ENVIRONMENT & ENERGY BULLETIN

Business Council of British Columbia
Est. 1966

VOLUME 13, ISSUE 1, FEBRUARY 2021

TRADING IN ORGANIZED LIGHTNING (ELECTRICITY): THE B.C. HYDROELECTRIC SYSTEM ADVANTAGE

HIGHLIGHTS

- Humans will trade with or without companies or countries because we cannot produce everything we need and want. Trade in 2020 represents 60% of GDP up from 1% 100 years ago.
- Electricity, like all forms of energy, is traded, but the exchange of electrons is unlike other commodities for one fundamental reason — electricity demand must always equal supply — a critical attribute for understanding trade in electricity.
- Another important attribute of electricity trade is that it happens regionally rather than continentally, and this is by design for reliability reasons. And for this reason, electricity trade happens every hour of every day, 365 days per year.
- The western interconnection — Western Electricity Coordinating Council — one of eight and the largest region in North America — generates about 800,000 GWh from ~274,000 GW of installed capacity, shipping it along 200,000 km of transmission lines, and delivering over thousands of kms of distribution lines to ~80 million people between Alberta and Baja California, Mexico.
- The British Columbia electricity system represents 10% of all generation and transmission in the WECC region but B.C. also has a significant comparative advantage because of its mostly hydroelectric generation and storage capacity — a highly flexible resource that can be ramped with relative ease to buy, shape, and sell electrons for the benefit of British Columbians.
- A transition to clean electricity is seen as the main solution to managing greenhouse gases. British Columbia has already achieved what most other jurisdictions dream about. As such we have a sizable comparative advantage and opportunity created by wise investments of the past.

WHAT IS TRADE?

In all these bulletins it is useful to begin with some fundamentals. Trade and electricity are two topics that are not always well understood. When they are put together, many assumptions are made, and some are incorrect.

Trade, for example. Simply put, it is a mutually beneficial and voluntary exchange of a thing or a service. Trade is always between people, individuals, groups of individuals often organized as companies, or countries. But countries generally do not trade per se.[1] Governments representing the people of a jurisdiction create the terms allowing them to trade with each other.

Absent countries, people would still trade. The entire world is linked by some form of trade. Trade has always existed among and between humans. We trade for things we do not have by offering things we do. Individuals trade their labour for money to buy goods and services from others. We trade our money at the grocery store for food, itself a product of trade. Companies trade wages for labour, and buy various other inputs, to produce services or things they then sell to consumers both at home and abroad. The combinations and

Electricity Fundamentals

It is a secondary source of energy derived from something else — coal, natural gas, uranium, water, wind, sun, and non-fossilized biomass.

It is measured by capacity and energy potential. Capacity is the maximum quantity that can be produced, usually calibrated in watts.

Energy flow is what we use; measured in watt hours.

Electricity is an instantaneous resource where supply and demand must always be in balance, requiring real-time, 24-7-365 monitoring and control.

It cannot always be substituted to do the work of other energy forms.

[1] Countries are a political unit with a "permanent" population, a defined territory, a system of rules (i.e., government), and the capacity to enter into relations with other sovereign groups of people. Countries are fluid. Boundaries often change as do the rules for how individuals cooperate.

permutations of what is bought and sold via voluntary commerce are infinite and constantly evolving. And over the past 200 years, the volume of trade (goods and services combined) in the world has grown dramatically, from 1% of global GDP in 1820 to 60% of GDP in 2020.[2]

The movement of goods and services — exports and imports — typically happens through trading hubs, like Vancouver, Hong Kong, Shenzhen, Shanghai, Los Angeles, London, and New York, all of which are seaport cities. And all communities host logistics centers and related infrastructure for the receipt, organization, and distribution of things we need and want.[3]

We gain from trade when we develop and sell from our most productive industries — these export-oriented industries have a large role in paying the bills for small jurisdictions like B.C.[4] And in the trade exchange, one party often has a comparative advantage. That is, they can produce something with the lowest opportunity cost.[5] As well and collectively, people living in a location are endowed with both tangible and intangible resources related to that location. Canada's and British Columbia's size and geography give us an advantage (still) in natural resources, particularly energy, including electricity, and minerals along with forestry and some segments of agriculture. These natural resource industries make up about half of Canada's international merchandise exports.

In terms of the benefits, trade in electricity is no different from trade in other goods. But the exchange of electrons cannot be explained by conventional models of international trade. In fact, the market design is significantly different and more complex than for common commodity markets. This is true for one fundamental reason — with electricity, demand and supply must always be in real-time balance, as dictated by physics. This is a key fact for understanding the nature of electricity trade, as is its inherently regional nature.

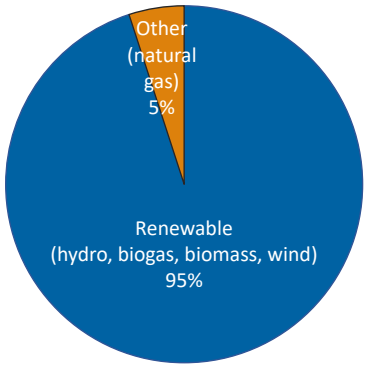
THE ELECTRICITY SUPPLY CHAIN AND MARKET PARTICIPANTS

Electricity really is organized lightning. Generators mechanically produce electrons. The high voltage transmission system moves the charge down the "transportation" highway to the distribution system for delivery to end-use customers. If demand is greater than supply, outages might happen, absent trade. When supply is greater than demand, there are only four options: incrementally use more of it, store it if there is a system to do so, waste it, or trade it to a party that may in turn ramp down its own generation in favour of buying from someone else. When supply is greater than demand, there are also opportunities for trade.

British Columbia's System

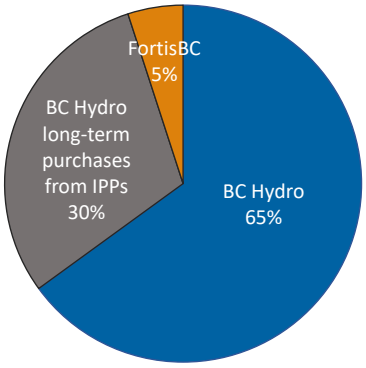
In B.C.'s "electricity upstream", there are a total of ~160 electricity generation facilities. About 78% of these are non-utility generators (e.g., independent power producers or self-generators). The rest are owned by B.C. Hydro or FortisBC. Virtually all non-utility generated electricity in the province is sold to B.C. Hydro.[6] Combined, non-utility generation represents ~30% of total electricity produced in the province. But most of the demand in B.C. is met via generation owned by either B.C. Hydro

FIGURE 1: **B.C. GENERATION RESOURCES (2020)**



Source: BC Hydro, FortisBC.

FIGURE 2: **B.C. GENERATION RESOURCE OWNERSHIP**



Source: BC Hydro, B.C. Utilities Commission, FortisBC.

[2] https://www.statista.com/statistics/268750/global-gross-domestic-product-gdp/.
[3] https://bcbc.com/dist/assets/publications/the-risks-of-needing-and-wanting-stuff/EEBv8n5.pdf.
[4] https://bcbc.com/insights-and-opinions/which-private-sector-industries-pay-the-bills-for-british-columbia, https://bcbc.com/insights-and-opinions/which-industries-pay-canadas-bills.
[5] Opportunity cost refers to the value of what you must give up in order to choose something else.
[6] https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/independent-power-producers-calls-for-power/independent-power-producers/ipp-supply-list-in-operation-20201001.pdf.

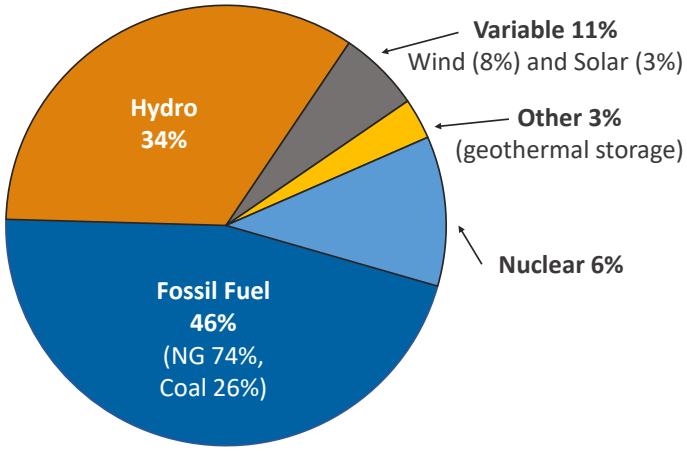
or FortisBC, with an overwhelming majority of this derived from projects on the Peace and Columbia rivers. In fact, the province's large hydroelectric facilities are key strategic assets. They are not only the foundation of B.C.'s ability to claim it has a 95% "clean" electricity system, but they are also critical to our ability to extract value from electricity trading.

In between generation resources and customers there are over 21,000 km of 69 kV to 500 kV transmission lines and over 70,000 km of distribution lines. This is the electricity "highway."

In terms of the "electricity domestic downstream" component, B.C. is home to 7 regulated electric utilities and 5 municipal utilities, enabling electricity service to most of B.C.'s ~5.1 million residents. B.C. Hydro is the largest regulated full-service utility, serving 93% of British Columbians. It also owns virtually all the high voltage transmission system. FortisBC serves 6% of electricity customers in the province, with other independently owned and municipal utilities servicing the remaining 1%. All customers receive electricity service and pay rates approved by the B.C. Utilities Commission or their own municipal entities.[7]

In 2019, domestic consumption accounted for 85% of the total output of all electricity producing facilities in B.C.;[8] about four fifths of this was delivered to the Lower Mainland and Vancouver Island, where the province's population is concentrated. Line losses[9] accounted for about 8% of the total generation. The rest is surplus that exists from time to time dependent on various factors but most importantly, weather.

FIGURE 3: **GENERATION RESOURCES IN THE WESTERN INTERCONNECTION**



Source: WECC, U.S. EIA.

Finally, B.C. has 7 transmission interconnections with Alberta and Washington state. These lines enable electricity to be traded with certain parties outside of B.C.

- One 500 kV line (5L94) runs between Cranbrook, British Columbia and Langdon, Alberta. It was built in 1986.
- Two 138 kV transmission lines (1L274 and 1L275) run between Natal, British Columbia and Pocaterra and Coleman, Alberta. Both were built in the 1950s.
- The B.C.-U.S. Intertie is comprised of 4 transmission lines — 2 500kv (5L51, 5L52), and 2 230kv lines (2L112 and the 2L277/ Teck Cominco Line 71, which is a private line).

The connections with Alberta have a nominal capacity of 1,000 MW to B.C. and 1,200 MW to Alberta. However, transfers from B.C. to Alberta are normally about 400 to 600 MW, while transfers from Alberta to B.C. are frequently about 100 MW to 200 MW during peak load hours, and up to 700 MW during off-peak hours due to operational and reliability considerations in Alberta. The interties between B.C. and the U.S. have a maximum rating of 3,150 MW north to south and 2,000 MW south to north.

Western Interconnection

The B.C. system is part of the western interconnection known as "WECC" (the Western Electricity Coordinating Council) — one of eight electricity regions in North America, all of which operate a-synchronously, an intentional design feature for reliability reasons.

It is complicated. Each region has many players, a variety of generation resources, and related infrastructure. WECC is unique in that it is the largest region, spanning a geography from Alberta to Baja California in Mexico, covering 2.9 million km². It is characterized by generation resources

[7] City of Nelson, City of New Westminster, City of Penticton, City of Summerland, City of Grand Forks who all buy wholesale electricity and resell.
[8] https://www.bcuc.com/Documents/AnnualReports/2020/BCUC%E2%80%93Annual-Report%E2%80%9318-19-v04%E2%80%9320200710-web.pdf.
[9] Electrical current has friction associated with it, called resistance. The transport of large amounts of electrical power over long distances creates losses from the heat dissipated as the current moves. The overall loss of electrical energy during its transmission from the power plant and consumers is between 8% and 15%.

that are often distant from load (the consumer) and long high-voltage transmission lines.

Some of the important electricity market participants who keep the system functioning are the entities responsible for reliability. These include B.C. Hydro, the Alberta Electric System Operator, the California Independent System Operator by agreement with others and referred to as RC West, and the Southwest Power Pool. These four entities are the "air-traffic controllers" for electricity trade.[10] Together they oversee, coordinate, assure the reliability of western bulk electricity, and ensure open and non-discriminatory transmission access.

The other players, hundreds of them, are enabled by the transmission infrastructure and the oversight provided by these entities. Collectively, the WECC system can deliver over 800,000 GWh of electricity generated from 274,000 GW of installed capacity, transmitted along ~220,000 kms of high voltage transmission lines to a population of more than 80 million.

This vast geography and diversity of supply present unique cooperation and trading opportunities. In fact, intraregional trade in electricity happens every hour of every day. It is an inherent part of an interconnected system like WECC and is effectively a shared insurance policy. It enables participants to rely on one another for maintaining supply even in the face of demand uncertainties, unexpected equipment failures, or other conditions that may create a physical imbalance in the flow of electrons.

For example, the winter of 2018/2019 brought significant challenges for B.C. Hydro that could not have been foreseen. These included low inflows to reservoirs and an unusually cold winter which increased heating load and was exacerbated by a pipeline explosion. Through an agreement[11] with Powerex, B.C. Hydro was able to secure electricity from sources within the western interconnection system to meet its obligations. Through trade, therefore, B.C. Hydro was able to manage potential short-term supply challenges created by a series of unplanned, coincidental events. This same reasoning applies to all participants in the interconnection network and makes for a more robust electric system.

HOW IS TRADE CONDUCTED?

Any entity, private or public, that is connected to the transmission system in the western interconnection network can participate in wholesale trade via Open Access Transmission Tariffs (OATT). B.C. Hydro's tariff[12] is modelled on the U.S. Federal Energy Regulatory Commission Order 888.[13] It requires all public utilities owning, controlling, or operating facilities used for transmitting electric energy in interstate commerce in the United States to allow for non-discriminatory service comparable to that provided by transmission owners to themselves. Of course, the B.C. Utilities Commission provides regulatory oversight within the province. But having an OATT is one precondition to trade, since all trade requires transmission to flow electricity from a generator to customers.

Trade happens in one of two ways — via bilateral contracts or an organized market. The former is between a single buyer and a single seller. The latter uses software to match demand with supply based on bids and offers. A large proportion of transactions in the western interconnection network are bilateral in nature. California and Alberta are different. They both use dynamic software that forecasts demand every few minutes. System operators then dispatch the lowest cost supply to meet the demand.

WHY BOTHER ENGAGING IN ELECTRICITY TRADE?

Trade in electricity is a rational response to managing risk and uncertainty. Absent trade, all jurisdictions, including B.C. would need to build more electricity infrastructure to address peak events. These are expensive capital

[10] For more information on reliability go here: https://www.nerc.com/Pages/default.aspx; Functional Model: https://www.nerc.com/pa/Stand/Functional%20Model%20Advisory%20Group%20DL/FMAG_Inf_Functional%20Model%20v6%20(clean).pdf.
[11] https://www.bcuc.com/Documents/Proceedings/2019/DOC_55225_B-1-BCH-2019-Powerex-Letter-Agrmt-Appl-Public.pdf.
[12] https://www.bchydro.com/toolbar/about/planning_regulatory/tariff_filings/oatt.html. FortisBC's transmission tariff also enables wholesale transactions. https://fbcdotcomprod.blob.core.windows.net/libraries/docs/default-source/about-us-documents/regulatory-affairs-documents/electric-utility/fortisbcelectrictariff.pdf.
[13] https://www.ferc.gov/industries-data/electric/industry-activities/open-access-transmission-tariff-oatt-reform/history-oatt-reform/order-no-888.

TABLE 1: **GENERATION RESOURCES BY SUB-REGION WITHIN THE WESTERN INTERCONNECTION 2019**

Fuel	B.C.	AB	PNW (WA, OR, ID, MT)	CA	Remaining WECC
Coal	-	23%	10%		39%
Hydroelectric	86%	1%	54%	19%	4%
Natural Gas	5%	61%	20%	43%	34%
Nuclear	-	-	4%	8%	10%
Other	-	3%	1%	1%	-
Other Renewables	9% (3% wind, 6% biomass)	12% (wind)	11% (9% wind)	29% (14% solar, 7% wind)	13% (5% solar, 8% wind)

Source: U.S. IEA.

investments. Customers must pay for them whether they are used or not. If built and not used, except occasionally, they also represent a sizable opportunity cost for the economy. And of course, there are inevitable environmental impacts from building new power facilities.

Furthermore, no load serving entity like B.C. Hydro or FortisBC can forecast or have a compliment of resources on hand that match demand with decimal-place precision. Therefore, short-term trade allows load-serving entities to respond in real-time to a sudden increase in demand by buying from the market. And over the longer-term, trade is useful in filling the gaps that go along with the lumpy nature of electric infrastructure development.

In a region like the western interconnection there are substantial synergies that come from the diversity and the distribution of supply. As more western states pursue 100% clean electricity and add big chunks of intermittent renewables to their domestic resource portfolios, the value and comparative advantages of the B.C electric system, and the opportunities for trade, should increase.

Despite being less than 10% of the total resources and transmission infrastructure in the wider western interconnection, B.C.'s hydro-based system is extremely flexible. Generators can be turned on and ramped up with relative ease and the storage capacity of reservoirs is sizable. Together, these two factors mean B.C. Hydro can buy less expensive electrons when others in the region must run their generation — at night when demand is low, or more recently and with greater frequency, in periods when there is a surplus of solar or wind generation — store them, and then shape, firm, and sell this electricity in peak periods when prices are higher. The profits from this exchange are reflected in domestic electricity rates, making them lower than they otherwise would be without trade. In the case of California, B.C. (and other Pacific northwest states with large hydroelectric resources) could add significant value by displacing generation from natural gas facilities that currently ramp up as the sun goes down and/or engage in longer-term trade arrangements that help the region meet collective greenhouse gas emission reductions. B.C. rate payers and taxpayers benefit from this trade, and using our system in this way may provide opportunities for additional clean resource development in B.C.

CONCLUSION

Electricity trade happens every hour. It is an important part of how electricity systems operate. As electricity demand increases in response to population and economic growth, along with the combined pledges by governments at all levels to reduce greenhouse gases through the addition of ever more intermittent and variable resources, the role of those jurisdictions with large hydroelectric systems will become more important. B.C.'s geographic location and wise past investments in generation and transmission create an outsized opportunity for the future.

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