Rubin, Jeff

Book

Economic opportunities from a changing climate

Centre for International
Governance Innovation

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About the Author

Jeff Rubin is a CIGI senior fellow. A Canadian economist and author, Jeff is a world-leading energy expert and former chief economist at CIBC World Markets. At CIGI, he is currently researching the impacts and opportunities for Canada in its transition toward a more sustainable economic model.

Jeff's work explores the future of Canada's oil sands in an emissions-constrained world, the divestment of Canadian fossil fuels, the case for a national carbon tax and the evolving value of Canadian resources.

One of the world's most sought-after energy experts, Jeff was one of the first economists to accurately predict soaring oil prices back in 2000. His first book, *Why Your World Is About to Get a Whole Lot Smaller*, released in 2009, was an international bestseller and was favourably reviewed in both *Time* and *Newsweek*. It was the number-one-selling non-fiction book in Canada and won the National Business Book Award.

Jeff released two further bestselling books through Random House Canada: *The End of Growth* (2012), which examines the impact of triple-digit oil prices on global economic growth; and *The Carbon Bubble* (2015), which examines how climate change would impact the Canadian economy and, in particular, the country's ambitious energy plans.

About the Global Economy Program

Addressing limitations in the ways nations tackle shared economic challenges, the Global Economy Program at CIGI strives to inform and guide policy debates through world-leading research and sustained stakeholder engagement.

With experts from academia, national agencies, international institutions and the private sector, the Global Economy Program supports research in the following areas: management of severe sovereign debt crises; central banking and international financial regulation; China's role in the global economy; governance and policies of the Bretton Woods institutions; the Group of Twenty; global, plurilateral and regional trade agreements; and financing sustainable development. Each year, the Global Economy Program hosts, co-hosts and participates in many events worldwide, working with trusted international partners, which allows the program to disseminate policy recommendations to an international audience of policy makers.

Through its research, collaboration and publications, the Global Economy Program informs decision makers, fosters dialogue and debate on policy-relevant ideas and strengthens multilateral responses to the most pressing international governance issues.

Executive Summary

Few countries have seen their economic aspirations frustrated by the imperatives of mitigating climate change as much as Canada, which once dreamt of parlaying its vast oil sands resource into becoming an energy superpower. However, global climate change, in conjunction with the national and international policies designed to mitigate it, will present some unique opportunities for the Canadian economy over the next several decades. Warming temperatures and longer growing seasons open the door to producing more value-added crops as the corn and soybean belts migrate north. The market for renewable wind and solar power in Canada is expected to see a quantum leap over the next decade and a half, as coal-fired power is phased out across the country. Stringent emission reduction targets in northeastern US states point to a growing market for Canadian hydro power, while there is a compelling economic case for Ontario to import comparatively cheap surplus hydro power from Quebec as an alternative to the costly refurbishing of its aging nuclear power plants. In the longer term, the melting of ice in the Arctic Ocean opens up the possibility of year-round shipping routes through the once-frozen Northwest Passage, which offers significant distance savings over traditional shipping lanes through the Panama or Suez Canals.

Introduction

The Canadian economy is one of the most emission-intensive in the world, and decarbonizing it will undoubtedly entail high costs and pose huge challenges. The collapse in oil prices has already had a devastating impact on investment in the oil sands, once the economy's most valuable resource. New federal regulations require the phase-out of low-cost coal power, on which Alberta, Saskatchewan, Nova Scotia and New Brunswick are still heavily dependent. And federal carbon taxes, which will climb to $50 per ton by 2022 (Harris 2016), will leave motorists paying more at the pumps every year.[1]

Not surprisingly, for these and a host of other costs, climate change — and the increasing government efforts to mitigate it — has often been perceived as negative or as a threat to the country's economic well-being. Unquestionably, those perceptions are correct when it comes to the future commercial viability of much of Canada's high-cost fossil fuel reserves. Less recognized, but no less important, are the potential economic benefits that climate change, and policies relating to emissions governance, are likely to bring. While the growing global commitment to restrict emissions may diminish the value of much of the country's hydrocarbon resources, other resources — in particular relating to the use of the country's water supply — promise to become far more valuable to the economy.

A High-latitude Breadbasket in a Warming Climate

Since Canada is a high-latitude country, its temperature has already risen at twice the rate of the global average and is expected to continue to warm at a multiple of global trends. While global climate change and the attendant restrictions it will impose on future carbon emissions pose huge constraints on the commercial viability of Alberta's vast oil sand deposits, it nevertheless makes some of the country's other resources potentially much more valuable. That is certainly the case with regard to the nation's arable land and fresh water — the essential building blocks of agricultural production. Instead of becoming the bitumen-based energy superpower envisioned by past governments, climate change has the potential to turn Canada into one of the world's principal breadbaskets.

Nowhere is that more apparent than on the Prairies, home to the bulk of Canadian grain production. The Prairies are getting progressively warmer and, like elsewhere in the country, the warming trend has accelerated since the 1970s. Prairie temperatures are expected to continue to rise over the next three decades. By 2050, temperatures are expected to be a full 2°C higher compared to the 1960–1990 average in the southern prairies and as much as 3°C higher

1 All dollar amounts are in Canadian dollars unless otherwise noted.

on the northern margins of western agriculture, such as the Peace River region (Bjerga 2012).

These temperature changes are, in turn, expected to have major ecological impacts. The US space agency NASA has identified the Prairies as one of the world's climate change hot zones, marked by profound changes in both flora and fauna (Prystupa 2012). Prairie grasslands will push farther north into what is now the boreal forest, which, in turn, will shift north, encroaching into territory that is now tundra.

Not all of these ecological changes will necessarily be positive for the economy. Warmer winters have already allowed the mountain pine beetle to chew up vast swaths of the western boreal forest.[2] But at the same time, a warming climate and its impact on growing seasons may open the door to some welcome migrants. While climate change is expected to adversely affect crop yields in most regions of the world, lengthened growing seasons, in particular on the Prairies, make Canada a rare exception. Historical records indicate that growing seasons — defined by the numbers of frost-free days — are already 26 days longer in Alberta than they were just 50 years ago, as a result of both earlier springs and later falls (Redekop 2014). And those seasons are expected to lengthen by as much as another one to two weeks over the next couple of decades.

Not only do lengthened growing seasons boost crop yields, but they also open the door to growing higher-value-added cash crops, such as corn and soybeans, that traditionally have not been successfully cultivated during the Prairies' short growing season. Prospects for growing these crops are heightened since, at the same time, seed companies such as Monsanto and DuPont Pioneer, which recognize how a changing global climate will shift agricultural production, are developing early maturing corn and soybean varietals. Monsanto recently launched a US$100 million 10-year program to develop early maturing hybrid corn seeds specifically suited for a warming Canadian prairie (Bjerga 2014), while its competitor, DuPont Pioneer, announced a US$35 million program to do the same (Atkins 2015).

Corn cultivation, although still a sliver of traditional prairie staples such as wheat or canola, is nevertheless booming. Production has literally doubled in each of the last five years as some 300,000 acres of prairie farmland are now devoted to corn cultivation, with most concentrated in southern Manitoba, which is typically the wettest area of the region (Arnason 2016). Monsanto estimates that prairie corn cultivation could increase by as much as eight to 10 million acres over the next decade (Bjerga 2014). That scale of expansion could make Canada, traditionally a corn importer, self-sufficient in the crop, or even a potential net exporter.

Soybeans have made even larger inroads into prairie farming than corn. Once virtually non-existent on the Prairies, in 2016 no fewer than 1.6 million acres were devoted to soybean crops in Manitoba and another 235,000 acres in neighbouring Saskatchewan (Heppner 2017). As in the case of prairie corn cultivation, a warming climate and the development of new hybrid strains that require shorter growing seasons are responsible for the rapid growth of this higher-value-added crop on the Prairies. Soybeans are already the third-most-important crop in Manitoba, behind only wheat and canola (Friesen 2014), and preliminary projections for 2017 point to a record two million acres of soybeans planted in the province.

The agricultural impact of a warming climate will not be restricted to the Prairies. Marginal land such as the long-forgotten Clay Belt, an area covering more than 180,000 km^2 in northern Ontario and northwestern Quebec, could suddenly become productive. Once the ancient lakebed of Lake Ojibway, which drained during the last ice age, the Clay Belt has outstanding soil fertility, but agricultural activity has long been stunted by brutally short growing seasons. With a 25 percent increase in heat units over the last three decades (McGrath 2014), there is already a thriving dairy industry on the Quebec side of the Clay Belt, and Ontario farmers are even experimenting with corn production, and yields may rise to commercially acceptable levels with a further warming of the region.

Climate change may bestow a double win for Canadian grain farmers. Not only does the northern migration of the corn belt open the door to growing a higher-value-added cash crop, climate change also threatens to adversely affect corn production in areas where it is traditionally grown, potentially rendering the crop even more valuable for new areas of cultivation.

2 See www.nrcan.gc.ca/forests/fire-insects-disturbances/top-insects/13381.

In today's interconnected global food market, crop failure in one part of the world can provide bonanzas to growers in other parts of the world. For example, a two-year drought in India, the largest grower and consumer of pulse crops in the world, has sent red lentil prices soaring and has created record exports for prairie producers, which have become India's number one supplier. In 2016, Canadian acreage devoted to pulse crops (lentils and peas) doubled. Eighty-five percent of the crop was exported, with roughly one-third going to India (Atkins 2016a). India's drought, and its sudden demand for Canadian pulse crops, may prove temporary, but the weight of scientific research indicates that global climate change will adversely affect corn production in many areas where it is currently grown on a much more permanent basis — in particular in the United States, home to almost 40 percent of world production (Goldenberg 2014), which in 2016 reached almost 40 billion bushels.[3]

The National Climate Assessment report — a collaborative effort by 13 different US federal agencies, drawing on the expertise of hundreds of climate change scientists in the United States — warns that climate change will have a growing adverse impact on US corn production over the next 25 years, and that those impacts will intensify later in this century (Melillo, Richmond and Yohe 2014). The increased frequency of days with temperatures over 35˚C, coupled with the heightened risk of drought, are expected to adversely impact crop yields in the Great Plains, the Midwest and in the southwest regions of the United States. Rising temperatures will result in higher rates of evaporation of soil moisture and plant transpiration and, hence, increased need for irrigation, just as rapidly depleting levels of fossil water such as the Ogallala Aquifer — the principal water source for at least eight western states and the source for much of the irrigation of the US corn and wheat belt — will make irrigation increasingly difficult.

Stress on water supplies has been building for decades throughout the largely semi-arid western United States. The massive Ogallala Aquifer is being drained at eight times the rate of replenishment. Water tables in Texas, Oklahoma and Nebraska, three key grain-growing states, have dropped by more than 30 m (Mills 2012). Nearly one-third of the Ogallala Aquifer in Kansas has been pumped out and another 39 percent is expected to be depleted in the next half-century (Plumer 2013).

In 2012, grain markets had a glimpse of what climate change could bring to the US corn belt, when blistering heat and the worst drought in more than half a century sharply curtailed production, resulting in a temporary 50 percent spike in global corn prices. In a rare reversal of the traditional direction of corn trade between the two countries, Canada exported surplus corn from Ontario to the United States following the drought (Nickel and Plume 2013).

Corn and soybean will not be the only agricultural migrants that a warming climate could bring to Canada. Climate change is projected to adversely affect most of the world's primary wine-producing regions, with traditional Mediterranean areas such as Bordeaux, the Rhone and Tuscany the hardest hit, potentially losing as much as one-third of their rainfall. Semi-arid wine-producing regions such as Australia and California are also expected to be heavily impacted, losing potentially more than half of the acreage presently used for cultivation of wine grape varietals. As a result, viniculture will migrate north to higher latitude regions.

In British Columbia's Okanagan, 2,400 km north of Napa and Sonoma in California, a warming climate is already revolutionizing wine production. Over the last two decades, harsh winters — which in the past killed root stocks — have become milder, allowing the wine industry to flourish in an area that traditionally was devoted to fruit farming. Similarly, a warming climate has allowed the development of a parallel wine industry in the Niagara Peninsula, another fruit belt that has been converted to larger-scale viniculture.

The Okanagan and the Niagara Peninsula may, ultimately, represent only a fraction of the acreage devoted to cultivating wine grapes in Canada. New areas of wine production such as Ontario's Prince Edward County, along the northern shore of Lake Ontario, and, more recently, Nova Scotia's Annapolis Valley, are continually emerging in a discernibly warming Canadian climate. According to some climate change studies, Canada could be one of the primary destinations world viniculture could move to as many of the traditional grape-growing areas of the world become too dry to support large-scale viniculture (Hannah et al. 2013).

3 See www.worldofcorn.com/#world-corn-production.

Water Management Will Be Key

Irrigation is critical for prairie agriculture and will be even more so in the future. The Prairies, the driest area of the country, account for three-quarters of all the irrigated farmland in Canada, with Alberta alone accounting for 60 percent of the national total (Prairie Adaptation Research Collaborative 2008).

Some of the Prairies' prime agricultural land is already water stressed. Agriculture in Alberta's South Saskatchewan River Basin, which holds the province's most productive land, is almost entirely dependent on irrigation. Farmers currently siphon off 2.2 billion m^3 of water every year from the South Saskatchewan River for irrigation, roughly one-third of the river's total flow.[4] The region accounts for less than four percent of arable land in the province, but produces 20 percent of its total agricultural output (Schreier and Wood 2013, 45).

While, on average, precipitation levels are not expected to change markedly over the balance of the century on the Prairies (a major advantage compared to what is expected for the US Midwest grain belt), climate change is already reducing spring runoff from the meltwater from the snowpack in the eastern Rockies — water that prairie agriculture is critically dependent on for irrigation. For example, the Athabasca Glacier, the source of the Athabasca River, which provides the oil sands industry with its massive water requirements, has already lost 60 percent of its volume since it was first measured in 1843 (Strandberg 2010). Meltwater from glaciers in the Rockies is declining at its fastest rate in the last 100 years, as are the glaciers themselves, as warmer winters are producing far less snow than in the past (ibid).

The impact of declining rates of meltwater will be felt even more if western agriculture continues to shift toward the cultivation of higher-value-added crops such as corn and soybeans, which typically require more water than traditional crops such as wheat. There are already water stresses in southern Alberta, as reduced snowfall, and hence mountain runoff, has led to declining stream flows in prairie rivers such as the Bow, Milk and Oldman. At the same time, a warmer and drier climate has meant that evapotranspiration (water lost to the atmosphere as a result of evaporation and transpiration by plants) draws 50 percent more water from southwestern Alberta farms than it did a century ago (Schreier and Wood 2013, 30).

As irrigation needs grow, more and more attention is likely to be focused on water supply and, potentially, water diversion. Currently, less than 10 percent of Canada's water is used for agriculture, a fraction of the demand that farming typically claims on most countries' water supplies. Canada is one of the most water-endowed countries in the world, holding between seven and 20 percent of the world's freshwater supply, depending on whether only renewable water or fossil water (legacy water left from the last ice age, such as the Great Lakes) is being measured.[5] Nevertheless, most of Canada's freshwater flows out of the reach of its population and away from where it can be used to support agricultural activity. For example, more than half of the country's water supply empties either directly into the Arctic Ocean or into Hudson Bay, including almost all the rivers that flow across the Prairies. Without these river sources for irrigation, most of the semi-arid Prairies would be unsuitable for large-scale grain production.

Will water diversion become necessary to take full advantage of a warming climate? Canada is no stranger to inter-basin water transfers, and has diverted more water than any other country; however, some 95 percent of water stored behind dams is used for hydro power rather than irrigation.[6] Irrigation projects, such as the long-proposed 100 km canal that would divert water from the South Saskatchewan River (Lake Diefenbaker) to the Qu'Appelle River Valley (Buffalo Pound Lake), are likely to become more attractive as farmers begin to rotate to more value-added — but more water-intensive — crops such as corn and soybeans.

Agricultural trade is already one of the fastest-growing export sectors, second only to the growth in financial services and insurance over the last decade. With a warming climate, it is likely to play an even larger role in the Canadian economy. As climate change brings about

4 See www.southsaskriverstewards.ca/the-south-saskatchewan-river-basin.html.

5 See www.ec.gc.ca/eau-water/default.asp?lang=En&n=1C100657-1#ws46B1DCCC.

6 See www.thecanadianencyclopedia.ca/en/article/dams-and-diversions/.

profound changes to global food production, Canada may find itself in something of a unique sweet spot, benefiting both in terms of higher crop yields and higher-value-added crops.

A Growing Market for Renewable Power

Replacing fossil fuels in power generation with renewable energy remains a key challenge for Canada in meeting its commitment reaffirmed at the twenty-first session of the Conference of the Parties (COP 21) to the United Nations Framework Convention on Climate Change to reduce carbon emissions 30 percent below 2005 levels by 2030. Electricity generation produced 11 percent of the country's greenhouse gas (GHG) emissions in 2014, with the bulk coming from Alberta, Saskatchewan, Nova Scotia and New Brunswick, which continue to rely heavily on coal-fired power generation (Environment and Climate Change Canada 2016, 11). The federal government has mandated an end to coal-fired generation by 2030 as part of its national strategy to address climate change, but will permit some coal-fired power plants to operate beyond 2030 if coal-burning provinces make compensating cuts to their other emissions. Alberta had already announced its intention to mothball its coal power plants by 2030, prior to the federal announcement.

Those commitments will require huge increases in the use of renewable power over the next decade and a half. Moreover, the use of renewable energy in transportation (the source of 23 percent of the country's annual emissions) is expected to rise steadily over time, as electric and hybrid vehicles claim a growing share of vehicle sales (ibid., 8).

Fortunately, natural conditions for wind and solar in Alberta and Saskatchewan, the country's two largest coal-burning provinces, are among the best in the country. In addition to having favourable wind conditions, the Prairies also boast the best solar conditions of anywhere in the country, with as much as 20–25 percent more cloud-free daylight than Ontario, where virtually all the country's solar power is currently generated (Blackwell 2016).

Saskatchewan and Alberta have both pledged to replace either all or much of their coal-fired power with huge increases in renewable power. Alberta seeks to double the power it gets from renewable sources from 15 percent to 30 percent over the next decade and a half. Neighbouring Saskatchewan has set a target of at least 50 percent renewable power by 2030. Between them there is a mandate for almost 7,000 MW of new renewable power over the next decade and a half (ibid.).

Much of this is expected to be met through rapid growth in wind and solar power, whose costs have fallen dramatically in recent years and are approaching grid parity. Hence, their expanded role in power generation on the Prairie provinces is unlikely to require large subsidies through generous feed-in tariff rates as they once did in Ontario. Burgeoning demand for wind and solar power on the Prairie provinces will likely see those industries that have grown up primarily in central Canada shift toward the west.

While wind and solar are both expected to post impressive gains, the bulk of renewable power in Canada will continue to come from hydro, which already accounts for more than 60 percent of total electricity production in the country. According to the Canadian Electricity Association, there is more than 160,000 MW of undeveloped hydro potential in the country.[7] But while hydro power may seem like an obvious candidate to replace coal-fired power, available surplus hydro power is not always located in proximity to markets served by coal-fired power generation, while lengthy transmission lines are costly, running over $2 million/km. For example, BC Hydro's 344 km Northwest Transmission Line that runs north of Terrace cost $736 million to build (*Terrace Standard* 2013). In addition, there are social licence and ecological issues arising from the reservoir impoundments created by large-scale dams. While, in theory, interprovincial power flows could help reduce dependence on coal, in practice, provinces have historically serviced their own power markets through government-controlled or directly owned power monopolies that have discouraged interprovincial electricity trade.

Transborder power flows have — at least until now — been more important than transprovincial flows. There are currently more than 30 transmission linkages between Canada and the United States (US Energy Information Administration 2015). While Canadian electricity imports represent less than

7 See http://powerforthefuture.ca/.

two percent of total US electricity sales, Canadian power is significant in key regional markets, in particular among a growing number of states that have committed to climate change mitigation policies that mandate significant reductions in future GHG emissions. For example, the New England states, where Canadian power imports are already more than 10 percent of electricity sales, have set a target of decreasing carbon pollution by between 35 and 45 percent below 1990 levels by 2030, and a longer-term goal of a reduction of between 75 and 85 percent of 2001 emission levels by 2050 (ibid.). Along with the state of New York, New England has been an important export market for surplus Quebec hydro, while Manitoba exports power to the US Midwest. The planned construction of new transmission lines adjoining those markets could significantly boost export capacity.

A number of new transborder transmission lines are being considered, including the Champlain Hudson Power Express, the New England Clean Power Link and the Northern Pass, each carrying about 1,000 MW of Quebec-based power to markets in New York and New England. In addition, Minnesota Power is constructing the Great Northern Transmission line, an 883 MW capacity line connecting it with Manitoba Hydro (adding roughly one-third to the province's export capacity) (Tiernan 2016). There are also plans to export power from Labrador's Muskrat Falls hydro project via underwater cable to Nova Scotia and from there, potentially, to New England power markets.

Notwithstanding these and other future potential transmission linkages to US power markets, the greatest opportunity for the country's largest producer of renewable energy, Hydro-Québec, may ultimately rest with transprovincial power exports to neighbouring Ontario. Recent developments in both provinces' power markets point the way for potentially unprecedented large-scale power deals. However, unlike hydro power exports to the United States, which, for the most part, replace the combustion of fossil fuels, power exports to Ontario are more likely to replace nuclear power.

Ontario faces a massive investment in upgrading its aging and costly nuclear power plants. Once blessed with "too cheap to meter" power from hydro and nuclear, Ontario's power costs over the last decade have been among the fastest rising in North America. For example, Toronto Hydro's residential customers pay more than 70 percent more per kWh than they did in 2006. By comparison, residential power users in the rest of North America have, on average, seen their electricity bills climb little more than 20 percent during the same period (Yauch 2016).

Whereas once-generous feed-in tariffs for wind and solar were commonly blamed for the province's high power costs, the primary culprit has been the huge overbuild of nuclear power-generating capacity, which must be operated on a continuous basis even when power prices are well below the cost of generation. Coupled with a 17 percent decline in peak hour electricity usage in the province over the last decade, Ontario's high-cost nuclear power plants generate a significant power surplus, much of which must be exported to the United States at well below cost.[8]

Despite growing public concern about soaring power costs, Ontario's electricity rates are poised to jump even higher under the province's announced plans of extending the operating lifetime of its Pickering nuclear power plant and refurbishing its aging Darlington nuclear power plant. The Pickering station, the fourth-oldest operating nuclear power plant in North America and situated in the most populous region of any nuclear power plant operating on the continent, is slated for closure in 2018, although the provincial operator is seeking to extend the operation of the plant until 2024.

Pickering's operating costs are already the highest of any operating nuclear power plant in North America, running around 8.2¢ per kWh, more than double what the power plant earns for power that is exported to the United States (Equiterre and the Ontario Clean Air Alliance 2016). According to its operator, Ontario Power Generation (OPG), operating costs are projected to rise steadily to 9.2¢ per kWh by 2020 if the plant is allowed to continue to operate.

The Darlington nuclear power plant, scheduled for a major refurbishing of all four of its nuclear reactors, will require a minimum $12.8 billion in capital spending if it is going to continue to operate much past this decade (Gibbons 2014). The proposed refurbishments would be completed by 2026. Many believe actual costs will be much higher as, on average, construction costs of nuclear power plants in Ontario have come in two-and-a-half times their original estimate (ibid.).

8 In 2015, the surplus dictated the export of 22.6 billion kWh — larger than the annual output of the Pickering nuclear power plant (Gibbons 2016).

To fund the cost of extending operations at Pickering and refurbishing the Darlington reactors, the OPG has asked its regulator, the Ontario Energy Board, for permission to almost double power rates from the two nuclear facilities — from the current rate of 5.9¢ per KWh to 10¢ per KWh by 2021. Moreover, the OPG indicated, in its recent rate application, the need to seek as much as 17¢ per kWh by 2026 (Ontario Clean Air Alliance 2017).

A number of environmental — as well as consumer — advocacy groups have proposed that instead of committing billions of dollars to refurbish aging nuclear reactors, the province could instead import surplus hydro from neighbouring Quebec at a fraction of the cost. Ontario Premier Kathleen Wynne recently took a tentative step in that direction by signing a seven-year contract with Quebec to import two terawatt hours of electricity at 5¢ per kWh — a fraction of the cost of refurbished nuclear power (ibid.). While the contract is modest — enough power for roughly 230,000 homes — it establishes an important precedent that opens the door to larger-scale agreements between two provinces that have historically regarded themselves as two solitudes when it comes to power sharing.

For Quebec — itself the fourth-largest producer of hydro power in the world — the Ontario contract is a welcome offset to reliance on spot price sales to neighbouring US states, where the advent of cheap power from burning shale gas has dramatically brought down prices for imported hydro power. Over 60 percent of Quebec's hydro export to the United States is sold at 3¢ per kWh (Equiterre and the Ontario Clean Air Alliance 2016). Moreover, the different seasonality in power demand between Ontario and Quebec make them well suited for power exchanges. Ontario's peak power usage is during the summer, when there is high demand for air conditioning, while Quebec's peak usage is during the winter, driven by the widespread use of electric heating in the province.

For a fraction of the estimated cost of maintaining the Pickering plant and refurbishing Darlington, the transmission network between the two provinces could be upgraded to facilitate large-scale power transfers. Ontario's Independent Electricity System Operator has estimated that at a cost of roughly $2 billion, the transmission network could be upgraded, including the construction of a new intertie near Cornwall, to handle as much as 4,288 MW of imported power from Quebec (Equiterre and the Ontario Clean Air Alliance 2016) — equal to almost 30 percent of the province's total electricity usage, obviating the need for either Pickering or Darlington. This cost is less than one-sixth of the current estimate for the refurbishment of the Darlington nuclear plant and, potentially, could be far less if Darlington's costs are over twice the original estimates, which has been the case for the cost of all past nuclear power plants in the province (Ontario Clean Air Alliance 2010).

Ontario and Quebec may not be the only two provinces where opportunities for interprovincial power swaps will exist. British Columbia Premier Christy Clark has proposed the construction of a transmission line to Alberta, which could import surplus hydropower from its neighbour to aid in the mandated phase-out of coal-fired power generation in the province. The cost of building a new transmission line between the two provinces is estimated to be in the range of $1 billion (O'Neil 2016).

Whether a replacement for base-load coal power in Alberta and Saskatchewan, or for aging and costly nuclear power in Ontario, renewables such as hydro, wind and solar are poised to see unprecedented opportunity in Canada over the next several decades as the country moves toward achieving its emission reduction targets. As more and more neighbouring US states mandate similar emission reduction targets that require a growing reliance on renewable power, there are likely to be further export opportunities. However, whether interprovincial or cross-border, the transfer of thousands of megawatts of new renewable power will require significant upgrading of existing transmission networks, including the construction of new transmission lines.

Year-round Shipping in the Northwest Passage

Arctic sea ice covered 7 million km^2 as recently as 1979.[9] Today, that area has been more than cut in half. The once-frozen ocean at the top of the world is melting, opening up long-sought-after Arctic shipping lanes through Canada's fabled Northwest Passage and Russia's Northern Sea Route. Ice-free Arctic sea routes are currently seasonal; however, the sea ice is melting much faster than earlier thought and recent climate models project that at the current rate of ice recession, both routes could be ice free in decades, providing year-round shipping routes that offer significantly shorter distances than either the Suez or the Panama Canals, where most global shipping is routed.

The opening waterways and dramatic recession of sea ice are the result of rapidly rising temperatures in the Canadian Arctic. Average summer temperatures in the region have already climbed to their highest levels in at least 40,000 years (and possibly in as many as 120,000 years) (Freedman 2013). In November 2016, temperatures at the North Pole were as much as 16°C warmer than historical averages, and Arctic ice coverage that month was the lowest since satellite measurements began in 1979 (Fountain and Schwartz 2016).

Large container ships carrying huge cargoes have already navigated these once-frozen passageways. In the summer of 2013, the *Yong Sheng*, a 19,000-ton Chinese cargo ship, sailed from the Chinese port city of Dailan to the European port of Rotterdam using the Northern Sea Route along Russia's Arctic coastline. The Arctic Ocean route shaved more than 4,000 km off the standard passage through the Suez Canal.

In September 2013, the *Nordic Orion*, a 225 m ice-strengthened Danish freighter loaded with British Columbia coal, sailed through the Bering Strait and needled its way through the once-frozen Northwest Passage on a journey to Finland, reducing the distance of the normal shipping route through the Panama Canal by about 1,000 km. In addition to the savings in route distance, the *Nordic Orion* was not bound by the weight restrictions that apply to passage through the Panama Canal's multiple locks, enabling the ship to carry 25 percent more coal than it would normally be allowed to hold. In 2013, as many as 71 ships sailed through Russia's Northern Sea Route, while only 17 sailed through the Northwest Passage (Struzik 2016).

9 See http://climate.nasa.gov/vital-signs/arctic-sea-ice/.

Competition from Russia's Northern Sea Route

Russia's Northern Sea Route currently has two advantages over Canada's Northwest Passage. The open water of Russia's Arctic coastline has experienced a greater rate of ice recession than the passageway through Canada's Arctic Archipelago, whose irregular contours trap and retain ice much longer. This advantage, however, should prove to be temporary, since by mid-century even the later-opening Canadian passageway could be ice free and open for year-round transport.

The second advantage is that, dating back to the Soviet era, Russia has sought to develop its Arctic coastline, while Canada has largely ignored its vast Arctic region. Arctic shipping was seen by the Kremlin as critical to the development of resource industries in Russia's vast northern hinterland, since most major river systems drain north and provide a natural means of transit to the sea. While much of the country's Arctic infrastructure was abandoned with the fall of the Soviet Union, it has seen a renaissance under President Vladimir Putin, who has declared the Northern Sea Route a national priority.

Over the last decade, Russia has re-established abandoned Arctic military bases that can provide essential search-and-rescue operations for Arctic shipping, and invested billions in upgrading and developing Arctic seaports such as Murmansk, the largest seaport north of the Arctic Circle. Russia has more than a dozen other Arctic seaports in various states of operational capacity.[10] Ships using those ports are, in turn, serviced by a fleet of 40 icebreakers, the largest such fleet in the world (Judson 2015).

10 Other Arctic seaports include Kandalksha, Vitino, Onega, Arkhngelsk, Mezen, Naryan-Mar Varndey, Amderma, Dikson, Dudinka, Igarka, Khatanga, Tiksi, Pevek and Provideniya.

Russia is by no means the only country considering the need for Arctic shipping infrastructure. Iceland is considering the viability of a deepwater port. China announced that five of its ships traversed the Northern Sea Route last summer and published a lengthy guidebook, *Guidance on Arctic Navigation in the Northwest Route*, to assist Chinese shipping companies that may soon also be using the Canadian route. And Portland, Maine, which is the first US eastern seaport that ships would reach when travelling from Asia through the Northwest Passage, is working on plans for a major port expansion to serve as a hub for Arctic shipping.

In contrast, Canada has done little to develop Arctic shipping or even to assert effective sovereignty over its vast Arctic waterways. In fact, much of Canada's early northern infrastructure, from the construction of the Alaska Highway to the Distant Early Warning radar stations, were built by the United States to counter perceived threats of attack from Japan during World War II and from the Soviet Union during the Cold War.

While Canada is a founding member of the Arctic Council (a network of eight countries — Canada, Sweden, Finland, Norway, Ireland, Denmark [Greenland], the United States and Russia — whose territory lies within the Arctic Circle), which seeks regional cooperation in managing the Arctic region, it has done little to build actual infrastructure in the region. The country's only Arctic port, Port Churchill, located on the southern coastline of Hudson Bay some 2,000 km south of the Northwest Passage, was closed in August 2016 by its American owner, Omnitrax, who bought the port from the federal government (Lambert 2016). It was the only northern seaport capable of handling vessels standard for international shipping. The previous Harper government promised to build an Arctic port around the old mining town of Nanisivik on Baffin Island, but never proceeded with the project.

Arctic Shipping Faces Fuel Cost Dilemma

In addition to a lack of shipping infrastructure, one of the greatest economic challenges facing the growth of Arctic shipping is the price of oil. While triple-digit oil prices rendered travelling greater distances more expensive, low oil prices have had the opposite effect. For example, there has already been a notable drop-off in cargo ships using the Northern Sea Route since the collapse in oil prices in 2014. In 2015, only eight ships used the Northern Sea Route, compared to a record high of 71 vessels in 2013, when world oil prices were still in the triple-digit range. If oil prices become permanently depressed because of global efforts to reduce carbon emissions, they will act as a powerful disincentive to the use of distance-saving routes.

However, the bunker fuel that powers the world shipping industry is a low-grade fuel that trades at a fraction of regular oil prices, and while the latter may ultimately be constrained by the need to reduce global emissions, the former may rise considerably as a result of the same pressures. Although emissions from the world's shipping industry fall outside the purview of international emission agreements such as COP 21, shipping is already one of the fastest-growing sources of global carbon emissions and the industry has attracted increasing world pressure to curb the amount of soot and sulfur it discharges into the atmosphere.

In response to such pressures, the International Maritime Organization recently agreed to cap the sulfur content of marine fuels sold around the world at 0.5 percent, which is as much as one-fifth lower than what is commonly found in bunker fuels (Cuff 2016). Industry estimates indicate that the cost of shipping fuel will double in 2020, when the new sulfur standards come into force (Khasawneh and Wallis 2016). In addition, the global shipping industry has pledged to introduce carbon emission reduction measures by 2023 and may well be forced to implement them sooner, adding even more to fuel costs (Harvey 2016). These worldwide shipping measures will become critical to the success of Arctic shipping, in particular if the International Maritime Organization agrees to phase out the use of lower-cost heavy oil for use in Arctic travel, which has been widely suggested as an environmental safeguard for the region.

The Impact of El Niño Droughts and Melting Permafrost on Shipping

While climate change is opening up new shipping routes in the Arctic, at the same time, it may impede transit along more traditional shipping routes. The recent El Niño-induced drought temporarily compromised the US$6.9 billion expansion of the Panama Canal to accommodate much larger vessels with three times the container capacity of ships currently using the locks (Atkins 2016b). The drought severely curtailed rainfall in the mountain headwaters that feed Lake Gatun, a man-made lake that accounts for roughly half the canal's route. Lower water levels, in turn, limited the draft of passing ships, forcing them to carry much lighter container loads than the widened canal was designed to accommodate.

Draft restrictions were lifted in June 2016 and the canal was almost flooded after Hurricane Otto hit the region in full force in November; however, the drought underscored how vulnerable the shipping route is to climate change. It is not clear whether the recent El Niño, or the preceding one in 1997-1998, are harbingers of future rainfall patterns in the region and, hence, water levels in the canal. Nevertheless, if these conditions prevail in the future, they could negate much of the commercial benefits of widening the canal and encourage alternative shipping routes that in the not-too-distant future may include the Northern Sea Route and the Northwest Passage.

Arctic shipping may receive another boost from the changing climate as melting permafrost poses increasing challenges to inland transportation routes that northern communities and resource industries depend on. The rapid melting of permafrost, which covers much of Canada's north (as well as Russia's), is already buckling roads and creating fissures, including along major northern thoroughfares such as the Alaskan Highway (Quinn 2016). Warmer winters and earlier thaws are also compromising ice roads. As road conditions deteriorate, diamond mines in the Northwest Territories have had to increasingly rely on expensive air transit, while shifting ground from melting permafrost along the banks of the Mackenzie River has even endangered pipelines.

While the primary commercial attraction of an ice-free Northwest Passage lies with international shipping routes connecting Asia with Europe or the eastern US seaboard, the region may also see a marked increase in domestic shipping. In addition to the already-growing industry of Arctic passenger cruises, the impairment of road connections due to melting permafrost could spur much greater dependence on year-round shipping to supply northern communities and provide vital transport links to resource industries in the region. If so, the climate change-induced shift in modes of transportation could skew resource development away from the interior and toward coastal regions.

Other Opportunities

Increased agricultural production of higher-value-added crops, greater use of renewable energy and the potential for year-round shipping in the Arctic Ocean are but some of the opportunities that climate change will bring. There are, of course, a myriad of other ones. While Canada is moving aggressively to curb emissions from its power sector, it still has to address the almost one-quarter of national emissions that originate from transport. Doing so will require further substantial investment in public transport, providing a growing market for the construction of buses and light rapid transit vehicles. The need to reduce future vehicle emissions could also trigger investment in high-speed rail along dense population corridors (that is, Windsor-Toronto-Montreal-Ottawa-Quebec City). And the electrification of transport will entail massive expansion in the production of electric and hybrid vehicles, as well as in the charging infrastructure along the nation's highways.

Policy Recommendations

Recommendation 1

The governments of Alberta and Saskatchewan need to conduct a full assessment of the water requirements of a shift in prairie agriculture to higher-value-added crops such as corn and soybeans to determine what changes in water management or inter-basin water diversion will be needed to take full advantage of the opportunities provided by lengthened growing seasons.

Recommendation 2

Transmission infrastructure should be upgraded to facilitate large-scale power exports from Quebec to Ontario. Building on its recent power-sharing agreement, Ontario and Quebec should consider joint transmission upgrades that would allow large-scale imports of cheap surplus power from Quebec in the neighbourhood of 5¢ per kWh. With potentially more than 4,000 MW of power available with upgraded transmission linkages, importing low-cost hydro power under long-term contracts from Quebec provides an attractive economic alternative to the costly refurbishment of Ontario's aging and high-cost nuclear power plants while, at the same time, reducing Hydro-Québec's exposure to the revenue risks from uncertain pricing of spot market sales. Similarly, British Columbia and Alberta should explore the viability of new transmission lines that would carry surplus BC hydro power to Alberta's still coal-dominated grid.

Recommendation 3

As part of its Pan-Canadian Framework on Clean Growth and Climate Change, the federal government should consider sharing the cost of needed upgrades of transmission lines across the country with provincial governments to facilitate greater interprovincial electricity transfers, as well as sharing the cost of establishing charging stations on major highways to promote — wherever possible — the increased use of hybrid and electric vehicles. This could be done through the $35 billion Canada Infrastructure Development Bank that the federal government has pledged to set up.

Recommendation 4

An Arctic strategy to develop shipping infrastructure should be established. If the economic promise of Arctic shipping is to be realized, Canada faces the huge task of mapping Arctic waters for safe passage routes; developing shipping infrastructure such as deepwater ports; and providing the necessary search-and-rescue stations to support commercial navigation. Not only will this be necessary to reap benefits from international shipping, but it could become essential for increased domestic usage of Arctic shipping lanes as land transit becomes more problematic across the melting permafrost of the North. The federal government needs to map out a strategy for building shipping infrastructure in the North, including assessing the feasibility of constructing a deepwater Arctic seaport.

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