Annual Planning Outlook

Resource Costs and Trends

March 2024

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1. Executive Summary

This module provides current and forecasted capital costs of wind, solar and battery storage resources and the operational considerations associated with these resources in the context of a supply mix that will continue to evolve as a result of decarbonization and electrification. In summary, the capital costs of wind, solar and storage resources are expected to decline over the next decade and the relative costs of energy production from these resources (when considered from the perspective of their lifetime capital/operating costs divided by their lifetime energy production – also referred to as the "levelized cost of energy") is forecast to be lower than many alternative supply resources. However, it's important to note that these resources have unique characteristics that limit their ability to meet reliability criteria due to their intermittent nature (in the case of renewables) and state-of-charge limitations (in the case of storage). In particular, the value from these resources experiences a diminishing return as more capacity is added to the system. For example, the value of adding additional megawatts of solar diminishes if the incremental demand to be served occurs at night. Similarly, the value of incremental storage resources is diminished as the demand curve is flattened by existing storage facilities, reducing opportunities for peak shaving and energy arbitrage. The move towards locational pricing is expected to result in significant co-optimization of resource participation in the IESO markets. While hybrid resources (e.g. wind-storage and solar-storage combinations) may allow for greater flexibility compared to stand alone renewables or storage, the value they may provide to an integrated electrical system, beyond that of the sum of value provided by their underlying components, is not clear.

Following on the IESO's 2022 Pathways to Decarbonization (P2D), this module examines approaches to resource cost evaluation that consider a resource's value to the electricity system. Notwithstanding these considerations, renewables and storage can cost-effectively provide electricity services that are essential to maintaining reliability and are expected to play an increasingly important role in electricity systems moving forward as Ontario moves to decarbonize its electricity system and broader economy.

2. Discussion

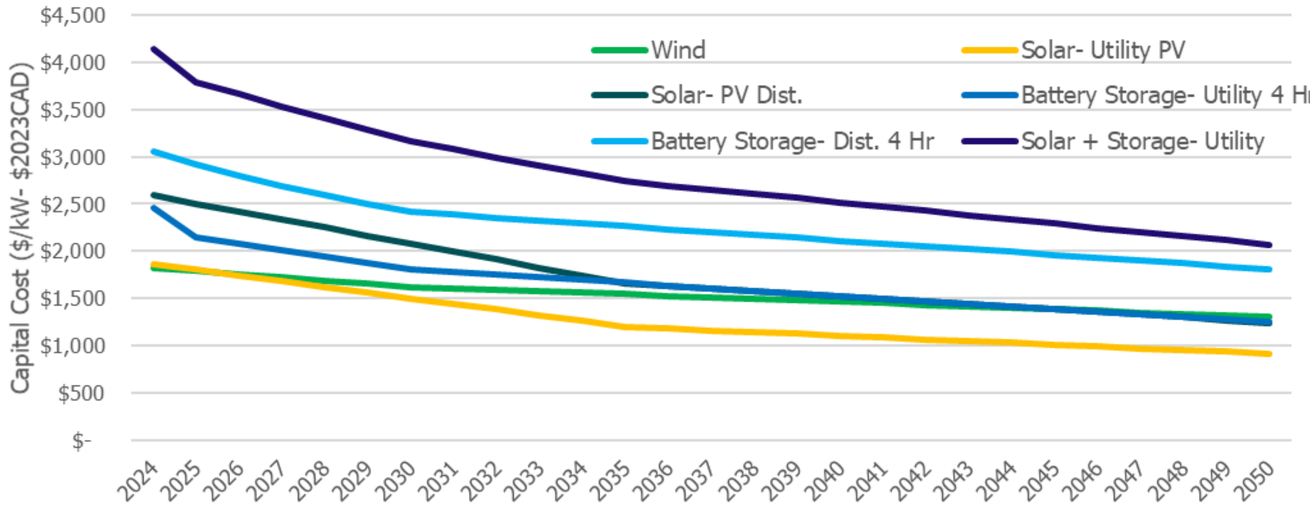
The IESO currently bases most of its forecasts for the cost of new renewable resources on the US National Renewable Energy Laboratory's (NREL) Annual Technology Baseline (ATB) report[1]. The ATB is an annual survey of resource cost projections that is a common reference point for both industry and academic studies. The cost forecasts used in this module are updated from the values that were used in the IESO's 2022 P2D study and are based on the 2023 NREL ATB report. NREL provides capital cost projections for wind generation and both utility-scale and distribution-scale installations of solar and storage. Utility-scale installations are larger scale installations that are purpose-built to provide electricity to the grid; distribution scale installations are smaller, located at individual customer/load sites and typically established to serve those individual loads (although are increasingly being aggregated together to provide electricity services to the broader grid).

2.1 Capital Cost Projections

Forecasts to 2050 for wind, solar photovoltaic (PV, both utility-scale and distributed), four-hour battery storage (both utility-scale and distributed) and hybrid solar and storage systems are shown in Figure 1. Costs for these resources are generally forecasted to decrease by approximately 20% by 2030, a further 20% by 2040, and a further 15% by 2050. Utility scale resource capital costs are lower than distributed resource costs, due primarily to economies of scale, but it is worth noting that distributed resources can be strategically sited to provide additional value to the system by deferring or avoiding investment in transmission or distribution infrastructure (as recently demonstrated through the IESO's York Region Non-Wires Alternatives Demonstration Project). Current capital costs of wind, solar PV, and battery range from approximately $1,800/kW to $3,100kW and are forecast to decline to $900/kW to $1,800/kW by 2050.

[1] NREL (National Renewable Energy Laboratory). 2023. "2023 Annual Technology Baseline." Golden, CO: National Renewable Energy Laboratory. https://atb.nrel.gov/.

Figure 1 | Wind, Solar PV, Battery Storage and Hybrid Resource Capital Cost Projections



2.2 Operating and Levelized Cost Projections

A comparison of capital costs, operating costs, and total levelized costs of energy (LCOE) of resources for 2024 and 2050 are provided in Table 1 and Table 2 respectively. The LCOE represents the lifetime cost of a resource divided by the lifetime energy production of that same resource. LCOE is a measure that can be used to compare the cost of different resources with unequal technology life spans, project sizes, capital costs, and capacity. However, LCOE is limited by its inability to value the reliability, flexibility and dispatchability of different resources, services that are critical to planning a reliable electricity system. For example, the ability of nuclear generators to produce power almost all hours of the year, or the ability of gas generators to quickly turn on and off to produce power anytime it is needed, is not captured in LCOE. Similarly, the limitations of intermittent renewable generators is not captured by LCOE. For example, solar and wind provide the most cost-effective energy when it is sunny and/or windy, which is reflected in the low LCOE. However, the LCOE does not reflect the inability of these resources to contribute to meeting system needs when it is not sunny and/or windy.

For 2024, the levelized cost is included both with and without the Investment Tax Credit (ITC) available to each resource, which was announced by the Government of Canada as part of the Fall 2022 Economic Statement. The ITC is not included in the 2050 forecasted costs as it will begin being phased out in 2034. The inclusion of the ITC generally reduces the LCOE of clean energy by 15-25%. The fuel costs for natural gas include the full forecasted federal carbon price, which reflects the expected emissions threshold decline to zero by 2030.

Table 1 | Upfront, Operating and Levelized Costs of Resources, 2024

Resource	Capital Cost ($/kW)	Fixed O&M ($/kW-year)	Variable O&M ($/MWh)	Assumed Capacity Factor	Fuel Costs ($/MWh)	Levelized Cost of Energy ($/MWh)	ITC Applied	Levelized Cost of Energy w ITC ($/MWh)
Wind	1,824	43	-	38%	-	48	30%	37
Solar- Utility PV	1,866	31	-	24%	-	69	30%	53
Solar- PV Dist.	2,588	27	-	15%	-	157	30%	117
Battery Storage- Utility 4 Hr	2,457	61	-	-	-	N/A	-	N/A
Battery Storage- Dist. 4 Hr	3,051	76	-	-	-	N/A	-	N/A
Natural Gas- SCGT	1,480	36	9	8%	63	262	-	262
Natural Gas- CCGT	1,645	46	3	12%	36	185	-	185
Nuclear	11,542	228	3	93%	10	140	15%	126
Nuclear SMR	13,821	178	3	93%	10	155	30%	119
Large Hydro	17,203	60	-	36%	Gross Revenue Charge	311	15%	270
Small Hydro	15,600	99	-	51%	Gross Revenue Charge	217	30%	165
Biomass	6,475	235	7	64%	106	232	30%	209

Table 2 | Upfront, Operating and Levelized Costs of Resources, 2050

Resource	Capital Cost ($/kW)	Fixed O&M ($/kW-year)	Variable O&M ($/MWh)	Fuel Costs ($/MWh)	Assumed Capacity Factor	Levelized Cost of Energy ($/MWh)
Wind	1,304	34	-	-	41%	33
Solar- Utility PV	914	19	-	-	26%	33
Solar- PV Dist.	1,244	15	-	-	16%	70
Battery Storage-Utility 4 Hr	1,249	31	-	-	-	N/A
Battery Storage-Dist. 4 Hr	1,809	45	-	-	-	N/A
Natural Gas-SCGT	1,171	30	9	84	8%	246
Natural Gas-CCGT	1,303	36	3	43	12%	160
Nuclear	11,542	228	3	10	93%	131
Nuclear SMR	13,821	178	3	10	93%	132
Large Hydro	17,203	60	-	Gross Revenue Charge	36%	311
Small Hydro	15,600	99	-	Gross Revenue Charge	51%	217
Biomass	5,168	235	7	106	64%	217

As shown in Table 1 and Table 2, wind and utility scale solar generation have the lowest LCOEs of any resource type, implying that, provided the wind is blowing and/or the sun is shining, these resources provide the best value electricity to the system. LCOE is highly dependent on assumptions regarding how frequently resources are generating, which is captured by the unit's capacity factor. Capacity factor is the average output of a resource over a period of time (usually one year) in megawatts (MW) divided by the installed (nameplate) capacity of that resource. For example, Table 1 and Table 2 use forecast capacity factors from the 2024 Annual Planning Outlook (APO) for natural gas generation; these values are 8% for single cycle unit and 12% for combined cycle units. In a system where the resource is used more or less frequently, the LCOE could decrease or increase materially.

The value of installing or bringing online an additional unit of any given resource type is highly dependent on the composition of the other resources in the fleet and the nature of the load to be served by those resources. On an LCOE basis wind and solar are forecasted to be the lowest cost technologies, but these resources don't provide firm capacity or meet the operability needs of the system. Due to their variable nature, wind and solar resources can't be relied upon to provide energy, capacity, operating reserve (OR) or other necessary services in all hours of the year. Natural gas is relatively more expensive to operate, due to the higher fuel costs, but is useful in providing capacity and operability services to the grid since it can be relied upon to be available in almost all hours of the year. Like natural gas, battery storage is highly flexible and, when charged, can be available to provide capacity, energy, OR and ancillary services. However, batteries can only inject energy for a limited number of hours before needing to recharge (note that the assessment above is for a 4-hour duration, which is equivalent to the capacity product procured in the capacity auction and ongoing IESO RFPs). Nuclear provides consistent baseload output, but a supply mix consisting solely of nuclear would be less flexible and limited in its ability to quickly adjust output in response to changes in demand. More broadly, all resources face practical limitations and considerations that include siting, permitting, land-use, financing and economic impacts that will influence resource availability and procurement.

2.3 Operational Features and Trends

Another useful way of comparing different resources is to consider their capacity contribution. Unforced capacity (UCAP) is one method of comparing the capacity contribution of different resources. UCAP measures the expected capacity contribution of a resource to meet peak system needs (i.e. the amount of actual capacity a resource can be expected to provide during summer or winter peak). The UCAP provided by a resource can differ between winter and summer. For example, the UCAP of solar resources is much higher in the summer than winter due to more available sunlight and the fact that winter peak demand tends to occur after the sun has set. Natural gas generation has a higher winter UCAP than summer, as the maximum output of a plant is inversely related to the ambient temperature (i.e. natural gas generators operate less efficiently in hot weather). Notably, the IESO forecasts Ontario will become dual-peaking beginning in the early 2030s. If decarbonization accelerates, this may occur earlier, and the system may become winter peaking. The move to a winter peak means that resources with a higher winter UCAP will become relatively more important during those periods of the year. This example illustrates how the value of different resources varies relative to the nature of the need being served and the other supply resources available (and the nature of the need is further described in greater granularity in the 2024 APO Supply, Adequacy and Energy Outlook Module); it is further illustrative of the type of dynamic that is driving system operators around the world to evolve the tools they use for evaluating the cost and benefit of individual resources and overall supply and demand management options.

UCAP% is the ratio of a resource's UCAP to its installed capacity (for example, a generator with a 100 MW capacity and a UCAP% of 18% would contribute 18 MW towards resource adequacy requirements). The UCAP% for wind, solar and batteries tends to decline as more of these resources are added to the supply mix. For example, as solar is added to the grid, it offsets the demand and shifts the need to later in the day. As a result, the UCAP% value declines as penetration increases. For battery storage, as more is added to the grid, it flattens the demand curve and spreads out the hours of the day when there is a need on the system, and as a result, the UCAP% of battery storage declines as penetration increases. System planners and operators have historically struggled to accurately capture the declining marginal contribution of resources to resource adequacy requirements as these contributions change dynamically in response to load and the rest of the supply mix. An industry standard approach to dynamic capacity contributions currently does not exist, but as progress is made on this challenge the IESO will incorporate best practices into its assessments. The UCAP%, along with a checklist of other electricity services a resource can provide, are provided in Table 3[2].

Table 3 | UCAP% and Electricity Services Provided, by Resource

	Summer UCAP%	Winter UCAP%	Energy	Continuous Power (> 4-Hour Duration)	Intermittent Energy	Operating Reserve	Ramping	Frequency Regulation
Wind	16%	29%	Yes	No	Yes	No	No	No
Solar	19%	0%	Yes	No	Yes	No	No	No
Battery Storage	95%	95%	No	Yes	No	Yes	Yes	Yes
Natural Gas	94%	94%	Yes	Yes	No	Yes	Yes	Yes
Nuclear	94%	94%	Yes	Yes	No	No	No	No
Hydroelectric	70%	78%	Yes	Yes	Yes	Yes	Yes	Yes
Biomass	94%	94%	Yes	Yes	No	Yes	Yes	Yes
Demand Response	75%	71%	No	No	No	No	No	No

When planning a power system, resources are typically procured to meet specific system needs. Given that different resources have unique operational limitations and capabilities, no single resource type by itself is likely to result in a cost-optimal, reliable and resilient system. The IESO's standard approach for assessing individual resources is as part of a broader portfolio of resources required to reliably and cost-effectively operate the system. With this approach, the relative costs and benefits of different resource combinations can be compared to find an optimal resource portfolio.

In conclusion, the costs of wind, solar and battery storage are declining. Due to their low fuel/operating costs, increasing penetration of these resources in Ontario is likely to lead to lower marginal costs for the electricity system. While variable renewables and battery storage can cost effectively meet many of the forecast system needs in Ontario, the technologies have inherent limitations and will need to work in concert with a portfolio of other resources to maintain a reliable and operable electricity system – just as Ontario relies upon a diverse resource mix today.

[2] The UCAP% for the table are taken from the IESO's 2024 Annual Planning Outlook with the exception of Battery Storage, which is from the Pathways to Decarbonization Study.

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