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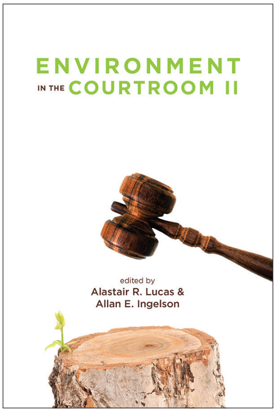

# ENVIRONMENT IN THE COURTROOM II

## Edited by Alastair R. Lucas & Allan E. Ingelson

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# 5

# Offshore Arctic Electricity Generation and Transmission Structures

*Magdalena AK Muir*[1]

## Introduction

Offshore and coastal electricity generation and transmission infrastructures have a unique role and importance in northern Canada and the Arctic. This chapter considers electricity generation and transmission and grid infrastructure in coastal and marine zones in northern Canada and the Canadian and European Arctic, including Russia. There is a consideration of the impact of generation and transmission on northern and Arctic environments and climate adaptation and mitigation, including the potential role of the courtroom. Lastly, the chapter concludes with recommendations for strengthening and providing for more adaptive and resilience of electricity generation and transmission infrastructure in these regions.

## Arctic and Northern Canadian Context

The geography, weather, development, and small populations in northern and Arctic Canada encourage decentralized energy use and generation. There is limited transmission and grid infrastructure, small urban settlements, and a few industrial mining and hydrocarbon projects with high energy requirements. Climate and other global environmental changes are making significant impacts throughout the region, with major implications for electricity generation, transmission, and infrastructure in coastal and marine regions.[2]

Industrial energy demand in these regions varies significantly with the opening and closing of remote mining and hydrocarbon operations. This industrial load has been historically satisfied by imported hydrocarbons and electricity generated by diesel. However, more efficient diesel generation, renewable energy, and alternative hydrocarbons such as natural gas, liquefied natural gas, and propane are increasingly being used or considered within industrial developments.

Other developing industries and sectors such as fisheries, foods, port and marine transport, and coastal and marine tourism require electricity generation and transmission infrastructure, and will evolve in the context of climate, global pandemics such as COVID-19, and other environmental and social changes.[3] The climate, topography, industrial development, and the small population of northern and Arctic Canada encourage a decentralized pattern of energy use with major electricity development focusing on industrial projects with overall high energy requirements and their adjacent communities. This industrial demand varies significantly with the opening and closing of remote hydrocarbon and mining operations that will be affected in the future by climatic and other environmental changes.[4]

Though the industrial load has traditionally been met by imported hydrocarbons and electricity generated by diesel, the high cost for imported hydrocarbons, the environmental implications for northern communities, and carbon emissions encourage the consideration of other options to generate electricity, with hydroelectric generation and solar energy being the preferred options.[5]

In 2014, the Standing Senate Committee on Energy, the Environment, and Natural Resources initiated a study of energy use and supply in Canada's territories. This resulted in the 2015 report entitled *Powering Canada's Territories*.[6] The report examined existing territorial energy systems and identified obstacles and opportunities facing each territory in making energy affordable, reliable, and sustainable for its residents and businesses, focusing on electricity generation and transmission.

The Standing Senate Committee on Energy, the Environment, and Natural Resources found northern electricity systems to be aging, underperforming, or functioning at capacity; that territorial communities were highly dependent on diesel generation; and that there was a lack of financial capacity by utilities and northern governments to advance major electricity generation and transmission projects due to small local rate and tax base, and territorial and local limits for borrowing.

Small remote communities predominantly rely on diesel generation. Electricity options are constrained for coastal and island communities, as these Arctic communities are far from southern electricity and natural gas grids.

A 2015 report noted that all three territories have developed energy strategies to promote and support renewable energy, increase energy efficiency, and reduce dependency on carbon-intensive fuels. In the Yukon and Northwest Territories (NWT), new opportunities for natural gas generation and biomass heating were diversifying the territorial energy mix. While coastal and island communities in the Nunavut Territory are solely reliant on diesel generation, this marine territory has some of the most abundant ocean current and tidal energy resources in the world.

Significant economic and technical challenges for Canada's northern communities include small, isolated land bases, the cost of transmission connections, and difficult environments for installation, maintenance, and repair. Finally, the 2015 report noted that all the territories have studied projects that would connect them to southern transmission systems but did not construct long-distance transmission lines as the costs were too high. For example, the Nunavut Territory explored hydroelectric projects but could not afford the costs of dams to supply Iqaluit and the Kivalliq coast. As a result, within that 2015 report, the Standing Senate Committee on Energy, the Environment, and Natural Resources suggested innovative financing, such as loan guarantees, to help the territories build these generation and transmission projects.[7]

Mining in northern Canada may actually be underdeveloped largely because of the high costs of electricity generation and transmission infrastructure. This has been referred to as Canada's largest infrastructure deficit and adds significant costs, resulting in exploration costs that may be up to six times higher than in southern Canada. Mine capital costs may be up to two and a half times more, and mine operating costs thirty to sixty percent higher. Combined, these large infrastructure costs hinder northern growth and affect competitiveness.

All mines have electrical generation and transmission challenges. For example, all six mines in the NWT and Nunavut are off-grid and require diesel power. In some cases, wind generation provides part of the energy. Due to remote locations, the costs and logistics for fuel are high in this region. There may also be carbon tax implications despite the lack of viable alternatives.[8]

Historic mines have also contributed to legacy infrastructure. Examples include Arctic communities such as Yellowknife in the NWT and Rankin Inlet in Nunavut; highways connected to mines near Yellowknife, Pine Point, and Fort Resolution in the NWT; the railway to Hay River and Pine Point; all three hydroelectric facilities in the NWT; the building and expansion of coastal and marine shipping and ports, airports and railways, microwave and internet communications.

The high cost for imported hydrocarbons and related environmental implications in northern and Arctic locations encourages the consideration of other options to generate electricity with hydroelectric, solar, or wind renewable energy being preferred options.[9]

Innovative infrastructure and renewable energy generation will continue to develop. For example, the proposed Kivalliq Hydro-Fibre Link, being developed by the Kivalliq Inuit Association and Anbaric Development Partners, is a 230KV electric system from northern Manitoba to the Kivalliq region of Nunavut that will delivery renewable energy and internet service to Nunavut communities and mines.[10]

Sustainability in northern and Arctic Canada is affected by transportation infrastructure, the reliability of the northern electrical system, alternative electricity generation, economic development, environmental protection, and adaption to climate change. Many of the challenges of northern transportation and related infrastructure will increase due to environment and climate change.

Longer-term impacts of climate change will be significant and have major impacts on operation and maintenance costs, as well as on the design and planning of capital projects with long-term infrastructure requirements.[11] These impacts and infrastructure needs have not all been determined or documented yet.

With climate change, shorter and warmer winters are accelerating permafrost degradation, which in turn affects the structural integrity of roads and increases maintenance and repair costs. Changing weather patterns also result in more freeze-and-thaw cycles, which increase damage to road and highway surfaces and maintenance and repair costs. Increased precipitation and permafrost degradation can also lead to an increase in erosion and subsidence on northern highways.[12]

Increasing navigability of Arctic marine waters is a significant issue leading to opportunities and potential challenges. For example, diminishing sea ice may allow for greater navigability, but more water traffic presents risks to coastal communities from oil and chemical spills, accidents and emergencies. There are also few docks and small ship harbours, which add to the costs of shipping, since materials and supplies must be transferred to barges or boats, moved to the beach, and off-loaded again.[13] The development of commercial fisheries in Canada's northern territories will require new and expanded ports and coastal infrastructure.[14]

Standards have a crucial role to play in addressing challenges in the electrical systems of the Canadian Arctic, which are subject to the Canadian Electrical Code.[15] The code covers a wide array of electrical systems and processes: the safety of electrical installations, the evaluation of electrical equipment or installations, power distribution and transmission circuits, industrial or institutional installations, and the inspection of electrical installation in residential buildings.

To illustrate, power quality and voltage fluctuations are more common in northern and Arctic Canada due to adverse weather conditions and wildlife interfering with transmission lines. Similarly, electrical equipment, designed and tested to operate in less extreme conditions, can be affected by deep and prolonged cold, and may perform or fail differently in extreme cold. In some cases, there may be challenges with grounding electrical systems. Safe distribution of electricity can be a challenge when overhead wiring is not feasible. Cold weather electrical applications may require specific standards, with one example being plumbing vent stacks that are heated to prevent vent freezing.

Alternative energy may assist in alleviating economic and environmental challenges resulting from heavy reliance on hydrocarbons. The reliance and use of hydrocarbons has led to a number of key economic and environmental challenges. Since almost all hydrocarbons are imported, they are costly and subject to delivery disruptions, and northern communities can face energy security challenges, as recently illustrated by Covid-19 disruption of supply chains. This reliance on hydrocarbons also has significant environmental effects, contributing to climate change and pollution, as well as adversely affecting the health of local communities and peoples.[16]

There are strong benefits in advancing the use of alternative energy sources, particularly low-impact renewable energy such as wind and solar photovoltaic technologies, since this offers energy security and diminishes adverse environmental impacts. Renewable energy options have been limited due to high installation costs, design issues, and lack of energy storage.

However, the potential for renewable energy is supported by decentralized electrical systems.

Another factor supporting other forms of renewable energy is the lack of financing among utilities and territorial governments for major hydroelectric projects. These factors make smaller scale and less capital-intensive renewable energy options more viable. Scientific research to develop smart energy systems, including combined heat and energy, and the integration of renewable generation and energy storage could be beneficial for advancing the uptake and application of renewable energy.

Biofuel and even modular nuclear reactors are being considered in Canada and elsewhere. For example, wood pellets have emerged as an alternative heating source in the NWT due to government strategies to advance biomass use. Standards have a crucial role in addressing such challenges. As will be discussed below, Russia is developing floating nuclear power plants (FNPP).

## ELECTRICITY GENERATION INFRASTRUCTURE

With very limited exceptions, electricity generation along Canada's Arctic coasts and throughout Nunavut occurs through diesel facilities that may be nearing the end of their life cycle and operating at capacity. All of Canada's northern territories and Arctic coasts and islands are engaged in ongoing examination and review of electricity generation options.

For example, NT Energy's twenty-year vision for electricity supply in the NWT[17] notes a more diversified electricity generation portfolio that includes different renewable energy sources and greater grid interconnection for the Mackenzie Delta and Beaufort Sea. This is a region that already has great supply diversification in a solar installation in Fort MacPherson and in the use of natural gas, and now propane, in Inuvik. Natural gas and propane "burn more cleanly than diesel fuel and they cause less contamination and produce fewer toxic pollutants and greenhouse gas emissions that impact on the environment and climate change."[18]

The Fort Simpson Solar Energy Project is the largest solar photovoltaic array, displacing diesel generation and reducing carbon emissions. The Northwest Territories Power Corporation (NTPC) owns and operates the system, which was built by SkyFireEnergy. The $1.07 million project cost was funded by the NWT government (the departments of Environment and Natural Resources and Industry, Tourism and Investment) with the balance of the project funded by NTPC, all through the territorial government's Energy Priorities Framework. On bright days, the project generates up to 100 kilowatts, supplementing the community's use of diesel, and reducing the generation of greenhouse gases (GHG) by approximately 76 tonnes annually.[19] In contrast, Nunavut's electricity, heating, and transportation needs are currently met primarily by diesel.

Natural gas exists on Arctic islands, but is neither produced nor located close to communities. The Qulliq Energy Corporation (QEC), formerly the Nunavut Power Corporation, relies on older diesel plants to generate electricity for communities. Diesel prices vary and must be shipped thousands of kilometres by marine transport, resulting in Canada's most expensive electricity.

QEC has considered developing hydroelectricity near Iqaluit. As a result of the natural lake and the high head, a small dam at Jaynes Inlet (Qikiqgijaarvik) could create water storage. Run-of-the-river hydro projects could then be used with the dam to supply Iqaluit with year-round electricity. QEC has considered using a public-private partnership to raise the money to build the plant, and there have been suggestions to use companies with experience building dams in Greenland in order to lower construction costs. However, costs, credit, and finance access for QEC and the Nunavut territorial government remain barriers to implementation.

Nunavut has wind resources, but it has not been cost effective to extensively develop them. Windmill projects in Kugluktuk, Cambridge Bay, and Rankin Inlet produced little energy and were expensive to develop. The technology is sensitive to cold weather, requires frequent maintenance, and onsite technicians are not always available. As a result, there are high costs to maintain and repair the windmills, and power bills have not been reduced. QEC has also considered using wind power to supply heat; a project in Cape Dorset may use wind turbines to heat water and provide heat for buildings.[20]

The Canadian High Arctic Research Station, based in Cambridge Bay, uses an innovative mix of renewable energy and energy efficiency measures. One of the objectives of the station is to focus on sustainable energy research for all the northern territories.[21]

Because of the small coastal and island populations in northern Canada, there have been consistent attempts to link industrial development, particularly mining and hydrocarbons, with electricity generation facilities so that an industrial consumer could support the development of generation. Successful examples of linking industrial development and electricity generation have occurred in the Yukon and NWT mining sector but are yet to happen in Arctic coastal regions, in part due to limited offshore hydrocarbon activity and the distance between remote mining sites and Arctic communities.

## COASTAL TIDAL, WIND, AND SOLAR OPPORTUNITIES IN NORTHERN AND ARCTIC CANADA

Tidal energy resources have been studied in northern Canada since 2006. Among the places identified as having the fastest tidal flows—and good potential for power generation—are the Hudson Strait in Nunavut and Ungava Bay in northern Quebec.

Quebec's theoretical potential for hydrokinetic energy has been estimated at 4,288 MW (38 terawatt-hours/year), only a portion (10 percent–15 percent) of which would be technically feasible. Over 97 percent of this Quebec resource is located near the Ungava Bay coast, a region far removed from Hydro-Québec's transmission system and major load centres in the province. There have been discussions of developing tidal power in Ungava Bay, but this is made difficult by costs, the remote location, and the fact that the bay is ice-free for only a small part of the year (approximately sixty days).[22]

## SCANDINAVIAN AND RUSSIAN RENEWABLE ENERGY GENERATION

Greenland has the most similar climate, environment, and population to Nunavut, but demonstrates a more sustainable approach to energy. Greenland is switching from diesel to hydroelectricity, with funding for dams from Nordic Investment Bank, and significantly lower hydroelectric construction costs than in northern and Arctic Canada.

Alternative energy technologies are also being explored. For example, a pilot plant in Nuuk uses hydroelectricity to electrolyze water into hydrogen and oxygen. Hydrogen is then stored for conversion into electricity, and on-demand heat, in a fuel cell. Excess heat from hydrogen production and fuel cells heats Nuuk as electricity is used by buildings or enters the local transmission system.[23] Research and financing are two of the reasons for this more sustainable energy approach.

Long-term European, regional, and national funding are available for the research and implementation of sustainable energy projects in Greenland and the Scandinavian Arctic, which in turn encourages the development and implementation of pilot and full-scale projects. The Nordic Investment Bank's mandate includes sustainable energy and climate. As a result, the bank has invested extensively in sustainable energy projects in the region including offshore wind development, hydroelectric projects that substitute for diesel generation, projects to increase energy efficiency, and combined power, heat, and water projects. This funding has led to successful implementation and operation of projects, which in turn encourages investments in other projects.

Within the Russian Arctic, switching to wind- and solar-diesel-hybrid energy, instead of relying primarily on diesel sources, is being considered. Extreme climate change and unpredictable weather conditions in the Russian Arctic complicate access to remote locations. Off-grid transmission mitigates concerns about energy security risks related to long transmission lines, such as disruption. Off-grid sources supply energy to about two-thirds of Russia's territory and to more than 80 percent of the Russian Arctic.[24]

Different problems with renewable energy sources across the Russian Arctic regions must be addressed and overcome with innovative local approaches. Wind energy in the largest wind potential areas (such as Tiksi or Anadyr) must use equipment designed specifically for these regions. In places with a milder climate, wind/diesel or wind/solar-diesel units produced positive results. The only large solar energy sector in Russia so far is in the Yakutia region.[25]

Nuclear power is another option: Russia and China have agreements to build nuclear power reactors in China and are working together to develop both nuclear and wind power projects for the Arctic regions.[26] The first industrial scale wind park above the Arctic Circle will be near Murmansk, and COVID-19 has not delayed the progress of construction. RusHydro has launched a wind power plant (900-kilowatt) in the Russian Arctic (Tiksi in the Yakutia region), which is designed to become part of an integrated energy complex that includes a diesel power plant.[27]

By far the most interesting development is the Akademik Lomonosov FNPP, commissioned on May 22, 2020 for the Pevek, Chukotka region in the Russian Far East. It is the first operational FNPP to deliver electricity and heat in the Russian Arctic. It was designed by Rosatom, the Russian state-owned nuclear energy corporation, which plans to mass-produce the power plant in shipbuilding facilities and then tow them to ports near locations requiring electricity, with the objective of providing energy to remote areas in an efficient and environmentally friendly way.[28]

The FNPP, at 144 metres long and 30 metres wide with a displacement of 21,000 tonnes, consists of a reactor vessel and a floating power unit (FPU). The FPU is equipped with two KLT-40S reactor systems, similar to those used on icebreakers, each with a 35 MW capacity. Refuelling of the reactor is required every three years, and spent nuclear fuel is stored onboard. The nuclear FPU is expected to last forty years, with the potential for the life cycle to be extended an additional fifty years before decommissioning. At that point, the FPU will be towed to a special deconstruction and recycling facility, leaving no spent nuclear fuel or radioactive waste behind in the Arctic.[29]

The facility is expected to be a steady source of energy for the port city of Pevek and the entire Chukotka Autonomous Okrug, Russia. Electricity generated by the FNPP is transmitted to coastal infrastructure situated at Pevek, with the onshore system being composed of a three-phase alternating current generator, main switchgear, and standby diesel generators. The plant cannot be removed from mooring, and there is a backup system that can keep the reactor cooling for twenty-four hours without an electricity supply.

The facility has already started to produce electricity in the isolated Chaun-Bilibino network, providing energy for 100,000 people and power for oil platforms. Rosatom head Alexei Likhachev stated: "It is perhaps a small step towards sustainable development in the Arctic—but it's a giant step towards decarbonization of remote, off-grid zones and a turning point in the global development of small modular nuclear plants. Floating nuclear power plants could help supply energy to remote areas without long-term commitments and without the need for large investments into conventional power stations on mostly uninhabitable land."[30]

In 2020, the Moscow Institute of Physics and Technology announced that construction had commenced on an international Arctic research station with the purpose of exploring environmentally friendly technologies aimed at supporting and maintaining remote settlements and facilities in the Arctic region. The station will have a modular structure and rely on renewable energy and hydrogen fuel, with energy autonomy provided by solar, wind, and hydrogen energy.[31]

## ELECTRICITY TRANSMISSION INFRASTRUCTURE

Currently there is no extensive electricity grid infrastructure, other than small community-based transmission systems, across any of the Canadian Arctic coasts and islands. Linking industrial development to transmission infrastructure has been considered but not realized for the NWT or Nunavut, particularly in the coastal and island regions. More expansive development of northern transmission infrastructure may occur in the near future, including linkages to northern mining development. For example, the NWT twenty-year vision for electricity supply projects the expansion and interconnection of transmission infrastructure for the Mackenzie Delta Beaufort Sea region.[32]

The Kivalliq Hydro-Fibre Link is being developed by the Kivalliq Inuit Association and Anbaric Development Partners and is a 230 kV electric system from northern Manitoba in the Kivalliq region of Nunavut that will deliver reliable renewable energy and internet service to Nunavut communities and mines. Regarding this link, Natan Obed, president of Inuit Tapiriit Kanatami has stated: "The federal government's ongoing work on the Arctic Policy Framework should include investment in telecommunications and renewable energy infrastructure to address these challenges and support infrastructure projects initiated by Inuit . . . The Manitoba-Nunavut hydroelectric power line transmission and fibre optics project would . . . create prosperity for Inuit in Nunavut that in turn benefits all Canadians."[33]

There is also the possible expansion of Hydro-Québec transmission infrastructure to Ungava Bay and the Hopes Advance iron mine project near Ungava Bay. The Hopes Advance iron mine would initially self-generate electricity using diesel from 2018 to 2025. After 2025, the mine is scheduled to be connected to the Hydro-Québec transmission system, as transmission expands to that region.[34]

A Greenlandic study[35] released in November 2015 suggests Greenland could generate enough hydroelectricity to supply its own needs and export excess power to Nunavut through an eight-hundred-kilometre submarine transmission line.[36] This study is part of a larger North Atlantic Energy Network (NAEN) proposed to link Iceland, the Shetland Islands of Scotland, Greenland, and Canada.

Greenland now supplies hydroelectricity to six of its towns, including the capital Nuuk, from five hydroelectric plants.[37] Greenland has studied hydroelectric generation potential since 1976 and, although potentially viable, NAEN suggests that more detailed studies are needed to determine if developing more hydro power might be economically feasible in the future.[38] Greenland still hopes to attain up to 90 percent of its electricity from hydroelectric dams by 2030.[39]

## OTHER CIRCUM-ARCTIC RENEWABLE ENERGY GENERATION AND TRANSMISSION

The Longyearbyen coal-fired power plant is Norway's only coal-fired plant, consuming 22,000 tons of locally produced coal, and producing approximately 50,000 tons of greenhouse gas emissions annually. To replace the existing coal-based electricity generation, transmission lines linking Svalbard Island with the coast of northern Norway are being contemplated.

A transmission line could provide wholly renewable energy and integrated wind supply, and support other innovations such as electric cars and boats. Svalbard already has the necessary expertise because of an existing submarine fibre optic cable linking the island to the mainland. However, the costs for the long-distance submarine transmission line are estimated to be between 323 to 539 million euros.[40]

Further submarine transmission lines have been proposed by NAEN between Greenland, Iceland, the Faroe Islands (Denmark), and Norway.[41]

Arctic Fibre is a three-phase submarine cable project, planned to connect Asia, Canada, and Europe through the Arctic Ocean. Phase 1–Alaska is a 2,250 km submarine fiber optic cable main trunk line between Nome and Prudhoe Bay. Phase 2–Asia plans to extend the backbone cable from the Nome branching unit west to Asia, with options for additional branches into Alaska. Phase 2 will thus create an option for a diverse path out of the United States to Asia. Phase 3–Canada-United Kingdom is intended to extend the subsea system east of Prudhoe Bay, the Alaska branching unit, along the lower Northwest Passage to Canada and continuing to the United Kingdom. Phase 3 will connect to northern Canadian communities and will provide a secure low transmission route from Europe to Asia, and a diverse route option out of North America to Europe.[42]

The Phase 1–Alaska was launched for service in early December 2017.[43] Quintillion Subsea Holdings LLC (Quintillion) acquired the assets of Arctic Fibre in May 2016.[44] Arctic Fibre was the third private sector company trying to bring fibre optic to Nunavut. However, the development of fibre optic broadband projects in the Arctic may require government help, as vast geography and small markets make it challenging for private sector initiatives.

More global and far-reaching transmission systems have also been proposed. For example, in 2015, the Chinese State Grid Corp. introduced the proposed Global Energy Interconnection (GEI), which envisions the Arctic as a source of renewable energy and proposes a global transmission infrastructure that includes the Canadian Arctic.[45] The *Wall Street Journal* has also profiled this initiative, which is breathtaking in its scope.[46]

The Global Energy Interconnection Development and Cooperation Organization (GEIDCO) is an international organization set up and tasked to promote the establishment of the GEI system, to meet the global demand for electricity in a clean and green way, to implement the United Nations "Sustainable Energy for All" and climate change initiatives, and to serve the sustainable development of humanity.[47]

An interconnecting subsea cable between Iceland and neighboring European countries has been discussed for decades. However, it is only recently that advancements in technology have made it a realistic option to connect Iceland with other European countries with such a cable. In 2010 the Icelandic electricity company Landsvirkjun started a new study to evaluate the feasibility of a high voltage direct current (HVDC) cable between Iceland and Europe, which would be the world's longest submarine HVDC power cable. The study addresses issues like potential business models, markets, and congestion management. The cable would be at least 1,000 km in length, which is almost double the length of the longest existing subsea HVDC cable today: the NorNed interconnector between Norway and the Netherlands. If the cable extended from Iceland all the way to the European continent (instead of only to Scotland) its length would be around 1,900 km. The maximum depth under the ocean would be about 1,000 m and the transmission capacity would probably be between 600 and 1,000 MW.[48]

The HVDC cable that will provide for the transmission of hydroelectricity from Norway and offshore wind energy from the United Kingdom between the two countries is proceeding.[49]

The Russia-Japan Energy Bridge was expected to start in 2020 but has not yet begun.[50] With a value of approximately 6 billion US dollars, the power plant, in the central part of Sakhalin, will have a capacity of up to 1050 MW generated by coal, and may be joined by a hydropower plant and direct current power line to La Perouse Strait, followed by a submarine power line to Japan.[51]

Similarly, construction on the Russia-North Korea Power Bridge (Primorye-Rosan), a project valued at approximately 3 billion US dollars, was expected to start in 2022. Although few details are known, the bridge would supply electricity from Primorye (Russia) to Rason (North Korea), and connect where the borders of North Korea, China, and Russia intersect.[52]

Interestingly, Emrod, a New Zealand company, has proposed to use wireless systems to transmit power between any two points that can be joined with line-of-sight relays (potentially thousands of kilometres apart). The system uses a transmitting antenna, a series of relays, and a receiving rectenna—the beams use the non-ionizing industrial, scientific and medical band of the radio spectrum (including frequencies used on Wi-Fi and Bluetooth). This ensures higher safety, and works in any atmospheric conditions, including rain, fog, and in the presence of dust. A prototype has been built by Powerco, New Zealand's second largest electricity distribution company, which will be the first to pilot this Emrod technology.[53]

## Northern Infrastructure Standardization Initiative

Standards are important for the future development of electricity generation and transmission infrastructure in northern and Arctic Canada.[54] The Northern Infrastructure Standardization Initiative (NISI) is designed to build a "climate-resilient" future with northern standards. Northern and Arctic Canada is highly vulnerable to climate change and is impacted by changing temperatures and precipitation patterns, permafrost degradation, and coastal erosion. Since 2011, the Standards Council of Canada (SCC) has been working with communities, standards development organizations, and experts to develop standards that consider climate change impacts on northern infrastructure design, planning, and management. NISI standards will help building owners and operators, and public and community infrastructure operators to build and maintain infrastructure in a changing climate. Some aspects of CSA standards addressing permafrost, extreme weather, and climate changes are discussed below.[55]

### *CSA S500:14 (R2019): Thermosyphon Foundations for Buildings in Permafrost Regions*

This standard "provides requirements for all life-cycle phases of thermosyphon foundations for new buildings on permafrost," (i.e. site characterization, design, installation, commissioning phases, and monitoring and maintenance phases). The objective is "to ensure the long-term performance of thermosyphon-supported foundation systems under changing environmental conditions."[56]

### *CSA S501:14 (R2019): Moderating the Effects of Permafrost Degradation on Existing Building Foundations*

Since permafrost degradation can cause damage to buildings or structures constructed on permafrost, this standard lays out the steps that should be undertaken to moderate the effects of permafrost degradation on existing buildings or structures including ports, roads, infrastructure, and coastal facilities.[57]

### *CSA Plus 4011:19: Technical Guide: Infrastructure in Permafrost: A Guideline for Climate Change Adaptation and CSA Plus 4011.1:19: Technical Guide: Design and Construction Considerations for Foundations in Permafrost Regions*

The standards are intended for individuals who have a role in planning, purchasing, developing, or operating community infrastructure in permafrost regions; and are intended to inform decision makers of the impacts of climate change on permafrost when considering new community infrastructure.[58]

### *CSA W205:19: Erosion and Sedimentation Management for Northern Community Infrastructure*

This "applies to the management of erosion and sedimentation risks, including the evaluation, planning, design, implementation, monitoring, and maintenance of erosion and sedimentation risk management strategies and mitigation measures" for infrastructure.[59]

### *CSA S505:20: Techniques for Considering High Winds and Snow Drifting and their Impact on Northern Infrastructure*

This particular standard "addresses risks to northern infrastructure due to wind, snow, and snow drifting."[60]

### *CSA 2501–500: Geotechnical Site Investigations for Building Foundations in Permafrost Zones*

Finally, this standard addresses the design of building foundations with consideration to the prevailing conditions at building sites.[61]

## Environmental Considerations Including the Role of the Courtroom

As electricity generation in the Canadian Arctic coasts and islands is still predominantly diesel, there are many adverse existing environmental aspects, including pollution, particulate matter, and GHG emissions. Any transition to less carbon-intensive hydrocarbons, such as natural gas and natural gas liquids, or hybrid diesel renewable energy systems, is likely to be environmentally and socially beneficial. Therefore, there is a positive environmental benefit for this transition and change.

In contrast, the expansion of the existing limited community-based transmission systems to more extensive transmission systems, high voltage long distance transmission systems, or submarine transmission systems, could potentially have adverse environmental implications. Some of these environmental implications are consistent with terrestrial and submarine transmission systems elsewhere,[62] while other environmental implications are specific to Arctic coasts and islands.

There are northern and Arctic-specific environmental implications for transmission lines, whether coastal or submarine, such as impacts on permafrost, ground stability, coastal erosion and ice scour, and the need to modify more southern construction techniques.

For example, like pipelines, these transmission lines and related structures might need to be insulated or cooled to avoid melting permafrost. For facilities located on river channels or coasts, such as in the Mackenzie Delta Beaufort Sea region, additional factors such as river ice break-up, ice jam flooding, coastal erosion, and sea-level rise would need to be considered.

For transmission lines and structures, changes in the ground thermal regime, drainage and terrain stability, all of which may result from a warming climate over the lifetime of such a transmission, must be considered.

There is also the need to closely monitor the performance of the transmission line and right-of-way to maintain line integrity and minimize environmental impact, which in the context of northern and Arctic communities may have to occur remotely, or by satellite-based monitoring.

The use of ice roads and all-season roads needs to be considered in relation to the construction, maintenance, and monitoring of transmission systems. Reductions in ice thickness associated with climate warming reduce the maximum loads that can be safely transported. Initially, modifications in ice-road construction could function as an effective adaptation. Over time, as ice roads become impractical, there will be a need to provide alternative transportation. If there is a navigable river, increased use of barge transport might be possible. Construction of all-weather roads may be an option, but these are more costly to build and maintain compared to winter roads and have greater environmental impacts and implications.

There are unique legal structures and processes, including co-management regimes under Canada's northern and Arctic comprehensive land claims agreements, which incorporate environmental measures and mitigation and which include the participation of local communities within their mandates, processes, and structures.[63]

Though the courtroom is not entirely excluded, many of the environmental and social issues in relation to electricity generation and transmission may initially and primarily be considered under these legal structures and processes.

As the electricity generation and transmission lines expand, or are linked to significant hydrocarbon or mining developments, fisheries, tourism, or settlements, there may be greater potential for communication, engagement, and dispute resolution to reach an agreement or address gaps or inadequacies for these structures and processes.[64]

## Conclusion

The chapter has discussed existing and proposed electricity generation and transmission for Canada's northern and Arctic coasts and islands. It has also briefly explored near-future and distant-future opportunities and innovations that may affect this region and the European and Russian Arctic. This entire circum-Arctic region is promising for climate adaptation and mitigation, future investment, policy development, and public-private partnerships for electricity generation and transmission projects.

### NOTES

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