Offshore Arctic Electricity Generation and Transmission Structures

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Introduction

Electricity generation and transmission structures have a unique Arctic context, which is discussed first in this paper. The paper then considers northern electricity generation structures, followed transmission infrastructure in Arctic coastal and marine zones. There is then a consideration of the impact of this electricity generation and transmission on the northern environment including the potential role of the courtroom. Last, the paper ends with brief conclusions.

Arctic Context

The climate, geography, industrial development, and small population in northern Canada encourages a de-centralized pattern of energy use with limited number of industrial projects with high energy requirements. This industrial demand varies significantly with the opening and closing of remote hydrocarbon and mining operations. Though this industrial load has traditionally been met by imported hydrocarbons and electricity generated by diesel, renewable energy and other forms of energy such as natural gas, liquefied natural gas and propane are also being used or considered. The high cost for imported hydrocarbons, and related environment implications in northern locations encourages the consideration of other options to generate electricity with hydro generation being one of the preferred options.[1]

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 Powering Canada's Territories.[2] 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 and at capacity; that territorial communities highly dependent on diesel generation; and finally that there was a lack of financial capacity by utilities and northern governments to advance major electricity generation and transmission projects due to small rate and tax bases. As the map illustrates below, remote communities predominantly rely on diesel generation. Electricity options are constrained for coastal and island communities in particular, as these Arctic communities illustrated in a map from that report are even farther from southern electricity and natural gas grids.

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[1] Muir MAK. Integrating Renewable Energy, Heat, and Water Quality and Quantity in Sustainable Energy and Water Projects for the Circum-Arctic and Northern and Remote Regions of Canada for QUEST International Conference: Smart Energy Communities in Cold Climates (2012) as located at http://arctic.ucalgary.ca/sites/arctic.ucalgary.ca/files/Nov-2012-MAKMuir-QUESTInternationalConference-Paper.pdf.

[2] Standing Senate Committee on Energy, the Environment and Natural Resources, Powering Canada's Territories (2015), see http://www.parl.gc.ca/Content/SEN/Committee/412/enev/rep/rep14jun15-e.pdf,

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

Significant economic and technical challenges for Canada's northern communities include due to small isolated sites, the cost of transmission connections, and difficult environments for installation, maintenance and repair. Finally, the 2015 report noted that all the territories have all studied projects that would connect them to southern transmission systems but did not construct the long distance transmission lines as the costs were too high. For example, the Nunavut Territory has explored hydroelectric projects but could not afford the costs of dams to supply Iqaluit and the Kivilliq coast. As a result within that 2015 report, the Standing Senate Committee on Energy, the Environment and Natural Resources has suggested innovative financing such as loan guarantees to help the territories build these generation and transmission projects. [3]

Electricity Generation Structures

Transition from Diesel Generation to Natural Gas and More Renewable Sources

With very limited exceptions, electricity generation on Canada's Arctic coasts, and throughout the Nunavut Territories occurs through diesel facilities which may be nearing the end of their life

[3] Standing Senate Committee on Energy, the Environment and Natural Resources, Powering Canada's Territories (2015).

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, the NWT Electricity Supply 20 Year Vision[4] 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 for a solar installation in Fort MacPherson and use of natural gas and now propane in Inuvik. The two graphics below from the 2013 Vision illustrate the existing electricity generation and transmission structures, and those anticipated within the next 20 years for the Mackenzie Delta and Beaufort Sea.

The Fort Simpson Solar Energy Project is the largest solar photovoltaic system in northern Canada, displacing diesel generation, and reducing carbon emissions. The Northwest Territories Power Corporation (NTPC) owns and operates the system which was built by a Canadian company, SkyFire Energy Solar. Funding was provided through the territorial government's Energy Priorities Framework, with 700,000 Canadian dollars contributed under the framework, and 60,000 Canadian dollars from NTPC. The solar array contains 258 panels rated at 235 watts each for a total of 60.6 kW. The system is connected to the Fort Simpson grid and provides enough energy for up to 10 houses or up to 8.5% of the minimum power requirements in the summer.[5]

[4] NT Energy, A Vision for NWT Power System Plan (December 2013). See http://www.pws.gov.nt.ca/pdf/Energy/A%20VISION%20for%20the%20NWT%20Power%20System%20Plan%20-%20December%202013.pdf

[5] Muir MAK. Integrating Renewable Energy, Heat, and Water Quality and Quantity in Sustainable Energy and Water Projects for the Circum-Arctic and Northern and Remote Regions of Canada.

In contrast, all of Nunavut's electricity, heating and transportation needs are met by diesel. Natural gas exists in Arctic islands but is not currently produced. Qulliq, 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 under marine transport, resulting in Canada's most expensive electricity.

Qulliq 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-river hydro projects could then be used with dam to supply Iqaluit with electricity year around. Qulliq has considered the use a public-private partnership to raise the money to build the plant, and there have been suggestions to use companies that built dams in Greenland due to lower construction costs. However, costs and credit and finance access of Qulliq and the Nunavut territorial government remain a barrier 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 produce little energy and were expensive to develop. The technology is sensitive to cold weather, high 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.

Qulliq has considered considering using wind power to supply heat; and a project in Cape Dorset may use wind turbines to heat water, and provide heat for buildings.[6] The Canadian High Arctic Research Station set to open in 2017 in Cambridge Bay will use an innovative mix of renewable energy and energy efficiency measures; and is also intended to have a focus on sustainable energy research for all the northern territories.

Greenland has the most similar environment and populations to northern Canada, but a more sustainable approach to energy. Greenland is switching from diesel to hydroelectricity, with funding for dams from Nordic Investment Bank, and significantly lower hydro construction costs than 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, while electricity is used by buildings or enters the local transmission system.[7] Research and financing are two of the reasons for this more sustainable energy approach.

Long term European, regional and national funding is 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

[6] Muir MAK. Integrating Renewable Energy, Heat, and Water Quality and Quantity in Sustainable Energy and Water Projects for the Circum-Arctic and Northern and Remote Regions of Canada.

[7] Muir MAK. Integrating Renewable Energy, Heat, and Water Quality and Quantity in Sustainable Energy and Water Projects for the Circum-Arctic and Northern and Remote Regions of Canada.
M.A.K. Muir. Bæredygtig energi i Norden, Kapitel 7.4 i Håndbog om Grøn Lov og Praksis, 2012.

successful implementation and operation of projects, which in turn encourages investments in other projects.

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 an industrial consumer could support the development of generation. Successful examples of linking industrial development and electricity generation have occur in the Yukon mining sector but not yet occurred in Arctic coastal regions, in part due to limited offshore hydrocarbon activity and distance between remote mining sites and Arctic communities.

Future Coastal Tidal, Wind and Solar Opportunities

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. There have 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 60 days.

For example, Québec's theoretical potential for hydrokinetic energy has been estimated to be 4,288 MW (38 TWh/year), only a portion (10%–15%) of which would be technically feasible. Over 97% of the Quebec resource is near the Ungava Bay coast, a region far removed from Hydro-Québec's transmission system and major load centres.[8]

[8] Hydro Quebec, A Renewable Energy Option: Hydrokinetic Energy (2015). See http://www.hydroquebec.com/sustainable-development/documentation-center/pdf/file-hydrokinetic.pdf

Electricity Transmission Infrastructure

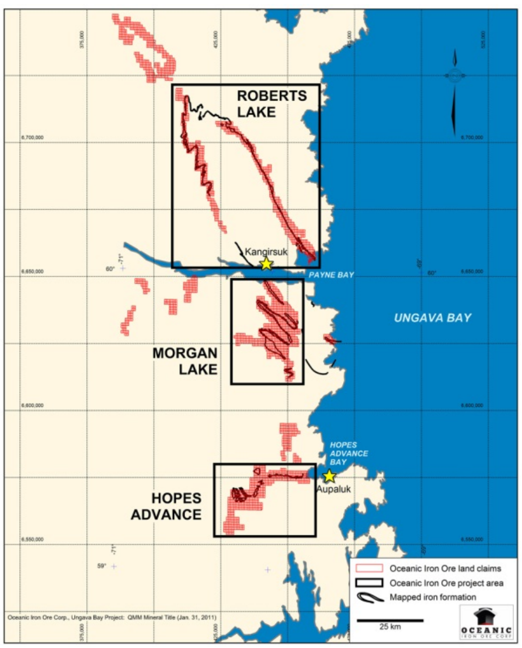
Current Transmission Infrastructure

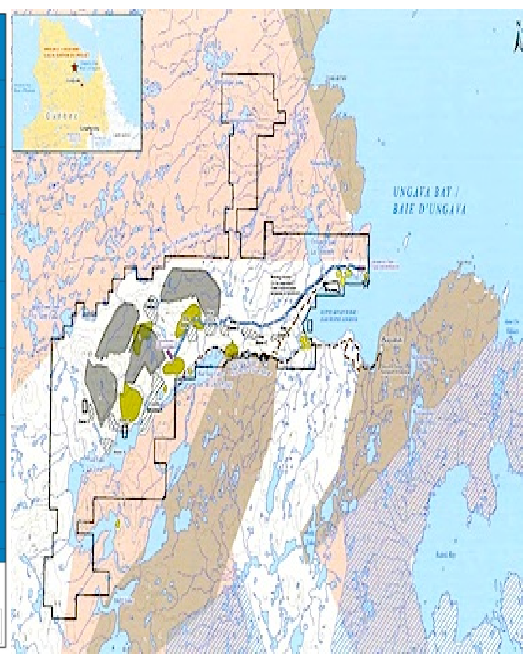
Currently there is no extensive electricity transmission infrastructure, other than community based transmission, across any of the Canada Arctic coasts and islands. There has been the consideration of linking industrial development to transmission infrastructure, but no realization in the Northwest and Nunavut Territories, particularly for Arctic coastal and island regions.

Future Canadian, Arctic and Global Infrastructure

More expansive development of northern transmission infrastructure may occur in the near future, including linkages to northern mining development. There is the example of Northwest Territories Electricity Supply Twenty Year Vision which includes projected expanded and interconnected transmission infrastructure for the Mackenzie Delta Beaufort Sea region.

There is also the possible expansion of Hydro Quebec transmission infrastructure to Ungava Bay as the Hope Advance iron mine project near Ungava Bay. The Hope Advance iron mine would initially self generate electricity using diesel from 2018 to 2025. From 2025, the mine is scheduled to be connected to the Hydro Quebec transmission system, as transmission expands to that region.[9]

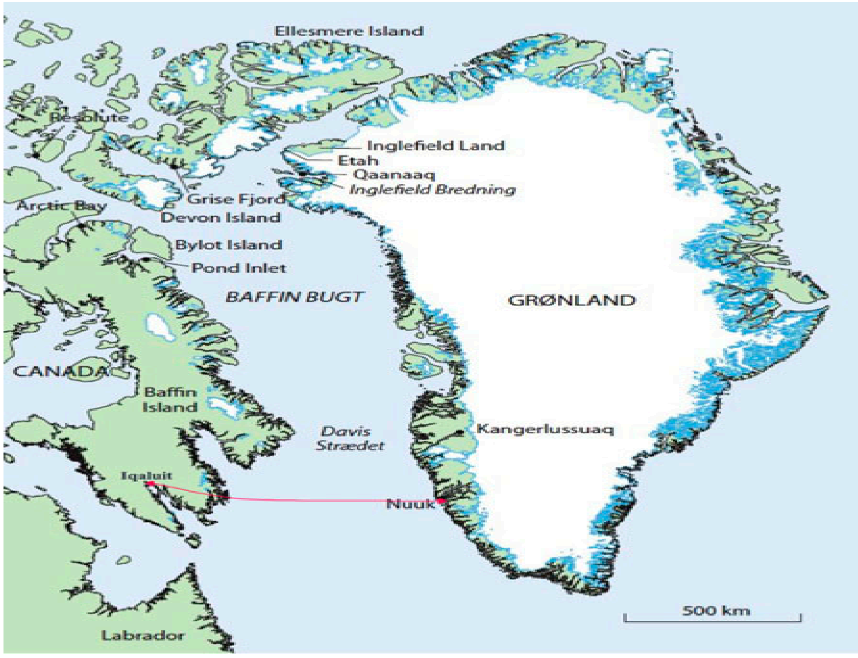




A Greenlandic study released in November 2015 suggests Greenland could generate enough hydro-electricity to supply its own needs and export excess power to Nunavut through an eight hundred kilometer submarine transmission lines, with illustration provided below. This study is

[9] Oceanic Iron Ore Corp, Investor Presentation (August 2016), see http://oceanicironore.com/_resources/presentations/08_25_2016Oceanic_Iron_Ore_Investor_PresentationAUG_2016.pdf.

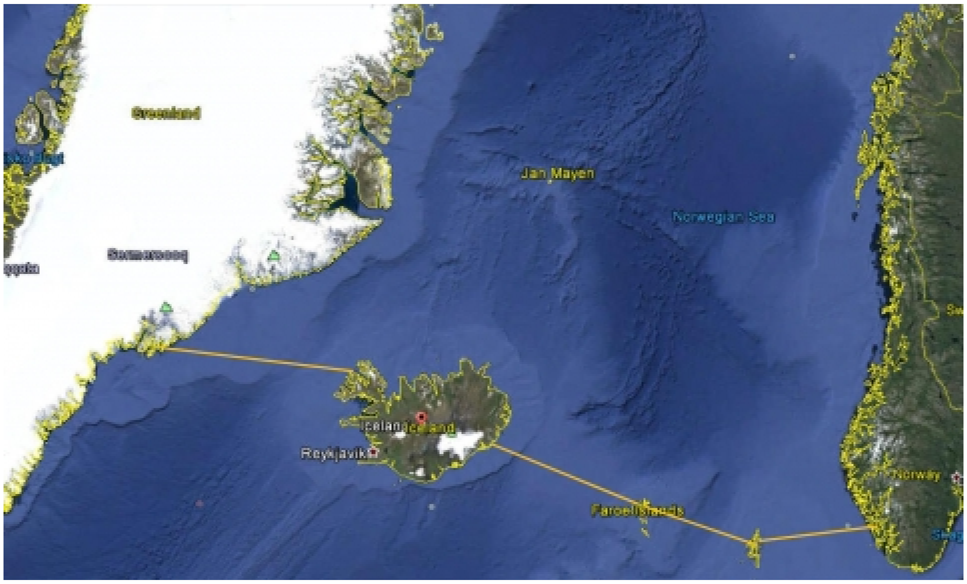
part of a larger North Atlantic Energy Network (NAEN) linking Iceland with the Shetland Islands, Greenland and Canada. Greenland now supplies hydroelectricity to six of its towns, including the capital Nuuk, from five hydroelectric plants. Greenland has studied hydro potential since 1976 and, although potentially viable, NAEN suggests that more detailed studies are needed to determine if developing more hydro power might be economically feasible in the future.[10]



Further submarine transmission lines have been proposed by NAEN between Greenland, Iceland, the Faore Islands (Denmark) and Norway.[11]

[10] Pehora, Brian, Greenland to Nunavut electricity exports? It just might be possible: Study finds undersea transmission cable could supply hydro-electricity to Iqaluit (Nunatsiaq News, January 14, 2016). See http://www.nunatsiaqonline.ca/stories/article/65674greenland_to_nunavut_hydro_exports_it_just_might_be_possible/.

[11] Enerati: the smart energy network website. Steps towards a North Atlantic energy network: North Atlantic have high renewable energy potential which could be exploited in North Atlantic electric grid (Downloaded October 5, 2016) See https://www.engerati.com/article/steps-towards-north-atlantic-energy-network



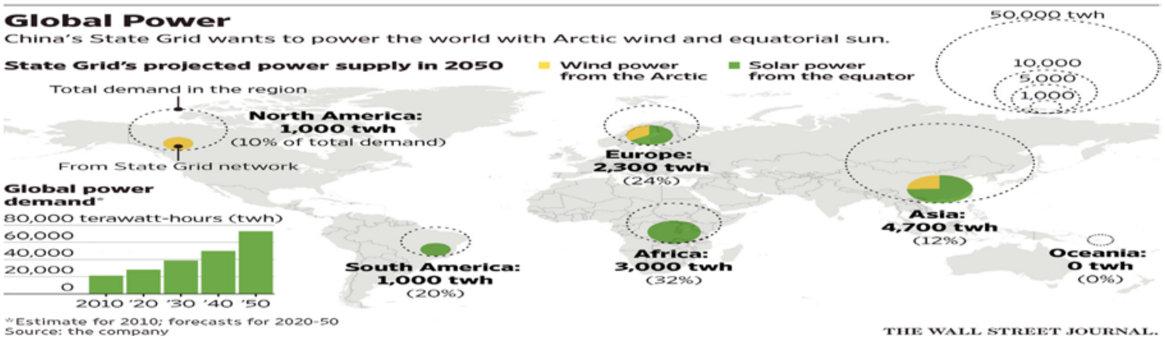
Elsewhere in circumpolar Arctic, transmission lines are being contemplated, such as linking Svalbard Island with the coast of northern Norway, and replacing the existing coal based electricity generation. The Longyearben coal fired power plant is Norway's only coal fired plant, consuming 22,000 tons of locally produced coal, and producing approximately 50,000 tons of greenhouse gas emissions annually.

The 2016 Independent Barents Observer article, Svalbard could turn from dirty coal to zero emission power supply, indicates that a transmission line could connect the island to the Norwegian mainline and provide wholly renewable energy, integrate wind supply and support other innovations such as electric cars and boats. There is an existing expertise and route for submarine cables, as Svalbard already has a fibre optic cable linking the island and the mainland. However the costs for this long distance submarine transmission line is estimated to be between 323 to 539 million euros. [12]

Photo of Svalbard coal fired generation facility: Thomas Nilsen

[12] Nilson, Thomas. Independent Barents Observer article, "Svalbard could turn from dirty coal to zero emission power supply" (August 23, 2016), see http://thebarentsobserver.com/arctic/2016/08/svalbard-could-turn-dirty-coal-zero-emission-power-supply

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, which envisions the Arctic as source of renewable energy, and proposes a global transmission infrastructure that includes the Canadian Arctic. The Wall Street Journal has also profiled this initiative, which is breathtaking in its scope. Various graphics from the China State Grid Corp. and the Wall Street Journal are provided to illustrate the scope of the initiative.[13]



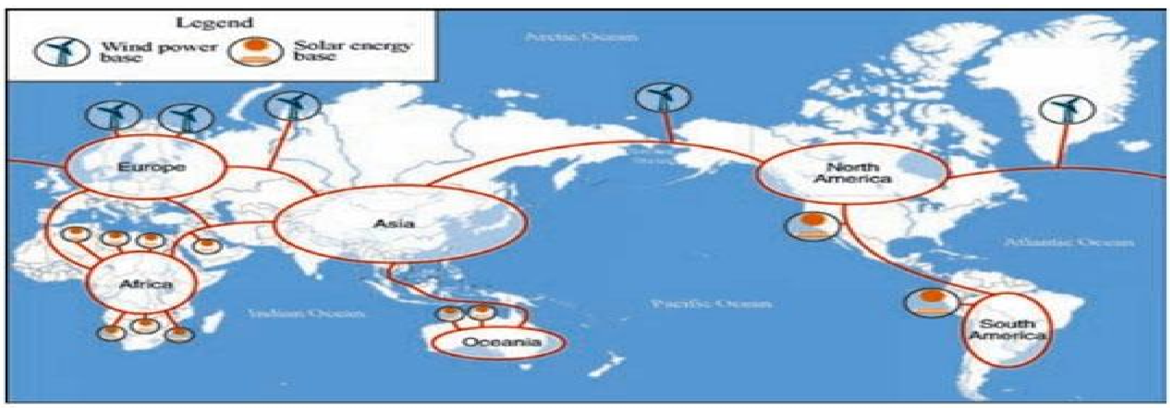


Illustration of Global Energy Interconnection

Illustration of the Actic's Channels for outgoing power transmission

[13] Spegele, Brian. China's State Grid Envisions Global Wind-and-Sun Power Network (Wall Street Journal, March 30, 2016) See http://www.wsj.com/articles/chinas-state-grid-envisions-global-wind-and-sun-power-network-1459348941 2016 International Conference on Global Energy Interconnection Opens in Beijing, found at http://www.geidco.org/html/qqnycoen/col2015100728/2016-06/01/20160601101607859323413_1.html

Environmental Considerations Including Role of the Courtroom

As current generation in the Canadian Arctic coasts and islands is still predominantly diesel, there are many adverse environmental aspects, include pollution and particulate matter, to greenhouse gas 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 very environmentally and socially beneficial. In contrast, the expansion of the existing limited community-based transmission systems to more extensive transmission systems, or high voltage long distance transmission systems, or submarine transmission systems, could potentially have adverse environmental implications. Some of these environmental implications are consistently to transmission systems across the global, while other environmental implications are specific to Arctic coasts and islands.

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

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 cold 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 becomes impractical, there will be a need to provide alternative transportation. If there is navigable river, increased use of barge transport might be possible. Construction of all-weather roads may be an option but are more costly than winter roads to build and maintain.[14]

There are unique legal structures and processes, including co-management regimes under land claims, which incorporate environmental measures and mitigation; and which include the participation of local communities within their mandates, processes and structures. 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 transmission lines proposals expand, or are linked to significant hydrocarbon or mining developments, there may be greater potential for litigation and challenges to address disagreements, gaps or inadequacies for these structures and processes.

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[14] Muir, MAK, Climate Impacts and Adaptation for Energy, Mining and Infrastructure in Canada's North has been undertaken, (2012), Arctic Resource Development and Climate Impacts, Adaptation and Mitigation research project as found at http://arctic.ucalgary.ca/sites/arctic.ucalgary.ca/files/December-2012-MAKMuir-ArcticResourceDevelopment-ClimateImpactsAdaptation.pdf.

Conclusions

The paper has detailed existing and proposed electricity generation and transmission for the Canadian Arctic coasts and islands, as well as briefly exploring near future and distant future opportunities and innovations that may affect this region. This is promising for policy development and investment.