WATERPOWER CANADA
HYDROÉLECTRICITÉ CANADA

Hydropower's Value to a Net-Zero Electricity Grid

A guidebook for policymakers

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Power Advisory · 55 University Avenue Suite 700, PO Box 32 · Toronto, Ontario M5J 2H7

EXECUTIVE SUMMARY

Modern interconnected electricity systems are among the largest scale and most complicated networks built. Operating such a grid involves carefully balancing synchronous generation and servicing connected loads while maintaining frequency and megawatt balance, maintaining voltage on transmission and distribution lines, and readying the electricity system for the next possible contingency. Much of modern society depends on system operators to have access to the tools and resources to ensure a well-functioning, reliable and resilient grid.

The electricity system throughout Canada can be seen as a collection of regionalized systems, aligned provincially and territorially. In many cases infrastructure development has been based on proximity to, and availability of, their fuel source, and in relation to their load. As Canada navigates the rapid transformation from its present state to one of net-zero carbon emissions, there are cases where the transmission networks in place will require expansion and development as they become powered more predominantly by variable renewable energy resources distributed over wider areas.

In addition, consumers of electricity are beginning to use this commodity in different ways: to power their vehicles; heat and cool their homes and businesses; and manufacture and distribute goods. These changes bring new challenges to how electric systems need to be planned and operated.

Hydropower plays a critical role as not only a provider of clean renewable power to a large proportion of Canadians, but also a source of essential grid services for system operators to maintain a balanced and reliable grid. Due to its association with dams and reservoirs for ponding water, fast responding power output, large and durable spinning mass, capability to store energy, and emissions-free production are amongst the features that make hydropower stand out as a priority generation type that has provided essential service to the grid in the past and will continue to do so with a greater level of importance in the future. Additionally, some hydro reservoirs can serve as energy storage over the very long term, from season to season, and can accommodate servicing loads in regions with high variability in electrical demand. Although inverter-based resources (IBRs) are increasingly being called upon to contribute more ancillary services of this nature, hydropower can inherently provide these services in a less complicated manner, without the need for conscious design and rating considerations, and at a reduced cost.

The purpose of this whitepaper is to provide its reader with an understanding of the technical needs of the electricity system from the perspective of the system planner and operator and illustrate the critical role that hydropower plays in addressing these needs. The whitepaper explores concepts such as electricity system frequency and inertia, power ramping and net demand variability, voltage and reactive power, grid ancillary services, and the ability to re-start the electricity grid in the event of a system collapse. The final section of this whitepaper uses some case studies from across Canada to further illustrate these concepts.

Hydropower, which has been a foundational technology in the development of Canada's electrical networks, will continue to play an important role in the pursuit of a "net-zero electricity" future. In some respects, hydropower is particularly well-suited to meeting future needs and as indicated in appended case studies, may even play a role in regional energy transformations provided that sufficient regional transmission infrastructure is available. Canada is endowed with ample hydropower resources, though they are dispersed throughout the country unevenly. Collectively maximising the use of this renewable, reliable, and flexible resource will require policymakers, system planners and operators, and participants in the electricity industry to jointly foster and maintain existing hydropower facilities within Canada and further develop additional resources. A prime consideration for utilization of hydropower as a continuing grid service is to ensure social acceptability for future development by engagement with Indigenous communities through the process of consultation and leading to potential partnership opportunities.

This whitepaper will highlight the considerations necessary to ensure that the effectiveness of the essential benefits provided by hydropower to the electricity grid continue, which in turn will ensure Canada is well positioned to leverage its hydropower resources and expertise into a new era of electricity generation and use.

> *"…fast responding power output, high inertia, the capability to store energy, and emissions-free production are amongst the features that make hydropower stand out…"*

1. DEFINITIONS

Ancillary Services: services used to help ensure the reliable operation of the power system. Ancillary services make up a relatively small component of all power system costs but are a critical part of the overall power system. Examples of ancillary services include: certified black start facilities; regulation service; operating reserve; load-shedding service; reactive support and voltage control service; and reliability must-run generation.

Black Start: a black start is the process of restoring an electric power station or a part of an electricity grid to operation without relying on the external electric power transmission network to recover from a total or partial shutdown.

Contingency: the loss or failure of a component of the power system (e.g., a transmission line), or the loss/failure of individual equipment such as a generator or transformer.

Dispatchable Resources: consist of energy-producing resources where the fuel input is known and thus, the output is relatively stable and secure, and holds the ability to be set at a desired power output (e.g., hydropower, nuclear, natural gas, coal, etc.).

Non-Dispatchable Resources: consist of energy-producing resources where the fuel input is variable and thus, the output is subject to variability (e.g., wind, solar, etc.).

Electrical Power: the rate of delivery of electrical energy (measured in watts or millions of watts (MW)).

Electrical Energy: the energy that a power plant generates (measured in millions of watt-hours, MWh) and that a customer consumes (measured in thousands of watt-hours, kWh).

Electricity System: consists of all the elements needed to produce, transmit, and distribute power to end-use consumers. This includes, but is not limited to, generators, elements of the transmission and distribution system, and substation components.

Energy Storage: the capture of energy produced at one time for use at a later time to reduce imbalances between energy demand and energy production. Examples of energy storage include: batteries; pumped storage hydro; compressed air; hydrogen; and fly wheel.

Long Term Energy Storage: means shifting the storage time between charging and discharging by weeks or seasons and can be accomplished by storing water in reservoirs, lakes or forebays.

Frequency: the rate at which electrical current changes direction, measured in oscillations per second or hertz (Hz). The target frequency for electricity systems in North America is 60 Hz.

Generator: an electro-mechanical machine that converts mechanical energy (typically steam, water, combusted gas, wind) into electric energy.

Greenhouse Gases (GHG): emissions that are produced when hydrocarbons, such as natural gas and oil, are burned. GHGs include carbon dioxide (CO_2), methane, nitrous oxide, and fluorinated gases, all of which contribute to climate change.

Inertia: the tendency for a body in motion to continue in motion. In power systems, energy is stored in rotating generators and motors and when there is loss of energy supply due to a contingency and the power system frequency declines, inertial energy is released providing a temporary power source. This temporary response – which is strongest from large rotating equipment (e.g., hydro generators or synchronous condensers) – is critical to support the power system until other generators are able to detect and respond to the failure.

Inverter-Based Resources (IBR): variable energy resources (wind turbines, solar panels) that are used to produce electrical energy from wind or sunlight using a solid-state inverter.

Net-Zero Emissions: an economy that either emits no GHG emissions or offsets its emissions (e.g., through actions such as tree planting or employing technologies that can capture carbon before it is released into the air).

Voltage: the pressure in an electrical circuit to cause energy to flow (measured in volts and thousands of volts, kV).

2. INTRODUCTION

Canada's electricity grid is undergoing a transformation driven by a shifting landscape in technology, environmental policy, and the evolving needs of electricity consumers. The electricity industry has always been dynamic, but the pace of change is accelerating, new forms of variable renewable energy sources (wind and solar generation) are penetrating power markets at a pace unseen before, and the role of electricity in the "net-zero" economy will increase sharply if Canada is serious about its 2050 climate change target. To address the adverse impacts of carbon emissions, the federal government of Canada has begun to implement ambitious policies to arrive at an electricity sector with "net-zero" emission of GHG[i], which by clarification may include some low-emitting resources that are offset by other actions, by 2035. The result is electricity generation moving away from coal and natural gas as fuel sources towards electricity produced from renewable sources and clean fuels. In addition, electrification of sectors such as vehicle transportation, space heating and cooling, manufacturing, and the production of clean fuels (such as hydrogen) will serve to accelerate growth in electricity demand and change the way electricity is presently used nation-wide. For the electricity industry these goals represent a compounded challenge – electricity production is changing and the demands on the grid are growing.

Canada is rich in renewable energy sources and has a long history of using renewable energy, especially hydropower, to produce electricity. The energy transformation outlined above is an opportunity for Canada to leverage its existing sources of renewable energy and develop new forms of clean, non-emitting electricity. This future also presents opportunities and challenge for electricity planners, grid operators, and markets across the country to ensure that Canadians have access to a reliable and cost-effective electricity system as we undergo this energy transformation.

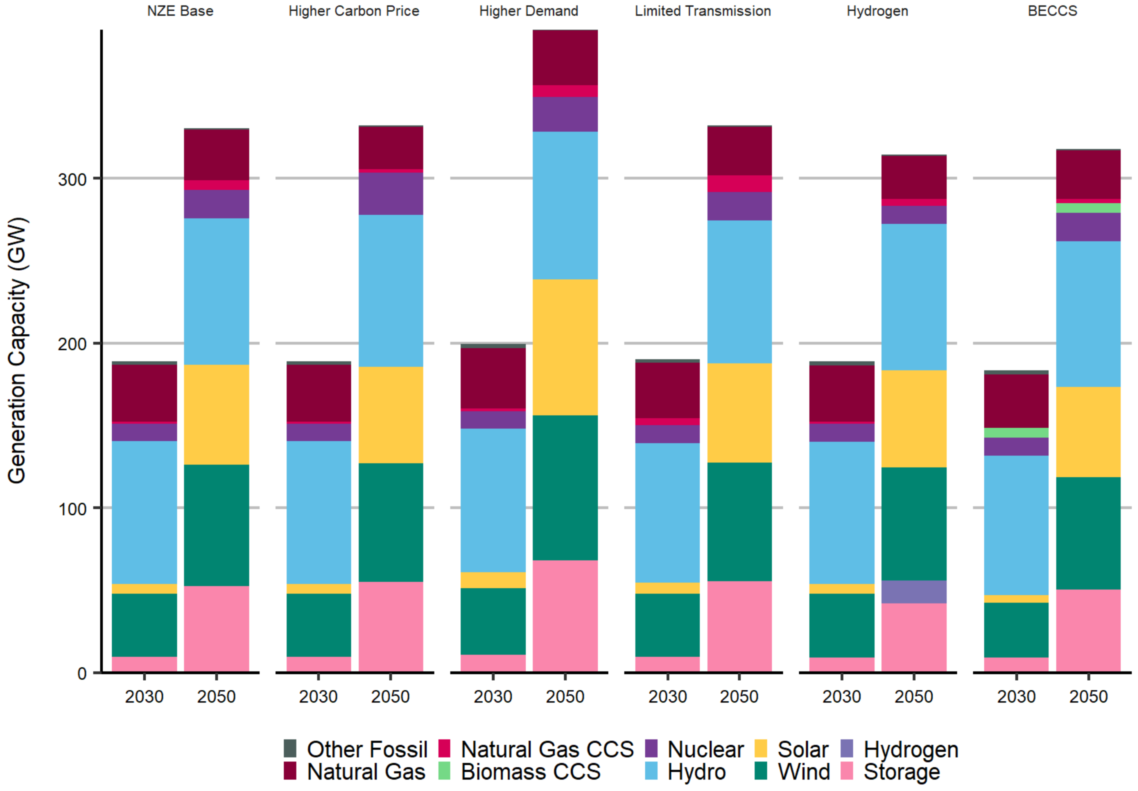


Figure 1: Forecast installed generation capacity in Canada (2030 and 2050) under various net-zero electricity scenarios. Source: CER[ii]

This paper focuses on the essential grid services that hydropower provides and the importance of these services in ensuring system reliability. From the generation perspective, maintaining electricity system reliability comes down to two operating principles: 1) ensuring that the electricity system balances supply and demand, such that adequate generation can be routed to load centres as required; and 2) recovering quickly from a major contingency that impacts supply and/or demand.

An electricity system operator (e.g., utility or a system operator administering a wholesale market) not only requires the ability to call upon a pool of generation to provide the energy that load demands, but also to dispatch an array of services (traditionally called ancillary services and referred to in this report as "essential grid services") that are necessary for the transmission grid to deliver such energy.

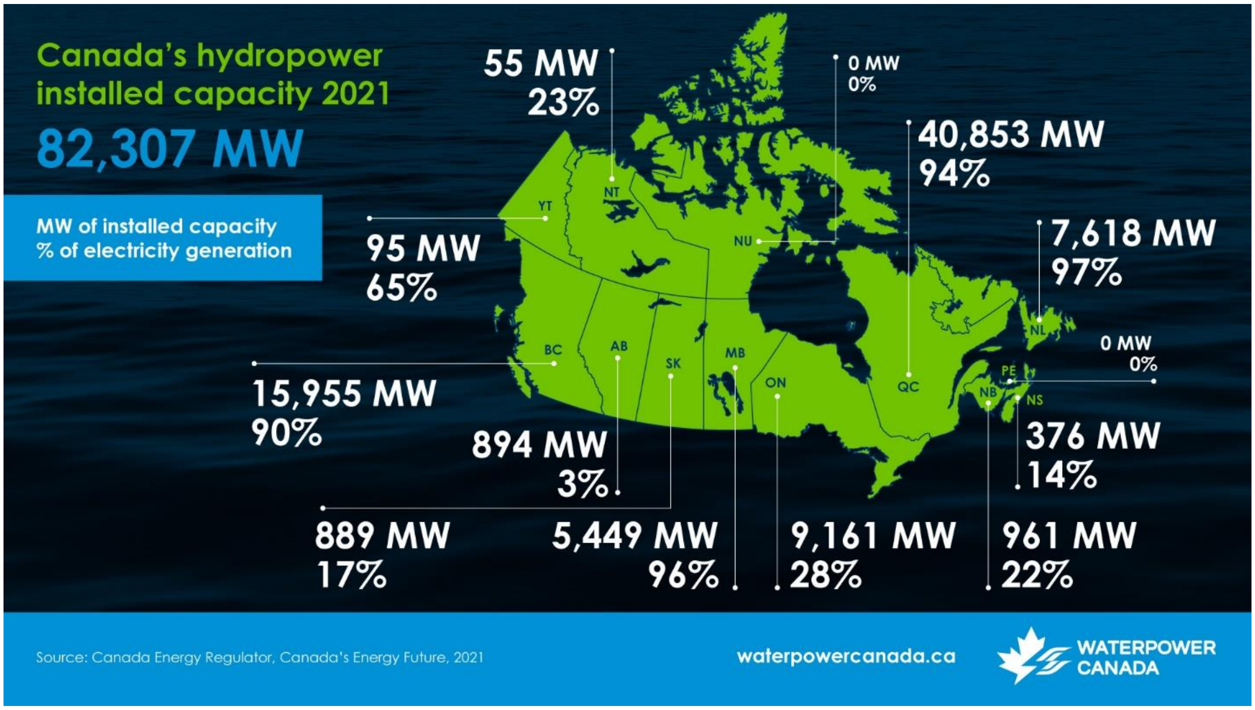
Essential grid services are "essential" to ensuring that loads can be adequately supplied without interruption and their importance will be amplified as the grid moves towards meeting net-zero targets. Consumers consider electricity to be a 'non-negotiable' energy supply resource that is available on demand without interruption. As electrification of sectors advance, this expectation from electricity consumers will only be reinforced.

Historically many essential grid services offered by hydropower units have been intrinsic to the generation, transmission, and distribution equipment of the electrical grid, built-in as part of the design and function of these components. In many electricity systems, system operators secure numerous essential grid services without a market to price and procure them. Hence, their value is not readily apparent. As the electricity grid continues to evolve with deployment of new sources of generation and electrification of new sectors, policymakers and system planners need to determine how best to maintain and manage essential grid services.

"Canada is rich in renewable energy sources and has a long history of using renewable energy, especially hydropower, to produce electricity."

3. HYDROPOWER IN CANADA

Hydropower has been used to produce electricity across Canada since the late 19th century. In the early days of hydropower production, power grids that spanned the country were not in place as they are today. Rather, generators supplied localized grids in electrical islands across the country. In the last 100 years, hydropower has grown to become the majority source of electrical power for the country, accounting for approximately 60% of all electricity generated domestically. Canada has also established itself worldwide as a source of expertise in hydropower development, engineering, and operations. Hydropower has provided and continues to provide Canadians with reliable electric power and a source of energy that many Canadian provinces produce and export. Though Canada has an abundance of hydropower resources, development and use of hydropower is dispersed throughout the country, with the provinces of British Columbia, Manitoba, Québec, and Newfoundland and Labrador producing their electricity almost exclusively with hydropower. The following diagram[iii] illustrates the installed generation capacity of hydropower resources by province throughout the country; it demonstrates the concentration of existing hydropower resources in specific provinces.



Source: Canada Energy Regulator, Canada's Energy Future, 2021

Figure 2: Map of Canada showing the installed hydropower capacity of each province as well as the percentage of installed capacity in each province that is hydropower generation.

Source: WaterPower Canada

In Canada, much of our hydroelectricity is produced when water is stored in a reservoir behind a dam. The "potential energy" of this water is converted to kinetic energy when it flows upon release from the reservoir into the penstock and is channelled downward past a turbine causing it to spin and rotate a shaft interconnected to a generator. "Run-of-river" hydropower is also common where water from a river simply flows directly into the penstock where it produces electricity, again in the same manner. "Pumped storage" is another type of hydropower. At pumped storage facilities, water is pumped up to an elevated reservoir for temporary storage. When electricity generation is required, the water is released to produce electricity in a manner similarly to traditional reservoir hydropower. “Hydrokinetic” is a less common approach in which a turbine is placed in a riverbed or tidal area to directly capture and convert the energy in the water flow. The most obvious role of generators is to produce power to match energy demand by electricity consumers to ensure continuous steady supply. However, hydropower is also an established provider of essential grid services.

This paper will outline the many benefits, in terms of grid services, that hydropower provides to the complicated task of maintaining balance on the electricity system.

A hydropower turbine being serviced. This turbine is driven by a volume of water which can be adjusted relatively quickly, making it suitable for providing certain grid services.

4. KEY GRID SERVICES

4.1 Realities of Reliable and Resilient Grid Operations: Now and into the Future

This section describes and explains:

- Synchronization and Frequency;
- Frequency Support;
- System Ramping for Contingency and Net Demand Variability;
- Voltage and Reactive Power; and
- Black Start

Synchronization and Frequency

The North American electrical system runs at a system frequency of 60 Hz (cycles per second). To achieve this, every generator connected to the electrical system must be spinning in unison, a concept referred to as synchronization. Any deviation in frequency originating in one part of the system ripples to all other parts of the system. The job of maintaining system frequency mainly falls to electric generators by moderating power output to help the entire electrical system to either speed up or slow down to achieve 60 Hz.

Frequency Support

Whenever there is inadequate generation to supply load demand, generators start to slow down (i.e., frequency declines). If the imbalance is not large, generation output is adjusted over a period of minutes to restore frequency. However, if a contingency results in a sudden and large energy imbalance, such as when a large generator trips offline, the frequency decline can be so large and rapid as to put the grid at risk. When this happens, the energy stored in the inertia of generators helps to provide critical support until generator output can be adjusted to correct the energy imbalance.

When a generator trip occurs and frequency falls below 60 Hz, system inertia will determine how much the frequency initially declines. During this period, generators must also increase power output to assist in recovering system frequency back to 60 Hz. Most generators contribute to the frequency recovery via a mechanism called ‘governor action’. Governors are devices that measure frequency and control the speed and output of a generator, typically by controlling fuel input to turbines that power these generators. Though most generators have governors, the amount and accessibility of power that is immediately available differs across generators, mainly determined by the type of generator and its source of energy and the settings of the governor.

Figure 3 depicts system-wide frequency upon experiencing a typical disturbance event such as the sudden loss of a large generator. The system typically experiences a rapid frequency decline (arresting period), a partial recovery of the frequency due to the automatic local action of generators responding to the frequency decline (rebound period), and a full recovery of frequency due to generators responding to new dispatch directions initiated to re-balance the grid and system frequency at 60 Hz.

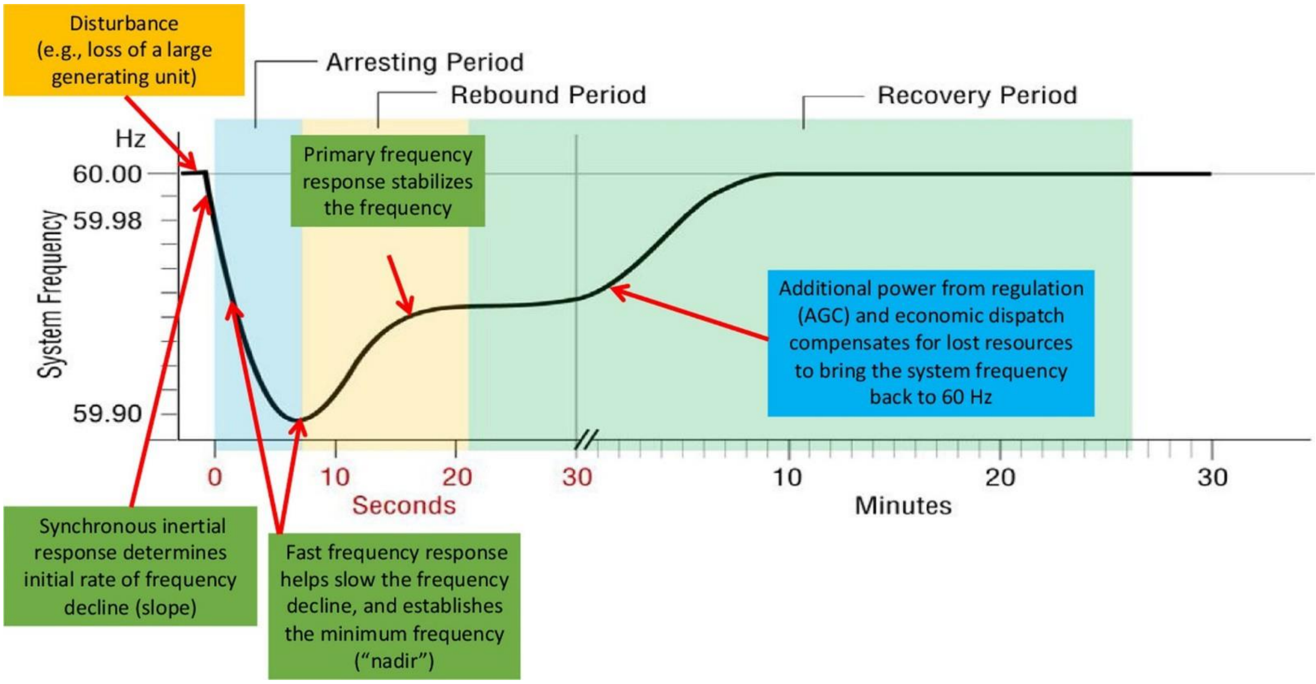


Figure 3: System-wide frequency during a significant frequency impacting event.

Source: The Electricity Journal[iv]

System inertia will determine the inherent frequency stability of a system; the more inertia, or spinning mass, on an electric system, the less that frequency is subject to deviation upon experiencing a system contingency. Hydro turbines and generators tend to be much larger and heavier than other generation technologies and thus can play an important role in the frequency stability of the grid.

Beyond providing intrinsic inertia, hydropower is also a high-quality resource in providing frequency response. Recall from the previous section that frequency deviation (or how far frequency falls) is mainly a function of inertia; however, frequency response (or how well frequency recovers after an adverse event), especially the immediate response of the system, is a function of governor action. The majority of the large hydropower generators have governors to control speed and frequency by altering the water flow that reaches the turbine. However, not all governors provide equal response to frequency deviations. The highest quality frequency response is both ample (able to provide large output changes), fast, and sustained. Many grid resources face trade-offs between these three qualities. Hydropower resources are highly capable of providing all three – particularly where water is readily available from the reservoir storage, as is often the case with large hydro projects.

“Hydro turbines and generators tend to be much larger and heavier than other generation technologies and thus can play an important role in the frequency stability of the grid.”

System Ramping for Contingency and Net Demand Variability

Key to maintaining electricity system reliability is balancing supply and demand. Imbalances can arise from perturbations in electrical supply or demand. Contingencies involving the loss of generators or transmission to deliver energy can, as discussed above, require rapid responses to restore balance. “Contingency Reserve” is a grid service in which generators are selected to respond quickly and for prolonged periods when called upon by system operators. Hydropower generators are well-suited to this task because they can respond with additional output much faster than many other generation technologies, and to the extent that they have reservoir storage, continue to do so for prolonged periods.

Load variability is increasingly being called “net demand variability” recognizing that the effects of fluctuations in the sun shining on solar panels and the wind blowing at wind farms appear to grid operators as increased load variability.

In addition to system ramping to address contingency response, balancing the system through normal peaks and valleys throughout the typical load day is carried out by dispatching resources to meet the projected load profile. Certain types of variable renewable resources, namely wind and solar, are sometimes categorized as non-dispatchable resources since their fuel source can be significantly variable during periods when the wind ceases to blow, or the sun is clouded over or darkened. These non-dispatchable energy sources serve to delivery energy to the grid, but their reliability for constant steady supply of energy can be questionable at times. Hydropower is one source of energy that is dispatchable and can be relied upon to deliver energy in the amount required, when called upon to do so. Hydropower is dispatchable by virtue of having a steady and reliable fuel source available. Hydropower facilities with large storage reservoirs are also able to participate in longer term dispatch processes that address daily, weekly, and seasonal demand fluctuations.

Hydropower resources are fast responding and flexible, meaning that they can provide large portions of their operating range in a very short time period and move power output continuously within this range, all without undue wear on components. For this reason, hydropower resources are ideal for addressing net demand variability and system conditions that require fast ramping (such as contingencies).

Historically, the dynamic that system operators faced when balancing supply and demand was dominated by the daily pattern of electricity demand. Demand patterns follow a relatively predictable profile, varying most often by day of the week (weekday vs. weekend) and time of year (winter profiles look different than summer profiles). This simplifies scheduling and dispatching generating units.

The future electrical system configurations bring new challenges to maintaining supply and demand balance. For example, wind and solar generation continues to be developed across Canada based on the declining costs of these supply resources, growing demand for these resources from customers, and goals and objectives to decarbonize the power system towards meeting net-zero targets. To ensure that the supply/demand balance and resultant frequency remain stable, supply resources such as hydropower generation will be increasingly needed to manage the power system to ensure reliability. Hydropower generators are well positioned to provide supply and flexibility required for system ramping, resulting from changes to demand and integration of wind and solar generation.

“Hydropower resources are fast responding and flexible…”

Voltage and Reactive Power

Balancing MWs and system frequency are not the only components of reliable grid operations. Another critical consideration faced during real-time operations is maintaining acceptable voltage levels and provision of reactive power. Electrical system voltage can be thought of as the magnetic pressure that enables the flow of useable power (MWs) on the grid. Voltage is supported and maintained by reactive power. More MWs flowing on a transmission or distribution line requires more reactive power to support that power flow. Large and high-capacity hydropower generators inherently have a high operating capability for supplying reactive power. By affording dynamic reactive reserve, they provide high short circuit capability which helps a power system recover from disturbances that depress voltages. Energy sources that are unable to supply adequate short circuit capability are less able to support recovery from disturbances.

Dynamic reactive capability is also essential for voltage stability of power systems. As the resource mix and demand patterns continue to change, energy flows on the transmission system can vary greatly from moment to moment, requiring activation of dynamic reactive reserves. IBR resources can be designed with controls that respond to dynamic reactive power needs; however, their capability will always be limited by the availability of the driving resource (wind, solar). Large energy storage resources (e.g., battery storage) connected via inverters equipped with the appropriate controls could also provide a reliable supply of dynamic reactive supply but that would require an additional investment.

Black Start Service

As the previous material in this section has illustrated, grid reliability and stability rely on electricity system components to function well within tight parameters. Allowing operation too far outside these parameters means that the electricity system risks destabilizing, and in extreme circumstances collapsing. While the total collapse of large portions of the grid is rare, the ability of generators to support recovery from a power system shutdown without relying on other generators is a valuable grid service. This service is commonly referred to as "black start" capability. Every system operator in North America has in place a black start plan, to lay out strategies and procedures to restart a grid upon complete electric system collapse. As a part of this plan, system planners must arrange to secure sufficient black start resources in any given jurisdiction. Hydropower generators play an extremely important role in provision of black start services. In many cases, these units meet all the desired attributes for provision of black start since their power source (water) is readily available, stations have low internal power requirements, restart is fast and simple, these units can operate efficiently, and they are resilient to wider swings in frequency that is typical during the early stages of system restoration, when frequency is unstable.

The need for black start capability was perhaps in greatest evidence following the 2003 Northeast blackout, where on August 14, 2003 upwards of 50 million people in Ontario and the northeastern United States experienced the largest power outage in the history of North America. After a detailed investigation, the causes for the blackout are now attributed to deficiencies in operations and procedures in the state of Ohio. As a result, a series of power swings ranging between 2,000 and 4,000 megawatts pulsed into Ontario's grid interconnections at Michigan and New York. In response, the northeastern United States power system, and portions of the Ontario power system began to shut down, interrupting 61,800 MW of load. Nearly all electricity service east of Wawa, Ontario was down. Small pockets of electricity service, tied to nearby hydropower generating stations, remained connected in Niagara and Cornwall. Restoration efforts continued for the better part of nine days until the state of emergency ended on August 22. Following the blackout, a joint Canadian-United States task force issued 46 recommendations, including that system operators review their black start and system restoration plans and procedures.[v]

“Hydropower generators play an extremely important role in provision of the black start services.”

4.2 Other Grid Services and Markets

In many cases, hydropower resources were constructed and operating in nascent electrical systems before they were fully interconnected with one another. System operators have often relied heavily upon hydropower resources to provide these essential services to support system operations, preserve transmission grid integrity or as a condition of interconnection operation between transmission networks. Although many ancillary products and grid services can be provided by a variety of generation types, the effectiveness of hydropower resources, with their fast and enduring response, high inertia and frequency responsiveness, and resiliency to weather and climate conditions makes it a favoured provider by system operators in any jurisdiction.

Inertia and frequency response from governor action (also called primary frequency response) have historically been an available component of hydropower generators, but one for which financial compensation has not taken place. As the energy transformation accelerates and traditional thermal generation sources that also often provided these capabilities retire, the availability of these services will become increasingly critical in nature.

Operating Reserves

Contingency reserves are one type of operating reserve and comprises generating capability held in reserve by system operators. In a market environment, providing operating reserves is typically a compensated service. These reserves must be available in a very short timeframe to make up for the loss of a major source of supply (such as the tripping of a large generator) or other system upset. Contingency reserves are often further divided into categories of spinning reserves – portions of an online generator (already spinning) that are held in reserve, and non-spinning or supplemental reserves from units not online but able to synchronize and provide power in a short timeframe.

Regulating reserve is another type of ancillary service that utilizes automatic generation control (AGC). This is a service that acts very much like cruise control on a motor vehicle whereby automatic signals are sent from a central control to any generators providing regulating reserve to increase or decrease their output according to the system needs. Regulating reserve acts as a first line of action for system operators when dispatching assets; it serves as the smallest initial adjustment to changes in net demand variability in the ongoing effort to ensure that supply exactly meets demand to maintain 60 Hz frequency. If a generation owner is providing AGC under a market agreement, it is likely that compensation is being paid for generator response to setpoint changes, as well as for having reserve capacity available to respond.

Together, contingency reserves and regulating reserves are called operating reserves. Hydropower resources are highly valued as providers of operating reserves because of their ability to provide large volumes of MW quickly. Hydropower resources can typically ramp up or down their entire operating range within 30 seconds. Another feature of hydropower resources that is increasingly valuable due to the increase in net demand variability is that relative to other

Role of Ancillary Services: Integrated Utilities and Deregulated Electricity Markets

Historically electricity was supplied from generators to end-use consumers by vertically integrated utilities. These utilities (either crown corporations or highly regulated private entities) planned, operated, and managed electrical grids at all stages from generation, through transmission and distribution, to end-use consumers (residential and industrial alike). In the integrated utility model, planners and operators build and use resources on the grid, such as generating stations and transmission equipment according to the technical needs of the system.

Faster ramping units will be used during steep ramp periods (such as the morning increase and evening decrease in electrical energy use) and slower ramping units will be used to serve “baseload” energy (the electrical demand that exists throughout day and evening). Resources with high inertia and frequency responsiveness will be kept online with spare capacity to ensure reliable operations under the most severe contingency.

Jurisdictions that have undergone deregulation in the last decades did so by separation from an integrated utility into components. Out of this came separate transmission and distribution companies, most of which remained regulated monopolies, and merchant generators that offered their priced commodity (MWh) into a wholesale electricity market. Competitive markets aimed to bring the least-cost generation online first through competitive pressure. Deregulated markets value the production of megawatts above all else and the services that are deemed essential to grid operation have been relegated to a by-product of these megawatts. Historically, there were sufficient by-product services available. This is changing and renewed attention is required to ensure an adequate level of ancillary services. are always available to support ongoing grid operation.

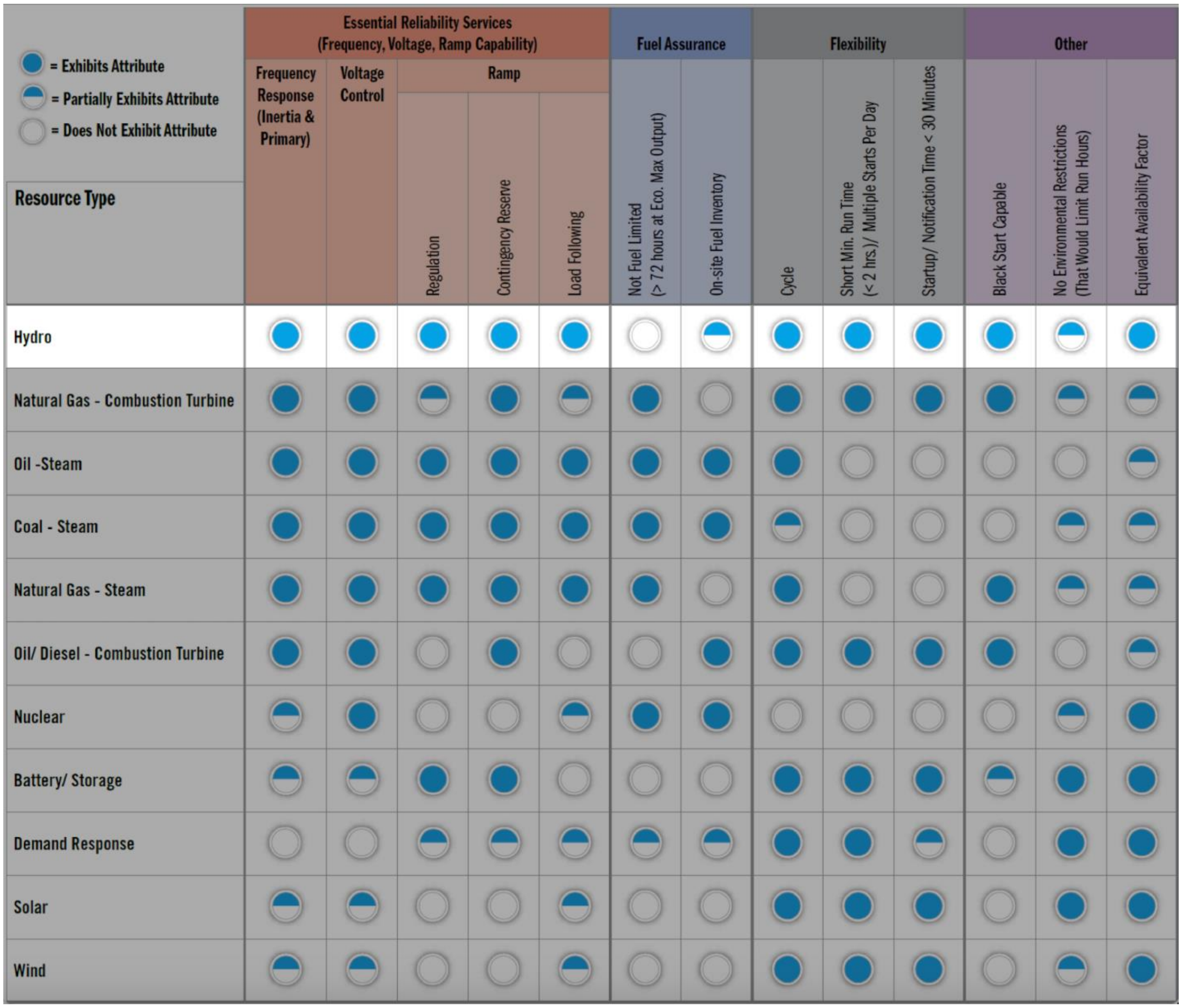
generation resources they do not suffer as much performance degradation from ramping up and down to produce energy and supply operating reserves.

In hydro-scarce jurisdictions, system operators have typically used their hydropower resources carefully, reserving them to provide the highest quality grid services including regulating reserve and contingency reserve. For example, in Alberta, where hydropower makes up 5% of total installed capacity, hydropower provides a disproportionately high volume of contingency reserve. In addition to providing additional power circuits from neighbouring regions to address the need for capacity support, energy market opportunities and promote the use of hydropower storage for long term and seasonal use, power system planners may also give heed to incorporating designs that allow these essential services afforded by hydropower facilities into hydro-scarce regions.

Ramping Reserve

Through the course of every day, load demands vary, sometime with significant variability between peaks and valleys. In the management of generating resources to meet these routine changes in load profiles, hydropower units are used and hold the advantage that they can be adjusted quickly and reliably to meet the desired objectives. With the increased prevalence of variable renewable energy sources, such as wind and solar power, comes the need for increased firm generation sources that can be provided by hydropower generators. In recent years, changes in net demand variability have prompted some system planners and operators in jurisdictions across North America to consider the introduction of new types of ancillary services (e.g., ramping reserves). Providers of ramping reserve will no doubt include hydropower resources.

> *“… the effectiveness of hydropower resources, with their fast and enduring response, high inertia and frequency responsiveness, and resiliency to weather and climate conditions makes it a favoured provider by system operators.”*



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○ = Does Not Exhibit Attribute

Resource Type	Essential Reliability Services (Frequency, Voltage, Ramp Capability)					Fuel Assurance		Flexibility			Other		
	Frequency Response (Inertia & Primary)	Voltage Control	Ramp										
			Regulation	Contingency Reserve	Load Following	Not Fuel Limited (> 72 hours at Eco. Max Output)	On-site Fuel Inventory	Cycle	Short Min. Run Time (< 2 hrs.)/ Multiple Starts Per Day	Startup/ Notification Time < 30 Minutes	Black Start Capable	No Environmental Restrictions (That Would Limit Run Hours)	Equivalent Availability Factor
Hydro	●	●	●	●	●	○	◒	●	●	●	●	◒	●
Natural Gas - Combustion Turbine	●	●	◒	●	◒	●	○	●	●	●	●	◒	◒
Oil -Steam	●	●	●	●	●	●	●	●	○	○	○	○	◒
Coal - Steam	●	●	●	●	●	●	●	◒	○	○	○	◒	◒
Natural Gas - Steam	●	●	●	●	●	●	○	●	○	○	●	◒	◒
Oil/ Diesel - Combustion Turbine	●	●	○	●	○	○	●	●	●	●	●	○	◒
Nuclear	◒	●	○	○	◒	●	●	○	○	○	○	◒	●
Battery/ Storage	◒	◒	●	●	○	○	○	●	●	●	◒	●	●
Demand Response	○	○	◒	◒	◒	◒	◒	●	●	◒	○	●	●
Solar	◒	◒	○	○	◒	○	○	●	●	●	○	●	●
Wind	◒	◒	○	○	◒	○	○	●	●	●	○	◒	●

Figure 4: Various types of generation compared by their ability to provide essential grid services[1].

Source: PJM Interconnection[vi].

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[1] Note that the fuel assurance of hydropower plants is greatly enhanced by reservoirs, which effectively provide storage capability for the plan. Such reservoirs can mean months of storage capacity, which, when released, is also cascaded to downstream plants that may have less in their own reservoirs but are guaranteed inflows from upstream reservoirs when water is released. Similarly, for a pumped storage facility, the fuel is also available on site.

5. CONCLUSION

Canada is undergoing an energy transformation toward a net-zero electricity grid supplying power to existing and new sectors. Wind and solar resources are quickly becoming an economical means of generating power and along with these new opportunities to develop a net-zero grid come new challenges to grid operations. Managing system inertia, frequency response, and system ramping have always been required and are changing resulting from integration of more variable renewable energy resources and embedded or distributed resources, along with an ever-increasing system load and changeable demand profile. In this transformed electricity grid, many sources of clean electricity need to pair with fast and flexible generation, a role where hydropower has performed admirably well in the past and is well suited for in the future.

In this transition, system operators will utilize more than ever, the essential grid services from hydropower generation. Hydropower’s ability to store large quantities of readily and quickly accessible power make it one of the highest quality sources of dispatchable power, able to meet the ramping requirements of the future. Inherent by design, the heavy components required to handle the volumes of moving water make hydropower an indispensable source of grid and frequency stability. Hydropower resources also operate at the high end of the reliability spectrum and are able to address power grid needs ranging from minor variations in energy demand or voltage support to large scale catastrophic events related to restoration of blacked-out power systems through the provision of black start capabilities.

Canada has a long history and a well-established base of expertise in the planning, development, and operation of hydropower resources. Though the country, in aggregate, is well-endowed with existing and potential hydropower resources, they are dispersed across the country unevenly and a plan to achieve a net-zero grid must also include the supporting infrastructure to seize the opportunity for hydropower resources to enable a reliable and clean grid across all of Canada. Providing certain grid services to hydropower-deficient areas from hydropower generation sources that are far away has challenges and cannot alone justify new interregional transmission lines. However, when combined with the opportunity to deliver additional capacity and energy, enabling the use of long term and seasonal storage, and the ability to provide grid stability, the benefits of access to hydropower and related grid services are far more advantageous.

Policymakers, in thinking about the near and longer term needs of the country’s electricity supply, could consider developing incentives or policies that will allow for the quicker buildout of hydropower. Given the unique and substantial grid benefits that hydropower provides, modification of market rules to better recognize the intrinsic value of hydropower will also be a welcome means of incentivizing development. It is also important to encourage more development of the transmission resources that are necessary for ensuring that the benefits of hydropower can be shared among the greatest number of the population, and to secure Increased recognition by Canada’s trading partners that hydropower is indeed a renewable resource. To tie this all together, Power Advisory recommends the development of a pan-Canadian blueprint setting out a shared hydropower strategy – developed collaboratively by the provinces, territories, and Federal government and accompanied by investment in public education to explain how hydropower contributes to Canada’s net-zero goals.

6. REFERENCES

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Image of IESO Control Room – Independent Electricity System Operator (cover page)

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APPENDIX 1: CASE STUDY – PRAIRIE DECARBONIZATION AND OPTIMIZING WESTERN HYDROPOWER

In Western Canada, the generation supply mix varies by province mainly due to hydrological and geological features. Hydropower resources are mainly located in the provinces of British Columbia and Manitoba, whereas the prairie provinces of Alberta and Saskatchewan utilize a much higher proportion of fossil-fuel in the form of coal and gas-fired generation. Alberta and Saskatchewan now face the challenge of decarbonizing their electrical systems to address climate change to meet both Federal and Provincial targets[2].

In the coming decades, the decarbonization of the prairie provinces will result in a dramatic shift in the electricity supply mix of Western Canada. Alberta and Saskatchewan will transform their grids from being primarily supplied by coal and gas to being heavily supplied by wind and solar, with gas playing more of a supporting role[3]. British Columbia and Manitoba, which are served almost exclusively with hydropower generation, will also see an increasing share of wind and solar generation added to their energy supply mix. In these latter provinces, hydropower generation and its value as a provider of energy and essential grid services is well established and expected to continue.

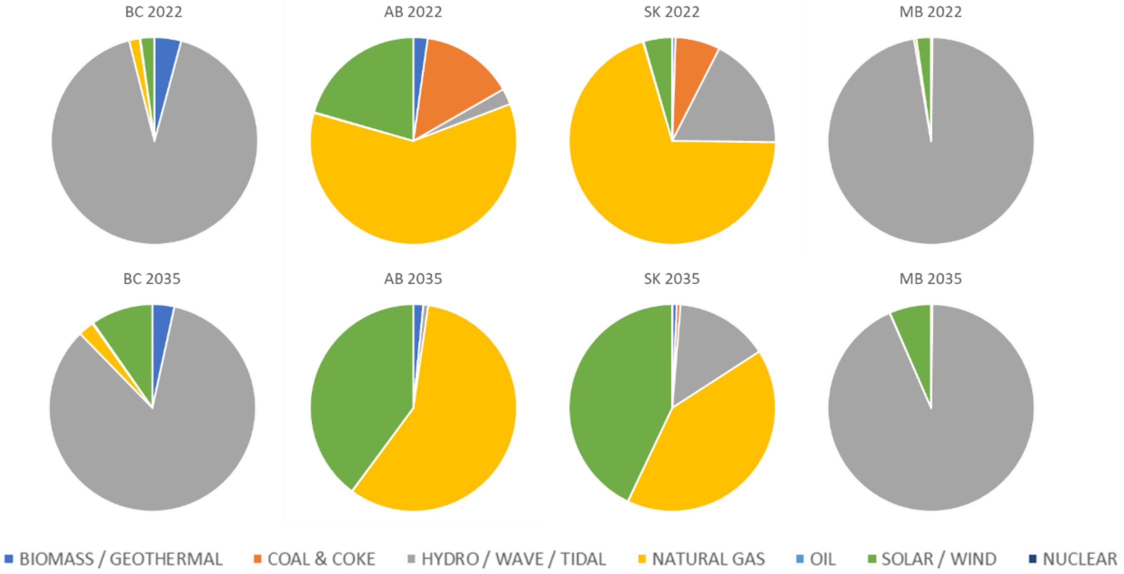

Figure 5: Total electricity production by generation source in 2022 & 2035 (forecast – Evolving Policies

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[2] The Canadian Federal Government has released a discussion paper on its Clean Electricity Standard laying out its goals for a nation-wide emissions-free electricity grid by 2035. The Province of Saskatchewan has in place its Prairie Resilience Climate Change Strategy that sets out targets to produce 50% of its electricity from renewable sources by 2030. In Alberta, the Alberta Electric System Operator is undergoing studies to assess pathways to a net-zero grid.

[3] To meet increasingly stringent emissions standards, future gas-fired generation will likely need to be paired with carbon-capture technology. However, the application of large-scale carbon capture is still in development and its commercial viability for grid-scale power generation is uncertain. Hydropower generation and its value as a provider of energy and essential grid services is already well established.

scenario), by western province. Source: CER[vii]

For Alberta and Saskatchewan, development of wind and solar generation will bring further challenges to operating an electrical system with much higher net demand variability, declining frequency responsiveness and loss of inertia resulting from replacing fossil-fuel generation with wind and solar[4]. In this grid transformation, there is an opportunity for Western Canadian provinces to cooperate in planning a coordinated approach to meeting future needs. By collaboration in the further development of transmission assets for capacity and energy transactions, the ability to also deploy and utilize hydropower-related grid services becomes available.

As Alberta and Saskatchewan undergo rapid decarbonization and bring significantly greater volumes of variable renewable energy resources online, optimizing the future development and use of hydropower resources from both their eastern and western neighbours and enabling flow of electricity to and from provinces is needed. From the perspective of an electrical system, power flows across provincial boundaries as easily as within provinces. As long as the transmission components on the interconnected grid are in-service, the transmission networks in each province will not only mutually support each other with inertia, frequency support, and balancing of generation supply, but also have the potential to result in significant GHG reductions. In western Canada, specifically between British Columbia and Alberta[5] and between Manitoba and Saskatchewan[6], additional interprovincial transmission infrastructure has the capability to economically reduce GHG emissions, as well as provided economic benefits.

To enable this future to be realized, system planners and policy makers must begin to consider reinforcing hydropower resources and supporting transmission infrastructure throughout Western Canada to enable rapid decarbonization, maintain reliable system operations, and ensure grid resiliency across geographically separated systems as a means to manage weather related renewable resource variability[7].

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[4] The Alberta Electric System Operator has begun investigating the declining frequency responsiveness of its system as a result of experiencing declining frequency stability on its system.

[5] The Natural Resources Canada (NRCan)-funded Western Regional Electricity Cooperation and Strategic Infrastructure (RECSI) Study (final report August 16, 2018) https://www.aeso.ca/assets/Uploads/RECSI-Western-Final-GE-Report.pdf

[6] The NRCan-funded SaskPower-Manitoba Hydro Regional Coordination Study (final report 2021) which considered the 2028 to 2049 time horizon concluded that an additional 500 MW of interprovincial transmission capacity would have significant environmental (~40 mTonne GHG) and economic benefits (exceeding $1 billion NPV). https://natural-resources.canada.ca/sites/www.nrcan.gc.ca/files/energy/clean/RECSI_WR-SPM_eng.pdf

[7] The North American Renewable Integration Study (NARIS), an international study conducted by National Renewable Energy Laboratory and funded by the U.S. DOE and NRCan emphasized the value of Inter-regional transmission expansion ($60 billion- $180 billion international grid benefits through 2050 in high renewable scenarios. https://www.nrel.gov/docs/fy21osti/79224.pdf

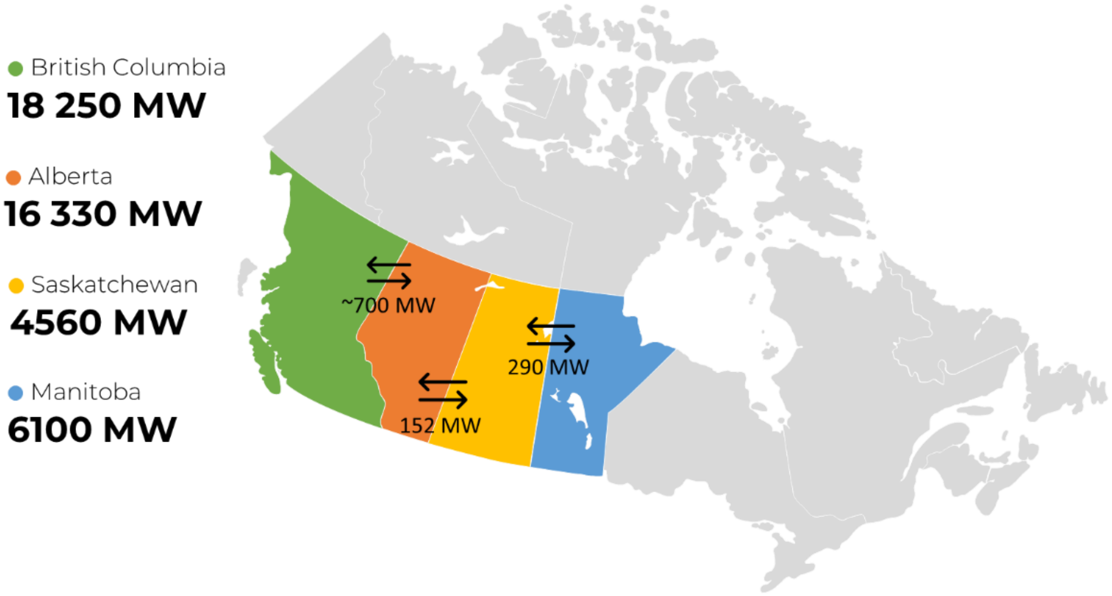


Figure 6: Western Canadian Grids: Total Generating Capacity and Inter-Provincial Transfer Capabilities.

Hydropower pairs extraordinarily well with variable renewable generation; when the wind is blowing and sun is shining, hydropower can run at reduced flow or “pond” its water supply and, in turn, supply the grid during periods of low wind and solar generation. Pairing hydropower with variable renewable generation allows system operators to optimize the use of both resources – hydropower resources can provide high-quality essential grid services while wind and solar generation can supply low-cost energy production. Reinforcing the principles of system integration and improving transmission connections between neighbouring Western Canadian provinces can enable a net-zero electricity system across all of Western Canada while ensuring a reliable and resilient grid.

APPENDIX 2: CASE STUDY – THE BENEFITS OF SECURE ENERGY STORAGE

In a similar manner to electricity grids across the country, Ontario will experience both increased electricity demand combined with an anticipated influx of emission-free generation based on forecast supply needs. While Ontario has not set net-zero targets, the Ontario Minister of Energy directed the Independent Electricity System Operator (IESO) in late 2021 to report back on a pathway to decarbonize Ontario's power system and a potential moratorium on building new gas-fired generation. By 2035, Ontario could have up to 6,700 MW of wind generation and 7,200 MW of solar generation capacity[viii] on an electricity system with peak demands of up to 27,800 MW[ix]. Energy storage will play a significant role in offsetting the impact that these resources will have on net demand variability. Ontario is also moving towards procuring additional baseload nuclear energy in the form of Small Modular Reactors and studying the potential for adding conventional additional hydroelectric capacity, both of which can be balanced against daily demand cycles with energy storage.

The integration of energy storage resources of all types has given system operators a tool to address the challenge of optimizing energy production and increasingly diverse resource mix to meet demand from electricity consumers during all hours. Hydropower resources are well suited to meeting demand when wind is calm, and the sun is not shining.

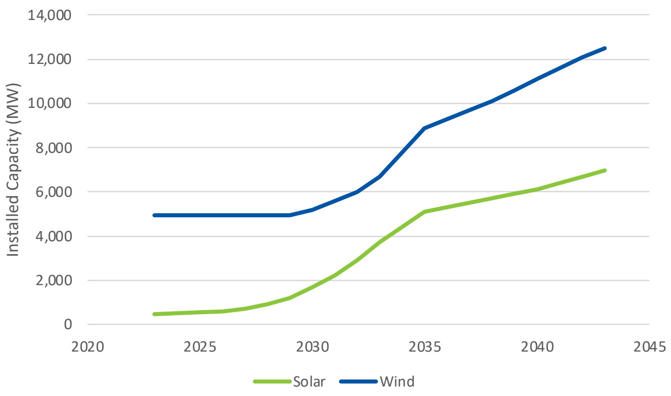
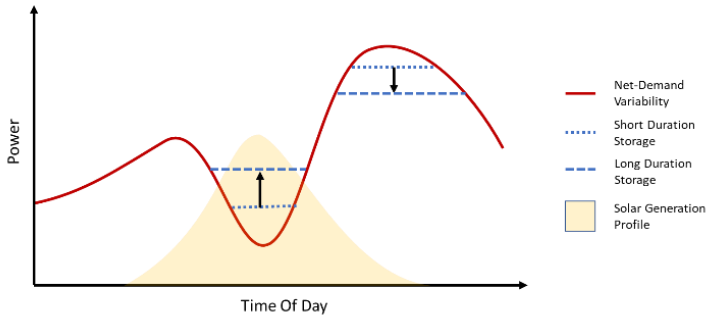


Figure 7: Projected Installed Capacity of Wind and Solar in Ontario, 2023 - 2043

Source: Power Advisory Ontario Forecast, April 2023

Energy storage resources can charge during periods of high renewable output from wind and solar and discharge at a later time whenever electricity is most needed. This can help "smooth" the output from renewable resources and ease the burden to build dispatchable and potentially high-emitting generation to meet system peaks. Pumped hydro storage is one of many types of energy storage (other examples are lithium-ion batteries, compressed air energy storage, etc.). All storage resources can assist in "shaving" peak demand but pumped hydro provides additional and unique benefits. For example, because of its relatively greater energy storage capacity, pumped storage is very aligned with enabling emission-free baseload energy supply (e.g., from nuclear generators) to be available to meet Ontario's demand requirements. This is especially important considering Ontario's significant supply of nuclear generation capacity.

Long duration and large capacity – all types of energy storage resources have limitations on how much energy they can store, and the limitation is directly related to the duration of time they are able to both charge and discharge. Pumped storage hydro typically provides multi-hour storage which may be suitable in offsetting variable generation in a daily timeframe.

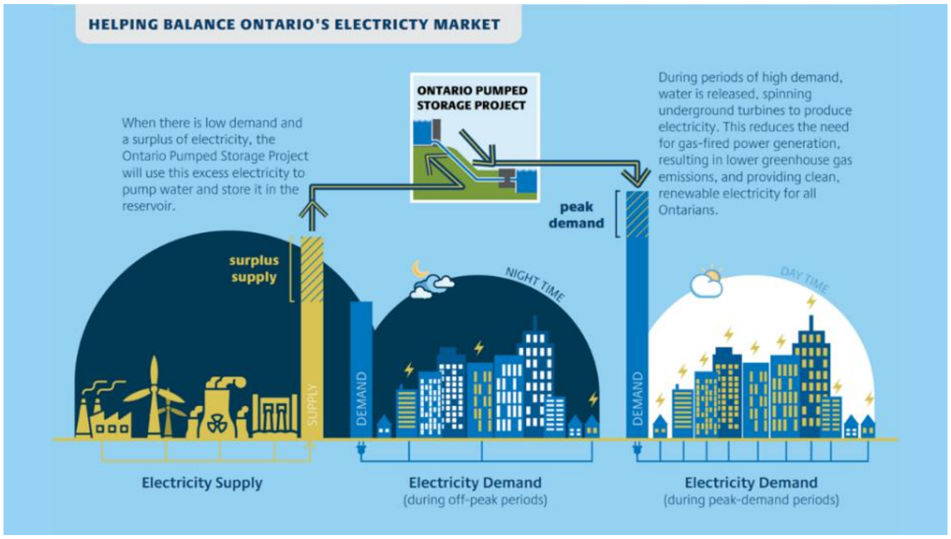


Low-cost and low-wear cycling – cycling (recharging and discharging) of energy storage resources stresses and degrades components, though the cost and impact of cycling varies across different types of energy storage. Although the impact of deep discharge and recharge cycling on the rate of degradation of battery energy storage systems is not well established, this cyclic action can precipitate especially high wear on components making it challenging for these technologies to provide some essential grid services such as regulating reserve[8]. Pumped hydro energy storage incurs less degradation than alternatives and units can cycle repeatedly and quickly with less incremental impact resulting in less frequent maintenance overhauls and component replacements.

Other benefits of pumped hydro storage include the ease of producing and acquiring critical components. Many components of pumped hydro storage resources are produced and distributed domestically or in North America. They are less sensitive to supply chain disruptions and are subject to less risk of securing components to maintain constant reliable operation. Human expertise on design, operations and maintenance of pumped hydro storage carries over from the traditional hydropower sector, where Canada has a strong legacy and skillset throughout the country.

One such project under consideration by TC Energy in Ontario is a large-scale hydropower pumped storage project at the 4th Canadian Division Training Center in Meaford, Ontario (the "Meaford Project"). The Meaford Project is an "open-loop" pumped storage hydropower facility that uses the natural lower reservoir of Georgian Bay[9] and constructed upper reservoir of approximate surface area of 375 acres and depth of 20 meters.

Figure 8: TC Energy's Proposed Pumped Storage Project. Source: TC Energy



The Meaford Project is designed to draw up to 1,000 MW for pumping and to provide 1,000 MW of firm generation capacity for 8 hours, or 8,000 MWh of energy storage. By operating in tandem with other grid-connected renewable resources, the project is expected to mitigate 490,000 tonnes of GHG emissions per year or the equivalent of 150,000 internal combustion cars taken off the road.

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[8] System operators are beginning to experiment with more sophisticated approaches to dispatching and utilizing energy storage that may minimize cycling costs.

[9] The lower inlet / outlet will be offshore, in deep water, to avoid sensitive near-shore aquatic habitat. The tailraces will be tunneled underground, and under the lake bed, connecting the powerhouse to the inlet/outlet.

By capturing excess power that would otherwise be wasted, and releasing it when needed at peak times, the Meaford Project would enhance the efficiency, flexibility, reliability, and security of the Ontario electricity supply system. It would also provide back-up power during grid disruptions and better integrate other power generation resources in the province. While true that disruptions of an extended duration could also over-use pumped storage hydro resources, the long-term capacity and energy available through these type of resources are more favourably positioned to address the longer periods of inconsistency. Collectively the Meaford Project will reduce costs of electricity for Ontario consumers by an estimated $23.1 billion over 40 years; with the project costing around $11 billion, this means that Ontario consumers would enjoy a net benefit of $12.1 billion – or over $250 million a year for 40 years[x].

Projects, similar to the Meaford Project, further build on Canada's hydropower industry heritage by adding innovative technology and approaches that can then be exported to the world. Relying on Canadian expertise in the engineering design, construction, and operation of large hydro projects, the Meaford Project offers an opportunity to extend that knowledge to large scale, state of the art pumped storage hydro project. This can lead to off-shore opportunities across the globe and highlight world class Canadian hydro knowledge to aid developing countries address decarbonization challenges and create jobs domestically.

APPENDIX 3: CASE STUDY – HYDROPOWER ENABLING AN ENERGY TRANSFORMATION FOR QUÉBEC AND ITS NEIGHBOURS

After many decades of implementing a long-term view of development and investment in hydropower resources and supporting transmission infrastructure, the province of Québec finds itself well positioned to meet the challenges of the electricity and energy transformation and support its neighbours in Ontario, Atlantic Canada, New York and New England to do the same. Hydro-Québec, the sole system planner, major hydropower provider, and system operator in Québec, is responsible for the planning, maintenance, and operation of its vast fleet of hydropower resources. Comprising 63 hydroelectric generating stations[10] with a total installed capacity of nearly 37,000 GW, Hydro-Québec's generation assets also include 29 large reservoirs with a combined storage capacity of over 178 TWh, as well as 684 dams and 92 control structures.

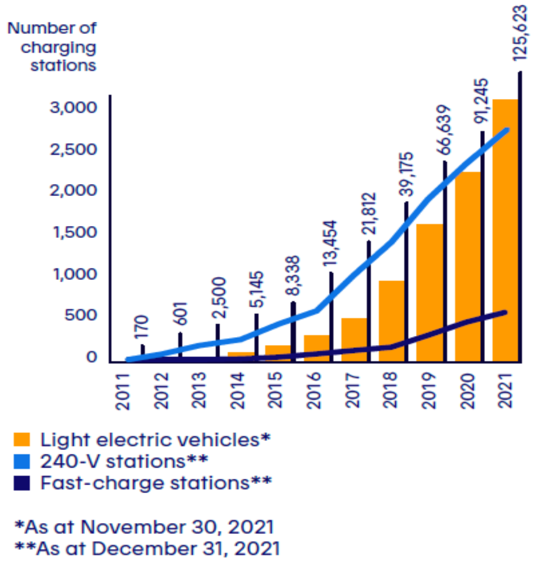

Figure 9 – Historical Trend in Vehicle Charging Stations in Québec. Source: Hydro-Québec 2022 Strategic Plan[xi].

Common to the other hydro-rich jurisdictions of Canada, Hydro-Québec plays a vital role in supporting its neighbours in supplying both capacity and energy[11]. This includes both other Canadian provinces and United States neighbours. The demand for Québec's hydropower resources and the essential grid services that it provides is growing. Refurbishing and retrofitting Hydro-Québec's resources as necessary, in addition to potentially building new large-scale hydropower facilities, will not only serve Québec but will also supply the entire region.

Québec's hydropower resources enable the province to address multiple dimensions of an energy transformation including integrating variable renewable generation sources, addressing the electrification of new sectors[12], and decentralizing electricity – all while maintaining confidence the system can continue to be operated reliably. In addition,

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[10] As well as 25 thermal plants with total installed capacity of 542 MW. https://www.hydroquebec.com/about/strategic-plan.html

[11] Support to neighbouring jurisdictions from hydro-rich provinces requires adequate electricity transmission. Québec operated 15 interconnections to the Ontario, New Brunswick, New York, and New England markets. https://www.hydroquebec.com/clean-energy-provider/

[12] The Government of Québec is mandating Hydro-Québec to increase the number of fast-charge stations to 2,500 by 2030, in line with the target of having 1.5 million electric vehicles on the roads by that time. The network of standard charging stations will also be strengthened as part of the Electric Circuit, a network of public EV chargers launched in 2012, with the goal of making charging stations more accessible in urban areas. In collaboration with the relevant municipalities and municipal organizations, Hydro-Québec will roll out up to 4,500 standard charging stations, mainly in city centres. https://theicct.org/publication/lvs-ci-quebec-can-en-feb22/

Québec plans to continue to support its neighbours to meet the same challenges by exporting on-demand power to address growing net demand variability in these external jurisdictions.

Notably, by 2030, Hydro-Québec forecasts an additional 20 TWh of increased demand internal to the province of Québec. In addition, Hydro-Québec has concluded power purchase agreements (PPAs) with neighbouring states in New England and New York for another 20 TWh of energy[13]. With this growing need for energy, Hydro-Québec estimates that its current installed capacity will need to be supplemented with new capacity and energy supplies. To address this need, Hydro-Québec will continue to plan for the maintenance and refurbishment of its existing hydropower fleet over the coming decades and look to integrate new sources of renewable energy such as wind and solar generation. It aims at increasing its generating capacity by 5,000 MW, launching projects designed to add 2,000 MW of capacity to existing hydropower generating stations by 2035 and developing by 2026, in partnership with local partners, a portfolio of wind energy projects totaling 3,000 MW.

The work on this has begun with Hydro-Québec's recent calls for tenders of 300 MW of wind generation and 480 MW of renewable generation, with energization of the generation procured under these initial tenders expected by 2026. Hydro-Québec anticipates being able to continue its ambitious plans to develop and integrate renewable generation and export power to its neighbours largely on the strength of its existing hydropower fleet. In its most recent Strategic Plan for 2022 to 2026, Hydro-Québec lays out

Paradigm 1
Our energy and capacity balances

While we've been able to rely on an abundance of available energy in recent years, an upswing in demand for our green electricity will tighten our balances. As a result, our priorities will shift from selling large quantities of energy to helping Quebecers become more energy-efficient and maximizing the value of our energy by targeting the most promising uses.

Paradigm 2
Our supply costs

Historically, our electricity supply costs have been low and stable, thanks in large part to the heritage pool of hydropower. However, the additional electricity purchases we will have to make to meet future needs will cost more. As a result, the energy transition will entail significant costs and we must find ways to keep these costs under control.

Paradigm 3
Our grid's design and operation

Our current power grid is unidirectional, delivering electricity from the generating station to our customers. However, the energy system of tomorrow will be multidirectional, integrating new energy resources and new technologies enabling customers to interact with our facilities and even with each other. We must adapt our operating methods in order to tap the full potential of these new resources and technologies.

Paradigm 4
Our infrastructure investments

Significant investments will be required to reinforce our grid and equip it to handle higher demand—all the more so given that some of our assets are aging and must be replaced or upgraded. We are therefore entering into a new major investment cycle that will last several years.

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[13] 9.45 TWh PPA dedicated to Massachusetts through the New England Clean Energy Connect project and 10.40 TWh PPA dedicated to New York through the Champlain Hudson Power Express project, an underwater and underground high-voltage direct current cable. The delivery of this power is critical to these jurisdictions that are struggling with their own decarbonization targets and seasonal constraints on gas networks for electricity generation and winter space heating. http://news.hydroquebec.com/en/press-releases/1516/energy-supply-contracts-get-green-light-from-massachusetts-another-important-milestone-for-hydro-quebec-and-lower-carbon-emissions-for-new-england/

four paradigm shifts in the coming years as a result of the energy transformation. Figure 10: Paradigm Shifts impacting Hydro-Québec. Source: Hydro-Québec 2022 Strategic Plan[xi].

Québec’s ability to reach such ambitious and varied targets rests on policies and plans laid out decades ago. The effort involved in development of hydropower resources and associated electricity transmission infrastructure includes engagement and commitment from a wide variety of stakeholders; comprehensive studying of land, water, and ecology, and policies that take a long-term view of the future of energy and the environment for generations of Canadians to come.

APPENDIX 4: CASE STUDY – THE ATLANTIC LOOP

The Atlantic Loop, sometimes referred to as the Atlantic Regional Transmission Loop, is a proposal to build new integrated electricity transmission connections between and among the Atlantic provinces and Québec to enable better flow of electricity – mainly hydropower generation – from Labrador and Québec to the rest of Atlantic Canada. Nova Scotia, particularly, is heavily reliant on fossil fuels to generate electricity, with coal and gas-fired generation currently meeting around 70% of the province's electricity needs, while around 30% of New Brunswick's electricity comes from GHG-emitting sources. As a result of both local policy and federal GHG emission reduction requirements, Atlantic Canada is looking to rapidly phase out its use of coal and oil for electricity generation and gradually reduce the use of natural gas; new sources of electricity and essential grid services are therefore needed. Hydropower is the ideal resource to provide firm generation capacity to the entire region, and indeed, concurrent with the phase-out of hydrocarbon-fuelled generation, major hydropower developments are underway or under development in the region:

- The Muskrat Falls project is an 824 MW hydropower facility that was completed in 2021 near the outlet of the Churchill River at Happy Valley-Goose Bay;
- The Churchill Falls project, further upstream, is one of the largest hydropower facilities in the world with an installed capacity of 5,428 MW, the PPA for which expires in 2041. There have been some suggestions that upgrades at the site could add additional capacity;
- The proposed Gull Island project, also on the Churchill River, would add an additional 2,250 MW of hydropower capacity if it were to be built;
- In Québec's Côte-Nord region on the Gulf of St. Lawrence, the 1,550 MW hydropower La Romaine project is nearly complete, with the final of four turbines recently beginning to output power to the grid; and
- The Québec government has recently signalled its openness to building additional new hydropower facilities within the province.

However, due to the remote locations of these facilities and without adequate transmission capacity, their full value cannot be realised. The Atlantic Loop would link these developments by providing high-capacity transmission links in a loop running between Labrador and Newfoundland, thence to Cape Breton Island and onward to mainland Nova Scotia, New Brunswick, Québec, and back to Labrador. Transmission connections between these jurisdictions already exist to varying extents, but they are insufficient to transmit the volume of hydropower that is either planned or under consideration. Although the Atlantic Loop is still in the planning phase, its advancement will prove to be of tremendous benefit to the whole of Atlantic Canada, as the region moves forward with decarbonizing its electricity supply. In addition to the non-emitting energy supply it would provide, the essential grid services provided by hydropower are also needed in the region. That is, because while there has been strong growth of solar and wind generation in various parts of Atlantic Canada, those resources come with their own challenges in terms of both intermittency and grid operations, as noted earlier in this paper.

Ultimately, the Atlantic Loop would bring the advantages of hydropower-based energy into a region with disparate, and in some cases little, access to it, while also being an excellent opportunity for collaboration between Crown corporations, local stakeholders, and regulators that would deliver a critical resource to the advantage of the entire region. Given that it connects multiple provinces, the planning work for the Atlantic Loop will require cooperation between those provinces and between the Federal government, which has indicated a willingness to use Canada Infrastructure Bank funds to finance at least part of the project. Although the planning process has slowed following the Nova Scotia government's implementation of caps on utilities' returns[14] – prompting concern from Emera, a key developer of a portion of the Atlantic Loop – the Federal Minister of Intergovernmental Affairs has indicated his continuing support for the project. Additionally, it is possible that a recent regulatory decision in Nova Scotia, which granted certain expenditures that Nova Scotia Power (a subsidiary of Emera) had requested[15], will help restore proponents' confidence in their ability to earn a reasonable rate of return if they move forward with developing the Atlantic Loop.

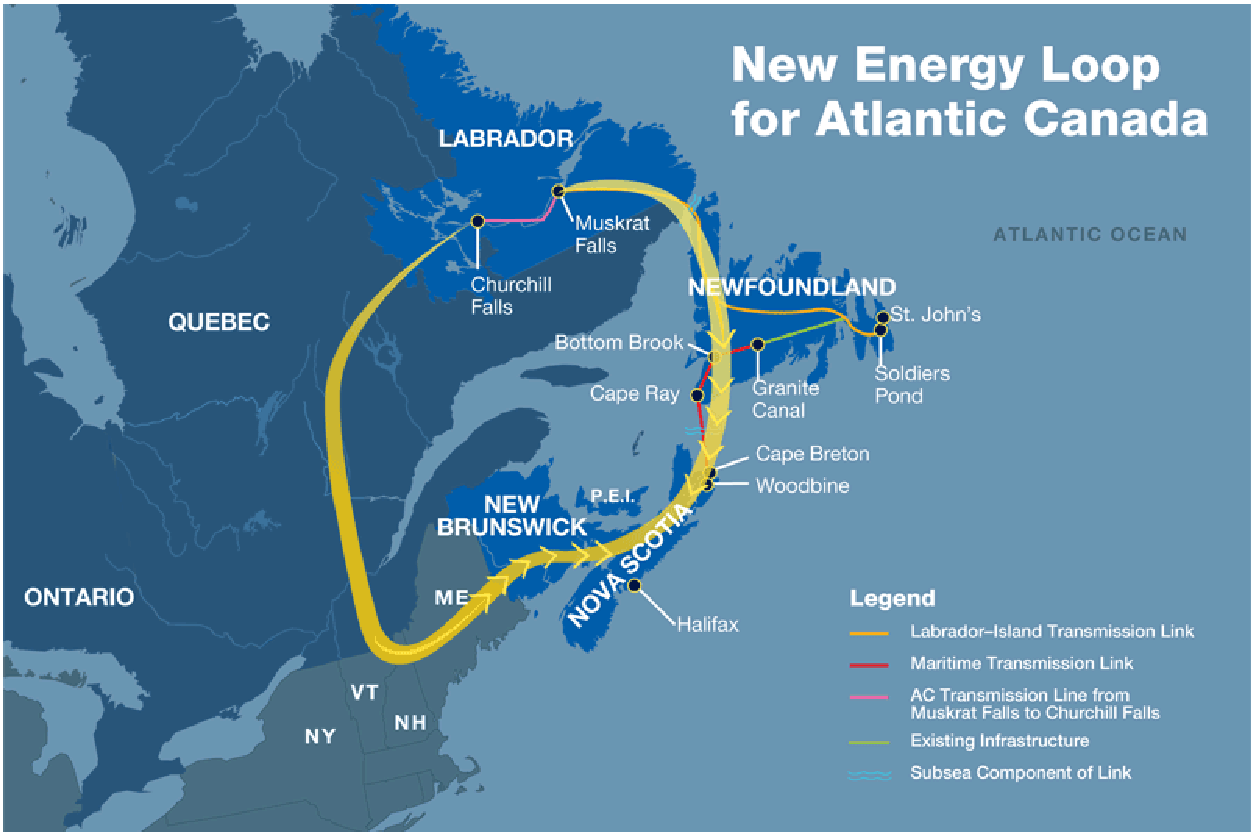

Figure 11: Representative map of the Atlantic Loop, including its constituent parts
Source: Emera Inc.[xii]

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[14] With amendments to the province's Public Utilities Act made via Bill 212, which received Royal Assent in November 2022 https://nslegislature.ca/legislative-business/bills-statutes/bills/assembly-64-session-1/bill-212

[15] See decision of February 2, 2023 in matter no. M10431 of the Nova Scotia Utility and Review Board https://nsuarb.novascotia.ca/sites/default/files/M10431%20-%20GRA%20Decision.pdf

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