TECHNOLOGY

INTERCONNECTED: CANADIAN AND U.S. ELECTRICITY

CENTER FOR CLIMATE AND ENERGY SOLUTIONS

Doug Vine
Center for Climate and Energy Solutions

March 2017

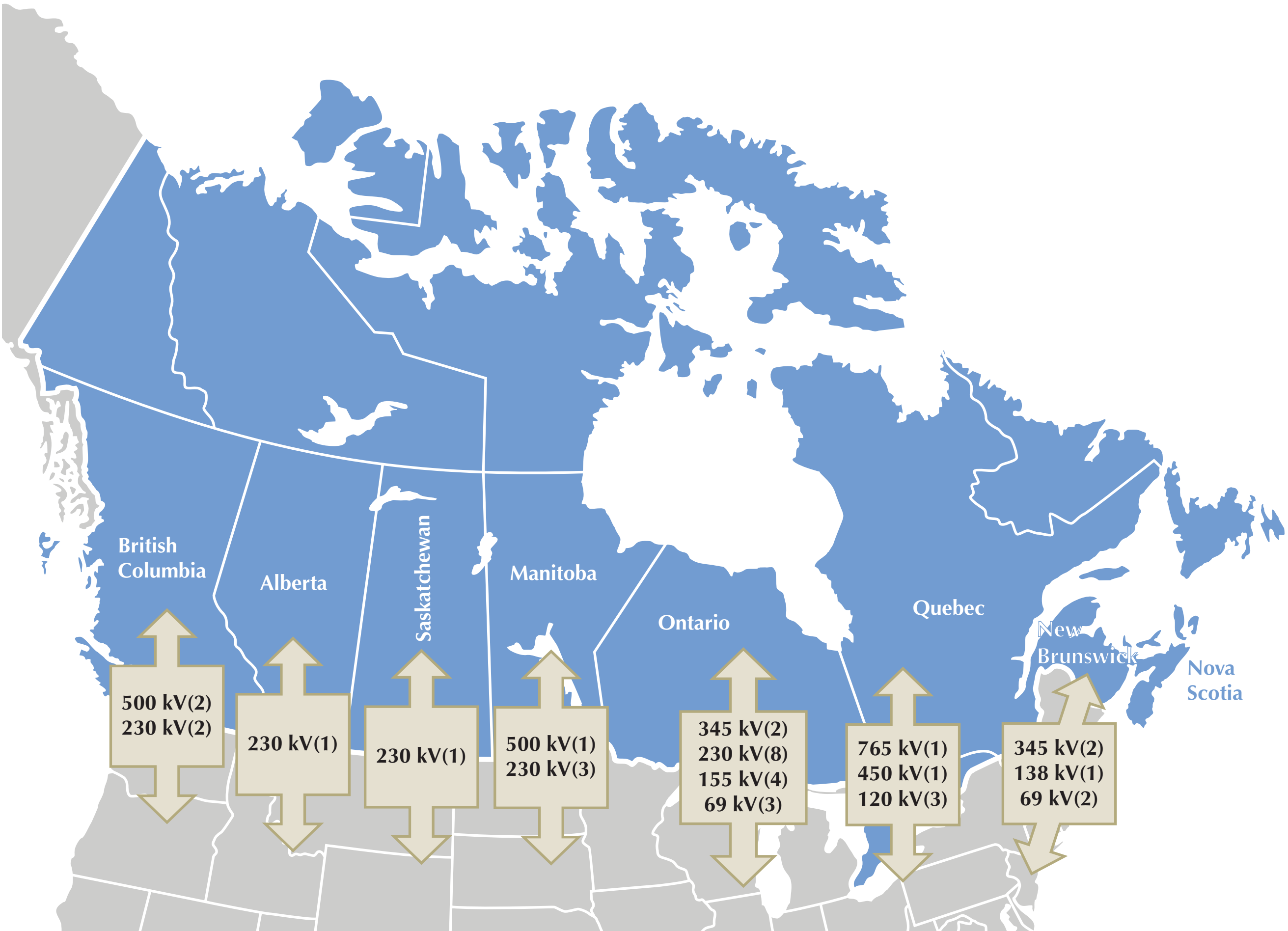
The U.S. and Canadian electric power grids are connected through 37 major transmission lines from New England to the Pacific Northwest. The interconnected North American power grid provides numerous benefits for Canada and the United States, including enhanced electric reliability, security, affordability and resilience as well as increased economic benefits. The two countries have worked together to improve service through markets, international regulatory bodies and various bilateral engagements. Increasing actions by provinces, states, cities and businesses are growing demand for clean energy. Due to the comparatively clean mix of Canadian electricity, increased exports 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, 37 major (i.e., greater than 69 kilovolts) two-way transmission connections imported and exported 82.4 million megawatt-hours (MWh) of U.S. and Canadian electricity in 2016 (**Figure 1**), enough to power 7.5 million average households.[1,2,3] 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 power to a formerly underserved region and increased safety through coordinated flood-risk management.[4] 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.[5] Despite uncertainty around U.S. federal climate policy, 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 intermittent renewable power.

This report summarizes the existing electricity relationship between Canada and the United States,

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



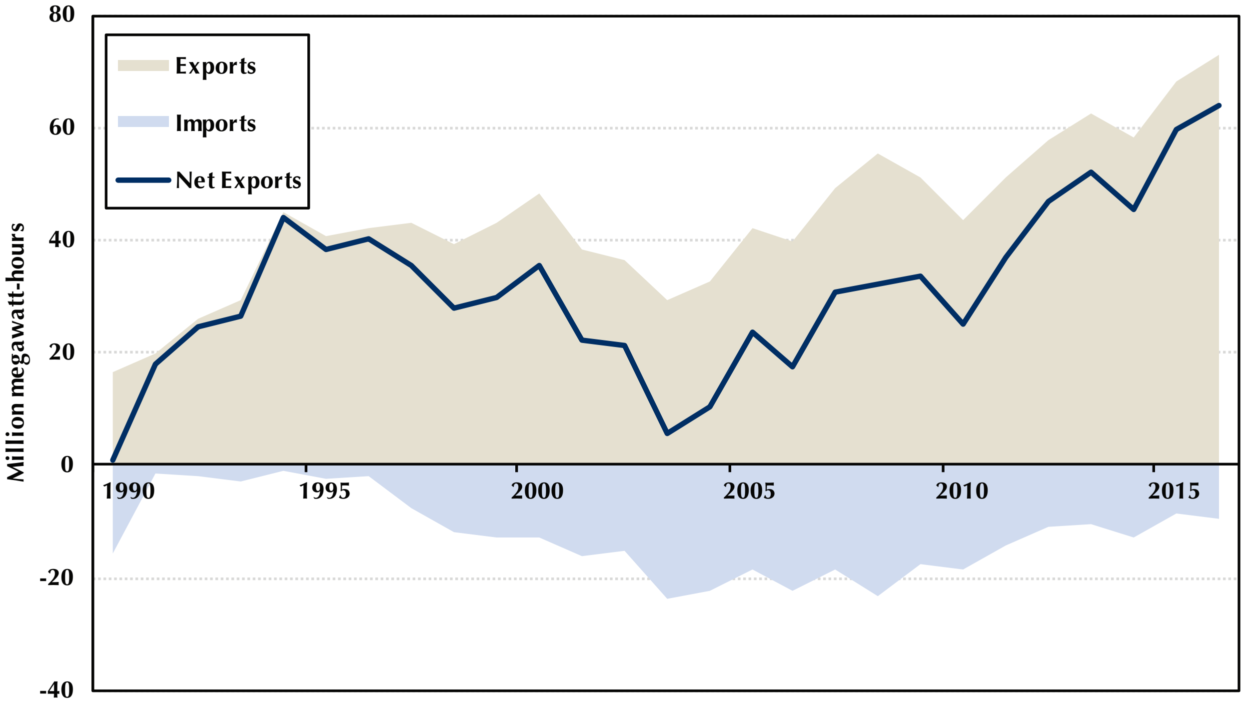
Note that kV stands for kilovolts, therefore 500 kV means 500,000 volts.
Source: National Energy Board (Canada) 2016.

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 and cities in achieving their clean energy goals.

ELECTRICITY RELATIONSHIP

Electricity systems and power markets are tightly integrated across the U.S.-Canadian border.[6] 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), and the PJM Interconnection, facilitate cross-border trading. In 2016, 23 states exported electricity from Canadian provinces with eight states (i.e., California, Maine,

FIGURE 2: Canadian Electricity Net Exports, 1990–2016



Source: "Commodity Statistics: Electricity: Electricity Exports and Imports: Table 2A and 2B," National Energy Board of Canada, last modified February 2017, https://apps.neb-one.gc.ca/CommodityStatistics/Statistics.aspx?language=english.

Michigan, Minnesota, New York, Oregon, Vermont and Washington) exporting more than 1 million MWh.[7] Also, international regulatory entities like the North American Electric Reliability Corporation (NERC) help ensure the power system functions uninterrupted across North America.[8] 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.[9] Specifically, 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 a different season—Canada 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]

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]

Since 1990, Canada's electricity exports to the United States have generally increased (**Figure 2**). In 2015, 68.3 million MWh was exported to the United States, which was 1.8 percent of total U.S. electricity consumption and about 11 percent of total Canadian generation. Canada also imports electricity from the United States at times to help it meet demand.[14] However, over the past 26 years, Canada has been a net exporter of electricity to the United States.[15] Around three-quarters of exports are traded short-term on power markets and the remaining quantities are sold through longer-term fixed contracts.[16] In 2016, Québec was the largest electricity exporting province to the United States, followed by Ontario, British Columbia, and Manitoba (**Figure 3**).[17]

ELECTRICITY MIX AND TRENDS

The electricity fuel source mixes of the Canadian and U.S. power sectors are quite different. Nearly 80 percent of Canadian electricity, compared with one-third of U.S. power, is derived from non-emitting sources, e.g. hydropower, nuclear, wind, solar and other renewables. In the future, power generation in both countries is expected to become cleaner, i.e., emit fewer greenhouse gas emissions. Due to its inherent storage capability, greater integration of Canadian hydropower in the future can enable the deployment of even greater quantities of intermittent U.S. renewables.

CANADIAN ELECTRICITY MIX

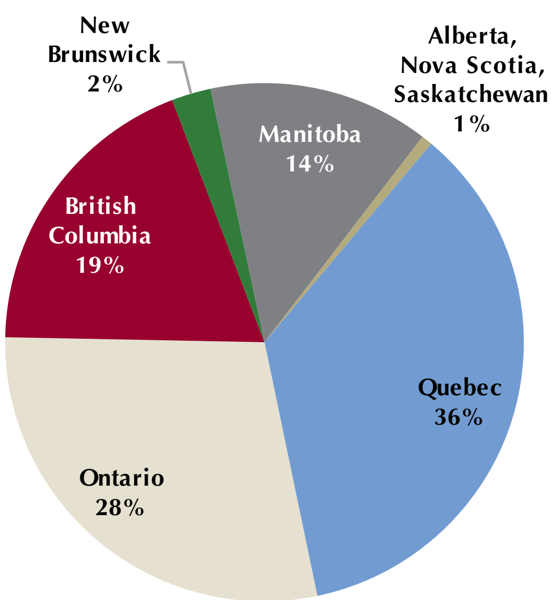
Canada generated more than 631 million MWh of electricity in 2015.[18] More than three-quarters of electricity generation came from extremely low emission sources with fossil fuels making up only 21 percent (**Figure 4**). Over the past dozen years, hydropower has contributed between 58 percent and 63 percent of total Canadian electricity generation.[19] Typically, the provinces of British Columbia, Manitoba, and Québec derive more than 90 percent of their electric power from hydropower.[20] 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 just 11 percent of Canada's greenhouse gas emissions.[21]

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 intermittent 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.[22]

CANADIAN ELECTRICITY TRENDS

From 2005 to 2014, Canada's electricity sector reduced its greenhouse gas emissions by 34 percent.[23] A large decline in coal-fired generation, a general increase in hydropower generation, and increasing renewable deployments (mostly wind power), offset by a considerable increase in natural gas- and oil-fired generation, led to this decline. Federal and provincial

FIGURE 3: Canadian Electricity Exports by Province, 2016



Source: "Commodity Statistics: Electricity: Electricity Exports and Imports: Table 2A," National Energy Board of Canada, last accessed February 2017, https://apps.neb-one.gc.ca/CommodityStatistics/Statistics.aspx?language=english.

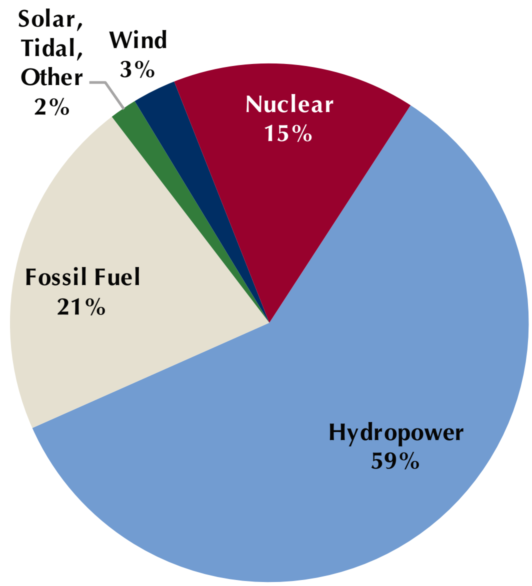
policies are expected to continue to reduce power sector emissions.[24]

In 2014, the province of Ontario achieved its 2003 coal phase-out commitment, retiring 7,560 megawatts (MW) of capacity over the period.[25] Since 2005, coal-fired generation nationally decreased by more than 30 percent, largely a result of Ontario coal retirements.[26] At the same time, hydropower capacity increased by more than 6,000 MW. In 2015, Canada had an installed hydropower capacity of more than 79,000 MW out of a total electric capacity of about 135,300 MW—about 58 percent.[27] Also, wind power capacity jumped from just 557 MW in 2005 to more than 11,000 MW in 2015. Finally, from 2005 to 2015, combined cycle power plant capacity, primarily fueled by natural gas, increased by 6,600 MW.[28] Generation from this plant type increased by 75 percent.[29]

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. Electricity sector emissions are expected to be 46 percent below 2005 levels in 2020 and 71 percent below 2005 levels in 2030.[30]

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—20 percent greater than the nation's total installed electricity capacity.[31] There is typically a sizeable difference, however, between the technical potential and economic feasibility of projects, and 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 early 2017, more than 2,600 MW of new hydro capacity was under construction.[32] Canada has also been a leader in carbon capture and storage technology (see **Box 1**)—a key technology for decarbonizing the electric power sector globally.

FIGURE 4: Canadian Electricity Generation by Fuel Type, 2015



Source: "Table 127-0007 Electric power generation by class of electricity producer, and Table 128-0014 Electricity generated from fossil fuels," Statistics Canada, February 2017, http://www5.statcan.gc.ca/cansim/a33?RT=TABLE&themeID=4012&spMode=tables&lang=eng.

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 4,087 million MWh of electricity in 2015.[35] Fossil fuels generated a little more than two-thirds of that electricity. Zero-emission power sources, such as hydropower, wind, solar, and nuclear power, generated the remaining third of U.S. electricity.[36] In 2015, hydropower contributed 6.2 percent of overall U.S. generation (**Figure 5**) and a little less than 19 percent of the nation's zero-emissions power. Wind and solar combined provided about 15 percent, and nuclear made up nearly 60 percent of zero-emission power. The power sector is responsible for 30 percent of U.S. greenhouse gas emissions.[37]

Due to weather variability, the amount of water available for use by hydropower facilities varies year-over-year. In 2011, with above-average rainfall, hydropower generated nearly 8 percent of total U.S. generation. In 2001, hydropower was responsible for less than 6 percent. Total U.S. hydropower capacity remained relatively static over that period.

U.S. ELECTRICITY TRENDS

From 2005 to 2014, the U.S. electricity sector reduced its greenhouse gas emissions by 15 percent.[38] For the past 10 years, electricity emissions have been declining due to

BOX 1: Carbon Capture and Storage

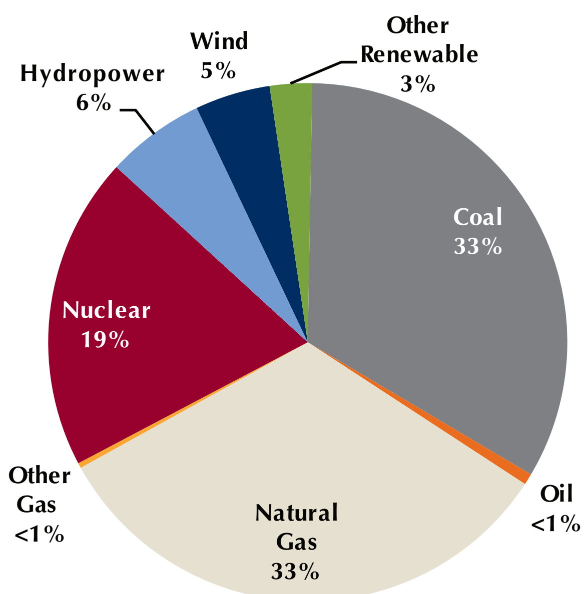
To keep global temperature change below 2 degrees Celsius (3.6 degrees Fahrenheit) relative to pre-industrial levels and avoid the worst effects of climate change, global net greenhouse gas emissions must be approaching zero by the second half of this century.

Key actions for decarbonizing the electric power sector globally include deploying more carbon capture 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. It was the world's first large-scale, post-combustion carbon capture project at a power plant. Since startup, it has captured more than 1.4 million metric tons of carbon dioxide (CO_2). In Canada, there are currently no further plans for electric utility carbon capture projects. However, the utility shares 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.

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, and federal and state policies.

FIGURE 5: U.S. Electricity Generation by Fuel Type, 2015



Source: U.S. Energy Information Administration, "Electricity Net Generation: Total (All Sectors). Table 7.2a." December 2016. Available at: http://www.eia.gov/totalenergy/data/monthly/#electricity.

Since 2005, coal-fired generation has fallen from 50 to 33 percent of the U.S. electricity mix, while less carbon-intensive natural gas-fired generation has risen from 19 to 33 percent. Additionally, renewable generation (particularly from wind, and more recently solar) has increased from less than one-half of 1 percent to more than 5 percent of total U.S. electricity generation. Offsetting these reductions, nuclear power is facing economic challenges with 6 reactors (around 4,800 MW) closing prematurely since 2012, and being primarily replaced by fossil fuels.[39] Notably, electricity demand has grown by just 0.2 percent per year on average over the past 10 years.[40]

Considering expected market prices and the current federal policy landscape (i.e., assuming the Clean Power Plan is not implemented), U.S. electric power sector emissions are projected to remain unchanged out to 2030.[41] Under this business-as-usual forecast, U.S. electricity demand is expected to grow by only 0.8 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.[42]

Although emissions are not expected to fall in the business-as-usual forecast (i.e., without federal action), there are several factors that will continue to influence the U.S. power sector emissions trajectory. Across states, cities and businesses, there is a growing desire for more clean energy. States like California, Maryland, and New York have recently increased the ambition of their clean energy targets (e.g. renewable portfolio standards, energy efficiency, and greenhouse gas reduction targets). This trend is likely to continue in other states. There are currently 29 states with renewable portfolio standards in the United States. In addition to states' efforts, 132 cities across the United States in the Compact of Mayors are currently committing to creating action plans to reduce their greenhouse gas emissions.[43] Additionally, 88 major global companies, many with large U.S. footprints, have publicly committed to the goal of using 100 percent renewable energy.[44] 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 significantly in the coming decade if deep-decarbonization policies are put in place, and transportation and other sectors (e.g., industrial and commercial) rely more heavily on a largely decarbonized electric power sector as an energy source in the future. Offsetting these drivers, an additional 7 nuclear reactors (around 6,400 MW) are scheduled to close prematurely between 2018 and 2025, though 4 new reactors (around 4,400 MW) should come on-line 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.[45] 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.[46] 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.[47] 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.[48]

At the national level, Canada plans to phase out traditional coal power in all its provinces by 2030.[49] 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.[50] 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 plans to ensure that all jurisdictions have a price on carbon, with the government setting the minimum allowable or floor price by 2018.[51] Additionally, the national government plans to pursue complementary measures like tightening energy efficiency standards as well as adapting and building more resilient infrastructure; its plans are highlighted in the *Pan-Canadian Framework on Clean Growth and Climate Change*.[52]

PROVINCIAL POLICY

Many of Canada's policies to combat climate change occur at the provincial level.[53] These include a carbon pricing program and coal phase-out in Alberta; a carbon tax in British Columbia; a cap-and-trade system in Québec; and a soon-to-be implemented cap-and-trade system in Ontario, following on the heels of its successful coal phase-out in 2014.

In Alberta, the Specified Gas Emitters Regulation (passed originally in 2007 and updated in 2015) provides an intensity-based target for power and industrial facilities above 100,000 tons of CO_2 equivalent per year.[54] The law requires an annual intensity reduction of up to 4 percent, and a maximum cumulative reduction of up to 20 percent. Alternatively, firms can contribute 30 Canadian dollars (CA$) per ton to the Climate Change and Emissions Management Fund, or purchase either credits from other firms or approved offset credits. Alberta's Climate Leadership Plan builds on earlier regulation and introduces a carbon price of CA$30 per ton in 2018 for coal-fired generators.[55] Additionally, the plan phases out coal generation and adds 5,000 MW of renewable electric capacity by 2030.[56]

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 to its present level of CA$30 per metric ton of CO_2 equivalent.[57]

Québec has a provincial greenhouse gas reduction target of 20 percent below 1990 levels by 2020. A key measure to achieve that goal 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.

In early 2017, Ontario initiated actions to implement its cap-and-trade program to reduce provincial emissions.[58] Businesses are required to participate in the program if they import electricity, are a facility or natural gas distributor that emits at least 25,000 metric tons of greenhouse gases per year, or if they are a fuel supplier that sells more than 200 liters of fuel per year.[59]

OPPORTUNITIES AND CHALLENGES FOR FURTHER INTEGRATION

Nearly 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 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 creates an opportunity for exporting additional Canadian electricity to the United States.

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.[60] 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 political matters with many stakeholders to satisfy.

Finally, clean energy policies like U.S. state and city greenhouse gas reduction targets or state renewable portfolio standards (RPS), and their treatment of international power imports from Canada, will have a direct impact on the future level of exports 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 early 2017.[61] 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. First Nations, native people in Canada, have been directly impacted by hydropower project development without serious consultation in the past. Today however, they are given a hearing and some of their issues are addressed as part of the development process. 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.

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.[62] 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.

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 MW high-voltage direct current (HVDC) transmission line from the Canadian border to New York City expected to go into service in 2021.[63] Additionally, the Lake Erie Connector is a 1,000 MW HVDC line that is expected to link Ontario's Independent Electricity System Operator (IESO) and PJM in 2020.[64] Also in the northeast, the proposed Northern Pass Transmission Line from the Canadian border to a substation in Franklin, New Hampshire, will provide 1,200 MW of hydropower from Hydro-Québec to the New England power grid, but project developers are still working with stakeholders to resolve cost-responsibility, environmental, and social issues.[65] 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.[66] In the upper Midwest, the U.S. Department of Energy recently granted a presidential permit for the Great Northern Transmission Line.[67] The line from the Canadian border to a substation near Grand Rapids, Minnesota, will provide 883 MW of capacity, 383 MW of which will be used to deliver hydroelectric power from Manitoba Hydro to Minnesota Power's customers.[68] This project should be especially beneficial from the perspective of zero-carbon electricity, as it will allow Minnesota to back up intermittent wind power with hydropower and send any excess wind power to Manitoba.[69] Siting and building new transmission is a challenging, multiyear process. Using "Smart from the Start" policies and siting criteria can help.[70]

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.[71] 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 in 2011, two Canadian hydropower generators secured long-term PPAs with U.S. utilities. Minnesota Power and Manitoba Hydro agreed to a 15-year deal for 250 MW, beginning in 2020.[72] Also in 2011, the Vermont Public Service Board approved a 26-year, 225 MW PPA between Hydro-Québec and 20 Vermont electric utilities.[73]

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.[74]

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. Some, including Massachusetts and New York, are explicitly considering Canadian electricity to meet their clean energy goals. Massachusetts passed an energy bill last year that requires utilities to solicit long-term contracts for 1,200 MW of hydropower or other renewable resources, opening the door for additional Canadian hydropower consumption.[75] An increasing RPS 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.[76]

Looking longer term, power sector demand could grow significantly across North America if deep-decarbonization polices are implemented and transportation and industry rely more heavily on the power sector as a low-carbon energy source. This would directly increase demand for all zero-emission electricity sources.

CONCLUSION

The interconnected North American power grid provides benefits and opportunities for Canada and the United States. Electric reliability, security, affordability, and resilience are improved on both sides of the border, 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.

KEY OPPORTUNITIES AND CHALLENGES

- Developing new electricity infrastructure (e.g. transmission lines) remains one of the key challenges to additional integration.
- In most 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 intermittent renewables, as it currently plans to do in Minnesota.
- 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.
- Demand for clean electricity could grow significantly across North America if deep-decarbonization polices are implemented and transportation and industry rely more heavily on the power sector as a low-carbon energy source.

Over the past 10 years, both the Canadian and U.S. electricity mixes have become much cleaner and this trend is likely to continue. Incorporating more low-carbon electricity on either side of the border can help each country achieve its clean energy goals.

ENDNOTES

1 The average U.S residential utility customer uses around 10.8 MWh of electricity per year. "Table5_a: 2015 Average Monthly Bill – Residential," U.S. Energy Information Administration, last accessed February 27, 2017, http://www.eia.gov/electricity/sales_revenue_price/pdf/table5_a.pdf.

2 "Average electricity consumption per electrified household," World Energy Council, last modified May 2016, https://www.wec-indicators.enerdata.eu/household-electricity-use.html.

3 In 2016, Canada exported 73.1 million MWh and imported 9.3 million MWh – a total of 82.4 million MWh of electricity. Assuming the average U.S. and Canadian residential utility customer uses around 11 MWh of electricity per year – 82.4 million MWh of traded electricity divided by 11 MWh of electricity per average household equals 7.5 million household supported per year.

"2016 Electricity Exports and Imports Summary," National Energy Board (Canada), February 22, 2017, https://www.neb-one.gc.ca/nrg/sttstc/lctrct/stt/lctrctysmmr/2016/smmry2016-eng.html.

4 Transforming the Nation's Electricity System: The Second Installment of the QER, "Chapter VI Enhancing Electricity Integration in North America," U.S. Department of Energy, January 2017, https://energy.gov/sites/prod/files/2017/02/f34/Chapter%20VI--Enhancing%20Electricity%20Integration%20in%20North%20America.pdf.

5 Ibid.

6 "Quadrennial Energy Review: Chapter VI: Integrating North American Energy Markets," U.S. Department of Energy, April 2015, http://energy.gov/sites/prod/files/2015/08/f25/QER%20Chapter%20VI%20North%20America%20April%202015.pdf.

7 "Electricity Exports and Imports Statistics: Table 3A," National Energy Board (Canada), last accessed March 23, 2017, https://apps.neb-one.gc.ca/CommodityStatistics/Statistics.aspx?language=english.

8 Ibid.

9 "National Electric Grid Security and Resilience Action Plan," Executive Office of the President, December 2016, https://www.whitehouse.gov/sites/whitehouse.gov/files/images/National_Electric_Grid_Action_Plan_06Dec2016.pdf.

10 "North American Energy Infrastructure Act Will Bolster U.S.–Canada Electricity Relationship," Energy & Commerce Committee U.S. House of Representatives, May 7, 2014, https://energycommerce.house.gov/news-center/press-releases/north-american-energy-infrastructure-act-will-bolster-us-canada.

11 "Integrated Canada-U.S. Power Sector Modeling with the Regional Energy Deployment System (ReEDS)," Andrew Martinez et al., National Renewable Energy Laboratory, February 2013, http://www.nrel.gov/docs/fy13osti/56724.pdf.

12 "Quadrennial Energy Review: Chapter VI: Integrating North American Energy Markets," U.S. Department of Energy, April 2015, http://energy.gov/sites/prod/files/2015/08/f25/QER%20Chapter%20VI%20North%20America%20April%202015.pdf.

13 "Fuel Diversity," Edison Electric Institute, last accessed February 22, 2017, http://www.eei.org/issuesandpolicy/generation/fueldiversity/Pages/default.aspx.

14 Stephane Bordeleau, "Where Canada's Surplus Energy Goes," CBC News, March 31, 2011, Available at: http://www.cbc.ca/news/canada/where-canada-s-surplus-energy-goes-1.1109321.

15 Canadian Electricity Association. "Electricity 101." August 2014. Available at: http://www.electricity.ca/media/Electricity101/Electricity101.pdf.

16 "Electricity Exports and Imports Statistics: Table 2A," National Energy Board (Canada), last accessed February 27, 2017, https://apps.neb-one.gc.ca/CommodityStatistics/Statistics.aspx?language=english.

17 Ibid.

18 "Electric Power Generation: Table 127-0007," Statistics Canada, last accessed February 27, 2017, http://www5.statcan.gc.ca/cansim/pick-choisir?lang=eng&p2=33&id=1270007.

19 Ibid.

20 Ibid.

21 "National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada - Executive Summary," Environment and Climate Change Canada, April 14, 2016, https://www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=662F9C56-1#es-4.

22 Jennifer Delony, "Minnesota regulators conditionally approve certificate of need for Great Northern transmission line," Transmission Hub, May 18, 2015, http://www.transmissionhub.com/articles/2015/05/minnesota-regulators-conditionally-approve-certificate-of-need-for-great-northern-transmission-line.html.

23 "National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada - Executive Summary," Environment and Climate Change Canada, last accessed March 1, 2017, https://www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=662F9C56-1#es-4.

24 "Canada's Second Biennial Report on Climate Change," Environment and Climate Change Canada, last accessed March 2, 2017, https://www.ec.gc.ca/GES-GHG/default.asp?lang=En&n=02D095CB-1.

25 Melissa Harris, Marisa Beck, and Ivetta Gerasimchuk, *The End of Coal: Ontario's coal phase-out*, (Manitoba, CA: International Institute for Sustainable Development, 2015), https://www.iisd.org/sites/default/files/publications/end-of-coal-ontario-coal-phase-out.pdf.

26 "Electricity generated from fossil fuels, annual (Gigawatt hours), 1995 to 2015: Table 128-0014," Statistics Canada, last accessed February 27, 2017, http://www5.statcan.gc.ca/cansim/pick-choisir?lang=eng&p2=33&id=1280014.

27 "Installed generating capacity, by class of electricity producer, annual (kilowatts)," Statistics Canada, last accessed February 27, 2017, http://www5.statcan.gc.ca/cansim/a33?RT=TABLE&themeID=4012&spMode=tables&lang=eng.

28 Ibid.

29 "Electricity generated from fossil fuels, annual (Gigawatt hours), 1995 to 2015: Table 128-0014," Statistics Canada, last accessed February 27, 2017, http://www5.statcan.gc.ca/cansim/pick-choisir?lang=eng&p2=33&id=1280014.

30 "Canada's 2016 greenhouse gas emissions Reference Case," Environment and Climate Change Canada, last accessed March 22, 2017, https://www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=1F24D9EE-1.

31 EEM Sustainable Management. 2007. "Study of Hydropower Potential in Canada." Available at: https://canadahydro.ca/reportsreference/external-reports. The technical potential is the maximum amount of electric capacity that could be added based on water flows, elevation, geography and so on. Considering environmental and economic factors, among other things, the total electric capacity that would be feasible is smaller than the technical potential. A study of this type has yet to be conducted.

32 New, large greenfield hydroelectric projects include: Keeyask 695 MW (Manitoba), Site C 1,100 MW (British Columbia), and Muskrat Falls 824 MW (Newfoundland and Labrador).

33 " Boundary Dam Carbon Capture Project," SaskPower, last accessed March 15, 2017, http://www.saskpower.com/our-power-future/carbon-capture-and-storage/boundary-dam-carbon-capture-project/.

34 "BD3 Status Update: February 2017," SaskPower, March 6, 2017, http://www.saskpower.com/about-us/blog/bd3-status-update-february-2017/.

35 U.S. Energy Information Administration. "Total Energy: Table 7.2a." Available at: http://www.eia.gov/totalenergy/data/monthly/#electricity.

36 Nuclear and hydropower are zero-emission sources in the sense that they emit no greenhouse gases from their primary generation activities. These sources can have very low levels of emissions from operation of emergency generators, HVAC, etc.

37 "Sources of Greenhouse Gas Emissions," U.S. Environmental Protection Agency, last accessed March 7, 2017, https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.

38 "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014," U.S. Environmental Protection Agency, last accessed March 1, 2017, https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2014.

39 "Fort Calhoun becomes fifth U.S. nuclear plant to retire in past five years," U.S Energy Information Administration, October 31, 2016, https://www.eia.gov/todayinenergy/detail.php?id=28572.

40 "Total Energy: Table 7.6," U.S. Energy Information Administration, last accessed March 21, 2017, https://www.eia.gov/totalenergy/data/monthly/#electricity.

41 "The Clean Power Plan, which is currently stayed pending judicial review, requires states to develop plans to reduce CO2 emissions from existing generating units that use fossil fuels." "Annual Energy Outlook 2017," U.S. Energy Information Administration, January 5, 2017, https://www.eia.gov/outlooks/aeo/pdf/0383(2017).pdf.

42 "Annual Energy Outlook 2017," U.S. Energy Information Administration, January 5, 2017, https://www.eia.gov/outlooks/aeo/.

43 "Commit," Compact of Mayors, last accessed on March 27, 2017, https://www.compactofmayors.org/resources/.

44 "Companies," RE100, last accessed March 27, 2017, http://there100.org/companies.

45 "Appendix I - Quantified economy-wide emissions targets for 2020," United Nations Framework Convention on Climate Change, last modified 2014, http://unfccc.int/meetings/copenhagen_dec_2009/items/5264.php.

46 Katie Reilly, "Read the Remarks From the 'Three Amigos' Summit Press Conference," Time, June 29, 2016, http://time.com/4388789/three-amigos-summit-transcript-obama-nieto-trudeau/.

47 Ibid.

48 "Canada's Second Biennial Report on Climate Change," Environment and Climate Change Canada, last accessed March 2, 2017, https://www.ec.gc.ca/GES-GHG/default.asp?lang=En&n=02D095CB-1.

49 Paul Vieira and Judy McKinnon, "Canada Aims to Fully Phase Out Coal Power by 2030," *Wall Street Journal*, Last modified November 21, 2016. https://www.wsj.com/articles/canada-aims-to-fully-phase-out-coal-power-by-2030-1479739247.

50 "Reduction of Carbon Dioxide Emissions from Coal-Fired Generation of Electricity Regulations (SOR/2012-167)," Environment and Climate Change Canada, last modified November 2016, https://www.ec.gc.ca/lcpe-cepa/eng/regulations/detailReg.cfm?intReg=209.

51 Justin Trudeau, "Prime Minister Trudeau delivers a speech on pricing carbon pollution in the House of Commons (speech, Ottawa, Canada, October 3, 2016), Justin Trudeau, Prime Minister of Canada, http://pm.gc.ca/eng/news/2016/10/03/prime-minister-trudeau-delivers-speech-pricing-carbon-pollution.

52 "The Pan-Canadian Framework on Clean Growth and Climate Change," Government of Canada, last accessed on March 23, 2017, https://www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework.html.

53 "POLICIES IN KEY COUNTRIES," Center for Climate and Energy Solutions, last accessed March 13, 2017, https://www.c2es.org/international/key-country-policies/policies-key-countries.

54 "Specified Gas Emitters Regulation," Alberta Environment and Parks, February 9, 2016, http://aep.alberta.ca/climate-change/guidelines-legislation/specified-gas-emitters-regulation/.

55 "Climate Leadership Plan," Alberta Government, last accessed March 13, 2017, https://www.alberta.ca/climate-leadership-plan.aspx.

56 Ibid.

57 "B.C.'s Revenue-Neutral Carbon Tax," British Columbia, last accessed March 13, 2017, http://www2.gov.bc.ca/gov/content/environment/climate-change/policy-legislation-programs/carbon-tax.

58 "Cap and trade," Ontario, last accessed March 13, 2017, https://www.ontario.ca/page/cap-and-trade.

59 Ibid.

60 Transforming the Nation's Electricity System: The Second Installment of the QER, "Chapter VI Enhancing Electricity Integration in North America," U.S. Department of Energy, January 2017, https://energy.gov/sites/prod/files/2017/02/f34/Chapter%20VI--Enhancing%20Electricity%20Integration%20in%20North%20America.pdf.

61 New, large greenfield hydroelectric projects include: Keeyask 695 MW (Manitoba), Site C 1,100 MW (British Columbia), and Muskrat Falls 824 MW (Newfoundland and Labrador).

62 "Regulatory Side-by-Side Governing Permitting of Cross-Border Electricity Transmission Facilities between the United States and Canada," U.S. Department of Energy, July 2015, https://energy.gov/oe/downloads/regulatory-side-side-governing-permitting-cross-border-electricity-transmission.

63 "Champlain Hudson Power Express: Project Development Portal: About the Project." Transmission Developers Inc., last accessed March 2017, http://www.chpexpress.com/about.php.

64 "Lake Erie Connector: Project Overview," ITC December 2014, last accessed March 2017, http://www.itclakeerieconnector.com/project-overview.

65 "Project Overview," The Northern Pass, last accessed February 2, 2015, http://northernpass.us/project-overview.htm; Allie Morris, Concord Monitor, "Northern Pass officials willing to bury more transmission lines, but how much more?" November 18, 2014, http://www.concordmonitor.com/news/work/business/14412887-95/northern-pass-officials-willing-to-bury-more-transmission-lines-but-how-much-more; John Herrick, VT Digger, "Hydro-Quebec looking south to new markets." March 24, 2015, http://www.concordmonitor.com/news/work/business/14412887-95/northern-pass-officials-willing-to-bury-more-transmission-lines-but-how-much-more.

66 "The Project," Atlantic Link Emera, last accessed March 15, 2017, http://www.atlanticlink.com/en/home/the-project/default.aspx.

67 "PP-398 MINNESOTA POWER," U.S. Department of Energy, last accessed March 2017, https://energy.gov/oe/downloads/pp-398-minnesota-power.

68 Minnesota Power, "Great Northern Transmission Line: Federal approval of a construction agreement for the Great Northern moves international transmission project forward." December 2014. Available at: http://www.greatnortherntransmissionline.com/news/federal-approval-construction-agreement-great-northern-moves-international-transmission-project-forward/.

69 Evan Ramstad, Star Tribune, "Minnesota Power files for new power line from Canada to Iron Range. April 16, 2014, http://www.startribune.com/business/255513641.html; for more information see Minnesota Power, "Great North Transmission Line," http://www.greatnortherntransmissionline.com/files/8314/2349/4330/MP-GNTL_Handout_v13_20150109.pdf.

70 Carl Zichella, Johnathan Hladik, "Finding a Home for Renewable Energy and Transmission," America's Power Plan, September 2013, http://americaspowerplan.com/wp-content/uploads/2013/09/APP-SITING-PAPER.pdf.

71 World Bank Group, "Public-Private Partnership in Infrastructure Resource Center," accessed February 5, 2015, http://ppp.worldbank.org/public-private-partnership/sector/energy/energy-power-agreements/power-purchase-agreements.

72 Minnesota Power, “Hydro,” accessed February 6, 2015, http://www.mnpower.com/Environment/Hydro.

73 Nancy Remsen, Burlington Free Press, “Board approves power deal with Hydro-Québec.” April 18, 2011. Available at: http://archive.burlingtonfreepress.com/article/20110418/NEWS03/110418018/Board-approves-power-deal-Hydro-Quebec.

74 Natural Resources Defense Council, “Carbon Pollutions Standards Fact Sheet: Iowa.” May 2014, http://www.nrdc.org/air/pollution-standards/files/cps-state-benefits-IA.pdf.

75 Shira Schoenberg, “Massachusetts Legislature passes renewable energy compromise bill,” Mass Live, August 1, 2016, http://www.masslive.com/politics/index.ssf/2016/08/massachusetts_legislature_vote_1.html.

76 Marie J. French and David Giambusso, “With Indian Point closing, Quebec sees an opportunity for hydropower,” Politico, January 17, 2017, http://www.politico.com/states/new-york/albany/story/2017/01/with-indian-point-closing-quebec-looking-to-make-a-deal-108767.

CENTER FOR CLIMATE
AND ENERGY SOLUTIONS

The Center for Climate and Energy Solutions (C2ES) is an independent, nonpartisan, nonprofit organization working to forge practical solutions to climate change. Our mission is to advance strong policy and action to reduce greenhouse gas emissions, promote clean energy, and strengthen resilience to climate impacts.

2101 WILSON BLVD. SUITE 550 ARLINGTON, VA 22201 703-516-4146 **C2ES.ORG**