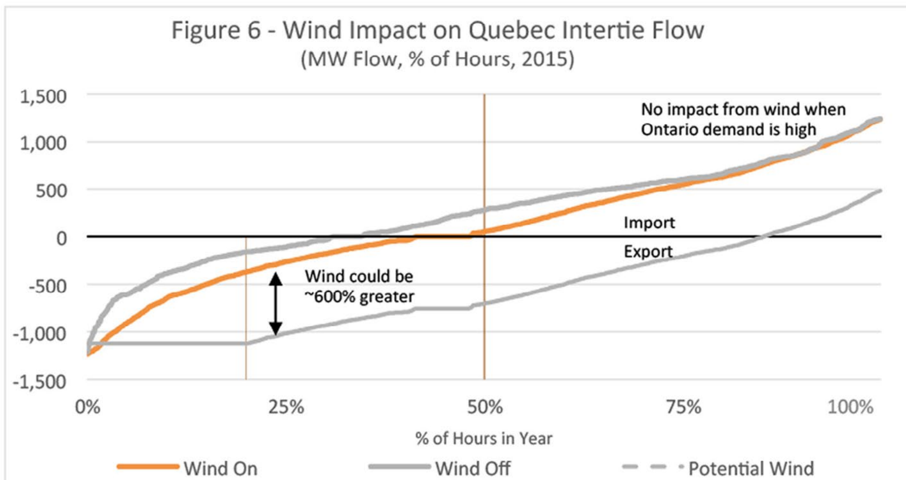
[12] Original analysis [Brouillette, 2016] assumed the "Reference Use" of "Wind Off" generation was all productive, leading to the estimated wind-generation cost of $314/MWh. Assumption here is "Reference Use" has same productive value as "Wind On" generation..

[13] There are no readily accessible data sources that identify Ontario's costs for wind-farm transmission investments. U.S. Energy Information Administration [EIA, 2015] and Hydro Quebec annual report data [Hydro Quebec, 2009] were used to estimate wind connection costs.

[14] See http://www.ieso.ca/power-data/price-overview/global-adjustment.

[15] An intertie is a transmission facility that connects two separately operated transmission systems.

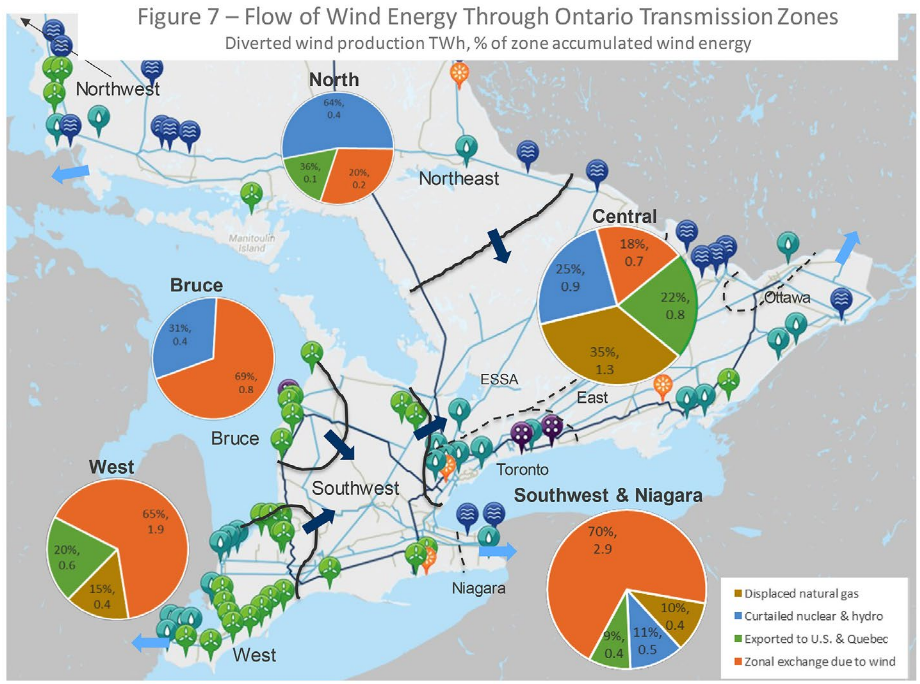
Currently, the interties with Quebec are used only moderately [Brouillette, 2017]. Had Quebec wanted the benefit of wind energy in 2015, the interties could have accommodated up to six times more wind energy flows to Quebec throughout almost the entire year (Figure 6). Similarly, Ontario could have imported more electricity from Quebec more than 95 per cent of the time, if Ontario required it. Expanding intertie capacity is thus not necessary to achieve at least some benefit from storing Ontario wind energy in Quebec's reservoirs right now. However, when Ontario's load is highest and stored energy from Quebec is most needed, Ontario already imports as much electricity from Quebec as desired – regardless of wind output.



Source: IESO 2015 hourly wind generation and intertie flows for the 1,250 MW High Voltage Direct Current (HVDC); Brouillette, 2016.

"Existing interties could accommodate six times more wind."

Finally, the propagation of wind generation within and through Ontario's transmission system zones limits how much wind output is presented to Quebec (Figure 7). Despite wind's characterization as a distributed energy resource, it shows little geographic diversity [Adams and Cadieux, 2009; Brouillette, 2016]. Wind generally blows



Source: IESO 2015 generator by zone image, hourly demand, zonal flows, intertie flows and generation by source; Brouillette, 2016.

similarly across Ontario from west to east, somewhat sooner along the shores of the Great Lakes where most of Ontario's wind farms are located. Similar to much of Ontario's generation, wind output must be transmitted long distances through Ontario's transmission system zones to reach Ontario's load centre in the Greater Toronto Area (GTA). Inter-zone power flows result from real-time mismatches between load and generation within each zone. All zones outside the Central Region are low-demand areas with relatively substantial wind-generation capacity. This mismatch leads to curtailed supply and increased exports from those zones.

Only two-thirds of the wind output in the West and Bruce zones is transmitted into the Southwest. Of that, only about 70 per cent is transmitted to the Central Region. Less than 10 per cent of the wind energy in the West, Bruce or Southwest and Niagara zones supports greenhouse gas (GHG) reductions within those zones. As a result, only one-half of total provincial wind output makes it to the Central Region and the GTA where most of Ontario's electricity demand exists. In the Central Zone, approximately one-third of the received wind energy reduces GHG-producing, gas-fired generation and more than 40 per cent results in curtailed nuclear and hydro generation. The remainder is exported to Quebec and represents only 11 per cent of total wind output, as shown in Figure 4.

"Ontario wind and Quebec hydro are poor dance partners."

The existence of unused intertie capacity underscores that import/export practices are more highly related to the patterns of supply, demand and pricing in the two provinces than the presence or absence of wind generation. With the mismatch between wind output and consumer demand, enhancing the capacity of the interties to accommodate wind offers no value to either Ontario or Quebec under the provinces' current supply-and-demand balance – they are poor dance partners.

SUMMARY

The characteristics of intermittent wind generation are very different from the patterns of electricity demand. With most of Ontario's wind farms in southwestern Ontario, only 11 per cent of wind generation output is available at the Quebec border. The existing interties are already capable of handling up to six times more intermittent wind energy than in 2015. The reason more wind-based transactions do not happen, despite available intertie capacity, is evident from the price signals: there is already so much intermittent wind generation in the Great Lakes region that demand is over supplied, prices are collapsing and generation must be curtailed. The province should reconsider its 2013 commitment to ongoing deployment of wind resources as these challenges will increase if Ontario proceeds to double wind capacity to the projected ~6,500 MW.

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IESO Data: 2015 Intertie flows by hour. Hourly actuals requested from the IESO in 2016

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