PPAs FOR RAINY DAYS

Energy Storage for Corporate Buyers

BUSINESS RENEWABLES CENTRE
CANADA

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Created in collaboration with
ENERGY STORAGE CANADA

Introduction

An emerging opportunity for organizations

As Canadian jurisdictions make strides towards the goal of a fully decarbonized electricity grid, there is a prime opportunity for energy storage to be one of the key tools used to achieve this target.

Organizations should consider how energy storage could fit into their energy procurement strategies and increase their impact on emissions reduction.

What is energy storage?

The concept is familiar to most: energy storage devices save energy for later use long after it is produced. You charge your phone battery at home so that you can use it throughout the day without being stuck sitting next to a wall outlet.

But when it comes to large, grid-level storage, the use of energy storage is not quite as widespread. Traditionally, the use of grid-level electricity comes right after its production. By separating energy production from energy use, energy storage complements the generators by increasing the flexibility of the entire system.

The role of storage on a decarbonized grid

In general, saving energy when it is abundant or cheap and then releasing it when it is scarce or expensive can help smooth out the fluctuations of the grid. This concept works particularly well when storage is used as a complement to intermittent wind and solar energy generation. By saving some energy for a literal rainy day, storage can increase the usage of wind and solar energy past the times when the wind is blowing or the sun is shining, thus increasing the hours of the day when carbon-free energy can be used.

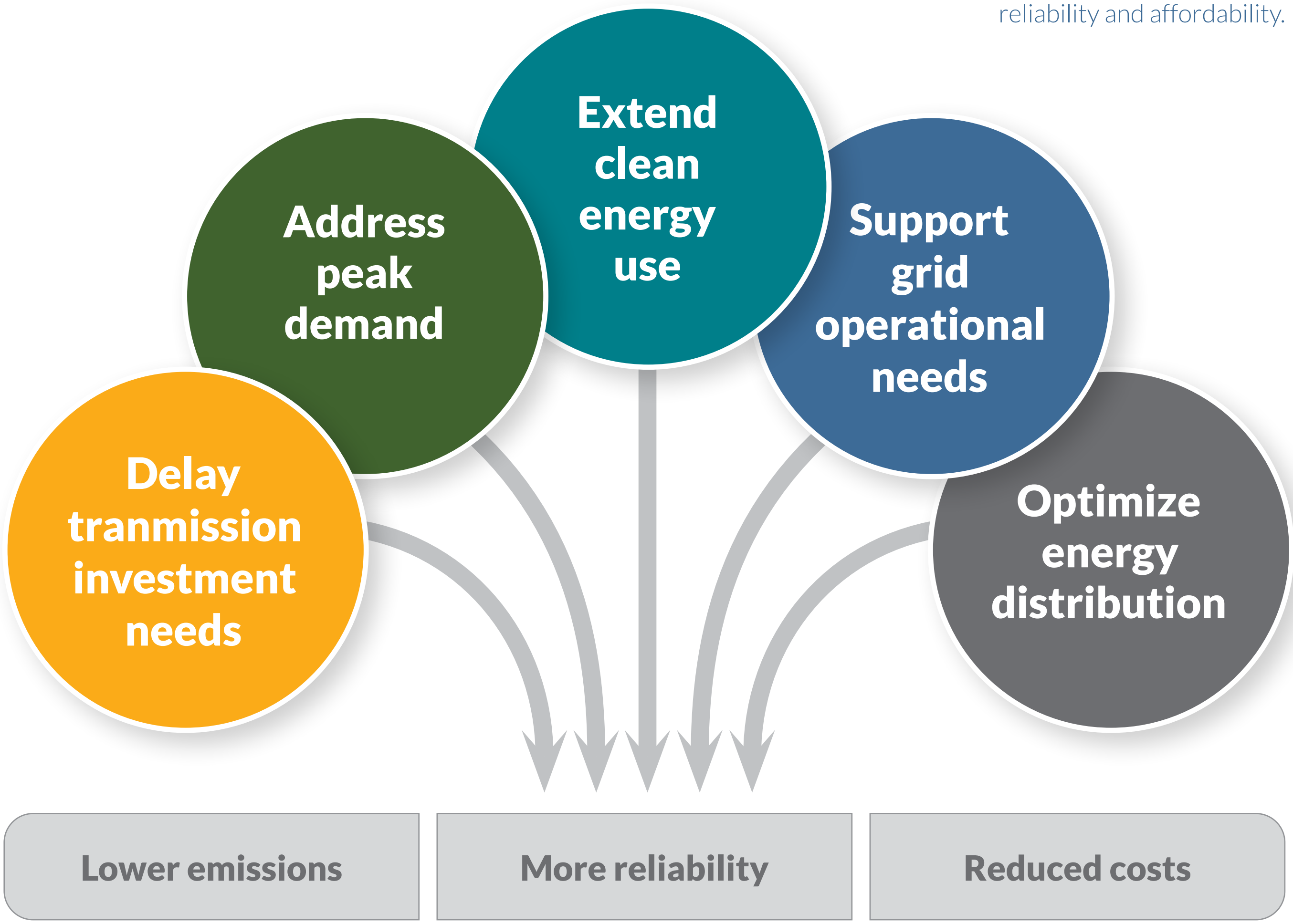
Pairing storage with wind and solar can also help avoid situations when generating facilities are required to stop production due to transmission congestion, called curtailment.

It also allows more wind and solar generation to be built in locations where a generating project might have been deemed uneconomical on its own, thus lowering the cost of electricity for ratepayers.[1]

Another way to use energy storage is to save energy

1 Affordability and Utilities, Affordability and Utilities 2022-23 Annual Report Annual Report (Government of Alberta, 2023), 25. https://open.alberta.ca/publications/2817-4550#summary

FIGURE 1
Grid-level energy storage provides a bouquet of benefits that combine to advance decarbonization, reliability and affordability.



for peak demand situations. Dispatchable energy sources like natural gas "peaker" plants — which can be fired up relatively quickly — are often used to provide sufficient energy in these short-term situations. Releasing energy from storage units here can reduce the role of these "peaker" plants, which can use 50 per cent more natural gas than combined cycle gas plants.[2]

Many energy storage technologies can release energy very precisely, allowing them to replace the reliability services that traditional generators have supplied. One example is providing stand-by power on short notice to handle unexpected mismatches between generation and demand.

Overall, the addition of energy storage capacity on a grid that has increasing amounts of renewable energy can further reduce grid emissions, increase its reliability and lower costs for ratepayers.

2 Mark Dyson, "4 Ways Demand Flexibility Can Enable a Low-Carbon Grid ," RMI, October 1, 2015. https://rmi.org/blog_2015_10_01_4_ways_demand_flexibility_can_enable_a_low_carbon_grid/

Types of storage

There are a wide range of technology types for grid-level energy storage, each with unique characteristics that make them suitable in different contexts. Most energy storage technologies take in and put out electricity, but, notably, thermal technologies may take in electricity and output heat for direct use.

Electro-chemical	Chemical	Mechanical	Thermal mechanical	Thermal
Batteries	Hydrogen	Flywheel	Compressed air	Latent heat
Redox flow		Pumped hydro	Liquid air	Sensible heat
		Gravity-based		

FIGURE 2
Overview of energy storage technologies grouped by the form of the stored energy

Notable options

Table 1 highlights several of the prominent energy storage mechanisms. However, as with any developing field, there are many others that are not included here that may become notable options in Canada.

Batteries are electrochemical devices and are one of the most popular types of storage systems. Based on the chemical structure of the system, battery energy storage systems (BESS) can be divided into two categories. The first involves a unified electrical and chemical structure comprising lead-acid, lithium-ion, sodium-sulfur, or nickel-cadmium battery storage. The second category has the active substances stored outside the base, and the electrolyte solution flows through the cells when needed by the pumps. These are called flow batteries.

Considering the characteristics of the technology and its prevalence in Canada, this primer will cover lithium-ion and vanadium redox flow battery storage technology.

TABLE 1
Overview of selected energy storage options

	Lithium-Ion Battery	Vanadium Redox Flow Battery	Pumped-Storage Hydropower	Compressed Air
Notable Features	Short-term, fast response	Long-duration storage Non-flammable and non-explosive	Large footprint Long-duration storage Restricted to locations with suitable geography	Long-duration storage
Technology Readiness	Established technology, already in commercial use	Deployed, but smaller projects	Established technology, already in commercial use	Smaller projects deployed, larger in construction
Typical Storage Duration	4 hours [A]	2 – 12 hours [B]	>8 hours [C]	>6 hours [E]
Round-Trip Efficiency [D]	80-85%	65-75%	70-80%	45-70%
Lifetime [F]	10-15 years <3,500 cycles	15-25 years >10,000 cycles	30-50 years <50,000 cycles	30-40 years <30,000 cycles
Capital Costs ($/kW) [E,F]	$1,200 - $2,400 (For power capacities of 1–10 MW and durations of 2–4 hours)	$2,200 - $5,800 (For power capacities of 1-10 MW and durations of 2–10 hours)	$2,300 - $3,500 (For power capacities of 100-1,000 MW and durations of 4-10 hours)	$1,450 - $1,600 (For power capacities of 100-1,000 MW and durations of 4–10 hours)
Storage Type	Electrochemical	Electrochemical	Mechanical	Thermal-mechanical

A Paul Denholm, Wesley Cole and Nate Blair, Moving Beyond 4-Hour Li-Ion Batteries: Challenges and Opportunities for Long(er)-Duration Energy Storage (National Renewable Energy Laboratory, 2023), 4. https://www.nrel.gov/docs/fy23osti/85878.pdf

B Invinity, "Invinity VS3-022 Six Pack™ Vanadium Flow Battery," 2023. https://invinity.com/wp-content/uploads/2023/03/Invinity-VS3-022-Vanadium-Flow-Battery-Data-Sheet-MAR00016-2023-01.pdf

C LDES Council and McKinsey & Company, Net-zero power Long duration energy storage for a renewable grid (2021). https://www.mckinsey.com/~/media/mckinsey/business%20functions/sustainability/our%20insights/net%20zero%20power%20long%20duration%20energy%20storage%20for%20a%20renewable%20grid/net-zero-power-long-duration-energy-storage-for-a-renewable-grid.pdf

D Mohammadhossein Deihimi, Navid Rezaei, Mehrdad Gholami and Hadi Tarimoradi, "Advanced energy storage system in smart grids: power quality and reliability," in Emerging Trends in Energy Storage Systems and Industrial Applications (Department of Electrical Engineering, University of Kurdistan, 2023), 423.

E Vilayanur Viswanathan, Kendall Mongird, Ryan Franks, Xiaolin Li, Vincent Sprenkle, and Richard Baxter, 2022 Grid Energy Storage Technology Cost and Performance Assessment (U.S. Department of Energy, 2022). https://www.energy.gov/sites/default/files/2022-09/2022%20Grid%20Energy%20Storage%20Technology%20Cost%20and%20Performance%20Assessment.pdf

F Capital costs per kW are dependent on the duration of the energy storage system. The shown costs do not include the Clean Technology Investment Tax Credit, which would offer a tax refund of up to 30% of the capital cost of electricity storage systems in Canada. Costs are converted from USD to CAD with a conversion rate of US$1 = C$1.34

Lithium-ion

Lithium-ion is the most popular battery chemistry due to its medium-to-high energy and power density, its rapid response, and its relatively mature supply chain. It is the same chemistry found in your smartphone battery. However, this type of battery is also known for its relatively short lifespan. Technology and processes are moving quickly for lithium-ion, causing rapid improvements in performance and price. Lithium-ion battery costs have seen an 80 per cent price decline in the past decade.[3]

SOURCE: Northland Power (www.northlandpower.com/en/projects-and-updates/oneida-energy-storage.aspx)

Oneida Energy Storage

Located in Jarvis, Ontario, Oneida Energy Storage is expected to be one of Canada's largest energy storage projects when it comes online in 2025. The stand-alone lithium-ion battery storage project will have a capacity of 250 MW/1,000 MWh. The project is being developed through a partnership with Northland Power, NRStor, the Six Nations of the Grand River Development Corporation (SNGRDC), and AECON.[4] The project is part of a 1,200 MW energy storage procurement by the system operator in Ontario, the largest ever in Canada.[5]

3 BloombergNEF, "Top 10 Energy Storage Trends in 2023." https://about.bnef.com/blog/top-10-energy-storage-trends-in-2023/

4 Marco Chown Oved, "Ontario has just unveiled the largest electrical-grid battery project in Canada," *Toronto Star*, February 10, 2023. https://www.thestar.com/news/canada/ontario-has-just-unveiled-the-largest-electrical-grid-battery-project-in-canada/article_2115f030-3ad2-5fe1-9c62-050e0b18f507.html

5 Brady Yauch and Travis Lusney, "May 2023 Ontario Electricity Market Update: IESO Announces Initial Results of E-LT 1 RFP and Same Technology Upgrade Solicitation," *Power Advisory*, June 19, 2023. https://www.poweradvisoryllc.com/reports/may-2023-ontario-electricity-market-update-ieso-announces-initial-results-of-e-lt-1-rfp-and-same-technology-upgrade-solicitation

Redox flow

Vanadium redox flow battery is the most developed and commercially available flow battery technology. The main difference between redox flow batteries and other forms of batteries is the separation of battery cells and the electrolyte tank. This enables longer lifetimes, resulting in lower costs when compared with lithium-ion batteries.[6] However, vanadium is a difficult resource to extract in large quantities.

This technology is considered to be in a demonstration phase, and not yet deployed at large scales. With development spurring here in Canada and across the world, vanadium redox flow batteries have the potential to be used for utility-scale storage projects, microgrids, renewable energy integration and grid smoothing.

SOURCE: Elemental Energy (https://elementalenergy.ca/project/chappice-lake-solar-storage/)

Chappice Lake Solar-Storage

Located just north of Medicine Hat, Alberta, this project combines 14 MW[7] of solar capacity with a 2.8 MW / 8.4 MWh[8] flow battery system. It is the first project in Alberta to deploy flow battery technology at utility scale. The project comes from a partnership between Elemental Energy and Cold Lake First Nations, with the storage technology supplied by Invinity Energy Systems. It became operational in 2023.

6 Nancy W. Stauffer, "Flow batteries for grid-scale energy storage," *MIT News*, April 7, 2023. https://news.mit.edu/2023/flow-batteries-grid-scale-energy-storage-0407

7 Elemental Energy, "Chappice Lake Solar-Storage." https://elementalenergy.ca/project/chappice-lake-solar-storage/

8 Andy Colthorpe, "Invinity to deploy vanadium flow battery at solar-plus-storage project in Alberta, Canada," *Energy Storage News*, February 3, 2022. https://www.energy-storage.news/invinity-to-deploy-vanadium-flow-battery-at-solar-plus-storage-project-in-alberta-canada/

Pumped storage hydropower

Pumped storage hydropower (PSH) is the most commonly used form of grid-level energy storage, comprising 96 per cent of global storage capacity.[9] While much of the PSH capacity was built in the 20th century, new installations are once again being deployed as the need for energy storage grows. The system moves water from a lower location to a higher reservoir when energy demand is low and produces electricity by channelling the stored water downhill through turbines.[10]

Depending on the reservoirs, PSH can be classified into open or closed-loop systems. Closed-loop projects produce power from water that is initially pumped into the reservoir, and then repeatedly cycled up and down. They do not have a significant natural inflow of water to either their upper or lower reservoir. By contrast, in open-loop systems, the upper or lower reservoirs have a continuous water connection to a natural body of water. Oftentimes it is in conjunction to a river with hydroelectric generation.

Pumped storage development relies on finding appropriate geography. Recent studies have estimated that Canada has approximately 8,000 GW of potential across 1,200 different sites.[11]

Sir Adam Beck Pump Generating Station

Located in Queenston Heights, Ontario, this pumped storage system is part of a larger hydropower plant that was first commissioned in 1922. Water is supplied by the Niagara River and is pumped into a 20-million cubic metre reservoir for storage during off-peak periods.[12] That is the equivalent of 8,000 Olympic swimming pools! When demand is high, this water is then diverted towards the hydroelectric generators to generate electricity. This 174 MW pumped storage unit is owned by Ontario Power Generation.

SOURCE: Power Technology (https://www.power-technology.com/projects/sir-adam-beck-hydroelectric-power-complex-niagara-falls)

9 Andrew Blakers, Matthew Stocks, Bin Lu and Cheng Cheng, "A review of pumped hydro energy storage," *Progress in Energy* 3 (2021), 2. https://iopscience.iop.org/article/10.1088/2516-1083/abeb5b

10 Water Power Technologies Office, "Pumped Storage Hydropower," *Office of Energy Efficiency & Renewable Energy*. https://www.energy.gov/eere/water/pumped-storage-hydropower

11 Elizabeth Ingram, "Canada has more than 8,000 GW of pumped storage potential," *Hydro Review*, August 30, 2023. https://www.hydroreview.com/hydro-industry-news/pumped-storage-hydro/canada-has-more-than-8000-gw-of-pumped-storage-potential/

12 Canada Energy Regulator, "Market Snapshot: Pumped-storage hydro – the largest form of energy storage in Canada and a growing contributor to grid reliability." https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2016/market-snapshot-pumped-storage-hydro-largest-form-energy-storage-in-canada-growing-contributor-grid-reliability.html

Advanced compressed air

Combining mechanical and thermal energy storage enhances capabilities from both technologies, which is what advanced compressed air energy storage (A-CAES) does. During off-peak hours, renewable energy is used to inject air into an underground cavern for high pressure storage. When electricity demand is high, the compressed air is withdrawn to drive a turbine to generate electricity.[13]

A-CAES, similar to pumped hydro, offers long-duration energy storage, but with added benefits like flexible siting and reduced ecosystem impacts. Compared to battery storage, A-CAES can be deployed at a larger scale and has a longer lifespan.

SOURCE: Hydrostor (https://hydrostor.ca/projects/the-goderich-a-caes-facility)

Goderich Energy Storage Facility

Located in Goderich, Ontario, this partnership between Hydrostor and NRStor was the world's first commercial advanced compressed air energy storage system when it came online in 2019. It is used on the grid for peak demand scenarios as well as operational services that improve grid reliability. Compressed air is stored in an underground salt cavern that once was used for brine and table salt production. The system has a capacity of over 10 MWh and can output 1.75 MW of peak power while charging at a rate of 2.2 MW.[14]

13 Archie Robb, "Can compressed air energy storage solve the long-duration dilemma?" *Renewable Energy World*, April 12, 2023. https://www.renewableenergyworld.com/storage/can-compressed-air-energy-storage-solve-the-long-duration-dilemma/

14 Hydrostor, "Goderich Energy Storage Facility." https://www.hydrostor.ca/goderich-a-caes-facility/

Buying storage

How storage fits into corporate procurement

As discussed above, grid-level energy storage capacity can provide many benefits. Helping to enable these projects through corporate procurement allows organizations to increase their grid decarbonization impact.

Alongside these community-level benefits are specific gains that can support an organization's goals.

Willow Rock Energy Storage Center

In January 2023, Canadian developer Hydrostor and Central Coast Community Energy, a California Community Choice Aggregator, entered into a 25-year power purchase agreement offtaking 200 MW / 1,600 MWh of an upcoming advanced compressed air energy storage project, Willow Rock Energy Storage Center.

The energy storage system will provide 8-hour duration storage and is planned to be used during high demand scenarios, reducing the need for additional "peaker" facilities and deferring transmission line upgrades.[15] The entire project will be able to store 4,000 MWh of energy, providing 500 MW of power for eight hours, and is expected to come online in 2028.[16]

SOURCE: Hydrostor (https://hydrostor.ca/projects/willow-rock-energy-storage-center)

15 Hydrostor, "California Moves Closer to Carbon-Free Electricity Goals as Central Coast Community Energy Signs 25-Year Power Purchase Agreement with Hydrostor," news release, December 19, 2023. https://www.globenewswire.com/en/news-release/2023/01/12/2587944/0/en/California-Moves-Closer-to-Carbon-Free-Electricity-Goals-as-Central-Coast-Community-Energy-Signs-25-Year-Power-Purchase-Agreement-with-Hydrostor.html

16 Andy Colthorpe, "First offtake deal signed for 500MW/4,000MWh advanced compressed air energy storage project in California," *Energy Storage News*, January 13, 2023. https://www.energy-storage.news/first-offtake-deal-signed-for-500mw-4000mwh-advanced-compressed-air-energy-storage-project-in-california/

Achieving next-generation organizational goals

While many organizations have a goal of using 100 per cent renewable energy by a certain date, some organizations are looking beyond this target in the pursuit of greater impact.

Some organizations have a goal of achieving 24/7 carbon-free energy. This means that for every hour of the year, their purchased renewable energy is generating enough energy to match their usage.[17] This is more granular than standard 100 per cent renewable energy targets, which look to match purchases with usage based on an entire year in aggregate. Calculating generation and usage by the hour introduces the challenge to match usage in parts of the day when generation is low, but business operations are still running, like at night.

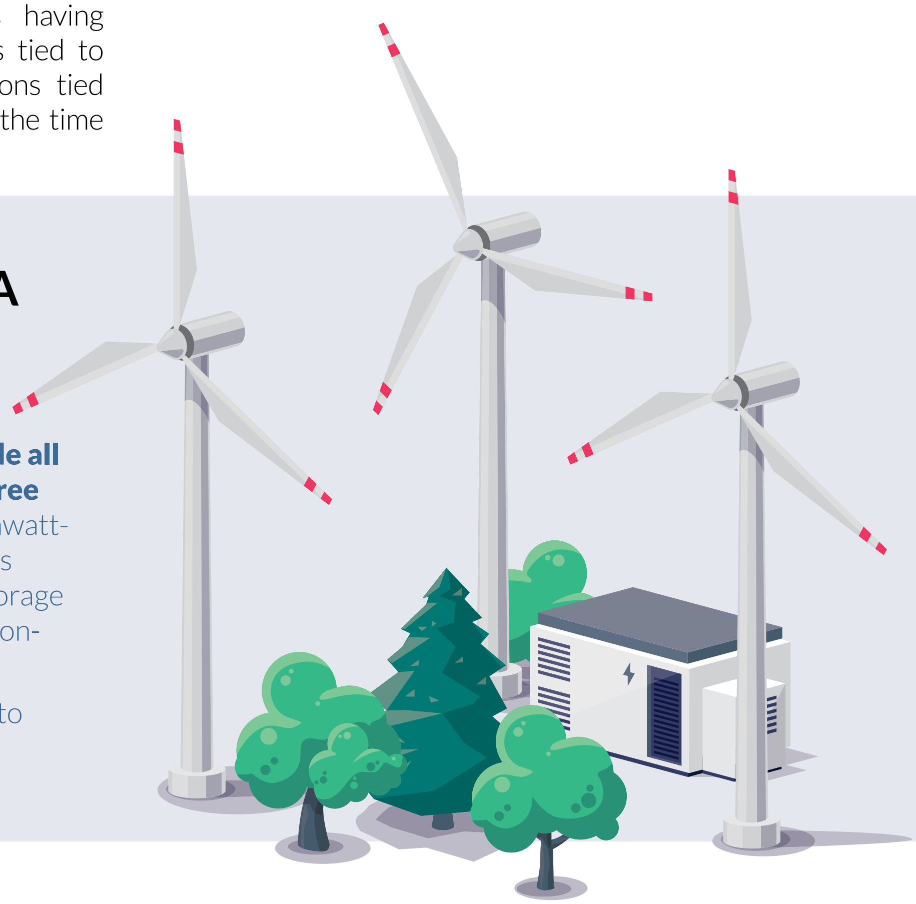
Other organizations seek to use emissions matching to achieve carbon neutrality, defined as having avoided emissions that equal the emissions tied to their electricity consumption.[18] The emissions tied to electricity on the grid vary depending on the time of day and the underlying generation portfolio of the particular grid from which it is drawn. An organization would calculate the emissions tied to their usage pattern, and then procure renewable energy that displaces enough fossil fuel-based generation to match these emissions.

Regardless of the goal, energy storage is a key tactic for organizations to deploy. It helps reach 24/7 carbon-free energy by allowing wind and solar energy to be distributed across the day to cover all of an organization's energy use. And it can also support emissions matching, by facilitating the use of clean energy during the times of day that have high carbon intensity to increase the amount of avoided emissions.

TC Energy and Loblaw PPA

In May 2023, Canadian retailer Loblaw entered into a power purchase agreement with TC Energy for **enough power to provide all its Alberta operations with 24/7 carbon-free electricity**. The purchase includes 300 megawatt-hours per year of renewable electricity across wind and solar sources, as well as pumped storage hydropower capacity to help spread the carbon-free energy around the clock.

Components of the program are anticipated to come online in 2025.



17 24/7 Carbon-Free Energy Compact. https://gocarbonfree247.com/

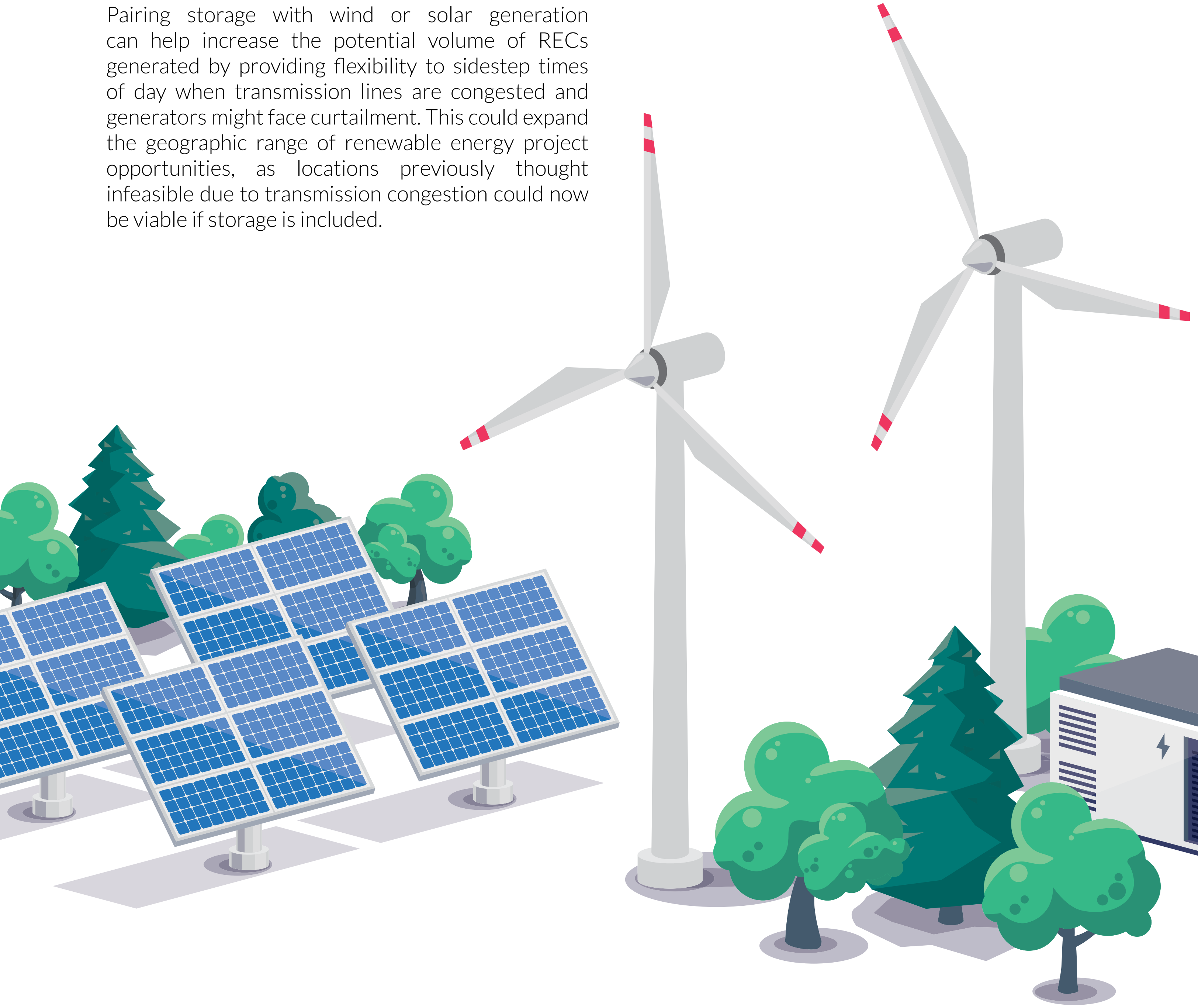
18 Hua He, Alex Derenchuk, Aleksandr Rudkevich and Richard Tabors, *Paths to Carbon Neutrality* (Tabors Caramanis Rudkevich, 2023), ii. https://tcr-us.com/uploads/3/5/9/1/35917440/paths_to_carbon_neutrality_white_paper_april23.pdf

Maximizing the value of renewable energy generation

A renewable energy certificate (REC) is only generated if the energy makes it onto the grid. During the times of day when many power plants are generating, such as during a sunny afternoon, some transmission lines may get so congested that nearby generating facilities are required to stop sending energy to the grid. For those facilities, that means a loss in potential REC generation.

Pairing storage with wind or solar generation can help increase the potential volume of RECs generated by providing flexibility to sidestep times of day when transmission lines are congested and generators might face curtailment. This could expand the geographic range of renewable energy project opportunities, as locations previously thought infeasible due to transmission congestion could now be viable if storage is included.

Lastly, the flexibility that storage provides a power plant project provides potential economic savings through storing when the price is low and releasing when the price is high. These savings could be passed onto the buyer organization and should be accounted for in the power purchase agreement.[19]



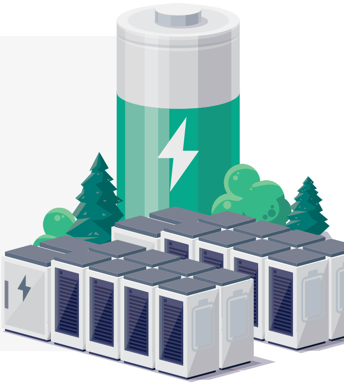
19 Zeigo, "Can PPAs Unblock Access to New Battery Projects?" August 16, 2023. https://www.zeigo.com/2023/08/16/can-ppas-unblock-access-to-new-battery-projects/

Considerations forintegrating storage into PPAs

Along with the benefits of including energy storage comes a bit of added complexity. There are a few additional considerations that are not sufficiently covered by traditional PPA models.

How will the storage be used?

Deciding to include storage in a PPA is just the first choice to make. The next decision is to figure out how the storage will be used. There are various ways to use storage and renewable energy that align with the buyer organization's goals. Here are some potential considerations:



- Will the stored energy be reserved for peak grid demand situations?
- Will it be primarily used to mitigate curtailment?
- Will it be used as frequently as possible to sell energy at high prices?
- Will it be used to lower the organization's demand peaks, to lower demand charges?
- Is 24/7 renewable energy the goal?
- When should the storage system be replenished?

The project stakeholders must agree on the deployment of the storage system, as it will have significant impact on the technical design, pricing and operations.

Additional operational, safety and environmental considerations

Adding a different type of technology to a wind or solar project will bring along a new set of operational, safety and environmental considerations.

To share a few examples: batteries need to be managed against leakage or overheating, pumped hydro impacts to local ecosystems need to be understood and minimized, and maintenance plans for flywheel systems need to be agreed upon. It is important to work through how these elements will be managed and how different risks will be shared amongst all parties.[20]

Some considerations that should be integrated into the PPA include:

- Who has controlling rights over the storage system?
- Who is responsible for the physical maintenance of the equipment?
- For batteries, what are the allowable operating parameters?
- For batteries, at what level of degradation will they be replaced? And who will manage this process?
- How are potential risks like fires and leakage being handled?
- What steps will be taken to minimize local ecosystem and community impact of storage systems? In particular, pumped hydro systems could have a large impact on the land.
- For newer technologies, how will unforeseen risks be distributed across stakeholders?
- How will equipment be handled at end of life, and who will manage this process?

20 Amandeep Kaur, "Batteries + Storage: The Implications of Integrating a Battery Energy Storage System into Renewable Energy Power Purchase Agreements," *Oil and Gas, Natural Resources, and Energy Journal* 7, no. 4 (2022), 935. https://digitalcommons.law.ou.edu/cgi/viewcontent.cgi?article=1360&context=onej

Conclusion

The next frontier of corporate energy procurement is here.

Energy storage and the opportunities that come with it help complement renewable energy generation and achieve a new level of grid decarbonization.

As organizations see the relevance of storage in achieving ambitious climate commitments, energy storage is quickly becoming integrated within PPA contracts. Storage enables organizations to pursue next generation sustainability goals that further their impact.

This primer highlights some of the relevant storage technologies in Canada to help understand what options exist for buyers in their next PPA. PPAs with energy storage can be complex, so interested buyers should be clear about how they want to use storage to best suit their needs.

The next frontier of corporate energy procurement is here, and BRC-Canada is excited to support organizations through the process. Energy storage is still evolving, and we will continue to update this primer to include the latest technologies and strategies regarding energy storage integrated PPAs.

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