CLEAN CONNECTION: CANADIAN AND U.S. ELECTRICITY

CENTER FOR CLIMATE AND ENERGY SOLUTIONS

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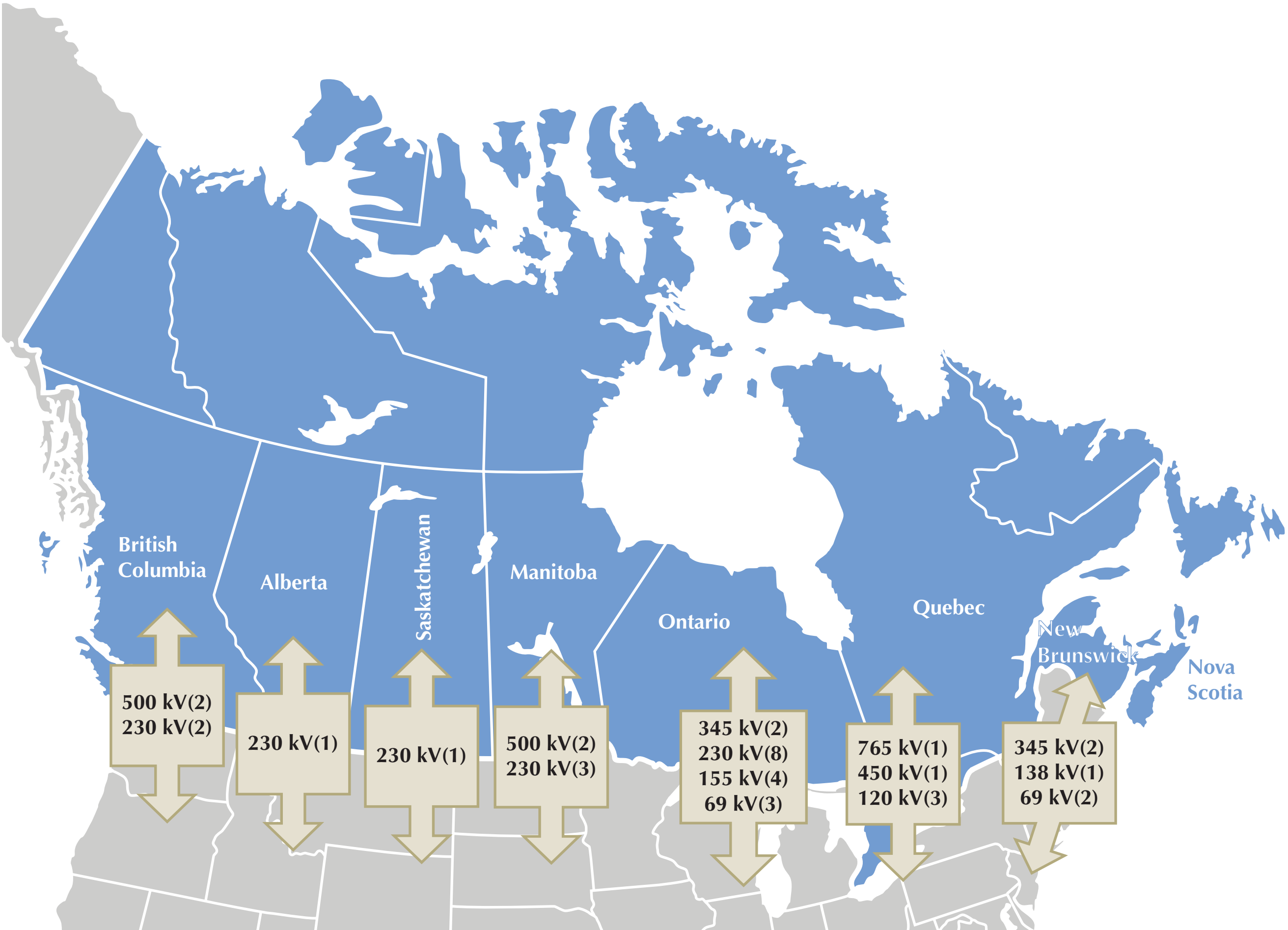
The U.S. and Canadian electric power grids are connected by dozens of transmission lines from New England to the Pacific Northwest. The interconnected North American power grid enables two-way trading and benefits both Canada and the United States with enhanced electric reliability, increased environmental (i.e., lower carbon and air pollution) and economic benefits (i.e., affordability), security, and resilience to increasingly frequent extreme weather events. The two countries have worked together to improve service through markets, international regulatory bodies and various bilateral engagements. Both nations have prioritized climate change mitigation, leading to greater action by provinces, states, cities and businesses and a growing demand for clean electricity. Connecting more low-carbon electricity (i.e., wind, solar, nuclear and hydro) on both sides of the border with additional transmission capacity can increase trade and enable a more efficient build out of clean electricity infrastructure, helping ensure each country achieves its clean energy goals even more affordably and reliably. Due to the comparatively clean mix of Canadian electricity, increased trade could assist the United States as well as individual states and cities in achieving their clean energy goals. Furthermore, the inherent storage capability of Canadian hydropower can help states integrate greater quantities of intermittent renewable power.

INTRODUCTION

The U.S. and Canadian economies are highly integrated. There is no better illustration of this connection than the North American electricity grid. Across the U.S.-Canadian border, around three dozen major (i.e., greater than 69 kilovolts) two-way transmission connections imported and exported 77.3 million megawatt-hours (MWh) of U.S. and Canadian electricity in 2020 (**Figure 1**), enough to power 7 million average households.[1] An interconnected grid enhances system reliability, security, affordability and resilience on both sides of the border. In the Pacific Northwest, the integrated grid has contributed to economic growth by delivering low-cost

FIGURE 1: Major Transmission Interconnections between Canada and the United States



Note that kV stands for kilovolts, therefore 500 kV means 500,000 volts.

Source: Canada Energy Regulator 2016 and C2ES.

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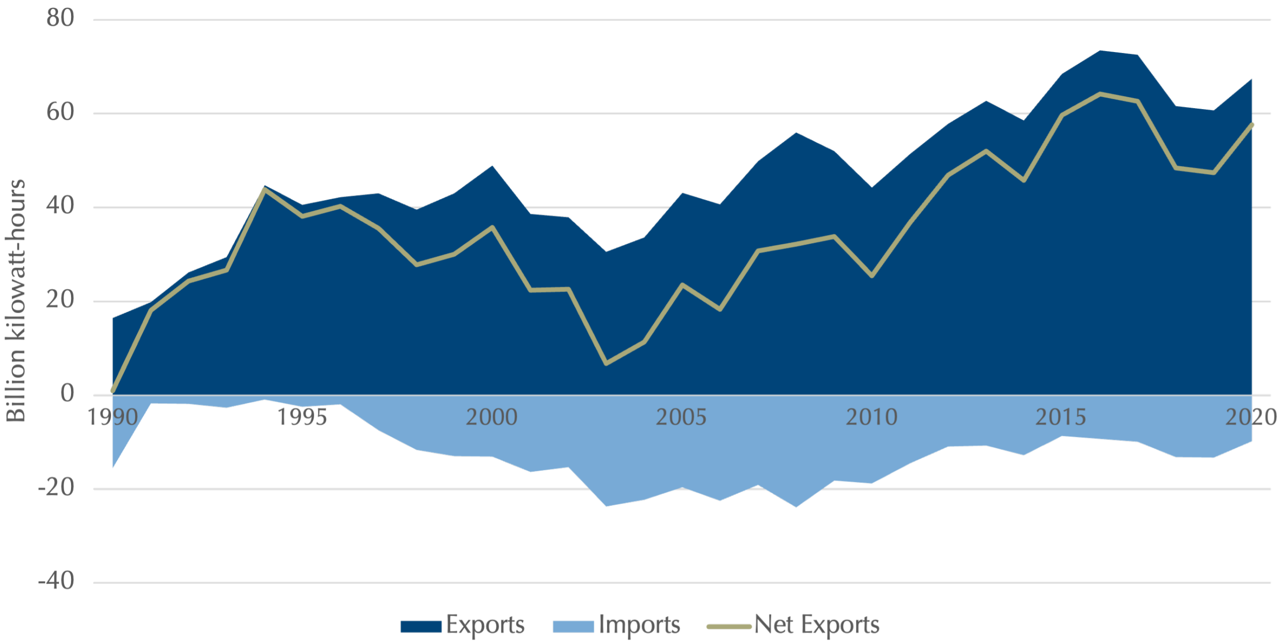
power to a formerly underserved region and increased safety through coordinated flood-risk management.[2] In New England, electricity imports from Québec and New Brunswick contribute to lower wholesale power costs and deliver an annual economic benefit in the range of $103 million to $471 million.[3] As noted in recent bilateral discussions, both countries are looking to completely decarbonize their economies before mid-century; expanding cross-border transmission capacity could significantly reduce the costs of necessary clean electricity buildout (i.e., solar, wind, hydro, nuclear and battery storage) in Canada and the United States.[4] Additionally, states like New York and Massachusetts are looking to Canadian hydropower to help achieve their clean energy goals. Furthermore, Minnesota is taking advantage of the storage capability of Canadian hydropower to help it integrate greater quantities of variable renewable power.

This report summarizes the existing electricity relationship between Canada and the United States, including areas of international cooperation and electricity trade. Next, the report provides an overview of the Canadian and U.S. power sectors, noting existing electricity source mixes and trends. Then, the report summarizes key Canadian climate-related policies both at the federal and provincial level. Finally, the report highlights opportunities and challenges that exist for additional integration of the two systems that could assist the United States as well as individual states, cities, and companies (operating on both sides of the border) in achieving their clean energy goals.

FIGURE 2: Canadian Electricity Net Exports, 1990 - 2020



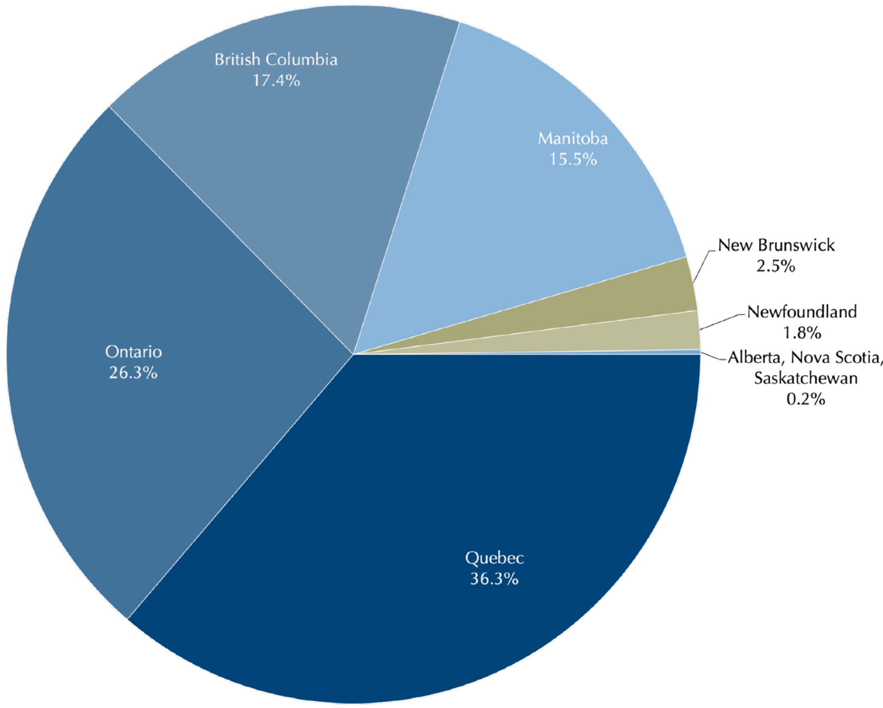
Source: "Commodity Statistics: Electricity: Electricity Exports and Imports: Table 1," Canada Energy Regulator, last modified March 2021.

ELECTRICITY RELATIONSHIP

Electricity systems and power markets are tightly integrated across the U.S.-Canadian border.[5] Provincial and U.S. power grids are physically interconnected. Power markets, particularly ISO New England (ISO-NE), the Midcontinent Independent System Operator (MISO), New York Independent System Operator (NYISO), Northwest Power Pool (NWPP), Southwest Power Pool (SPP), and the PJM Interconnection, facilitate cross-border trading. In 2020, 26 states imported electricity from Canadian provinces, with more than 1 million MWh electricity flowing through lines crossing at eight states (California, Maine, Michigan, Minnesota, New York, North Dakota, Vermont and Washington).[6] Also, international regulatory entities like the North American Electric Reliability Corporation (NERC) help ensure the power system functions uninterrupted across North America.[7] From a national security standpoint, the United States and Canada collaborate (e.g. share information and expertise) to protect the grid from cyber and other threats, enhance response and recovery efforts, and work toward creating a more secure and resilient future electric grid.[8] Mutual assistance is a hallmark of the system. Examples are numerous: in 2018, Hydro One deployed forestry staff to assist with response efforts related to wildfires; Minnesota Power came to help Manitoba Hydro restore power following an October 2019 winter storm; and in April 2020, Hydro Québec sent crews to help restore power in Maine after a late-season severe winter storm.[9] Most recently, during the February 2021 severe weather events in the United States, Manitoba Hydro and SaskPower provided support to MISO and SPP.

The U.S. and Canadian electricity grids are connected at about three dozen locations stretching from New England to the Pacific Northwest.[10] Since electricity demand peaks in each country during different seasons (in general, Canada peaks in the winter and the United States in the summer) the sharing of reserve services across the connected grids reduces the need for new capacity in both countries.[11] Diversity exchange agreements can also reduce the need for new capacity in both countries, with reserve sharing being another benefit to interconnection outside of seasonality considerations. This may be especially important if electrification of economies shifts demand peaks in some cases.

Figure 3: **Canadian Electricity Exports by Province, 2020**



Source: "Commodity Statistics: Electricity: Electricity Exports and Imports: Table 2A," Canada Energy Regulator, last accessed March 2021.

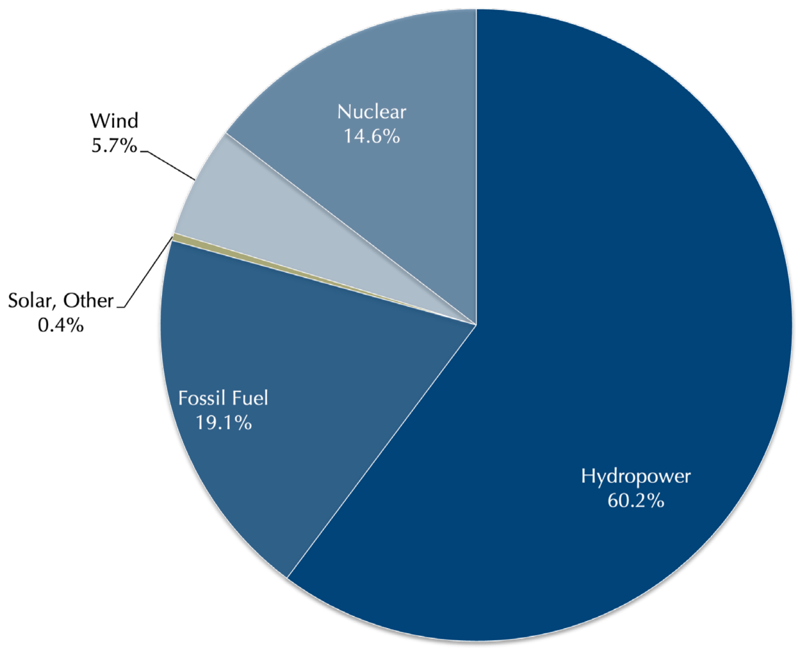
An interconnected North American electricity system provides additional benefits. An expanded electricity market creates economies of scale, which can lower operating costs that ultimately lead to lower electricity costs for end-users.[12] Additionally, integration brings together a greater diversity of electricity sources, which protects against fuel unavailability, fuel price uncertainty, and regulatory uncertainty, while increasing overall reliability and security.[13] During a recent and sustained extreme cold outbreak across the Great Plains, two provincial power utilities (i.e., SaskPower and Manitoba Hydro) were able to deliver surplus Canadian power to help meet unprecedented levels of U.S. demand.[14]

Since 1990, Canada's electricity exports to the United States have generally increased (**Figure 2**). In 2020, 67.5 million MWh was exported to the United States, which was 1.7 percent of total U.S. electricity production and about 11 percent of total Canadian generation. Canada also imports electricity from the United States at times to help it meet demand.[15] However, over the past 30 years, Canada has been a net exporter of electricity to the United States.[16] Around three-quarters of exports are traded short-term on power markets and the remaining quantities are sold through longer-term fixed contracts.[17] In 2020, Québec was the largest electricity exporting province to the United States, followed by Ontario, British Columbia, and Manitoba (**Figure 3**).[18]

ELECTRICITY MIX AND TRENDS

Currently, the electricity fuel source mixes of the Canadian and U.S. power sectors are quite different. Nearly 81 percent of Canadian electricity, compared with 39 percent of U.S. power, is derived from non-emitting sources, e.g., hydropower, nuclear, wind, solar and other renewables. In the decade ahead, power generation in both countries is expected to become even cleaner. In recent bilateral discussions, the President declared the goal of achieving a carbon neutral power sector in the United States by 2035, and the Prime Minister reiterated Canada's ambition to reach 90 percent non-emitting power generation by 2030.[19] Moreover, the leaders agreed to take a "coordinated approach" to advance clean electricity targets, including infrastructure and cross-border transmission development.[20] Due to its inherent storage

Figure 4: Canadian Electricity Generation by Fuel Type, 2020



Source: "Table 25-10-0015-01 Electric power generation, monthly generation by type of electricity," Statistics Canada, last accessed March 18, 2021, .

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capability, greater integration of Canadian hydropower can enable the deployment of even greater quantities of variable U.S. renewables, and, at the same time, minimize the total amount of clean generation capacity that needs to be deployed on either side of the border, increasing the likelihood of power sector decarbonization in both countries well before mid-century.

Canadian Electricity Mix

Canada generated more than 636 million MWh of electricity in 2020.[21] More than 80 percent of electricity generation came from extremely low emission sources with fossil fuels making up only 19 percent (**Figure 4**). Over the past dozen years, hydropower has contributed around 60 percent of total Canadian electricity generation.[22] Typically, the provinces of British Columbia, Manitoba, and Québec derive more than 90 percent of their electric power from hydropower.[23] In a wetter than average year, hydropower contributes a higher percentage of total electricity thereby further reducing the amount of (and emissions from) fossil fuel generation. Because of this generation mix, the electric power sector is responsible for less than 9 percent of Canada's greenhouse gas emissions.[24]

A heavy reliance on hydropower, however, is not without some risk because there is an obvious connection between supply and precipitation levels. The potential for drought and excessive rainfall exists in British Columbia, Manitoba, Newfoundland and Labrador, Ontario, and Québec – the primary hydropower-producing provinces. To ensure availability of electricity supply from hydropower, electric utilities use the historical record of watershed precipitation (decades of inflow data) to establish a planning baseline. This baseline may be established by taking the lowest, average, or median flow on record. Utilities want to ensure that they have sufficient hydropower capacity to meet expected demand even under extremely low inflow conditions. As a result of this conservative planning approach, there is often excess energy generated and sold under higher-than-baseline flow conditions.

Some hydropower facilities also have multiple-year reservoir storage available, which also greatly reduces the risk of having to reduce production during low-water years. This storage capability provides additional value in the form of generation flexibility, which allows system operators to adjust hydropower output quickly to meet changing needs on the grid. Flexibility is especially important as more variable renewable sources such as wind and solar are added to the mix. For example, a utility agreement will allow Minnesota Power to sell excess off-peak wind generation to Manitoba Hydro and buy back firm hydropower when needed; a sufficiently interconnected grid (i.e., necessary transmission) makes this arrangement possible.[25]

Canadian Electricity Trends

From 2005 to 2018, Canada's electricity sector reduced its greenhouse gas emissions by 46 percent.[26] A large decline in coal-fired generation, a general increase in hydropower generation, and increasing other renewable deployments (mostly wind power), offset by a considerable increase in natural gas- and oil-fired generation, led to this decline. Federal and provincial policies, including a recommitment to nuclear power, are expected to continue to reduce power sector emissions.[27]

In 2014, the province of Ontario achieved its 2003 coal phase-out commitment, retiring 7,560 megawatts (MW) of capacity over the period.[28] Since 2005, coal-fired generation nationally decreased by more than 50 percent, largely a result of Ontario coal retirements.[29] At the same time, hydropower capacity increased by more than 8,000 MW. In 2017, Canada had an installed hydropower capacity of more than 80,000 MW out of a total electric capacity of about 145,200 MW—about 55 percent.[30] Also, wind power capacity jumped from just 557 MW in 2005 to more than 13,000 MW in 2019.[31] Finally, from 2005 to 2019, electricity generated using natural gas (from industrial and electric power sectors) increased by 90 percent.[32]

In 2016, Ontario Power Generation (OPG), the government-owned corporation that runs Ontario's nuclear power plants, embarked on an ambitious plan to refurbish 75 percent of its reactor capacity, which will ensure their operation for an additional 30 years.[33] In 2018, Natural Resources Canada, a group of provincial and territorial governments, and power utilities launched a small modular reactor (SMR) roadmap to focus on additional benefits from nuclear power. While the power sector is responsible for just 9 percent of Canada's total greenhouse gases, SMRs can help decarbonize electricity and heat-related emissions, particularly in challenging remote locations. For example, a strong market opportunity exists in supplying heat and power to widely scattered, indigenous, First Nation communities and other isolated populations in the far north, who currently rely on expensive and dirty diesel generators for electricity. Micro-reactor powered microgrids in these locations could make a serious dent in carbon dioxide and black carbon emissions, saving money and improving the environment. There are further opportunities in remote oil, natural gas, and mining operations. Canada is working cooperatively with the United States on a number of fronts, including developing new designs, testing, and devising new licensing models to help deploy this promising technology as soon as possible.

Other policies that Canada has put in place, including a coal phase-out discussed in more detail in the next section, are projected to make its electricity generation even cleaner. Canada has a vast potential to increase its non-emitting electricity generation portfolio. A 2006 study by the environmental consulting firm EEM found that the total technical potential for new hydro across all provinces and territories was around 163,000 MW—12 percent greater than the nation's total installed electricity capacity.[34] There is typically a sizeable difference, however, between the technical potential and economic feasibility of projects, and some environmentalists and indigenous communities in Canada have expressed concerns around large scale hydropower development. Still, power companies are actively taking advantage of a portion of this potential capacity. As of mid-2020, more than 3,200 MW of new large hydro capacity was under construction.[35] Canada has also been a leader in carbon capture utilization and storage technology (see Box 1)—a key technology for decarbonizing the electric power sector globally.

U.S. Electricity Mix

By contrast, the U.S. electric power sector is much larger and more fuel diverse than the Canadian system. The United States generated more than 4,000 million MWh of electricity in 2020.[36] Fossil fuels generated a little more than 60 percent of that electricity. Zero-emission power sources, such as hydropower, wind, solar, and nuclear power, generated the balance of U.S. electricity.[37] In 2020, conventional hydropower contributed 7.3 percent

Box 1: Carbon Capture, Utilization, and Storage

To keep global temperature change below 2 degrees Celsius (3.6 degrees Fahrenheit) relative to pre-industrial levels and avoid the worst effects of climate change, global net greenhouse gas emissions must be approaching zero by the second half of this century.

Key actions for decarbonizing the electric power sector globally include deploying more carbon capture, utilization and storage on new and existing fossil fuel plants (and/or phasing them out over time), increasing the amount of nuclear generation, becoming more energy efficient, and significantly increasing the amount of renewable electricity.

In late 2014, electric utility SaskPower switched on a refurbished unit 3 at its Boundary Dam coal-fired power plant in Estevan, Saskatchewan.[101] It was the world's first large-scale, post-combustion carbon capture project at a power plant. Since startup, it has captured nearly 4 million metric tons of carbon dioxide.[102] SaskPower continues to share its expertise with interested parties, and it is hoped that the project will serve as a model for development in other parts of the world.

In the near future, Capital Power is planning to capture carbon dioxide from its Genesee Generation Station, just outside of Edmonton, and create the world's largest carbon nanotube production facility.[103] Production of carbon nanotubes not only keeps carbon dioxide out of the atmosphere, but they can also displace the amount of carbon-intensive materials (e.g., cement and steel) needed for final products.[104]

of overall U.S. generation (**Figure 5**) and more than 18 percent of the nation's zero-emissions power. Wind and solar combined provided nearly 27 percent, and nuclear made up 50 percent of zero-emission power. The power sector is responsible for 27 percent of U.S. greenhouse gas emissions.[38]

U.S. Electricity Trends

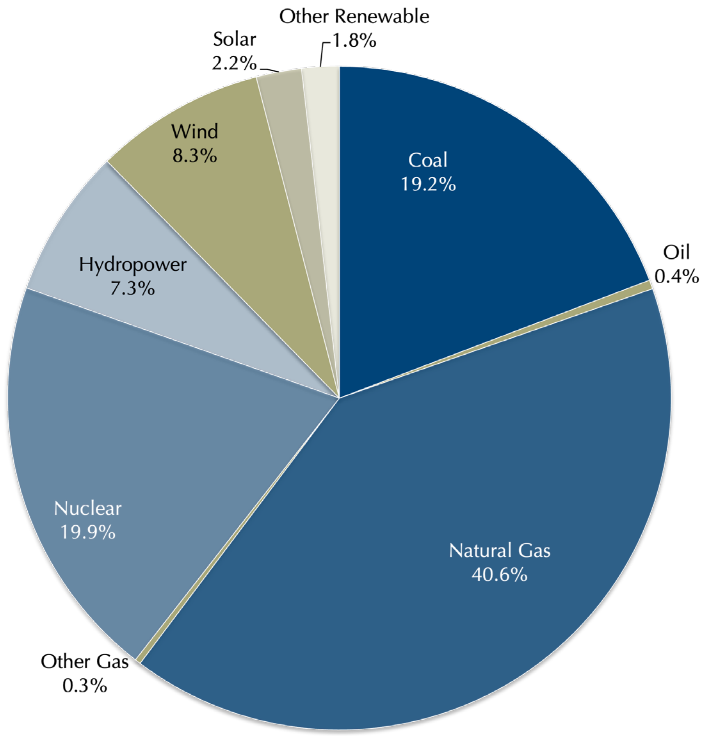
From 2005 to 2020, the U.S. electricity sector reduced its greenhouse gas emissions by 40 percent.[39] For the past 10 years, electricity emissions have been declining due to several factors, including a shift from coal to natural gas, growth in renewable energy, and level electricity demand. This change has occurred due to a combination of market forces, regulations, federal and state policies, and company action.

Since 2005, coal-fired generation has fallen from 50 to 19 percent of the U.S. electricity mix, while less carbon-intensive natural gas-fired generation has risen from 19 to 41 percent. Additionally, renewable generation (particularly from wind, and more recently solar) has increased from less than one-half of 1 percent to more than 10 percent of total U.S. electricity generation. Offsetting these reductions, nuclear power is facing economic challenges with 11 reactors (around 8,600 MW) closing prematurely since 2012, primarily being replaced by fossil fuels.[40] Notably, electricity demand has grown by just 0.2 percent per year on average over the past 10 years.[41]

Considering expected market prices and currently adopted federal and state policies, U.S. electric power sector emissions are projected to decrease 394 million metric tons (24 percent) from 2019 levels by 2030 or 49 percent below the 2005 level.[42] Under this business-as-usual forecast, U.S. electricity demand is expected to grow by only 0.2 percent per year on average out to 2030, and solar, wind and natural gas combined cycle plants are expected to provide the majority of future U.S. electric capacity additions.[43]

A political shift in the United States has once again put climate change front and center at the federal level. In his first few days in office, President Biden rejoined the Paris Agreement and issued a raft of climate-focused executive orders.[44] A key plank of the new administration is an ambitious pledge to make the U.S. power sector carbon neutral by 2035. The core of his climate plan is likely to be formed in a massive, recently announced, infrastructure bill (i.e., The American Jobs Plan) expected to be passed later this year.[45] The legislation will likely include investments in new power generation, electric grid infrastructure (including new transmission lines)

Figure 5: U.S. Electricity Generation by Fuel Type, 2020



*Source: "*Electricity Net Generation: Total (All Sectors). Table 7.2a.*" U.S. Energy Information Administration, March 18, 2021.*

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and the electrification of transportation, among many other things. The bill could also include a clean electricity standard (CES), an effective market mechanism for decarbonizing the electric power sector, but this would be challenging.[46] There are also CES bills in various stages of development in Congress that recognize Canadian electricity imports as clean. Also, the Biden administration is likely to promulgate new pollution rules through the U.S. Environmental Protection Agency (EPA) for greenhouse gas emitters, which could help drive down emissions as a complementary policy to legislative efforts, but there are scant details at this time.

At the subnational level, i.e., across states, cities and businesses, momentum for clean energy continues. States like California, Massachusetts, Maryland, and New York have recently increased the ambition of their clean energy targets (e.g., clean electricity standards, energy efficiency, and greenhouse gas reduction targets). This trend is expanding with nearly 20 states now with either statutory or binding legislation, legislative goals or executive orders to achieve 100 percent clean electricity by 2050 or earlier.[47] In addition to states' efforts, 187 cities across the United States in the Covenant of Mayors are currently committing to creating action plans to reduce their greenhouse gas emissions.[48] Additionally, 290 major global companies, many with large U.S. footprints, have publicly committed to the goal of using 100 percent renewable energy.[49] As of April 2021, 72 U.S. electric utilities have announced some type of emission reduction target and 49 have set carbon-free or net-zero emission goals by 2050.[50] The combined actions of cities and businesses, which are not well captured by national models (i.e., a typical business-as-usual forecast) could help drive power sector emissions lower in the years ahead. Next, U.S. electricity demand could increase more significantly in the coming decade if deep-decarbonization policies are put in place, and transportation and other sectors (e.g., industrial and buildings) rely more heavily on a largely decarbonized electric power sector as an energy source in the future. Offsetting these drivers, an additional 4 nuclear reactors (around 4,100 MW) are scheduled to close prematurely between 2021 and 2025, though 2 new reactors (around 2,200 MW) should enter service over the same period. If policies are not put in place to address the challenges facing the existing nuclear power fleet, an even greater number of reactors might be forced to retire prematurely, leaving the United States with a great deal of zero-emission power to replace to continue its progression toward lower emissions.

KEY CANADIAN CLIMATE-RELATED POLICY

Environmental policies designed to combat climate change and protect air and water quality, ecosystems, and human health, directly affect the electric power sector. Key Canadian climate-related policies at the federal and provincial levels and their impacts on the power sector are summarized here.

Canadian Federal Policy

Over the past decade, the Canadian federal government has been a party to several international climate agreements. In 2009 as a party to the Copenhagen Accord, Canada agreed to reduce economy-wide emissions 17 percent below 2005 levels by 2020.[51] Then in 2015 as a party to the Paris Agreement, it pledged to reduce economy-wide emissions 30 percent below 2005 levels by 2030. In 2016 during the North American Leaders Summit, Canada, Mexico, and the United States announced a goal of 50 percent clean power generation (e.g. hydro, nuclear, and other renewables) across the continent by 2025.[52] In his statement at the summit, then-President Barack Obama acknowledged that insufficient infrastructure, particularly transmission capacity, could be an issue in achieving this target.[53] In recent U.S.-Canada bilateral discussions, even higher levels of clean electricity are now being pursued – 90 percent non-emitting power generation by 2030.[54] And, in the recent Leaders Summit on Climate, Canada increased its Paris Agreement emission reduction target to 40 – 45 percent below 2005 levels by 2030.[55] To help achieve these goals, policies to encourage additional hydropower and other renewable electricity generation are being put in place at all levels of Canadian government.[56] That said, in many cases, the process for deploying new generation remains lengthy and challenging.

At the national level, Canada plans to phase out traditional coal power in all its provinces by 2030.[57] Regulations on new coal-fired power plants, which set a performance standard of 420 tons of CO_2 per gigawatt hour, commenced on July 1, 2015.[58] The regulation is expected to spur a shift to lower-emitting natural gas-fired generation, non-emitting renewables, or fossil fuel-fired generation with carbon capture and storage. To further encourage this shift, the federal government has implemented a carbon price across all jurisdictions (i.e., the *Greenhouse Gas Pollution Pricing Act*) with the government setting the minimum allowable or floor price.[59]

Additionally, the national government plans to pursue complementary measures like tightening energy efficiency standards and driving technology innovation as well as adapting and building more resilient infrastructure. Its environment and climate plans are most recently highlighted in *A Healthy Environment & A Healthy Economy,* released in December 2020. The plan includes a proposal for an increase in the carbon price by 15 Canadian dollars per year starting in 2023, rising to CA$170 per metric ton in 2030. Further efficiency, transportation, industrial and other measures to help Canada achieve its climate goals were recently announced through the nation's budget process.[60]

In late March 2021, the Canadian Supreme Court upheld the federal government's ability to set a minimum price on GHG emissions, which serves as an important backstop to provincial actions and a strong climate signal to businesses and governments at all levels on both sides of the border.[61]

Provincial Policy

Canada also has notable policies to combat climate change at the provincial level. These include subnational climate action plans, greenhouse gas emission targets, carbon pricing programs, and renewable energy standards.[62] Specifically, Alberta and Ontario are pursuing programs to incentivize large emitting facilities to decarbonize; British Columbia is targeting fossil fuels with its carbon tax; and Québec is continuing with its cap-and-trade program. Importantly, provincial policies must be at least as stringent as existing federal policies, which serve as a national backstop.

In Alberta, the Technology Innovation and Emissions Reduction (TIER) Regulation (passed originally in 2007 and updated several times) provides an intensity-based target for power, oil and gas, and industrial facilities above 100,000 tons of CO_2 equivalent per year.[63] The law requires facilities to reduce their emission intensities relative to industry standards or specific benchmarks.[64]

Alternatively, firms can contribute CA$40 per ton to the TIER Fund, or purchase either credits from other firms or approved offset credits.[65]

In 2019, Ontario introduced its Emission Performance Standards (EPS) program.[66] The EPS applies to a defined group of large greenhouse gas-emitting facilities from electricity, chemicals, and metals among others, which will need to meet sector-based emission limits.[67] Facilities that beat emission targets can earn tradeable 'compliance instruments'; facilities that fall short of their compliance obligation can purchase compliance instruments from other EPS participants or pay for 'excess emission units' distributed each year.[68]

In July 2008, British Columbia introduced a carbon tax of CA$10 per metric ton of CO_2 equivalent on the purchase and use of fossil fuels within the province. It covers gasoline and other transportation fuels, natural gas, propane, and coal. The tax rate increased by CA$5 per year through 2012, and the rate is scheduled to increase to CA$50 on April 1, 2022, from the current CA$45 per metric ton of carbon dioxide equivalent.[69]

Québec aims to be a leader in energy efficiency and renewable energy output in 2030.[70] A key measure to achieve its goals is an emissions trading system, which took effect in January 2013. It covers the power sector and a broad range of industrial facilities. From 2015 onward, the program expanded to include the supply of transportation fuels, including gasoline and natural gas. The program is linked to California's cap-and-trade program so that allowances and offsets accepted in one program can be used in the other to comply with their obligations.

OPPORTUNITIES AND CHALLENGES FOR FURTHER INTEGRATION

More than 80 percent of Canadian electricity is derived from non-emitting sources, i.e., hydro, nuclear, wind, solar, and other renewables. Policies at the federal and provincial level are expected to make Canada's electricity even cleaner in the years ahead. Due to its conservative planning approach, there is often excess hydropower electricity that is generated and sold under higher-than-baseline flow conditions. Therefore, exported electricity is typically even cleaner than the total Canadian electricity mix. Additionally, provinces are adding more renewable capacity (e.g., hydro and wind) as part of their strategies to phase out coal. This, too, creates opportunities for exporting additional Canadian electricity to the United States. In recent bilateral discussions, in an acknowledgement that expanding clean electricity deployments will need to be supported by sufficient infrastructure, President Joe Biden and Prime Minister Justin Trudeau "agreed to take a coordinated approach to accelerating progress towards sustainable, resilient, and clean energy infrastructure, including encouraging the development of cross-border clean electricity transmission."[71]

Along with nuclear and geothermal power, hydropower (with reservoir storage) is an especially valuable zero-emission electricity source for the grid because it is capable of providing (baseload) power on demand. All of these technologies can complement variable renewable electricity sources without emissions, thereby enhancing system reliability in a sustainable way. Moreover, large hydropower is able to function like long-duration energy storage and provide critical black start capability after an outage, improving system resilience. And, large, spinning hydropower turbines (along with other large dispatchable electricity sources) provide crucial inertia or reactive power to support the voltages needed for power delivery.[72]

However, physical, financial, policy, and political constraints must be overcome to increase Canadian electricity flows to the United States. Additional infrastructure, including new electricity generating facilities and new transmission lines, are required.[73] Furthermore, without bilateral contracts in place, it can be challenging to obtain project financing for new transmission or hydropower project development. Also, new power projects, transmission infrastructure, and power contracts are subject to a variety of state, provincial, and federal regulations, which can become highly politicized with many stakeholders to satisfy. Finally, clean energy policies like U.S. federal, state and city greenhouse gas reduction targets or federal and/or state renewable/clean portfolio standards (RPS), and their treatment of international power imports from Canada, will have a direct impact on the future level of imports to the United States.

As noted above, the provinces of British Columbia, Manitoba, Ontario, and Québec trade the majority of electricity with the United States (**Figure 3**). While electricity sources are more diversified in Ontario, hydropower is responsible for more than 95 percent of electricity generated in British Columbia, Manitoba, and Québec. In a typical year, Manitoba, Ontario, and Québec generate more electricity than they require, providing an opportunity to participate in export markets.

New power projects face challenges. More than 2,600 MW of new hydropower capacity was under construction in Canada as of mid-2020.[74] Some of this new generation will meet expected domestic demand growth, and some will replace retiring thermal plants. New projects face scrutiny from a range of sources. Indigenous communities have been directly impacted by hydropower project development without serious consideration in the past. Today, however, there are consultations early in the development process where their concerns are given a fair hearing and are constructively addressed. Some environmentalists on both sides of the border have expressed opposition to new, large hydropower projects. However, power companies have been working to address and mitigate their concerns. In recent years, advances have been made in the design of facilities to minimize flooding and impacts on fish, including migratory fish. Additionally, new hydropower plants in Canada are being built far from populations, where there is little agriculture or existing infrastructure. Indigenous people are now partners in new hydropower (and other) projects; for example, four Manitoba First Nations have the right to own up to one-quarter of the Keeyask Project.[75] Furthermore, in the coming months the Government of Canada is expected to codify the rights of indigenous peoples and help achieve the goals of the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP), which, among many other things, "promotes their full and effective participation in all matters that concern them" and a pathway toward meaningful reconciliation.[76]

Similarly, expansion of the high-voltage transmission system can be difficult, requiring lengthy permitting at several levels of government. At the bilateral level, the U.S. Department of Energy and Natural Resources Canada collaborated to assemble regulatory and statutory requirements for transmission deployment, which was developed to create a greater understanding of the process.[77] In most instances, individual Canadian provincial electrical grids are more connected to bordering U.S. states than with adjacent provinces. Still, additional transmission capacity will be required to increase electricity trade and achieve full electricity decarbonization.

Several new cross-border transmission lines have been proposed, most along existing rights-of-way; these lines are dependent upon the requisite demand from the respective states. For example, the Champlain Hudson Power Express is a 1,000 – 1,250 MW high-voltage direct current (HVDC) transmission line from the Canadian border to New York City expected to go into service in 2025.[78] Additionally, the Lake Erie Connector is a 1,000 MW HVDC line that would link Ontario's Independent Electricity System Operator (IESO) and PJM with construction expected to begin later this year or in 2022.[79] Also in the northeast, the New England Clean Energy Connect (NECEC) Transmission Line from the Canadian border to a substation in Lewiston, Maine, will provide 1,200 MW of hydropower from Hydro-Québec to the New England power grid; construction on the line began in early 2021.[80] Further east, the Atlantic Link is a proposed subsea HVDC transmission line that plans to deliver 900 MW of electricity from Saint John, New Brunswick to Massachusetts.[81] In November 2016 in the upper Midwest, the U.S. Department of Energy granted a presidential permit for the Great Northern Transmission Line to run from the Canadian border to a substation near Grand Rapids, Minnesota.[82] In June 2020, more than 8 years after it was initially proposed, the line was energized and is now delivering hydroelectric power from Manitoba Hydro to Minnesota Power's customers.[83] This project will be especially beneficial from the perspective of zero-carbon electricity, as it will allow Minnesota Power to back up variable wind power (sited in North Dakota) with hydropower and send any excess wind power to Manitoba.[84]

A recent International Trade Commission (ITC) study further highlights this dynamic. Within an interconnected electricity system, hydropower with reservoir storage acts as a dispatchable, highly flexible power supply (i.e., can be ramped up and down quickly) and as long-duration electricity storage.[85] The ITC paper cites the Minnesota-Manitoba example as well as Denmark's ability to deploy large quantities of variable wind power (i.e., 49 percent of total generation in 2019) with firm, transmission connections to hydropower resources in Norway and Sweden.[86]

Another recent study from MIT demonstrates the favorable cost implications of implementing this type of trading relationship, as adding transmission to firm Canadian hydropower significantly reduces the overall renewable capacity that needs to be constructed on either side of the border to achieve a 100 percent clean power grid. The study shows that this bi-directional power sharing provides cost benefits to Canada and the United States; 4 GW of new transmission capacity from Quebec to New England and New York could save $2.4 and $3 billion a year, respectively.[87] [88]

Across the Canadian-U.S. border, the opportunity exists to replicate this model. Still, siting and building

Table 1: Smart from the Start Siting Policies and Criteria

• Consult stakeholders early and involve them in planning, zoning, and siting.	• Establish, when possible, pre-screened resource zones for development.
• Collect and use geospatial information to categorize the risk of resource conflicts.	• Incentivize resource zone development with priority approvals and access to transmission.
• Avoid land and wildlife conservation conflicts (including national parks and other protected areas) and prioritize development in previously disturbed areas.	• Consider renewable energy zones or development sites that optimize the use of the grid.
• Avoid cultural resource conflicts (historic sites, tribal resources, etc.).	• Maximize the use of existing infrastructure,including transmission and roads.
• Identify excellent renewable energy resource values.	• "Mitigation that matters" (durable and planned conservation improvements at larger scales).
	• Where zoning is not feasible (as in much of the Eastern Interconnection), use siting criteria based on the above principles.

Source: America's Power Plan (2013)

new transmission is a challenging, multiyear process, especially large, high-voltage projects that cross many jurisdictions. In general, federal permitting appears to be working, though local level issues seem harder to resolve. Using "Smart from the Start" policies and siting criteria can help (**Table 1**) and the U.S. Department of Energy (DOE) Regulatory and Permitting Information Desktop (RAPID) Toolkit is a valuable reference resource.[89]

Another promising approach that could ease transmission siting difficulties involves undergrounding and co-location in existing rights-of-way. While burying or undergrounding can cost ten times the amount of overhead transmission, it can increase system resilience and mitigate public opposition by eliminating visible infrastructure.[90] Undergrounding still requires transmission projects to get all of the necessary permits and can require the use of eminent domain to access the land on the planned route (which can spur lots of public opposition), but co-location can eliminate some of those hurdles. For example, the Direct Connect Development Company is advancing the SOO Green HVDC Link to bring 2,100 MW of clean electricity from western Iowa to the Chicago suburbs, via underground high-voltage transmission sited along existing railroad (and other transportation) rights-of-way to minimize environmental and visual impacts and avoid eminent domain issues.[91] [92] With future additional HVDC links, Direct Connect seeks to repeat for clean energy transmission the successful model previously used to build out the nation's fiber optic network.[93]

Electricity generators that have a power purchase agreement (PPA) in place are likely to find it easier to obtain financing for new power projects. A PPA is a long-term contract for electric power between a power generator and a purchaser, often an electric utility.[94] Generators value PPAs because the agreements guarantee a predictable revenue stream for delivered power over many years, while utilities like these contracts because they secure electricity price certainty in what can be a volatile market. Notably, two Canadian hydropower generators secured long-term PPAs with U.S. utilities, though there are many examples. Minnesota Power and Manitoba Hydro agreed to a 15-year deal for 250 MW, beginning in 2020.[95] Also in 2019, the Massachusetts Department of Public Utilities approved a 20-year, 9,554,940 MWh annual PPA between Hydro-Québec and 3 Massachusetts electric utilities for deliveries via the NECEC.[96]

Building new generation and new transmission, along with crafting PPAs, are subject to regulation from state, provincial, and federal agencies. Within these regulatory processes, projects and contracts face challenges from various stakeholders. Additionally, hydropower projects face competition from other forms of electric generation. For example, a public utility commission might be more inclined to approve a new natural gas-fired power plant because it would save ratepayers money relative to other forms of generation. In most instances, a state RPS excludes large hydropower and favors other sources of generation, namely small hydro, wind or solar power. Additionally, states may prefer to develop their own in-state generation because of the jobs that in-state electric power projects bring.[97]

Despite climate policy uncertainty at the federal level, several U.S. states (and cities) continue to create demand for clean energy through their policies (e.g., setting greenhouse gas reduction targets or otherwise increasing the ambition of their clean energy programs), creating opportunities for increased use of imported clean energy from Canada. Moreover, as noted earlier, many states and municipalities have now expanded their approach to electricity supply by employing or proposing Clean Energy/Electricity Standards that expand the clean resources that can qualify – including large scale hydro, nuclear power, and fossil fuels with CCUS, among others. Some states, including Massachusetts and New York, are explicitly using Canadian electricity to help meet their clean energy goals. Massachusetts through its PPA secured around 1,100 MW of baseload hydropower.[98] An increasing RPS (i.e., 70 percent renewable energy by 2030) and a planned closure of a nuclear plant in New York have increased attention on the Champlain Hudson Power Express transmission line, which would deliver 1,000 MW of hydropower from Quebec to New York City.[99] New York recently modified its clean energy standard (CES) in order to increase the amount of clean electricity entering the New York City zone, and some Canadian hydroelectric resources could be eligible.[100]

Looking longer term, power sector demand will grow significantly across North America as decarbonization policies are implemented and transportation, industry, and buildings rely much more heavily on the power sector as a low-carbon energy source. Demand for all zero-emission electricity sources will increase, but clean, firm, dispatchable sources like nuclear and hydro are especially valuable for a reliable, affordable, and resilient power system. This represents a massive opportunity for clean electricity providers and for the United States and Canada to continue to collaborate.

CONCLUSION

The interconnected North American power grid provides benefits and opportunities for the United States and Canada. Due to the comparatively clean mix of Canadian electricity, increased electricity exports (even in the near term) can assist the United States as well as individual states, cities, and businesses in achieving their clean electricity goals. Furthermore, the inherent storage capability of Canadian hydropower can help states integrate greater quantities of variable renewable power, while maintaining reliability and enhancing resilience. Correspondingly, two-way connectivity and trade allows Canada to rely on U.S. generating capacity during its winter peak (avoiding building and maintaining of redundant assets), and it also helps bolster Canadian hydro storage during periods of high U.S. (and Canadian) renewable production.

Moreover, cross-border transmission improves electric reliability, security, affordability, and resilience, ensuring the power system functions uninterrupted. Additionally, it creates economies of scale, helps reduce wholesale power prices and brings together a greater diversity of electricity sources.

Both Canada and the United States are seeking to achieve broad economywide decarbonization within the next few decades, and clean connected electricity is the cornerstone. Further electricity integration can help achieve these goals in a reliable and affordable way. Policy signals are needed today to help incentivize investment decisions and create the necessary regulatory environment to continue the integration that can achieve these critical climate objectives.

KEY OPPORTUNITIES AND CHALLENGES

- Developing new electricity infrastructure (e.g., transmission lines) remains one of the key challenges to additional integration.
- In many instances, state renewable portfolio standards exclude large hydropower projects and do not address international imports of electricity.
- The U.S. can further leverage the storage capability of Canadian hydropower to balance variable renewables, as it currently does in Minnesota.
- Adding transmission increases reliability, resilience, and affordability in decarbonizing economies on both sides of the border.
- Actions by provinces, states, cities and businesses are growing demand for more clean energy.
- Along with in-state measures, importing Canadian electricity can help decarbonize a state's electricity mix, as Massachusetts, Minnesota and New York are finding.
- Demand for clean electricity will grow significantly across North America as decarbonization policies are implemented and transportation, industry and buildings rely much more heavily on the power sector as a low-carbon energy source. Widespread electrification will gradually lead to shifts in peak demand, as the timelines to develop new resources and support infrastructure can be lengthy.

ENDNOTES

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