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THE EXPANDING ROLE OF RENEWABLES IN THE GLOBAL ELECTRICITY MARKET

HIGHLIGHTS

- There is continuing strong world-wide growth in renewable electricity capacity — 154 GW between 2014 and 2015, a 9% increase — and global investment possibilities on the order of three quarters of a trillion dollars between now and 2040.
- Canada meets 80% of its electricity needs from renewable resources, primarily hydro, one the highest rates in the world. The IEA's 450 scenario goal is for 58% of global electricity to be generated from renewables by 2040.
- British Columbia generates 98% of its electricity from renewable sources — exceeding the IEA's 450 scenario goal by 40 percentage points!
- BC has a large collection of varied domestic renewable electricity options and opportunities that could close the 2% gap and achieve 100% reliance on renewable power.
- There are substantial global market opportunities to export BC and Canadian know-how and expertise to assist in the development of renewable electricity projects and sell related services. We should leverage what we already do well.
- BC and Canada are leaders in the renewable electricity sector. We should be proud of our achievements, not discouraged by those who claim, misleadingly, that we are laggards.

THE WORLD VIEW

Renewable energy is an ongoing and very active electricity sector conversation. But in the context of energy systems transformation, the discussion is now broadening to include opportunities and new technologies for heating and transportation. The latter two sectors represent 60% of world final energy consumption[1], and there is now an increasing focus on integrating renewables beyond traditional applications.

In 2014, about 15% (~2,700 GW) of global final energy demand took the form of electricity. Of this amount, 23% (630 GW) came from renewables, primarily hydro. In 2015, total installed renewable power capacity increased by 9%, or 154 GW.[2] The data shows renewable energy is becoming a larger part of global final energy demand.[3] With a New Policies goal of 37% of electricity generated from renewables, the world is two-thirds of the way there.[4]

At the end of 2016, 170 countries had renewable energy targets or policies of some kind in place.[5] Given the current growth trajectory, achieving the IEA's New Policies 2040 goal might be possible. Doing so depends on a variety of technical factors, including the design of power markets and operating protocols, costs/GWh, managing the impacts of adding renewable capacity on existing grid infrastructure, developing new control technologies,[6]

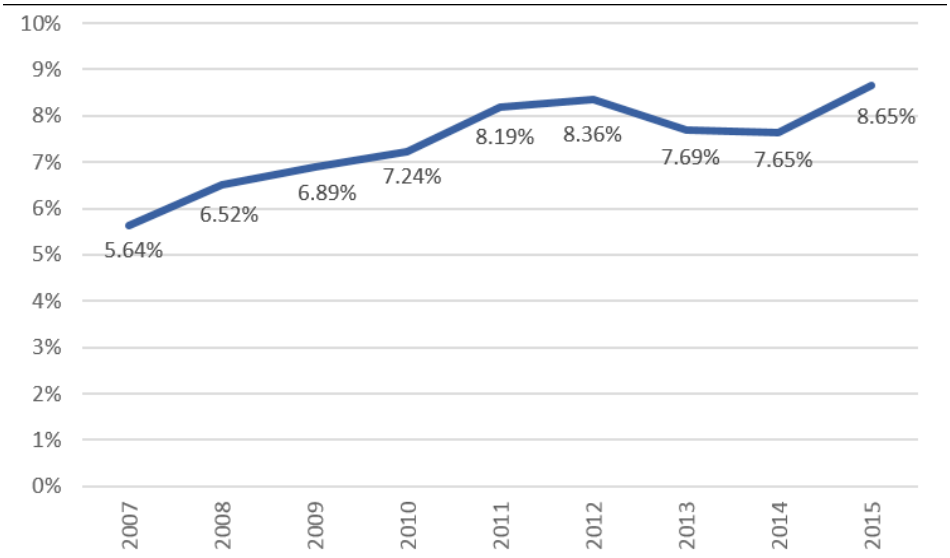
[1] http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=3802.
[2] The estimated extra energy from 154 GW at a 33% capacity factor is an additional 445,000 GWh.
[3] http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=2738.
[4] The IEA has three scenarios for trends in global energy supply and demand: Current, New Policies, and 450. See this Business Council blog for more details: http://bcbc.com/bcbc-blog/2017/global-energy-profile-in-2040.
[5] http://www.iea.org/policiesandmeasures/renewableenergy/.
[6] Control system engineers analyze, design, and optimize complex systems consisting of integrated coordination of mechanical, electrical, chemical, metallurgical, electronic or pneumatic elements. Control engineering deals with a diverse range of dynamic systems, including human and technological interface. http://ieeecss.org/CSM/library/1996/june1996/02-HistoryofAutoCtrl.pdf.

spatial requirements,[7] and — most importantly — the implementation of new storage capability to provide for improved system adequacy and flexibility. At the same time, significant land-use and land-access issues come with all forms of energy development, along with the uncertainties associated with global geopolitical upheaval. These factors could dampen the enthusiasm of public and of private investors to lay out large sums of capital to rapidly expand the role of renewables in the world energy system. On the other hand, the domestic orientation of most electricity markets and the recent strong renewable investment momentum may moderate the effect of such negative forces.

CANADA

By any standard, Canada is a global leader in renewable electricity. We are the third largest hydroelectric producer[8] — China produces 96.9 million tonnes of oil equivalent (MToe), Brazil 32.6 MToe, and Canada 32.2 MToe. China's production is roughly three times Canada's, but it has 38 times the population. Canada is also an energy export nation whereas China is a major net energy importer. Much of our domestic final electricity demand is served by non-emitting sources — 80%, in fact.[9] So, despite what critics sometimes say about Canada's energy profile, in truth we are already on top. With a capacity factor of 51%, we lead the world by a significant margin on this performance measure (Table 1). This

FIGURE 1: **PERCENT CHANGE IN GLOBAL RENEWABLE ELECTRICITY CAPACITY ADDITIONS FROM THE PREVIOUS YEAR**



Source: Renewable Energy Statistics 2016, IRENA.

THE FUNDAMENTALS

A refresher on the fundamentals is necessary to understand the scope, relative size and potential for renewables in a system dominated by carbon sources of energy.

Capacity is the maximum electric output an electricity generator can produce under specific conditions. Nameplate capacity is determined by the generator's manufacturer and indicates the maximum output of electricity a generator can produce without exceeding design limits. No generating unit operates at 100%. Factors such as operating costs, market conditions, technological constraints, and the availability of the necessary resources also determine how much a generator runs.

Energy is the amount of electricity a generator produces over a specific period of time. For example, a generator with 1 megawatt (MW) capacity that operates at that capacity consistently for one hour will produce 1 megawatt hour (MWh) of electricity. If the generator operates at only half that capacity for one hour, it will produce 0.5 MWh of electricity. Many generators do not operate at their full capacity all the time. A generator's output may vary according to conditions at the power plant, fuel costs, and/or as instructed by the electric power grid operator.

Capacity factor is the ratio of a power plant's actual output over a period of time, to its potential output if it were possible to operate at full nameplate capacity continuously. Most intermittent renewables have a low capacity factor. For example, in 2015, wind and solar were 9% of Canadian capacity but generated only 5% of the country's total electricity that year.

Measurement:

MW = 1 watt*10^6

GW = 1 watt*10^9

TW = 1 watt*10^{12}

1 MWh = 1MW*8,760 hours

Capacity factor = actual GWh generation / potential GWh generation

Source: National Energy Board and US Energy Information Administration.

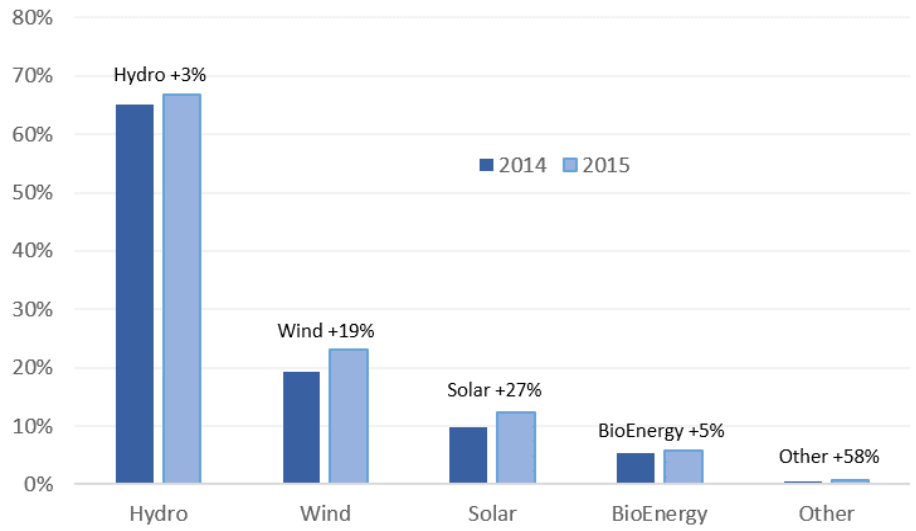
[7] http://bcbc.com/publications/2016/book-review-ipower-density-a-key-to-understanding-energy-sources-and-uses/i.
[8] https://www.worldenergy.org/data/resources/resource/hydropower/.
[9] http://unfccc.int/files/focus/long-term_strategies/application/pdf/canadas_mid-century_long-term_strategy.pdf.

is important: it means that for every unit of installed generation, Canada gets between 3% and 31% more energy from those resources than anywhere else in the world.

Within Canada, British Columbia, Manitoba, Quebec, and Newfoundland and Labrador have a long-term competitive edge with virtually all electricity demand filled by renewable electrons. Granted, new capacity additions have been modest – a 25% increase between 2006 and 2015 — due to both a slow growth economy and community opposition to all types of infrastructure development. It is not only oil and gas facilities that suffer the wrath of environmental groups and other critics, but also proponents seeking to advance wind, small hydro, and bioenergy projects. This is concerning. Energy is the "oxygen" of the global economy. Without exaggeration, modern civilization was quite literally built by harnessing energy.[10] Without adequate energy, our standard of living is materially lower. It is especially problematic when commentators and politicians in comparatively affluent economies like Canada tell citizens and decision-makers in emerging economies to forego the undoubted gains in living standards that flow from the development and use of energy.

The electric sector is constrained by physical delivery through transmission and distribution systems. Electricity must be used as it is produced. It cannot be shipped like other carbon-based forms of energy. Therefore, most electric systems have a domestic infrastructure focus. But Canada, the United States, and Mexico

FIGURE 2: **INTERNATIONAL RENEWABLE ENERGY AGENCY (IRENA) 2016 RENEWABLES CAPACITY DATA (EX NUCLEAR) AND PERCENT CHANGE BETWEEN 2014 AND 2015**



Source: Renewable Energy Statistics 2016, IRENA.

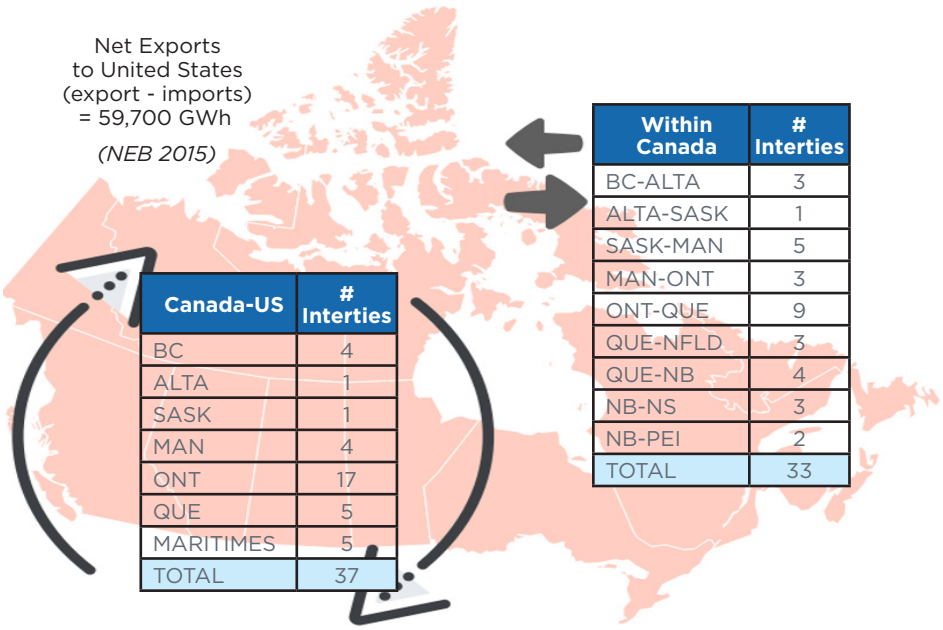
TABLE 1: **TOTAL INSTALLED ELECTRIC CAPACITY**

Total Capacity (GW)	2006	2014	% Change	2014 Capacity Factor (GWh actual/GWh potential)
World	1031	1965	90%	33%
Africa	25	36	47%	43%
Asia	292	780	167%	31%
Central America + Caribbean	7	12	78%	39%
Eurasia	65	90	38%	34%
Europe	272	493	81%	28%
Middle East	11	17	64%	20%
North America	211	327	55%	38%
Canada	**75**	**94**	**25%**	**51%**
USA	123	215	75%	32%
Oceania	17	26	54%	34%
South America	133	183	38%	48%

Source: Renewable Energy Statistics 2016, IRENA.

[10] Energy for Economic Growth: Energy Vision Update 2012, World Economic Forum. Tracking Clean Energy Progress 2013, International Energy Agency.

FIGURE 3: **WITHIN CANADA AND CANADA-UNITED STATES ELECTRIC INTERTIES**



Canada-US	# Interties
BC	4
ALTA	1
SASK	1
MAN	4
ONT	17
QUE	5
MARITIMES	5
TOTAL	37

Within Canada	# Interties
BC-ALTA	3
ALTA-SASK	1
SASK-MAN	5
MAN-ONT	3
ONT-QUE	9
QUE-NFLD	3
QUE-NB	4
NB-NS	3
NB-PEI	2
TOTAL	33

have a distinct advantage in this area. There are more than 30 grid interconnections[11] between Canada and the United States, along with regional grid coordination – eight regions[12] — and common North American reliability standards.[13] This means we can not only export electricity but also help each other meet the unique needs of managing an electric system with diverse supply sources, while also collaborating to reduce continental greenhouse gas emissions linked to the production and use of power. But make no mistake, there are a host of challenges to deal with before a fully integrated North American electrical system can be realized. To begin with, Canada has less energy transfer capability west-east than north-south, despite an almost equal number of interconnections. So what is our priority? Do we want to take a domestic or a more North American approach to energy issues?

BRITISH COLUMBIA

To put BC in perspective, 98% of our electricity is generated from renewable resources. BC Hydro meets 80% of all electricity demand in the province. Twenty-eight percent of BC Hydro's total installed capacity is produced by renewable private sector projects,[14] or 4.5 GW of the total ~15.8 GW of installed capacity (Table 2). About 26% of BC Hydro end-use electricity is accounted for by private sector renewable sources. When viewed in the context of total BC domestic electricity,[15] Independent Power Producers (IPPs) who have contracts with BC Hydro meet 30% of provincial end use demand.[16] All other investor owned utilities, of which there are five, sell only renewable energy purchased wholesale from BC Hydro or generated from hydro facilities like those owned by Fortis BC. British Columbia already exceeds the IEA's NP 2040 electricity goal — 37% from renewables — by 2.5 times. Moreover, we have surpassed the IEA's 450-scenario goal of 58% renewable electricity, as has Canada.

TABLE 2: **RENEWABLE IPPs SELLING TO BC HYDRO**

	Installed GW	GWh*
Biogas	0.018	127
Biomass	0.797	3,158
Energy Recovery	0.024	141
MSW	0.025	166
Non-Storage Hydro	1.818	6,676
Storage Hydro	1.287	4,925
Solar	0.001	2
Wind	0.487	1,365
TOTAL Renewable IPP	4.456	16,560
BC Hydro	11.4	48,445
TOTAL BC Hydro + IPP	16.885	65,005
IPP % of BC Hydro	26%	25%

* Firm energy is assumed to be equal to the annual average energy based on the assumption of steady state supply.

Source: BC 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.

[11] http://www.electricity.ca/media/ReportsPublications/CEA_16-086_The_North_American_E_WEB.pdf.
[12] Regional Entities: Florida Reliability Coordinating Council, Midwest Reliability Organization, Northeast Power Coordinating Council, Reliability First Corporation, SERC Reliability Corporation, Southwest Power Pool, RE Texas Reliability Entity, and Western Electricity Coordinating Council (WECC).
[13] http://www.nerc.com/pa/Stand/Pages/ReliabilityStandards.aspx.
[14] 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 (19,762 GWh/51,000 GWh). BC Hydro supplies 80% of BC's electricity.
[15] http://www.bcuc.com/Documents/AnnualReports/2016/DOC_45758_BCUC_AR2015_FINAL.PDF.
[16] 16,559.70/~55,000 = 30%.

TABLE 3: **POTENTIAL NEW RENEWABLE BC/BC HYDRO ELECTRICITY OPTIONS**

					Utility Delivered Levelized Cost Estimate $/MWh	
	% of Total	# Projects Potential	GWh/year	Capacity (MW)	Low	High
Biogas	0.09%	12	134	16	56	156
Biomass	6.62%	15	9,772	1,226	132	306
Geothermal	4.06%	18	5,992	780	90	593
MSW	0.29%	3	425	50	83	204
Run of River*	16.61%	1,169	24,543	1,149	143	1,170
Solar	0.04%	10	57	12	341	954
Tidal	0.97%	12	1,426	247	264	581
Wave	1.70%	16	2,506	259	453	820
Wind - offshore	38.38%	43	56,700	3,819	182	681
Wind - onshore	31.25%	121	46,165	4,271	115	365
		1,419	**147,720**	**11,829**		

* Based on a supply cost of $500/MWh unadjusted cost

Source: BC Hydro ROR Update and Resource Options Update, Results Summary, October 2016.

Are there any opportunities left? Yes, some projects are needed to meet growing domestic demand and to close the existing 2% gap, assuming BC policy-makers wish to do so. Other renewable projects can be developed to supply the North American export market if we choose to pursue further sales to markets in Alberta and the United States.

This future supply may be filled from a variety of renewable projects. Table 3 summarizes BC Hydro's most recent resource options update.[17] Many of these, while not economic now, may become so as time passes. Investing in the sector is a long-game; patience is important. In the meantime, BC can also use its abundant natural gas resources, if needed, to help meet domestic demand.[18]

STORAGE

What is critical for future development of renewables in both BC and around the world is viable and economic storage options — mechanical, electrochemical, thermal, and chemical. Storage enables more energy arbitrage, frequency regulation, demand-charge reductions, back-up power, and load shifting/time of use management of the inherent intermittent energy output associated with most renewable electricity resources other than hydro.

Arguably, BC's hydroelectric base is an enviable source of storage capability. The question is whether we should transform the province's existing highly efficient system that still provides British Columbians with relatively inexpensive electricity,[19] into one more focused on supporting non-firm renewable resources. Ultimately, this is something policy-makers must tackle.

[17] https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/regulatory-planning-documents/integrated-resource-plans/current-plan/0300a01-nov-2013-irp-appx-3a-1.pdf.
[18] Although the 2010 Clean Energy Act effectively precludes using natural gas as a power source.
[19] See map on page 4 of http://www.hydroquebec.com/publications/en/docs/comparaison-electricity-prices/comp_2015_en.pdf. In 2015, BC had the second lowest average residential rates, the fifth lowest industrial rate.

That aside, pumped storage (mechanical) is currently an almost competitive opportunity in BC, with an estimated dependable 465 MW of capacity at a cost of $100/MW.[20] Batteries are another option. Nascent today, over time battery storage could revolutionize the electric sector and be a major disruptor of the traditional, vertically integrated utility business. This would be a shift "back to the future" in terms of distributed generation, inasmuch as most electric systems started as small projects servicing town street lighting needs – and, in BC, mining communities in the late 1880s.

But renewable energy is where BC and to some extent Canada have a competitive advantage in the engineering and environmental services industries. We know how to build high quality renewable projects producing optimal gigawatt hours. There is no point adding additional GW of renewables for the sake of being able to brag about total capacity. What is important is meeting actual energy demand, something we excel at doing. The Business Council believes Canada and BC should be actively marketing our technical, engineering, and management know-how in electricity to the rest of the world. In this sector, as in many others, we need to be a trading nation.

CONCLUSION

When it comes to renewable energy, the world has a long way to go to catch up to BC and Canada. The IEA and the International Renewable Energy Agency suggest there is an electric sector investment requirement of $770 billion between now and 2030 (mostly in emerging economies).[21] Our priority should be meeting domestic demand, where it makes sense and is cost effective, while also looking at ways to leverage what we do well to increase our global market presence and earn a substantial return on the investments we have made to date.

AUTHORED BY

Denise Mullen
Director, Environment and Sustainability
Business Council of British Columbia

[20] At BC Hydro's Mica generating facility.
[21] The IEA estimates the need for $44 trillion renewable and non-renewable energy investment to 2040.