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HAIL ELECTRICITY!

HIGHLIGHTS

- Energy is a defining feature of who we are as Canadians, not least through its unusually prominent role in public and political discourse in the past decade. We export all forms of energy and rank 6th in the world for both total and per capita electricity production.
- B.C. scores an A+ on the composition of fuel sources used to generate electricity, with more than 95% coming from non-greenhouse gas emitting sources. If we were a country, we would be at the very top of the global list for reliance on renewable electricity. Canada's electricity sector is also the envy of the world, with about 80% of the electrons produced from carbon-free sources — 59% water, 16% nuclear, 6% other renewables (biofuels, tidal, solar, and wind) and the balance thermal.
- There is no Canadian or North American transmission grid. Instead, there are 6 reliability regions, all of which are members of the North American Electric Reliability Corporation. This poses interesting regulatory and infrastructure development challenges, as does the whole energy sector in Canada, where the provinces have the primary responsibility.
- Electricity is seen as one of the major solutions to the problem of rising global greenhouse gas emissions. Indeed, all countries that have made visible progress in reducing such emissions in the last 10-15 years or so have done so in large part by shifting fuel use in the electricity sector, supported by ongoing technology improvements and the normal capital replacement process.
- We must not dismiss the energy requirements of the digital economy for cooling and to power the infrastructure needed to process and move unimaginable amounts of data. Total generation, and by extension emissions, to meet the growing demand for energy from the rapidly expanding digital economy is likely to rise markedly over time. Billions of tiny phones leave a not-so-tiny energy and environmental footprint, and the computing power needed to fuel the digital economy poses questions about resource use.
- A transition to a less carbon-intensive economy using electricity as the input fuel for all manner of activities means more installed renewable capacity compared to a traditional system, in order to generate enough gigawatt hours to meet increasing demand. This has far-reaching implications, including reduced efficiency given the intermittent nature of many renewables, sizable spatial requirements, reliability challenges, and innumerable regulatory hurdles — including project review and permitting processes which, in Canada, take too long and cost too much.

SETTING THE STAGE

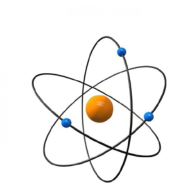
Energy is THE universal currency, something that is "critical for human existence, a reality precluding any rank ordering of [fuel] importance."[1] It is the "oxygen" of both modern and emerging economies and underpins much of human civilization.[2] Without energy in its various forms, we would not have the high standards of living now enjoyed in advanced economies, nor the comforts of modern life like heat, light, and power for homes, transportation, food diversity, water and wastewater systems, technology, and industries that produce an astonishing variety of goods and services. This standard of living is sought after by the rapidly growing middle classes across the emerging world.

Energy is a defining feature of who we are as Canadians, not least through its unusually prominent role in public and political discourse

[1] Smil, Vaclav. 2017. Energy and Civilization, A History. Massachusetts Institute of Technology, p. 4.
[2] World Economic Forum, Energy for Economic Growth: Energy Vision Update 2012, Tracking Clean Energy Progress 2013, International Energy Agency.

over the past decade. The quantity and diversity of Canada's energy resources is a huge asset, one that very few other nations can match. We are an exporter[3] of all forms of energy — coal, oil, natural gas, uranium, and electricity — supporting hundreds of thousands of jobs, generating multiple tens of billions of dollars in income, and providing substantial revenues to governments. And while Canada represents only 4% of the world's energy production,[4] our extensive reserves of energy have enormous potential to help meet growing global demand in a sustainable and relatively climate-friendly manner.

THE ELECTRONS



To the point of this bulletin, Canada's electricity sector is the envy of the world, with about 80% of the electrons produced from carbon-free sources — of which water is the dominate fuel (~59% of the total), followed by nuclear (~16% of the total). Other fuels including biofuels, tidal, solar, and wind, combined provide ~6% of the renewable electrons produced in Canada and of course we still also produce and use some thermal electrons. Canada is ranked 6th in the world in both total and per capita electricity production (all fuels).[5]

In B.C., we score an A+ on the composition of fuel sources used to generate electricity, with more than 95% coming from non-greenhouse gas emitting sources. If B.C. were a country, we would be at the very top of the global list for reliance on renewable electricity.[6]

Like Canada, B.C.'s biggest electricity fuel source is water harnessed between the 1960s and 1980s when most of the province's large hydroelectric plants were constructed. The dividend from this period is now being paid. Then, over the past 30 years, we have added independent power producer output to the mix, diversifying the marketplace, spreading risk, providing entrepreneurial business opportunities and opening new avenues for economic development among Indigenous communities. In total, independent generation now meets about 30% of current B.C. Hydro demand.[7] A majority of this comes from run-of-river projects,[8] taking advantage of key features of the province's natural geography — mountainous terrain and abundant water.

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WHAT'S IMPORTANT TO KNOW ABOUT ELECTRICITY?

Electricity is an amazing physical reality[9] — just ask anyone who watches lightning storms against a dark night sky. It is a secondary source of energy derived from something else — coal, natural gas, uranium, water, wind, sun, and non-fossilized biomass. Electricity is convenient and versatile, and at its immediate point of use it is the cleanest energy input. But electricity is only as clean as its source fuel, and it cannot always be substituted to do the work of other energy forms.

When we speak of electricity, it is often with reference to the quantity of new capacity, expressed as kilowatt (KW), megawatt (MW), gigawatt (GW), or terawatt (TW). But the much more important measure is the *flow of energy produced* at any given plant — expressed as KW hours, MW hours, GW hours (GWh) or TW hours (TWh). This flow depends in part on the power density of the fuels used, an extremely important concept for enabling comparisons[10] of the ability of different fuels to do work; power

[3] Environment and Energy Bulletin. 2018. Energy Production, Consumption and Trade: How Canada and B.C. Stack Up: https://bcbc.com/dist/assets/publications/energy-production-consumption-and-trade-how-canada-and-b-c-stack-up/EEBv10n3.pdf.

[4] https://yearbook.enerdata.net/total-energy/world-energy-production.html.

[5] http://world.bymap.org/ElectricityProduction.html.

[6] ALL countries that are rated highly in renewable generation have dominant hydroelectric systems. For example, Norway, often cited as a role model comparator for B.C./Canada, generates 97% of its electricity from water with the remaining 3% made up of wind, biomass, and solar.

[7] 2018/19 Annual Service Plan: https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/accountability-reports/financial-reports/annual-reports/BCHydro-Annual-Service-Plan-Report-2018-2019.pdf and IPPs currently supplying B.C. Hydro: 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.pdf.

[8] Of the ~5.2 GW of installed IPP capacity and 22 GWh of electricity generated, 92% is derived from renewables (i.e., non-storage and storage hydro, solar, wind, biogas, biomass, energy recovery and municipal solid waste), with most of that hydroelectric and the balance coming from a small subset of gas-fired thermal projects.

[9] Electricity is created when electrons spin around the nucleus of an atom, which also contains protons and neutrons. Protons and electrons both contain an electrical charge and are attracted to each other because they have opposite but equal electrical charges. Electrons can flow through a conducting material, such as the copper or aluminium.

[10] Smil, Vaclav. 2015. Power Density, A Key to Understanding Energy Sources and Uses. Massachusetts Institute of Technology, p. 21.

density also captures the spatial attributes of energy systems. The denser the fuel, the more work it can do per unit with fewer spatial requirements, even though the latter point strikes some as counterintuitive — yet the fact remains that fossil fuels are less spatially intensive than renewables. This is one of the reasons why fossil fuels are still dominant in global electricity generation and why, in part, nations like China and India continue to add new thermal generation facilities.

Electricity is ubiquitous and invisible in the lives of most people, at least in the developed countries. In Canada and B.C., we expect reliable service at relatively low-cost.[11] But unlike any other physical commodity, electricity cannot be stored. It is an instantaneous resource where supply and demand must always be in balance, requiring real-time, 24-7-365 monitoring and control. Absent storage, all electricity generated must be used essentially at the moment it is produced.

Storage is a topic *de jour* when it comes to the addition of intermittent renewable resources into electricity systems. Water in reservoirs is used to store potential energy, and because hydroelectric plants can be turned on and off with relative ease, they are enormously flexible in being able to integrate other resources — thermal plants are not as easy to operate, which is why they are often referred to as baseload or must-run. Batteries, another way to manage energy time of use, capture the potential in a chemical reaction causing a build-up of electrons that can be accessed later. Over the past few years, the potential for using electric vehicles (collectively a large distributed battery system) for grid services is gaining ground as we move back to the future towards a more distributed system.[12]

B.C Electricity Supply Mix

- 31 B.C. Hydro and 4 Fortis B.C. generating stations
- > 80,000 km of transmission and distribution lines
- Majority of capacity from B.C. Hydro Peace and Columbia River facilities, with ~86% of installed capacity and generation. Balance is located on Vancouver Island, the Lower Mainland and in the Fortis service area
- 123 IPPs contribute ~5.2 GW and ~22 GWh to B.C. Hydro supply
  - ROR Hydro: ~35%
  - Storage Hydro: ~23%
  - Biomass: ~17%
  - Thermal: ~13%
  - Wind: ~10%
  - MSW: ~0.8%
  - Biogas: ~0.6%
  - Solar: < 0.01%
  - ERG: < 0.003%

For example, in 2018 Massachusetts, New York, and New Jersey adopted energy storage targets, joining California and Oregon, who were the first to take this step. A growing number of utilities are including energy storage in their resource planning processes, and the U.S. Federal Energy Regulatory Commission (FERC) has issued Final Rule 841 on Electric Storage Participation in Regional Markets, applicable where they have jurisdiction.[13] The B.C. Utilities Commission has made a small foray into regulatory aspects of battery storage as it relates to electric vehicles but with no directives yet. Canada does not have a FERC equivalent and the responsibility for electric utility related decisions lies with provincial regulators.

Electricity travels via transmission and distribution lines — the grid. It is important to note that there is no Canadian or North American transmission grid. Instead, there are 6 reliability regions, all of which are members of the North American Electric Reliability Corporation.[14] These regions are electrically distinct and ensure the bulk power system is always able to supply the aggregate electrical demand and energy requirements of customers in that region. Interconnection among facilities in a region and coordinated operation within that region also ensure the system can withstand sudden disturbances, such as electric short-circuits or the unanticipated loss of system elements as a result of various contingencies. Integration and inter-connectedness are also fundamental to trade in electricity. But the coordination does not extend to between regions.

[11] Comparison of Electricity Prices in North America. 2019: https://bcbc.com/insights-and-opinions/comparison-of-electricity-prices-in-north-america.
[12] Electricity systems were not always integrated. This amalgamation began in the 1960s during the heyday of power systems development in the United States and Russia as strategic assets during the Cold War.
[13] Federal Energy Regulatory Commission. Order 841: Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators: https://www.ferc.gov/media/news-releases/2018/2018-1/02-15-18-E-1.asp.
[14] https://www.nerc.com/AboutNERC/Pages/default.aspx.

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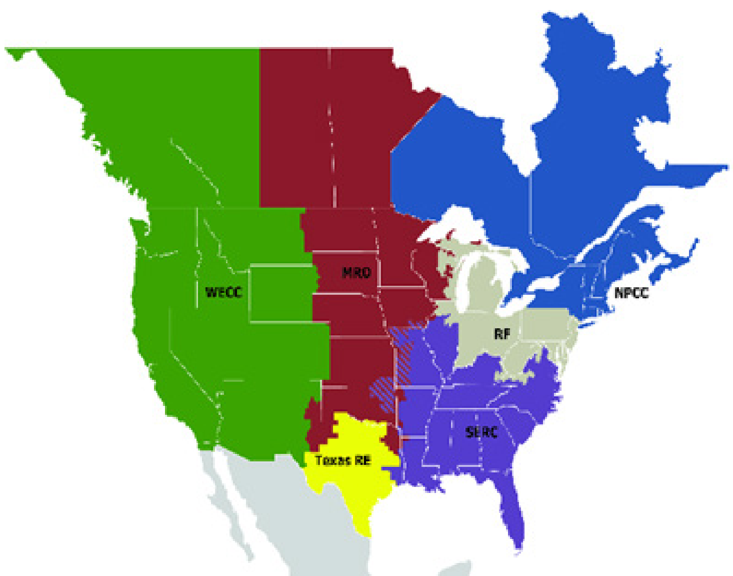
British Columbia belongs to the Western Electricity Coordinating Council (WECC)[15] whose members also include Alberta, 14 western states, and northern Baja Mexico. Our interconnection with western North America began in 1961 and the Columbia River Treaty. WECC is the largest alternating current electric grid, geographically, in North America, and it has the most diverse set of participants. Interconnection enables a more reliable B.C. system because we are not isolated within our borders and can share reserves and engage in beneficial trade in electricity.

ELECTRICITY AND GREENHOUSE GAS EMISSIONS

Electricity is seen as one of the major solutions to the problem of rising global greenhouse gas emissions. Indeed, all countries that have made visible progress in reducing such emissions in the last 10-15 years or so have done so in large part by shifting fuel use in the electricity sector,[16] a trend that has been supported by technology improvements and the capital stock replacement process.[17]

For example, virtually all U.S. emission reductions have come from the transition away from coal-fired to natural gas fired and renewable power generation.[18] Natural gas is the new dominant fuel in the U.S. power sector, now contributing more than 38% of generation output, surpassing coal in 2016. At the same time, renewables are making headway and in 2018 about 15 gigawatts (GW) of wind and solar generating capacity came online in the U.S. As of April 2019, renewable sources provided ~23% of total electricity generation to coal's 20% share, meaning the share of renewables is still far below Canada and B.C. levels.

The same goes for California, often viewed — at times mistakenly — as a benchmark for progress in tackling greenhouse gas (GHG) emissions. What the data shows is that overall in-state emissions have declined by 12% since 2008, the date when the state's cap and trade program was implemented. However, when electricity imports are included in the analysis, California's total emissions have dropped by only 6%.[19] As of 2018, almost 40% of the California generation mix (in-state and imports) still came from fossil fuel sources, primarily natural gas.[20] And while it is true that in-state fossil fuel generation has gone from 61% to 47% of supply, out-of-state fossil fuel imports have risen significantly.[21] So if one looks at California in a broader context, it turns out that its record is not so stellar, since it is importing more thermally generated power to help meet electricity demand. Regardless, the transition away from fossil fuels in its domestic electricity generation is directly related to California's reported GHG emissions reductions.



[15] WECC About: https://www.wecc.org/Pages/home.aspx.

[16] Two predecessor events had significant effects on reducing GHGs in Europe: (1) Between 1995 and 2010 a shift in the passenger vehicle fleet from gasoline to diesel, subsequently derailed by Dieselgate or Emissionsgate. (2) The madcow disease outbreak in the 1990s shrank the beef production and processing industry by 50% across Europe. Industrial agriculture is still a significant source of GHG emissions.

[17] Most of the U.S. coal plant fleet is > 40 years old and past its "end of life." Natural gas generation is less expensive from both fuel and cost of technology perspectives.

[18] Percent change from 2005 base year — electricity generation -28%, transportation -6%, industry -5%, residential -11% with commercial and agriculture both rising: https://cfpub.epa.gov/ghgdata/inventoryexplorer/#allsectors/allgas/econsect/all.

[19] The California cap and trade system is designed to protect its domestic energy intensive and trade exposed industries; it includes imports of electricity. https://bcbc.com/dist/assets/publications/b-c-s-current-carbon-pricing-system-neither-efficient-nor-fair-for-business/EEBv11n2.pdf.

[20] California Energy Commission: https://ww2.energy.ca.gov/almanac/electricity_data/electric_generation_capacity.html and https://ww2.energy.ca.gov/almanac/electricity_data/total_system_power.html.

[21] Between 2008 and 2018 California reduced in-state coal generation by 2,541 GWh (from 2,835 GWH to 294 GWh) but over time it has increased coal fired power imports so that they now contribute 9,139 GWh of the state's electricity mix.

TABLE 1: **GLOBAL ELECTRICITY GENERATION AND CAPACITY**

		Current Policies			Sustainable Development Policies		
	2018	2030	2040	Increase/Decrease 2018-2040	2030	2040	Increase/Decrease 2018-2040
Generation (TWh)	26,603	34,988	42,824	61%	31,800	38,713	46%
Installed Capacity (GW)	7,218	10,194	12,658	75%	11,042	15,478	115%
CO2eMT	13,818	14,951	16,595	20%	8,460	3,780	-73%
Carbon Intensity	476	394	360	-24%	237	81	-83%
Efficiency	42.1%	39.2%	38.6%	-8%	32.9%	28.1%	-14%

Source: IEA WEO 2019.

Germany is another often cited case study. Energiewende is the term that's used to summarize the country's planned transition to both a low-carbon and nuclear free economy.[22] The program is continuing to modify the German generation mix. In 2005, fossil fuels made up about 55% of total German electricity supply; in 2019, ~41% of the German electricity is from fossil fuels. The carbon intensity and thus emissions in the power sector have declined, because the proportion of natural gas generation has increased and the proportion of brown versus black coal has tilted in favour of the former, which has fewer carbon molecules. The overall result is that GHG emissions from the German energy sector (mostly electricity) are down by 21% since 2005, and overall country emissions have dropped by ~13%.[23]

Again, it is easy to paint a clear line between fuel-switching in the electricity sector to a country's reductions in GHG emissions. It is also important to reiterate that Canada has very few options in this regard, given the existing dominance of carbon-free electricity in the country — something that suggests achieving further emission reductions in Canada is likely to come with a higher marginal abatement cost than in jurisdictions that continue to rely heavily on fossil fuel-based electricity. B.C. has virtually no scope to cut GHG emissions in the electricity sector. At the same time, some provinces, such as Alberta and Saskatchewan do have more opportunities to "green" their electricity sectors compared to hydroelectric based provinces like B.C., Manitoba and Quebec. The geographic location of Alberta and Saskatchewan, sandwiched between two hydroelectric provinces, B.C. and Manitoba, underscores the possibility that greater trade in electricity across Western Canada could help to lower Canadian GHG emissions and accelerate Alberta's and Saskatchewan's efforts to shift away from coal-fired power.

WHAT DOES THE GLOBAL ELECTRICITY MIX LOOK LIKE?

In 2018, electricity met slightly less than 2/10th of global final energy consumption. In the future this share could rise to perhaps 3/10th under the International Energy Agency's sustainable development scenario, which seeks to meet the 2 degrees celsius aspirations of the Paris Agreement on climate change.[24]

Under three different modelled scenarios, the IEA explores the possible direction of future global electricity generation. We have chosen here to compare only Current Scenario (CS) and Sustainable Development Scenario (SDS), noting that the IEA's third modelled scenario is midway between these two.

Under the CS, where the world is assumed to make few changes to existing policies and measures, generation from fossil fuels declines from 64% to 55% of total TWh by 2040, nuclear stays the same (8%), and renewables increase from 26%

[22] https://www.energy-charts.de/energy_pie.htm?year=2005.
[23] https://www.umweltbundesamt.de/en/indicator-greenhouse-gas-emissions#textpart-1. Direction of emissions in Germany: transport +2%, commercial -2%, residential -30%, industry +5%, agriculture <-1%, waste and waste heat -12%, other +27%. Overall -13% primarily because of fuel switching in the electric sector and households.
[24] International Energy Agency. 2019, World Energy Outlook. Table Energy Demand: World.

to 36%, with the net result being a corresponding betterment in carbon intensity. A similar but more dramatic pattern follows from the SDS, as shown in Table 1. Interestingly and predictably, the efficiency of global electricity production declines significantly in this scenario, meaning more installed capacity is necessary to generate enough electrons to meet increasing demand. This is both positive and negative.

The positives include the need for more capital investment, creating economic activity, and reducing emissions. The negatives include the reduced efficiency of the power system (i.e., installed capacity versus output), since all fuels have varying power densities — with renewables on the lower end (i.e., from 0.1 W/m2 for biofuels to 2,000 W/m2 for natural gas[25,26]). As noted, renewables also have larger spatial requirements that will undoubtedly create land-use conflicts because the most ideal places for development are usually the same ones inhabited by people and other species. There are also yet to be resolved technical challenges with integration of intermittent renewables into existing electricity systems.

And finally, there is a rarely discussed issue, the energy requirements of the digital economy for cooling and to power the infrastructure needed to process and move unimaginable amounts of data. Estimates suggest the aggregate demands of information and communication networks in the digital and "green" economy claimed nearly 5% of worldwide electricity generation in 2012. This looks to be on track to reach 10% by 2020 and to grow further over time. Billions of tiny phones leave a not-so-tiny energy and environmental footprint,[27] and the computing power needed to fuel the digital economy poses some interesting and challenging questions about resource use.

CONCLUSIONS

Electricity is a versatile resource that is rightly seen around the world as one of the primary solutions to managing further accumulation of greenhouse gases in the atmosphere. Whether the world can install enough reliable renewable electricity over the next 20-30 years to meet increasing demand as well as replace old carbon-intensive capital stock is difficult to predict and represents a monumental task.

In Canada, we have few low-cost options to "green" the power sector, given the 80% share already provided by carbon-free sources. This is even more true in B.C. However, thinking more broadly and back-to-the-future, a modern distributed energy system has the potential to upend both the structure and the economics of the electricity sector. B.C. is well positioned given our mature independent power producer sector with experienced investors and operators who can take advantage of this situation in-province. Looking beyond our borders, B.C. can look at strengthening its physical interconnections with Alberta, which may open new business opportunities for B.C. companies.

Let's not dismiss the challenges.

A transition to a less carbon-intensive economy using electricity as the input fuel for all manner of activities means more installed renewable capacity compared to a traditional system in order to generate sufficient gigawatt hours to meet increasing demand, and then accepting the reduced efficiency that follows from the intermittent nature of many renewables. This outcome has significant spatial implications, reliability challenges, and innumerable regulatory hurdles, including project review and permitting processes that, in Canada and B.C., take too long and cost too much.

Let's also be clear that conventional power plants, a dominant source of system flexibility in modern electricity systems, are still needed. Increasing co-ordination to make better use of existing regional interconnections could yield economic and environmental benefits in North America. On the regulatory front, new tariff design and structures supporting system flexibility and new services are critical.

The task is gargantuan.

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[25] W/m2 = Watts/meters of land squared; https://bcbc.com/dist/assets/publications/book-review-power-density-a-key-to-understanding-energy-sources-and-uses/EEBv8n4.pdf.
[26] Total installed capacity * total hours in a year divided by generation = 26,603/((7,218*8,760)/1,000) = 42%.
[27] Smil, Vaclav. 2019. Growth. From Macroorganisms to Megacities. Massachusetts Institute of Technology, p. 500.