CCRE Commentary

APRIL 2019

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Renewables-based Distributed Energy Resources in Ontario: A Three-Part Series of Unfortunate Truths

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Council for Clean & Reliable Energy
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Disclaimer

The views expressed in this CCRE publication are those of the author, not the CCRE, and are based on the comprehensive analyses undertaken for Distributed Energy Resources in Ontario: A Cost and Implications Assessment, June 2018, commissioned by Ontario's Nuclear Advocacy Committee and the Power Workers' Union.

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Renewables-based Distributed Energy Resources in Ontario: A Three-Part Series of Unfortunate Truths

Part 1 - Intermittency Considerations

Marc Brouillette

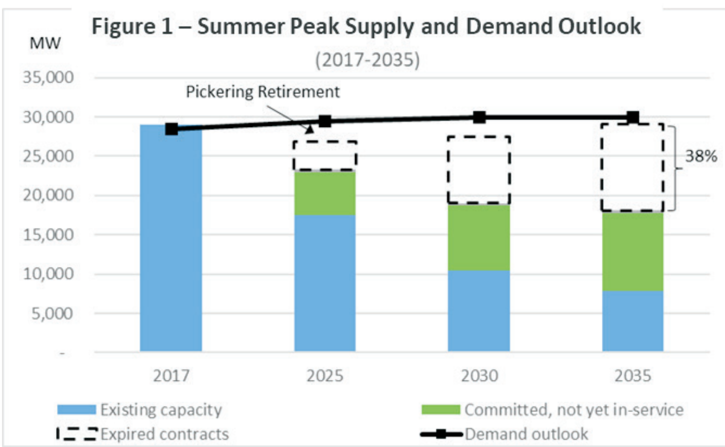
Today, there is significant public discussion regarding the potential for renewables-based distributed energy resources (DER) to supply Ontario's future energy needs and, at the same time, be the low-cost, low-emission supply alternative to fossil fuels. Renewables-based DER, consisting of wind and solar, form the basis of a vision for a 100-percent renewables future. Indeed, Ontario's 2017 Long-Term Energy Plan (LTEP) places significant reliance upon non-hydro renewables-based DER to address an expected gap in the province's electricity supply mix that will emerge over the next five to 15 years.

Unfortunately, the intermittency of wind and solar resources, resulting from Ontario's climate and geography, undermines their potential to meet the province's energy needs. With this Commentary, the CCRE launches a three-part DER examination focusing on the nature of renewables intermittency, the cost implications of renewables-based DER and their potential impact on Ontario's economy. This first commentary explores how DER intermittency interplays with storage and impacts its ability to meet the province's future energy needs.

"38% of Ontario's electricity capacity to be renewed by 2035"

ONTARIO'S EMERGING SUPPLY GAP

Ontario's LTEP identifies a growing capacity gap (Figure 1) in the province's electricity supply.[1] Filling this gap, caused by major future reductions in existing and committed capacity, requires the renewal or replacement of 38 percent of Ontario's generation capacity by 2035. First, the Pickering Nuclear Generating Station will retire before 2025, decreasing baseload supply by over 3,000 MW. As well, current contracts for renewables and gas assets, accounting for 35 percent of the current peak supply, will expire between 2025 and 2035. These known reductions will require decisions regarding new supply above baseload. Energy resources now committed to 2035 are low-carbon, low-cost assets to provide flexible baseload. Included among these resources are Ontario's hydro and refurbished nuclear fleet, biomass and energy exchanges with Québec.

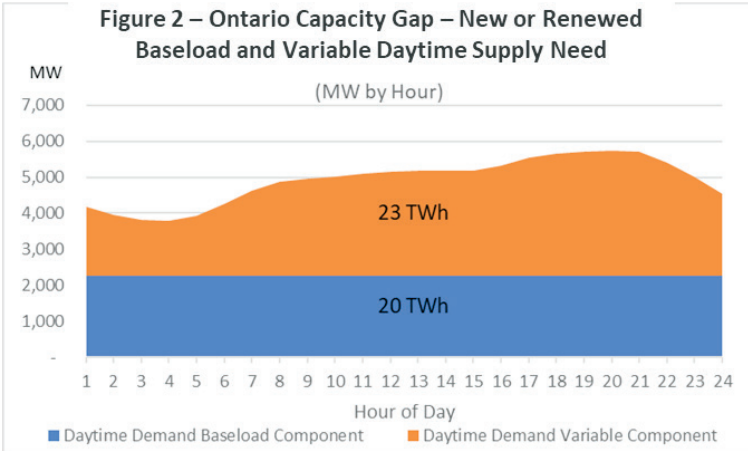


Source: IESO, Strapolec Analysis.

[1] Demand outlook includes peak demand plus required reserve margin.

"LTEP relies on storage to fill the capacity gap with intermittent renewables"

In 2035, the average daily demand profile suggests that to replace these expiring assets, 2,200 MW of baseload supply will be required to provide 20 TWh of generation. However, that alone will be insufficient. Indeed, 23 TWh or, an average 3,700 MW of dispatchable generation, will be required to supply the seasonally variable daytime demand (Figure 2).[2,3]



Source: IESO, Strapolec Analysis.

For its part, the LTEP presents renewables-based DER as a solution for this supply gap while recognizing that enhanced storage capacity is required to mitigate the effects of renewables' intermittent output.

THE ELUSIVE PROMISE OF ENERGY STORAGE

The LTEP focus on DER is intended to achieve two storage-enabled benefits.[4]

1. Underpinning the 100-percent renewables hypothesis is the belief that coupling distributed storage with renewables will mitigate intermittency and time-shift output to better match demand.
2. Integrating distributed storage functions with grid operations to provide system benefits beyond just smoothing intermittency will enable utilities to defer or avoid large capital investments.[5]

Yet, the degree to which the variable and seasonal nature of renewable generation impacts the ability of storage to deliver these benefits is not well understood.

TIME SHIFTING OF RENEWABLES OUTPUT

For renewables-based DER solutions to optimally supply critical daytime demand with reduced delivery system assets, the renewables and storage components should be co-located near the demand source. The ideal solar-plus-storage system design would match the average DER output to the average daytime demand, in effect emulating a natural-gas-fired generator at the "demand" location. For an average Ontario September day, for example, battery storage would be sized to capture 45 percent of the solar energy for reuse (Figure 3).[6]

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[2] The term "daytime demand" refers to the hourly demand in excess of the supply available from Ontario's flexible baseload supply (nuclear, hydro, biomass and imports from Quebec).

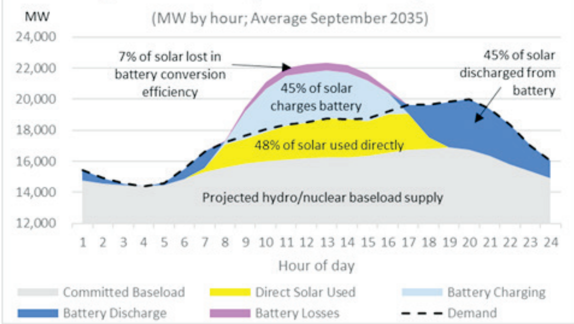
[3] This demand estimate comes from the consulting firm Strategic Policy Economics' forecast for 2035 based on LTEP assumptions. Figure 2 illustrates the annual average "daytime demand". However, the worst-case peak "variable daytime demand" is 9,000 MW, which only exceeds 6,000 MW one percent of the time. The model assumes a dedicated gas plant to supply the 3,000 MW difference. Combining the 9,000 MW of peak variable daytime demand with the 2,250 MW of baseload daily demand yields 11,250 MW. This is the 2035 equivalent of today's 9,700 MW contribution to peak from gas, solar and wind in Figure 2.

[4] See the IESO 2016 Energy Storage report.

[5] System benefits provided to utilities include improved grid flexibility, resiliency and reliability, along with higher asset-capacity factors for generation, transmission and distribution.

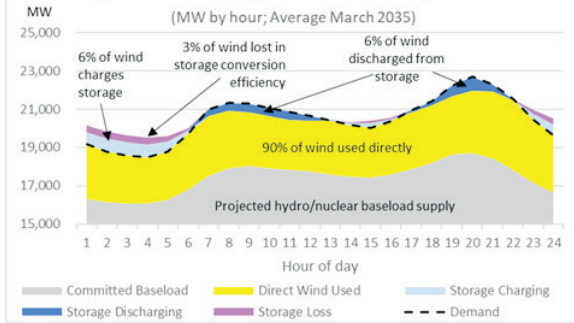
[6] September is used as it has 12-hours of daily sunlight and has both relatively high demand and solar output. Storage captures 52 percent of solar energy, but only 45 percent gets discharged, due to the 14 percent of roundtrip energy conversion losses typical of lithium-ion batteries.

Figure 3 – Sizing Solar DER Capacities



Source: IESO, Strapolec Analysis.

Figure 4 – Sizing Wind DER Capacities



Source: IESO, Strapolec Analysis.

Meanwhile, an optimal wind-plus-storage DER system in the month of March confronts a double peak in the average daytime demand, once in the morning and once in the evening (Figure 4).[7] Nine percent of the wind output would be directed to storage, leaving six percent to be time-shifted after the three-percent conversion loss.[8]

THE INTERMITTENCY CHALLENGE

The intermittency of wind and solar generation is a function of available wind and sunshine. In a solar-based DER system, the solar panel and storage capacity are optimally matched when the DER system average output meets demand (Figure 3). However, actual solar output can vary significantly from the average and can drop from its maximum level to near zero over the course of a day (Figure 5).

"Weather driven intermittency drives renewables and storage inefficiencies"

Figure 5 – Hourly Solar Output, September 2018

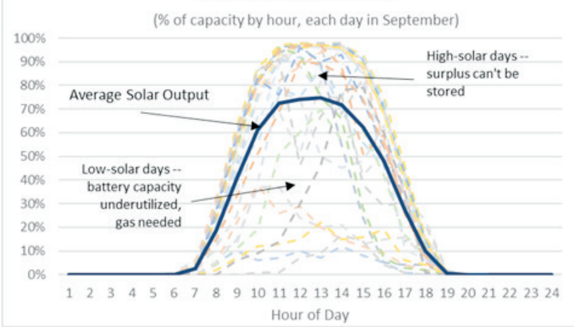
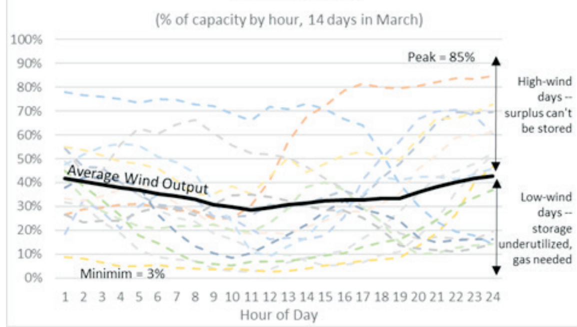


Figure 6 – Hourly Wind Output, March 2018



Note: In Figures 5 and 6, each coloured line represents a different day in the month.

Source: IESO, Strapolec Analysis. Source: IESO, Strapolec Analysis.

Clearly, output deviations from the expected average will impact the efficient use of the solar generation and storage components. When solar output in a day is greater than the battery's designed capacity, the surplus is wasted energy. Alternatively, when solar output is lower than designed capacity, the battery will not be fully charged, which leads to inefficient unused battery capacity. Furthermore, low solar output will leave the battery with insufficient energy after the sun goes down and a need for backup supply to make up for the unavailable solar and/or stored energy.[9]

Wind generation displays more extreme intermittent behaviour that magnifies the inefficiency of a DER system (Figure 6).[10] The average daily output appears to be uniform, with 30-percent higher output at night than mid-day. However, unlike solar, whose daily pattern is driven by the rising and setting of the sun, wind patterns do not have a regular daily profile that can be used to size the storage system. Wind can have high or low peaks at any hour of the day. The day-to-day output variation can drop dramatically over the course of a day and be as high as 85 percent of capacity one day, and as low as three percent the next.

[7] March reflects a high-wind output period as well as 12 hours of daylight.

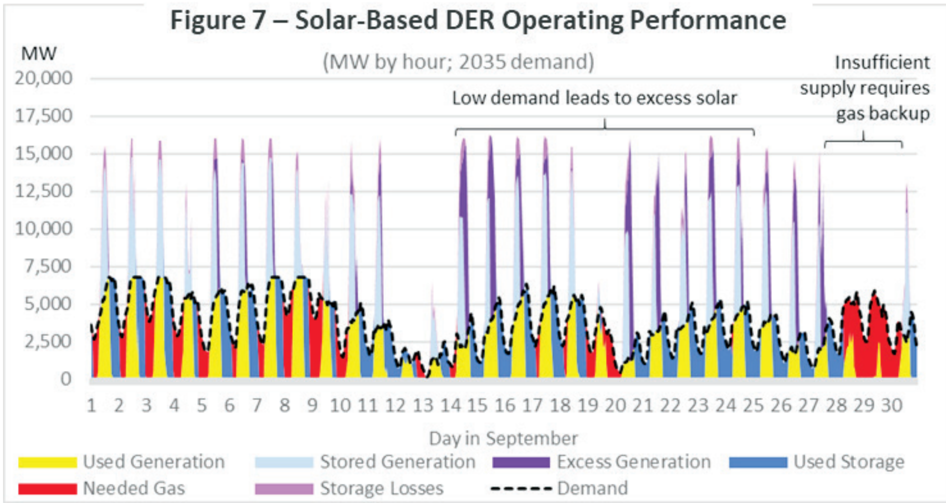
[8] Assuming wind is paired with compressed air-energy storage, the expected losses due to conversion in, and out of, storage are 35 percent.

[9] Optimal energy efficiency of the system has battery design size set to reflect average solar output per Figure 3.

[10] The wind output illustrated is for each day over a two-week period in March; the average represents hourly output for the entire month.

DEMAND VARIABILITY

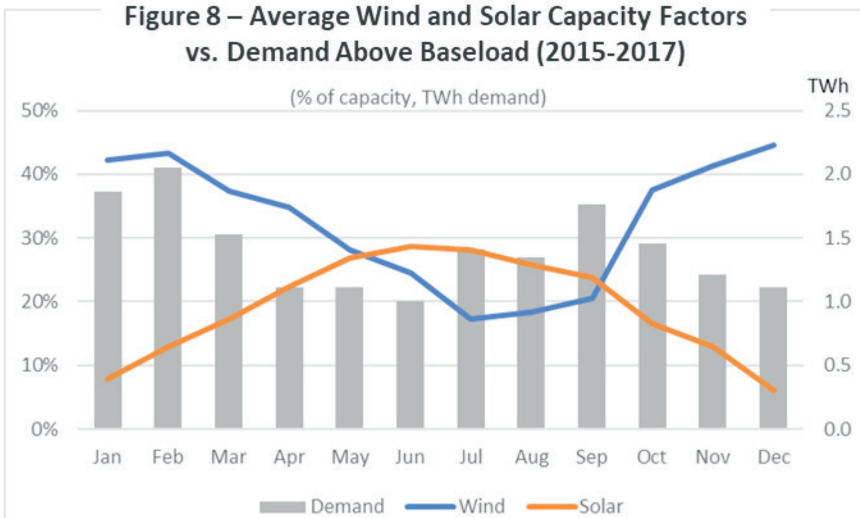
Demand fluctuations present challenges for DER systems because they impact efficiency – much like the intermittency of renewables. A solar-based DER system would require over 16,000 MW of solar capacity to meet Ontario's average September daytime demand in 2035. Contrasting solar output with hourly demand illustrates DER system operating performance and its use of storage (Figure 7). Demand tends to follow a weekly pattern, with lower demand on weekends. However, demand can also vary significantly day-to-day. In periods of higher-than-average demand, natural-gas-fired generation backup is required, even with high solar output.



Note: Ontario grid-connected solar output, 2015. LTEP Demand projected to 2035.
Source: IESO, Strapolec Analysis.

"Seasonal variations in wind and solar output waste 30-40% of output"

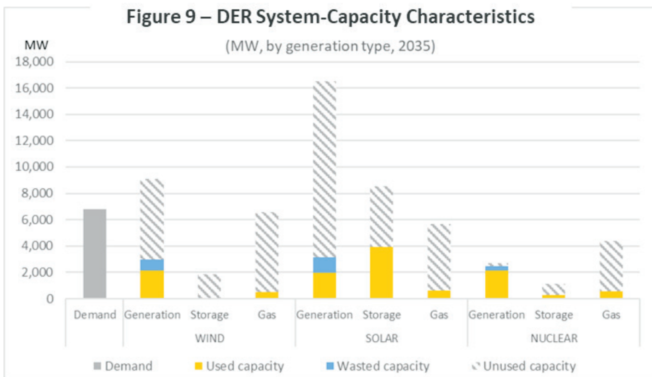
The implications of daily output intermittency and demand variability are further complicated by seasonal variations in renewables output (Figure 8). Average demand, wind output and solar output vary over the year. Solar has negligible output in winter, when average demand is highest, while wind has negligible output in the summer when peak demand occurs. Both supplies are mismatched with demand during the low-demand seasons such as the late spring, when solar peaks.



Source: IESO, Strapolec Analysis.

INEFFICIENT USE OF CAPACITY

Three scenarios, consisting of wind, solar and nuclear, contrast the impact of renewables intermittency and demand variation with the amount of storage and natural gas backup capacity required to meet Ontario's incremental supply gap (Figure 9). The nuclear scenario comprises distributed energy storage charged using the centralized nuclear baseload output. As noted, wind and solar renewables suffer from "unused capacity" due to weather impacts on generation output.[11] As well, all scenarios, even nuclear, produce "wasted capacity" from the interplay of generation output and demand variations.[12] Wind and solar waste 30 percent to 40 percent of generation output, as compared to nuclear with 14 percent wasted output.



Source: Strapolec Analysis.

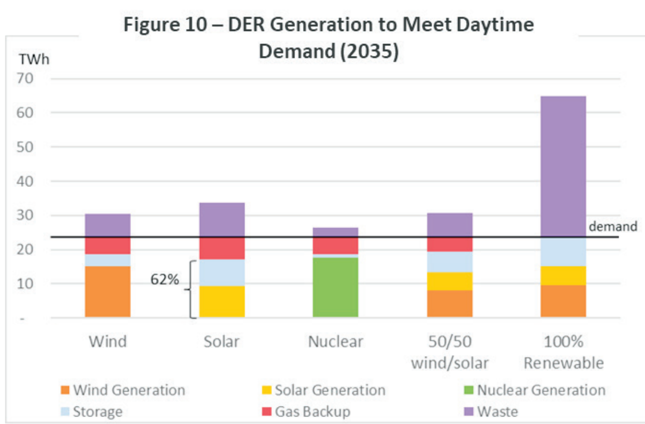
"No mix of wind and solar can materially address energy inefficiency"

The two renewables-based DER options require the installation of redundant gas backup that is able to almost fully meet demand on its own. Wind requires the greatest amount of backup natural-gas-fired generation capacity, 50 percent more than the nuclear option. For its part, solar requires 30 percent more backup generation compared to nuclear and 13 percent less than required by wind. Solar makes the greatest use of its installed storage capacity, 46 percent, while wind uses less than five percent and nuclear 25 percent.

CAPACITY EFFICIENCY NOT IMPROVED UNDER HYBRID RENEWABLES SCENARIOS

The efficiency of generation-capacity use varies among the DER options and is not improved by a hybrid solution of 50/50 wind/solar capacity or a 100-percent renewables solution with no gas generation (Figure 10).

As noted above, nuclear is the most energy efficient, wasting only 14 percent of output after storage losses. In contrast, solar with an optimized storage system wastes 38 percent of the solar output. Even the hybrid system that balances wind and solar capacity with better storage use leaves 28 percent of the energy wasted. The 100-percent renewable option would require three times more capacity compared to the 50/50 hybrid case to supply the same demand.[13] As a result, it would waste 64 percent of the renewables output. This renewables option would also require three times the storage capacity, resulting in 86 percent less storage being used in the wind scenario and 78 percent less for solar.



Source: Strapolec Analysis.

[11] Unused capacity for renewables is driven by intermittency, which has a consequential effect on utilizing the storage and gas assets. Nuclear unused capacity is a function of planned maintenance.

[12] Wasted capacity reflects generation that could not be stored or used directly at time of generation.

[13] Has 50 percent more wind and solar capacities than combining the individual wind-based and solar-based DER options..

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SUMMARY

In Ontario, intermittent renewable generation characteristics differ greatly from the patterns of energy demand. As a result, pursuing renewables to address Ontario's forecast capacity gap for supplying daytime demand requires redundant investment in storage and backup natural gas-fired generation capacity. Additionally, in a solar-based DER scenario, 38 percent of solar energy would be wasted, and 24 percent of Ontario's daytime energy demand would still have to be supplied by natural gas. The ambition of a 100-percent renewables future is less practical, as 64 percent of the energy generated would be wasted. In stark contrast, a nuclear-based solution would waste less than 15 percent of generation output.

The next installment in this three-part series of the CCRE Commentary will assess the operational simulations to identify the cost implications of these three DER scenarios – wind, solar and nuclear – and the potential implications for ratepayers. It will lay the foundation for the third CCRE Commentary of the series that will explore the economic implications of these choices for Ontario.

"Next installment of three-part series will address cost"

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